UNITED NATIONS ENVIRONMENT PROGRAMME

REGIONAL SEAS

Environment and resources in the Pacific

UNEP Regional Seas Reports and Studies No. 69

UNEP 1985

For bibliographic purposes this document may be cited as:

UNEP: Environment and resources in the Pacific. UNEP Regional Seas Reports and Studies No. 69. UNEP 1985.

REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

Environment and resources in the Pacific

UNEP Regional Seas Reports and Studies No. 69

UNEP 1985

EDITORS' NOTE

This volume brings together a number of papers presented at the 15th Pacific Science Congress organized by the Pacific Science Association in Dunedin, New Zealand on 1-11 February 1983. While the Congress treats scientific questions in the entire Pacific Basin, the papers collected in this volume focus on environmental problems relevant to the three regional action plans[1/] sponsored by the United Nations Environment Programme (UNEP) as part of its Regional Seas Programme[2/]. The majority of the papers came from sessions on Regional Co-operation on the Protection of the Environment intended to review the three Regional Seas Action Plans in the Pacific. With the kind permission of the organizers of the Congress, a selection of papers relevant to environmental problems in the region, originally presented in other sessions of the Congress, such as the General Symposium on Pacific Island Potentials organized by Ian L. Baumgart, are also included in this volume.

It is inevitable in a collection of papers such as this that there is great variability among the authors in style and approach, particularly since some papers were originally intended for oral presentation rather than publication. All, however, present points of view which are important to a consideration of the environment and resources of the Pacific and the directions that development should take in the region. While most papers are as presented at Dunedin, a few have been updated to include important developments in the months following the Congress. A summary of discussions at the Congress on inter-regional co-operation has also been added.

It will be apparent that there is some imbalance in the treatment of the three action plan areas. This reflects the Congress itself where papers were weighted more towards the islands rather than the continental margins and where participation from more distant regions, such as Latin America, was slight. The papers from South-East Asia and South America are also more technical in approach and more narrowly concentrated on marine and coastal pollution problems than those from Oceania. This reflects the different foci of their Action Plans and the greater development of their scientific capacity and data bases.

We hope that this volume will provide a useful record of environmental understanding in the Pacific and of the increasing extent of regional co-operation to deal with environmental problems.

Arthur Lyon Dahl
Jeremy Carew-Reid

1/ CPPS/UNEP: Action Plan for the protection of the marine environment and coastal areas of the South-East Pacific. UNEP Regional Seas Reports and Studies No. 20. UNEP, 1983.

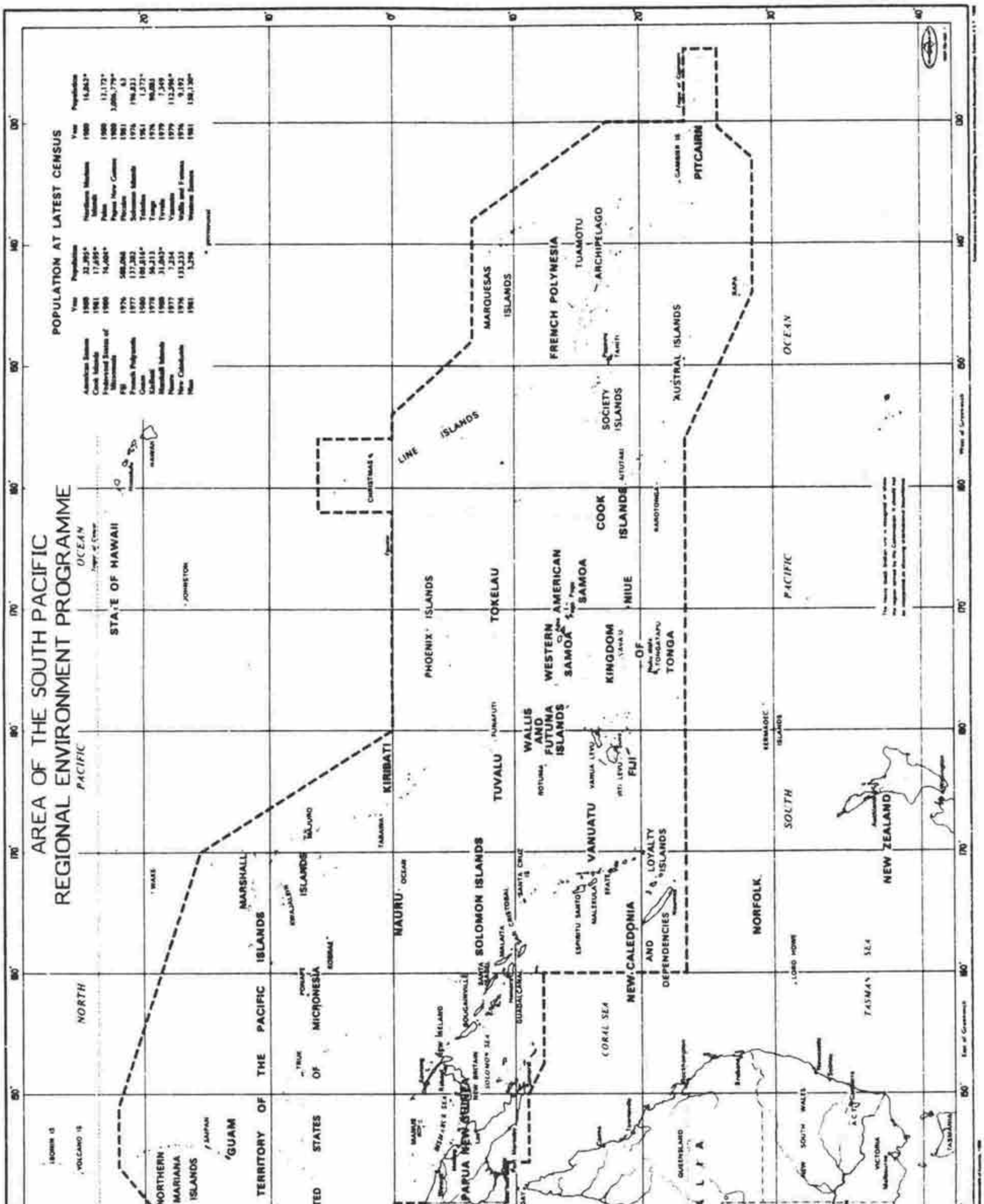
UNEP: Action Plan for the protection and development of the marine and coastal areas of the East Asian region. UNEP Regional Seas Reports and Studies No. 24. UNEP, 1983.

SPC/SPEC/ESCAP/UNEP: Action Plan for managing the natural resources and environment of the South Pacific region. UNEP Regional Seas Reports and Studies No. 29. UNEP, 1983.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

CONTENTS

SOUTH PACIFIC REGION


AREA OF THE SOUTH PACIFIC
REGIONAL ENVIRONMENT PROGRAMME
POPULATION AT LATEST CENSUS
NORTH
PACIFIC
OCEAN
STATE OF HAWAII
PHILIPPINE SEA
NORTHERN MARIANA ISLANDS
GUAM
TRUST TERRITORY OF THE PACIFIC ISLANDS
FEDERATED STATES OF MICRONESIA
MARSHALL ISLANDS
PALAU
NAURU
KIRIBATI
PHOENIX ISLANDS
LINE ISLANDS
TUVALU
TOKELAU
WALLIS AND FUTUNA ISLANDS
WESTERN SAMOA
AMERICAN SAMOA
COOK ISLANDS
NIUE
KINGDOM OF TONGA
FIJI
VANUATU
SOLOMON ISLANDS
PAPUA NEW GUINEA
IRIAN JAYA
NEW CALEDONIA AND DEPENDENCIES
LOYALTY ISLANDS
CORAL SEA
NORFOLK
NEW ZEALAND
TASMAN SEA
SOUTH PACIFIC OCEAN
FRENCH POLYNESIA
MARQUESAS ISLANDS
TUAMOTU ARCHIPELAGO
SOCIETY ISLANDS
AUSTRAL ISLANDS
PITCAIRN
AUSTRALIA
NORTHERN TERRITORY
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA

THE SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME

Arthur Lyon Dahl
B.P. 1146, Noumea, New Caledonia

ABSTRACT

The South Pacific Regional Environment Programme groups 22 island countries and territories to deal with their common environmental problems. It is a joint programme of SPEC, SPC, UNEP and ESCAP, with a secretariat based at SPC and financial support from UNEP as part of its Regional Seas Programme. The first preparatory phase began in January 1980 with the preparation of country reports and expert reviews of important topics. These provided an indication of government priorities and of the state of the environment in the region, leading to the adoption of a Declaration and Action Plan at the Conference on the Human Environment in the South Pacific in Rarotonga in March 1982. Priority areas of the Action Plan concerning legal measures, radioactivity, hazardous waste dumping, toxic chemicals, a network of pollution control centres, research on marine and coastal problems, traditional environmental knowledge and management, and environmental information and training are now being actively implemented, and further projects are in preparation.

Introduction

Each Regional Seas programme area has its own distinctive characteristics. The South Pacific Regional Environment Programme (SPREP) is unique in its origins and orientation, as is appropriate to a region consisting entirely of island states with well established regional organizations and traditions of co-operation. The earliest regional intergovernmental organization, the South Pacific Commission (SPC), is nearly as old as the United Nations, having been founded in 1947. In addition, the region has long been sensitive to environmental issues. The traditional island cultures have developed over generations within the constraints of their environment, and where resources were limited they generally evolved management strategies and controls to ensure that resource use was sustainable.

The term "South Pacific" is not strictly accurate, as the region includes not only all the tropical South Pacific Islands of Melanesia and Polynesia from Papua New Guinea to Pitcairn, but also extends northward through the islands of Micronesia, most of which lie north of the equator (see map at beginning of section). The region covers about 29 million km^2, almost seven times that of the Caribbean, which makes it by far the largest Regional Seas programme in area. The land area, on the other hand, is only 551,000 km^2, of which Papua New Guinea makes up 84%. There are roughly 3 million inhabitants in Papua New Guinea, and 2 million in the other 21 countries of the region, ranging from over 600,000 in Fiji to less than a hundred on Pitcairn. Population densities (persons/km^2) range from 6 or 7 in Papua New Guinea and New Caledonia to 348 on Nauru. The GNP per capita of US$ 1,775 (in 1978) is considerably below that of the Caribbean (SPC, 1982).

Origins

SPREP evolved out of a decade of regional environmental interest and activity. As far back as 1970, the South Pacific Commission proposed recruiting an ecologist on its staff, and this was supported by a resolution from the Regional Symposium on Conservation of Nature - Reefs and Lagoons, held in Noumea, New Caledonia in 1971 under the joint sponsorship of SPC and the International Union for Conservation of Nature and Natural Resources (IUCN), a meeting which identified many environmental problems of regional concern. The governments of the region approved the post and a special project on conservation of nature in 1973, and I was recruited from the Smithsonian Institution to take up the post of Regional Ecological Adviser in 1974. A wide variety of activities in environment and conservation were included in the SPC work programme until replaced by SPREP in 1980.

The SPC initiated discussions with the United Nations Environment Programme (UNEP) on possible co-operation in the region in mid-1974. Maurice Strong, Executive Director of UNEP returned the visit to SPC later that year, and in 1975, at a speech at the Pacific Science Congress in Vancouver, he proposed a "mini-Stockholm" conference on the environment for the Pacific. The UN Economic and Social Commission for Asia and the Pacific (ESCAP) also supported this suggestion. Further proposals from SPC lead to initial UNEP encouragement in 1976 for what was then called a comprehensive environmental management programme for the region. At the request of governments, the development of this programme became a joint activity between SPC and the South Pacific Bureau for Economic Co-operation (SPEC) the same year (SPC and SPEC, 1977). After a series of preparatory technical meetings of government experts, and the agreement of UNEP to provide initial funding, the South Pacific Regional Environment Programme was launched in January 1980.

South Pacific Regional Environment Programme

The first phase of the programme was designed to help the countries and territories of the region to identify their own environmental problems and priorities. Each government was requested to submit a country report to the programme (SPREP, 1981a, 1982a), and a number of experts were requested to prepare reviews on topics of regional interest (SPREP, 1981b). The process produced a "Stockholm-like" increase in governmental awareness of the significance of environmental concerns to their immediate interests. On the basis of this information, the SPREP secretariat was able to outline the state of the environment in the South Pacific (Dahl and Baumgart, 1982). It was clear that the South Pacific was no longer the carefree paradise of the tourist posters, nor was it yet the polluted Mediterranean. There was an obvious need for preventive measures before the environmental decline went too far.

The country reports showed that 60% of the countries had significant problems of soil erosion, more than half were concerned about the environmental impacts of the extraction of construction materials like sand and gravel, and 30% had major mining activity. Water shortages and water pollution also affected 60% of the countries. Loss of forest areas concerned 70%, and two thirds had problems of endangered species and nature conservation. More than half faced conflicts of land use and land tenure, given the limited land area available on many islands. In the coastal zone, reclamation and coastal erosion were each a problem in a third of the countries, overfishing and mangrove management were difficulties in over half, and three quarters suffered from significant pollution in coral reef areas. Waste disposal was a nearly universal problem; more than 90% had difficulties disposing of liquid wastes without creating pollution, and 60% could not find satisfactory means for getting rid of their solid wastes. Toxic chemicals such as pesticides, to which small islands are particularly vulnerable, were another worry for a majority of the region. Radioactivity was a special case, since the long continuing use of islands in the region for nuclear weapons tests and the proposals for ocean dumping of nuclear wastes have made this a major political issue. Finally, more than 60% of the governments were concerned about their population growth relative to the carrying capacity of their islands.

The preparatory phase of SPREP concluded with the Conference on the Human Environment in the South Pacific, held in Rarotonga, Cook Islands, in March 1982, at which ministers and other high level delegates from nearly all participating countries adopted a South Pacific Declaration on Natural Resources and the Environment, and an Action Plan for Managing the Natural Resources and Environment of the South Pacific Region (SPREP, 1982b).

It is significant that every single country and territory in the region participated actively in the preparatory phase of SPREP, showing the widespread support for the aims of the programme. Some countries even established environmental committees or bodies to implement their environmental priorities identified for SPREP.

Immediate priorities

The Action Plan adopted at the Rarotonga Conference identified a wide range of areas of environmental need, but certain priorities were also expressed. The programme therefore launched immediate activities in several of the priority areas. A technical group of international experts was organized to prepare a review of radioactivity in the South Pacific, so that the technical questions could be distinguished from the political and moral issues on this difficult subject (SPC/SPEC/ESCAP/UNEP, 1983; Bacon et al., this volume). A similar review was commissioned on the disposal of hazardous wastes in the Pacific Ocean (SPC/SPEC/ESCAP/UNEP, 1984). It was clear that the regional policies on this subject could only be implemented through international and regional legal agreements. SPREP therefore encouraged countries to become party to the London Dumping Convention, and organized a series of meetings to draft a Convention for the Protection and Development of the Natural Resources and Environment of the Pacific Region and associated protocols (SPREP, 1983a; Pulea, this volume).

Given the lack of baseline data on pollution by toxic chemicals such as pesticides and herbicides, and the reported extent of pollution by urban drainage and other liquid wastes, SPREP began consultations with regional universities and research organizations on the creation of a network of sub-regional pollution monitoring centres with analytical laboratories. The discussions also extended to research and training needs and the possible co-ordination of approaches, particularly with respect to the marine and coastal environments (SPREP, 1983b). A detailed feasibility study was commissioned of the mapping of coastal resources in the region for planning purposes, but resources were not adequate to undertake such a project immediately.

A major effort is being made in the area of environmental information and public awareness, including the preparation of a directory of research centres, a bibliography of environmental literature, and environmental radio broadcasts. Emphasis is placed on the importance of preserving what remains of traditional environmental knowledge and management practices for their possible usefulness in solving current problems. Approaches for training village leaders to better manage their own land and resources are being developed, since in the decentralized structure of the Pacific much responsibility for resource management will always rest at the local level. The programme also made provision for direct assistance to countries with specific problems.

Distinct features of SPREP

As mentioned above, the area of the South Pacific Regional Environment Programme is distinctive in consisting of tiny islands in a vast area of sea without nearby continental margins. Most the the 22 participating countries and territories (American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Island, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna, and Western Samoa) are micro-states struggling with problems of small size, isolation and a lack of resources. Five developed countries with territories or former territorial interests in the region (Australia, France, New Zealand, United Kingdom and United States) also support the programme.

Unlike most of the Regional Seas Action Plans, SPREP originated in regional environmental activities outside of UNEP, although UNEP assistance and encouragement help to bring it to fruition. It is based in strong regional organizations with a long history of regional co-operation in many fields. It has a unique structure, with a Co-ordinating Group representing the four co-operating organizations (SPEC, SPC, ESCAP and UNEP) which reports to the two major intergovernmental meetings in the region, the South Pacific Forum and the South Pacific Conference. The SPREP secretariat is located at the South Pacific Commission headquarters in Noumea, New Caledonia, and is currently headed by Dr. Jeremy Carew-Reid, SPREP Regional Co-ordinator. SPREP is thus a combined effort of the major intergovernmental organizations with environmental interests in the region, and is directly responsive the wishes of governments as laid down in the Action Plan and as reviewed at their annual meetings.

While UNEP has placed responsibility for the support of SPREP with its Regional Seas Programme Activity Centre, SPREP has always been concerned with all of the South Pacific environment, terrestrial as well as marine. On an island it would be artificial and unrealistic to separate the two. For the island countries, problems on land are at least as pressing as those in the sea, and the priorities of SPREP are weighted accordingly. SPREP also tries to be sensitive to the special geographic, economic, social and cultural dimensions of the region. It is not always possible to take the same approaches as elsewhere when there is a relative lack of scientific and technical capabilities, and the possibilities for independent national action in support of a regional plan are much more limited. All this emphasizes the importance of regional co-operation in resolving pressing environmental problems which is the basis of the South Pacific Regional Environment Programme.

REFERENCES

Bacon, M. P., G. Lambert, T. A. Rafter, J. I. Samisoni and D. J. Stevens. 1984. Radioactivity in the South Pacific Region. In A. L. Dahl and J. Carew-Reid [ed.], Environment and resources in the Pacific: a regional approach. UNEP, Geneva.

Dahl, Arthur Lyon, and Ian L. Baumgart. 1982. The state of the environment in the South Pacific. p. 47-71. In SPREP. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia. Reprinted as UNEP Regional Seas Reports and Studies, No. 31 (1983).

Pulea, Mere. 1984. Legal measures for implementation of environmental policies in the Pacific Region. In A. L. Dahl and J. Carew-Reid [ed.], Environment and resources in the Pacific: a regional approach. UNEP, Geneva.

SPC. 1982. South Pacific economies 1980: statistical summary. Edition No. 6. South Pacific Commission, Noumea, New Caledonia. 36 p.

SPC and SPEC. 1977. Comprehensive environmental management programme. South Pacific Commission, Noumea, New Caledonia. 73 p.

SPC/SPEC/ESCAP/UNEP. 1983. Radioactivity in the South Pacific. Topic Review No. 14, SPREP. South Pacific Commission, Noumea, New Caledonia. 211 p.

SPC/SPEC/ESCAP/UNEP. 1984. Hazardous waste storage and disposal in the South Pacific. UNEP Regional Seas Reports and Studies No. 48. UNEP, Geneva. 25 p. and appendices 114 p.

SPREP. 1981a. Country reports 1980-1981. Numbers 1-18. South Pacific Commission, Noumea, New Caledonia. 398 p.

SPREP. 1981b. Topic reviews 1981. Numbers 1-13. South Pacific Commission, Noumea, New Caledonia. 202 p.

SPREP. 1982a. Country report No. 19: Wallis and Futuna Islands. South Pacific Commission, Noumea, New Caledonia. 14 p.

SPREP. 1982b. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia. 71 p.

SPREP. 1983a. Report of the Expert Meeting on a Convention for the Protection and Development of the Natural Resources and Environment of the Pacific Region (Noumea, New Caledonia, 24-28 January 1983). South Pacific Commission, Noumea, New Caledonia. 42 p.

SPREP. 1983b. Report of the First Consultative Meeting of Research and Training Institutions in the South Pacific Region, Suva, Fiji, 18-20 April 1983. South Pacific Commission, Noumea, New Caledonia. 52 p.

DEVELOPMENT THEORIES IN THE PACIFIC ISLAND CONTEXT

Ken Piddington
Commissioner for the Environment
Wellington, New Zealand

ABSTRACT

The Pacific Islands are diverse in characteristics though sharing a common oceanic environment. The traditional value systems of the people are generally sufficiently strong to have imposed some mutation of Western economic concepts. In many islands subsistence economies are dominant.

Their economies are dependent on and vulnerable to influences from outside the region, but they possess a certain resilience so that statistical catastrophes do not instantly become human catastrophes.

Pacific nations, while placing high value on their independence, have established mechanisms of regional cooperation which are powerful influences on guiding appropriate development "in the Pacific Way". Important features of this philosophy are the insistence on the relevance of culture, custom, and tradition, and response to the instinct for resource conservation. These features provide an environmental ethic as an essential underlay to economic development.

In global terms the Pacific Islands approach to development is therefore potentially instructive.

Introduction

It is a pleasure to be on a voyage of rediscovery in this learned company. Exactly t years ago, as Deputy Director of the fledgling South Pacific Bureau for Econom Co-operation (SPEC), I was finding out about buying furniture and getting stationery print in Suva, Fiji. We were temporarily located in the old RNZAF Officers Mess, on the campus the University of the South Pacific. I began to learn about pay scales for office staff in developing country and about cockroaches and mosquitoes...

Around us on the campus, and in the capitals of the emerging states of the Sou Pacific, the debate about development was in full swing. The catch phrase of the debate a indeed the rallying point for the New Pacific was "The Pacific Way". This was the title of important set of papers produced by the South Pacific Social Sciences Association in 1973.

Many definitions were offered for what was meant by the phrase, but I have alwa drawn on that provided by my Director at the time, Hon Mahe Tupouniua:

> "Yes, I believe there is a Pacific way; there is a distinctive style of thinking which we can call the Pacific way of thinking. Most importantly, the Pacific way is capable of being applied to practical situations.
>
> "The Pacific way is a way of looking at things in relation to all the facts and circumstances involved in a given situation. It is a way which takes into account not merely the legal, the political, the social, and economic aspects; it takes into account the moral, ethical, and spiritual implications and consequences. By definition, therefore, the concept of justice is built in to the Pacific way.

"The Pacific way is concerned that 'nobody gets left out ' which is another way of saying that the Pacific way cares about the individual. And if nobody is left out, this means that everybody is in - which is what democracy is all about."

The definition is not about folklore, it is about the perennial struggle to lend a human face to the political process.

The "Pacific Way" undoubtedly did a great deal to capitalize on these feelings of solidarity through the new Pacific. It was a privilege to work closely with those statesmen, such as Ratu Mara, who had grasped the idea of a moment in history and related it to the day-to-day management of regional issues. For sheer persistence, one could not go beyond the outstanding Pacific leader whose contribution to regional diplomacy was overshadowed by the more sensational aspects of his domestic political career. I refer to the late Sir Albert Henry. When the historians work over the record of the 1970s, I would expect some of his speeches to be singled out as the encapsulation of the direction in which the Pacific was moving.

It is good to see Mahe Tupouniua taking his experience back to the Bureau as it begins its second decade, and I would like to acknowledge help provided by SPEC in the preparation of this paper.

The Pacific Context

For the sake of geographical precision, New Zealand is included in the "Pacific Island Context". Like Papua New Guinea it occupies some of the largest islands, but the fact remains that it shares the island situation. Indeed, traditional Western concepts of national development can be enriched by the mutations which are emerging in various models of development adopted around the Pacific. New Zealand, which in one sense has been a generous contributor to this process, now has the opportunity to see which aspects could lend breadth to its own view of development, which still tends to be two-dimensional.

The political changes of the last decade have resulted in a greater tendency to look at development in the Pacific not just in terms of the Forum members, or even South Pacific Commission members, but in a wider pan-Pacific perspective. This has meant that the Pacific Islands are seen more and more in relation to the Pacific Basin, the Pacific Rim, or whatever term might be current to describe the setting of our hemisphere. Geographical precision is not of concern; what is important is the fact that this is the area of the world which is generally seen as enjoying more favourable economic prospects than elsewhere.

Moves towards a Pacific Community are expected to increase, and a more formal grouping may emerge before the end of the century. Looking at the characteristics of the region, and the range of countries which might be included, it is useful to point out that the North/South problem does look soluble in the Pacific region. There are certainly a number of options available if the countries of the rim decide to join with the oceanic states to find joint solutions. This is in stark contrast with the dimension of the North/South issue elsewhere, where mounting evidence shows that the range of development options and regional solutions is narrow, and that the basis for political accommodation is often non-existent.

The political economy of the Pacific on the other hand does hold out some prospect that states with stronger economies will see sufficient joint interest in strategic terms, to accept the relatively low "insurance premium" which will maintain the development of weaker island economies. The collective purpose would be to exclude mischievous involvement by others, and achieve a consolidation of regional solidarity in the Island group (which has already suffered continuing division, particularly in the aftermath of colonialism). Models for the "insurance premium" can be seen in some of the post-colonial bounty, including that offered by New Zealand to the Cook Islands, Niue and Tokelau. The question that remains is, to what degree can these separate premiums be translated into a regional policy.

One of the prerequisites, if this is to happen, will be the maintenance by the Island states of their own commitment to regional co-operation. Progress over the last ten years has been steady, but it has lurched at times. Most of those involved in the effort to build regional cohesion would agree that much more dramatic results could have been achieved if on occasions the perception of individual interest (and the whims of some of the Island leaders) had given way to the more difficult but more enduring regional solution.

On the other hand, if any collective arrangements are to stick politically, they will have to take into account the simple fact that if you live on an island you have a different view of the world over the horizon from that of a continental culture. Islanders tend to be insular; a long way from the nearest neighbour; and vulnerable to economic and political upheavals on the other side of the world. Resources are slender and do not match the growing aspirations of the people. The ecological consequences of digging up islands for immediate wealth are worrying and reinforce all the other symptoms of insecurity. These are the feelings whether one is on the beach at Aramoana or Atafu; they are shared by most Pacific Islanders.

The process of building regional solidarity in the Pacific Island context will always be complicated by the huge disparities among the islands themselves. As a group, they are probably more diverse than any other geographical region, but this fact is obscured for many outsiders by the common oceanic environment. When the benefits of cohesion are obvious, as in the negotiation of aid projects to improve transport and communications throughout the region, this diversity will hardly count. But when it comes to individual commodities, individual investments and individual trade interests, the temptation to play one against the other or do special deals will often undermine the search for regional cohesion.

Economic development

Pacific Island economies cannot be lumped together as "developing countries". Any development theory for the Pacific has to adopt a more refined classification. The analogy with rental housing, dividing the economies of the region into four categories, may be appropriate:

Fully-furnished: ("Developed")	High per capita income, relatively even distribution of wealth, full infrastructure of communications and social services;
Partly furnished:	adequate funds for development, high per capita ("resource rich") income but uneven distribution, incomplete infrastructure;
Unfurnished: ("developing")	largely dependent on high capital inflows, fairly low per capita income, some growth capacity (eroded by inflation and other price/marketing problems);
Structurally unsound: ("least developed")	totally dependent on capital inflow, very low per capita income, no resources for development in the market sector.

In a recent article, Professor Fisk (1982) uses a much more sophisticated five-fold division of the last three categories. The establishment of exclusive economic zones (EEZ) has, for example, altered both the pattern of individual resource potential among Island nations, and the scope for regional co-operation in areas such as fisheries and offshore mineral investigation.

The important point is that there is a whole spectrum of development potential across the Pacific and a simplistic division into "haves" and "have nots" is not workable. In some cases, as Fisk points out, the development equation is not intrinsically insoluble; in other cases, the long term prospects are for permanent subsidy in one form or another.

One can however generalize in some respects. Most Island economies possess features of dependence and vulnerability which put them "at the end of the line" when it comes to global upheavals, such as the first and second oil shocks or the rise in inflation rates throughout the developed world. They do, on the other hand, enjoy a high degree of resilience. Statistical catastrophes do not instantly become human catastrophes. Insulation and isolation are still powerful influences on the pattern of development throughout the Pacific. This is why New Zealand should be included in the "Pacific Island Context".

A feature which all analysts have noted is the fact that traditional value systems are in most cases still sufficiently strong to bring about a substantial modification of classical development concepts. The subsistence economy is (in any case) dominant in many islands, and a sizeable informal economy operates throughout the Pacific. This is based on barter and non-monetary currencies, such as fine mats, home-grown produce or kinship obligations. The statement usually made is that there are no old people's homes in the South Pacific. It would be interesting to know on a statistical basis how many elderly people are in institutional care in New Zealand compared to, say, Oregon. The cultural environment is in other words a potent factor with far-reaching implications for the workability of development theories imported from elsewhere.

The aspirations for higher material standards of living are often in conflict with the traditional side of the culture, and this has created a set of unresolved tensions - economic, social and political. Although the option of reverting to self-sufficiency does exist in most cases, it can be ruled out as a realistic solution. It should however be reserved as a contingency in development planning, to deal with emergency situations or global catastrophes. It can also be a separate option for different individuals at different stages of life or career. In New Zealand we do not take sufficient account of the real economy in use of scarce resources (particularly overseas funds), represented by those who opt to work a piece of land on a subsistence basis. In Pacific Island terms, their efforts would be seen as a contribution to net national welfare.

However, this should not conceal the fact that development is going to be largely about cash incomes and that an ever-increasing proportion of young people in the Pacific Islands will be pursuing the material lifestyle they see on films, in tourist resorts and when they travel to Auckland. Honda and Sanyo have done more to change the modern Pacific than any economic or political theories. There is no turning back, and even in the most remote atolls we now see cash stores operating, with remittances coming in to finance the trade. The options for development put forward at election time throughout the self-governing Pacific, bring out the simple fact that the voters want more cash in hand. There is no choice over the inclusion of increased per capita income in any development plan. What does become important is what else you add in.

This is where the philosophy of the "Pacific way" can offer a clue. It seems that the development thinkers of the region almost instinctively add in three components which are important because of the cultural context. These are:

a) the social impact of development; where do people end up living, what does this mean for families, villages, whole islands?

b) the development of individual skills; in traditional terms, the acquisition of skills was a built-in process and most elders see no reason why the young should not carry on this tradition in a Western-type economy.

c) the need to conserve resources and derive maximum welfare from a sustainable level of resource use.

These elements are very familiar to anyone dealing with environmental assessment in New Zealand. Indeed, the NZ Commission for the Environment looks at particular projects in an objective manner and in the totality of their effects on the New Zealand environment. If there are gaps in the planning of a venture, e.g. in the provision of adequate housing, these will show up during the assessment process. Development theories for the Pacific Island context must retain the habit of looking at all the consequences of a project <u>before</u> it is endorsed by governments and other public authorities. The fullest involvement of the local community in the implementation stages is also essential. This is the best possible safeguard against harmful environmental effects.

The theoretical framework will also go beyond traditional sector-by-sector plans, and look at the interaction across sectors. Since the days of the National Development Conference, New Zealand has itself moved in this direction. Most of the development plans adopted in the Pacific have been "integrated" in this sense, and some of the work is recognized as being very sophisticated. The effectiveness of the theoretical plan will however come back to the three elements listed above, namely social impact, development of human resources, and conservation of natural resources. These elements will need to be integrated not only in theory, but also in practice.

Working through the list in reverse order, one should note that progress is being made at the regional level in articulating what needs to be done to complement the work already accomplished in fields such as:

- trade,
- transport and communications,
- co-ordination of aid flows and regional projects,
- technical assistance under SPC and other auspices.

Currently, discussions are well advanced on the South Pacific Regional Environment Programme (SPREP) and the regional priorities are being defined. It is notable that the principles of environmental management do not have to be debated in the South Pacific to the same extent as in New Zealand or, more particularly, in highly industrialized countries. The practice will be as difficult as anywhere else, particularly in respect of delicate reef and lagoon systems, but the political commitment is built into the philosophy of the present generation of Pacific leaders. Environmental policy is inseparable from the view which Pacific Islanders take of their stewardship role and their responsibility for the welfare of future generations. If this leads to analytical techniques which enable decision-makers to make judgements about intergenerational allocation of resources, it could assist in solving one of the central problems in the debate on environment and development.

The development of skills has, since the war, been part of the regional debate about education and development. However, it may be time to put it up for consideration in a more dramatic way as part of the agenda for the development debate. New Zealand will itself play a very significant part in skills development. This is already seen in the achievements of some of the Polynesian students who have grown up in New Zealand, and the concept needs to be nurtured and extended. The skills needed for Pacific Islands development in the next century will be very different from those fostered in the post-war phase. Between now and 1990 is the time to identify them.

It is the "social impact" which will create the greatest difficulties for planners and politicians. Social impact is about warts and carbuncles on the development process and how to remove them, or better, prevent them. The techniques for monitoring and analysis are well-developed but are vulnerable to poor science and sensationalism in the media.

On the other hand, all Pacific Island communities are going through the strains of adjusting to new circumstances, such as urban drift and the growth of formal economic activity. We can all learn from each other about the dictates of good social planning. The village and community mechanisms will simply not be operative through much of the Pacific in fifty years' time.

This area, which is linked to the key political factor of migration, needs therefore to be kept on the agenda. It will increasingly assume a regional dimension and the very significant movement of people which is already taking place will have to be reflected in the thinking about economic and social development.

Conclusions

To sum up, development theories in the Pacific will be subtle and many-dimensional instruments. There will be a pan-Pacific dimension, a regional (island) dimension and a set of bilateral and sub-regional dimensions. Categories applied to the stages of economic development will reflect the great diversity of the Pacific Islands. New Zealand will need to rethink its own relationship to these categories and to the overall process.

The Pacific will probably be a crucible for extensive experimentation with new models for development. These will be aimed at filling in some of the defects in Western concepts of development and will provoke a great deal of international interest. The integration of economic, social and ecological thinking into a single view of resource management will be the prize for those whose experiments succeed. The strong emphasis on human resources and skills will doubtless find wider application in other societies. Where mistakes are made, and they will be, the consequences can be reduced through genuine regional co-operation and disinterested aid or subsidies. It will continue to be part of the "Pacific way" to look after the weakest link. From that, the region will derive its ultimate strength.

REFERENCE

Fisk, E.K. (1982). Development and aid in the South Pacific in the 1980s. Australian Outlook 36:32-37. August 1982.

THE POTENTIAL FOR MANAGEMENT OF ISLAND ECOSYSTEMS

Arthur Lyon Dahl
B.P. 1146, Noumea, New Caledonia

ABSTRACT

The diversity of island environments and the evolutionary processes inherent in the island condition have produced a great variety of ecosystems in the different ecological regions of the Pacific. These ecosystems provide or maintain the natural resources on which most island communities depend. They also hold in their genetic diversity great potential for the future.

Island ecosystems tend to be fragile and easily disrupted or degraded, as demonstrated by trends in many parts of the Pacific. It is thus imperative to manage these systems if the resource base for human development and even survival is not to be damaged or destroyed.

Several resource management approaches are now being explored in different parts of the Pacific at both the national and regional level. Such approaches must be adapted to the special nature of island ecosystems if they are to succeed. Some types of development will have to be restricted to preserve essential island resources. The sustainable management of island ecosystems must be integrated with the social goals and development approaches of Pacific countries to achieve a balance particularly suited to island limits.

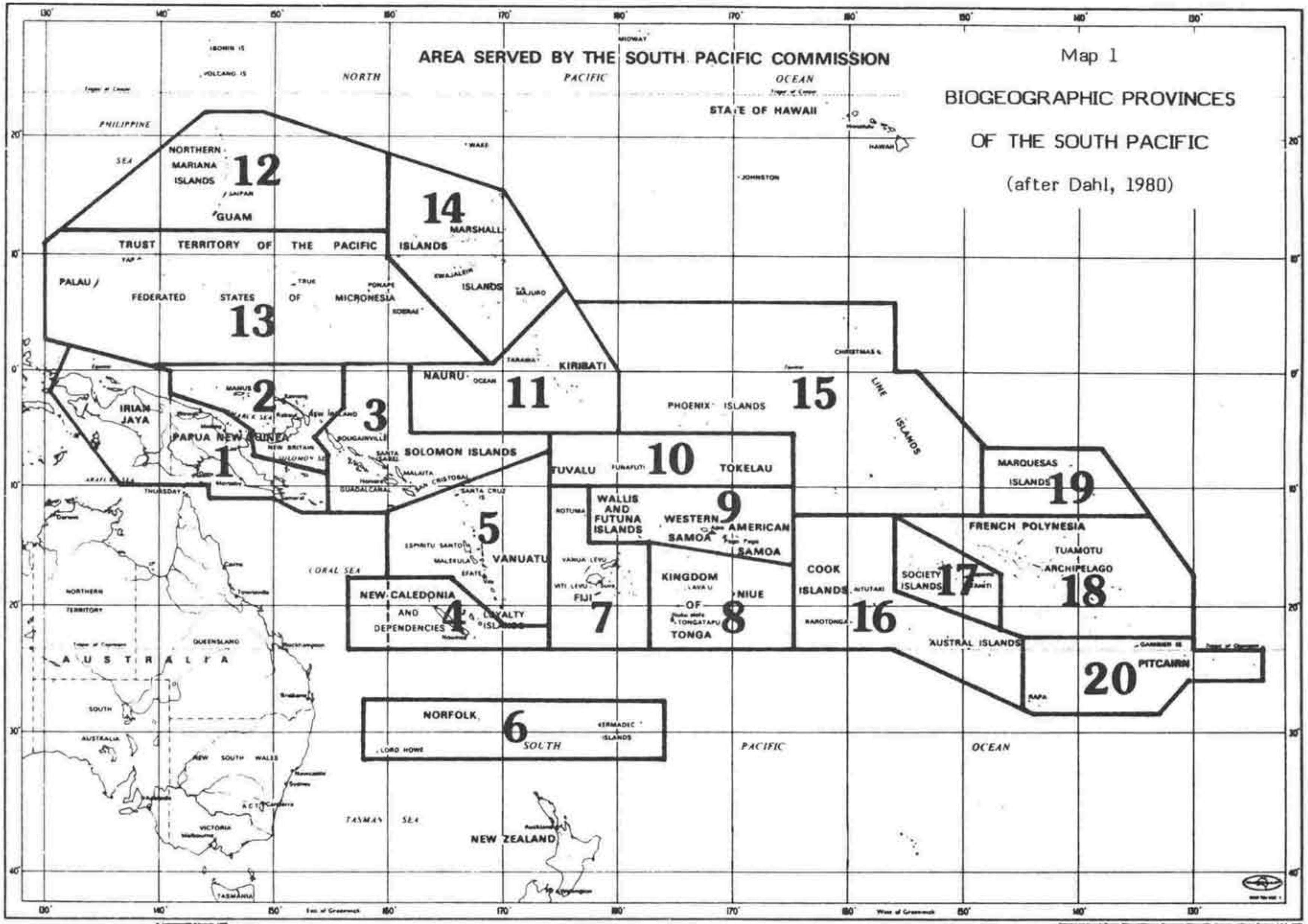
Man's future in the Pacific Islands depends in large measure on his ability to conserve and manage island ecosystems. Subsistence and commercial agriculture, forestry, fisheries, tourism, and even supplies of materials and traditional medicines, are all closely tied to the biological communities that differentiate the islands from lumps of barren rock in an empty sea. These ecosystems are also reservoirs of genetic diversity of world importance that should become increasingly significant in the future.

Island ecosystems have a diversity and specificity that present unique challenges for their preservation and management. The Regional Ecosystems Survey of the South Pacific Area (Dahl, 1980) estimated that there are about 2,000 types of ecosystems or biomes in 20 distinct biogeographic areas of the region (Map 1).

Some of these ecosystem types are widespread. The atoll/beach strand forest is made up of a few common and widely distributed species. Tropical lowland rain forests in the region are similar in type and structure while containing both widespread and more localized species. Coral reefs maintain similar ecosystem structure and function along extended gradients of species distributions and diversity.

Other ecosystems may be common in the region but rare and localized in particular countries or islands where they may be of special ecological significance, such as the limited mangrove areas in Samoa.

Conditions may restrict other ecosystems to rare isolated localities, such as the crater lakes of volcanic islands, and a few are even unique, as for instance a marine lake in Palau were a few species flourish in large numbers.



Map 1

BIOGEOGRAPHIC PROVINCES

OF THE SOUTH PACIFIC

(after Dahl, 1980)

Islands, of course, vary in the number and richness of their ecosystems depending on their size, form, origin and degree of isolation. Low coral atolls present a more limited set of environments than high volcanic islands, which are in turn generally less rich that large islands of continental origin. Each island, therefore, has unique features that make it difficult to extrapolate detailed management plans or approaches from elsewhere.

Vulnerability

Island ecosystems are particularly noted for their fragility and their susceptibility to degradation. They have evolved in isolation, often from a limited number of accidental species introductions or, in the case of continental islands, from primitive ancestral stocks. Predators were few and the need for competitiveness or defenses limited. The equilibrium of introductions and extinctions was determined by island size and isolation, among other factors. Island biogeographic theory predicts that any reduction in the area of a community or habitat will lead to simplification and the loss of species (MacArthur and Wilson, 1967).

To date, modern man's "management" of island ecosystems has been largely negative, destroying natural systems and converting them to other uses or leaving them as abandoned wastelands. Forests are cut, cleared or burned; soil is exposed to erosion by wind and rain; aggressive species are introduced and run rampant. At times all that is left is worthless land barely supporting worthless plants. Where mineral resources are present they are mined, leaving a rocky desert behind, and the wastes are often dumped in the nearest river. Some islands such as Banaba (Ocean Island) have been so degraded by mining that their populations have had to be evacuated. In the lagoon and on the reef, people fish with dynamite and poison, dredge and fill, spill toxic chemicals and oil, and let their wastes push ecosystems to the point of collapse. The number of natural areas protected from such degradation in parks and reserves is pitifully small in relation to the need (Dahl, 1980).

The recent report on the State of the Environment in the South Pacific, prepared by the South Pacific Regional Environment Programme (Dahl and Baumgart, 1982), has documented how widespread such damage has become throughout the Pacific Islands.

It is thus imperative that we learn to manage island ecosystems if the resource base for human development and even survival on the islands is not to be damaged or destroyed.

Island environmental management

Management of an ecosystem means actively intervening in the composition or functioning of the system to achieve certain ends. Such management is particularly justified on islands where human activity has degraded or destabilized an ecosystem to the point that it can no longer recover on its own. The goal of management should be to restore the ecosystem to its natural state, or at least to maintain its desirable and useful qualities in spite of the changed conditions brought about by human use. For instance, if a forest tree depends on fruit eating pigeons for its seed dispersal and the pigeons have been hunted to extinction, then artificial seed dispersal or planting of the tree would be necessary to ensure its survival. Management might equally involve exterminating introduced pest species, breeding an endangered or exploited species in captivity and releasing the young in the wild, or recreating vegetation where it has been destroyed.

Ecosystem resource management is inevitably constrained by island limits and by our lack of adequate scientific understanding of many island ecosystems. Effective management must respect and balance both ecological imperatives and economic constraints. It must be part of development, aiming to achieve the goals of development in terms of sustainable human betterment. It must also complement the social and cultural dimensions of each island society. This will be difficult, and we are far from having all the answers.

Some interesting approaches now being tried in the Pacific Islands may show possible directions for new management strategies. These include small scale village-level forestry projects in Vanuatu, agro-forestry experiments in Papua New Guinea, and rotating coral reef reserves in New Caledonia and Hawaii. Training materials to strengthen natural resource management at the village level are being developed with the support of the South Pacific Regional Environment Programme. The revival of traditional management techniques is also being encouraged.

It is possible to establish some general guidelines for adapting ecosystem management to islands. Integration of development needs and multiple use of resources are essential on an island. Land areas are too limited on all but the largest islands to permit the allocation of significant land areas to single uses as is commonly done on continents. For instance, agricultural land may need to be managed simultaneously for water catchment and as habitat for an endangered bird species, with the development of the land being modified to be compatible with its other roles. Many overlapping uses of the same area or resource will be the rule. Planning will need to look at the island as a whole, to ensure that all needs of man and the natural environment are provided for, and to prevent any one activity from threatening other essential resources. This may require modification of the land tenure and land use systems and legislation imported by colonial governments which have tended to define ownership in absolute "all or nothing" terms. What islands need are approaches closer to many traditional land tenure systems, where, within a general context of family or tribal ownership, it was possible to hold certain limited rights, such as to farm for the duration of the crop, to hunt or to collect building materials. Such systems encouraged multiple compatible uses, and allowed greater flexibility and efficiency in land use. For instance, rotating gardens and extended fallows allowed traditional agriculture to respect the limited fertility of many island soils.

Development has concentrated many human activities in the coastal zone, creating resource use conflicts. Such zones must be managed as an integrated system to ensure that terrestrial development is compatible with reef and lagoon management.

The scattered isolated nature of island communities places more responsibility for environmental management at the local level, and prevents the kind of centralization common in the government structures and bureaucracies of continental developed countries. Traditionally most small island communities had their own experts on fishing, farming, the forests, land use, etc., but colonization and modern systems of education have broken down these traditional systems and prevented the transmission of traditional knowledge to succeeding generations. It will be necessary to recreate this local expertise, bringing it together with a modern scientific understanding of resource management.

The inherent limits of the island situation will make it necessary to restrict some kinds of development. Toxic and hazardous chemical use, for instance, must be restricted or prohibited where a single accident could contaminate an entire lagoon or water supply. Single crop agriculture may be too vulnerable given the inherent variability in many island environments; extensive land clearing and uncovering of soils may damage water catchments and produce irreparable soil loss. Many modern technologies are inappropriate in an island context where they have a short useful life and are beyond the maintenance capabilities of small island communities. They are only a waste of capital and foreign exchange. For example, a modern automobile designed for driving all day on a superhighway may rust out in one to two years after going 10,000 km on an atoll with 30 km of road and a speed limit of 40 km/hr.

Other types of development may solve long-standing island problems and should be encouraged. Modern communications technologies may permit creative solutions reducing the isolation of island communities. Microcomputers may similarly be able to compensate in some ways for the lack of specialization inherent in small island societies.

Such approaches working towards the sustainable management of island ecosystems and towards appropriate development within island limits should help to reverse the trend towards decreasing island self-sufficiency and permit island people to face the future with confidence and dignity.

REFERENCES

Dahl, A.L. 1980. Regional ecosystems survey of the South Pacific area. Technical paper No. 179. South Pacific Commission, Noumea, New Caledonia. 99 p.

Dahl, A. L. and I. L. Baumgart. 1982. The state of the environment in the South Pacific. p. 47-71. In South Pacific Regional Environment Programme. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia. Reprinted as UNEP Regional Seas Reports and Studies, No. 31 (1983).

MacArthur, R. H. and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey. 203 p.

AGRICULTURE, SIZE AND DISTANCE IN SOUTH PACIFIC ISLAND FUTURES

R. Gerard Ward
Research School of Pacific Studies
Australian National University
Canberra, Australia

ABSTRACT

Agriculture is usually considered to be the keystone of Pacific Island economies. This paper examines the scope for development of various agricultural systems within the Pacific Islands.

The effects which small size, insularity and distance from markets and sources of inputs all have on the agricultural potential of the islands are considered.

The Pacific Island States include the world's smallest independent or semi-independent countries in terms of population. They also include some of the smallest in land area; some of the largest if their Exclusive Economic Zones are included; some of the most isolated; and some of the most fragmented and dispersed. These features all bear on the agricultural resources of the Pacific islands; on the assessment of them, and on their use potentials.

In this paper I will outline the general pattern of resource potentials in the region; describe the agricultural systems through which these resources were used in the past; indicate some trends in the commercial and non-commercial segments of agriculture today; and suggest the directions which agricultural resource use is likely to take in the next few decades. Small size, both of individual islands and states, and great distances, both between islands and states, and from markets and sources of imports will obviously influence these directions.

Resource potentials

It is important to recognize a basic division between the larger Pacific Islands States, the Melanesian States of Fiji, New Caledonia, Vanuatu and Solomon Islands on the one hand, and the smaller, Polynesian or Micronesian states on the other. The former have larger land areas and more varied landforms. Their range of elevation and exposure give climatic variety. Their surface water resources are greater and more secure. Their fish resources are greater as a result of their wider areas of shallow seas, and with both demersal and pelagic species, they have greater potential for artisanal and industrial fisheries. Forest resources are more extensive and there is greater variety in landforms, climate and soils.

The atolls of Kiribati, Tuvalu, Tokelau, the Northern Cooks and the Tuamotus lack surface water, have little soil, and lie exposed to the risk of tsunami or hurricane. Their range of crops is inevitably narrow. Even on the higher volcanic islands of Polynesia, the flora and fauna are less varied than in the western Pacific and the variety of environmental conditions more restricted.

It may be argued that this contrast in environmental variety was of limited significance in creating inequality in opportunity in the socio-economic systems of pre-contact times. With some obvious qualifications, a relatively narrow range of crops was grown throughout the region. Almost everywhere communities could and did produce virtually all their essential needs from the local environment, with a minimum of dependence on trade or exchange. Almost all types of land could and did support some population.

The situation is very different today. Recent decades have seen a drastic revaluation of land resources as a result, first, of the introduction of new crops (or the elevation to positions of prominence of formerly minor crops); second, of the change from production for own consumption to production for the market; and following this, third, a change in the criteria for accessibility. There is now much greater variation in the value of one location against another. Assessing this value, size of island, and distance from new commercial nodes are increasingly important.

Joseph Banks's well-known description of the beneficence of the breadfruit in Tahiti is typical of the early assessments by Europeans of the agricultural resources of the South Pacific Islands:

> "....These happy people whose bread depends not on an annual but on a Perennial plant have but to climb up and gather it ready for baking from a tree which deep rooted in the Earth scorning equaly the influence of summer heats or winter rains never fails to produce plenty..." (1963: 330)

It was this image that was remembered, rather than the fact that when Banks made a circuit of Tahiti, breadfruit was in short supply and he recorded that he had "not seen ten ripe ones hanging on the Trees the whole way" (1963: 307). The misconception that lush vegetation indicated fertile soils suitable for permanent cultivation, lasted a long time. In 1875 de Ricci described the "mass of luxuriant tropical foliage" (1875: 3) on Kadavu and claimed that "the soil is very fertile, being capable of producing everything that requires a tropical climate" (1875: 5). The image was sustained by tracts which sought to attract settlers and, indeed, initial yields of many crops often promised more than subsequent harvests produced. But this view overlooked the fact that swidden cultivation and fire had removed the forest from large areas in the drier parts of Fiji, New Caledonia and a number of the Polynesian high islands. The early clearing caused considerable erosion. The fact that at the time of contact much of this type of land supported few people - an indicator of poor soils - was often overlooked by Europeans who believed grass covered hills betokened good grazing.

Experience gradually taught European settlers what the islanders already knew - the only soils of the larger, high islands which would support nearly continuous cropping were the riverside alluvials (where floods and their silt were vital to fertility maintenance, but meant a high risk of damage), the colluvial soils at the base of slopes, certain volcanic soils, or the man-made soils of irrigated terraces or raised swamp beds. The "luxuriant tropical foliage" was a veneer which, if stripped off, laid the soils beneath open to rapid degradation. In recent decades soil surveys have revealed and quantified the limited potential of the lands of Melanesia. Almost 40 per cent of Fiji's land is "considered quite unsuitable for agricultural development on present knowledge" (Twyford and Wright, 1965: 219) - only 19 per cent is first class arable land. Only 12 percent of the Solomon Islands has "above-average agricultural potential" (Hansell and Wall, 1976: 135). In New Caledonia only 2 per cent of the area is "good agricultural land" and 13 per cent "good grazing land". Fifty per cent is "mediocre à tres mediocre" or suitable only for conservation in a natural state (Latham, 1981). The high volcanic islands of Polynesia do not have significantly better prospects. Fifty-one percent of Western Samoa is low-to-very-low natural fertility and a further 35 percent is too stony for mechanized agriculture (Wright, 1963: 88-89). Only 22 per cent of Rarotonga and 8 per cent of Mangaia have been classed as "suitable for annual and tree crops" with a further 9 and 41 per cent respectively having potential for tree crops alone (Grange and Fox, 1953: 10).

The atolls, a narrow strip of sand on a coral platform, rarely rise more than two or three metres above sea level, and generally have no surface water. Plants, and people, depend on the fresh water which floats in a fragile lens above the salt water permeating the underlying coral. Drought is a constant risk in those atolls nearer the equator and many are uninhabited because of this. Therefore, Kiribati (now that the Banaba phosphate has been completely mined), Tuvalu, the Northern Cooks, the Tokelaus, and the Tuamotus - all atoll regions - have a very impoverished land resource. On the other hand extensive lagoons and the reefs are productive. The atolls often support relatively high densities of population dependent almost entirely on a few crops, artisanal fishing, and now remittances and overseas aid. The Gilbert Group (with 80 percent of Kiribati's population) had a crude population density of 195 per square kilometre in 1978; Tuvalu 288 in 1980. It is very doubtful whether population densities of this level can be sustained by the agricultural or marine resources of the atolls at the levels of welfare which their people have come to expect.

Past agricultural systems

Let me outline key features of the agricultural systems practised in the region in the past, and describe a number of important changes which have occurred. Throughout the region variations of swidden agriculture were practised - short periods of cultivation followed by bush fallows of varying length. Intercropping was practised, with yams, taro, sweet potato, bananas and, later, crops such as maize or cassava, being grown in the same plot. This strategy protected the soil, lengthened the harvesting life of a garden and reduced clearing and maintenance work. A number of varieties of one species were often planted in the one plot. This reduced the risk of disease affecting a whole garden and again spread the harvest period. The system was robust in the face of risk - whether from disease, insect attack or natural hazards. It was flexible. It was highly productive in relation to labour inputs and planted area. Fruit and nut trees (especially the coconut) provided essential components of the diet. In conjunction with foods which were gathered, hunted, or caught, these systems provided a varied and nutritionally sound diet.

Labour was mobilized on a basis of reciprocity within the kin or community group. Reciprocal obligations incurred in agricultural work might be met by participation in a range of other activities related to the community's social, political or security needs as well as in other agricultural activity. Thus the maintenance of the agricultural system depended on the maintenance of the socio-political system, and vice versa. Surpluses produced over and above direct subsistence needs powered much of the social system - food and its production had many non-dietary functions (Lea, 1969).

The basic system had many elaborations. Post-harvest elaborations included storage techniques and pit fermentation to cover seasonal shortages. Terracing and irrigation (sometimes with complex hydrological works) were practised. In swamp areas raised beds were built to control the water table. Composting was used. On atolls, Cyrtosperma was grown in baskets of compost set in pits dug down to the level of the fresh water table. All these types of intensification tended to raise the level of security of food supply but, initially at least at the cost of considerably increased labour inputs. The intensification may have resulted from population pressure, or other pressures, arising from the needs for security in defence, environmental hazard, or social production. The intensification may have been a causal factor itself.

The agricultural systems I have sketched obviously varied from place to place but the most marked variant occurred on atolls where soil conditions prevented the growing of the full range of root crops and much greater reliance was placed on the coconut, pandanus and fruit and nut trees.

Robust and satisfactory as it was for subsistence, this form of agriculture was soon placed under stress as communities were partially incorporated into the commercial system. The early barter of foodstuffs for steel tools, cloth or other manufactured goods had limited effect as a potential surplus of tubers was usually available in the ground. But once harvested these were perishable, difficult to transport and had a limited market. Pressure from missionaries, chiefs, traders, or governments, or the grower's own desire to accumulate trade goods, led to the addition of new crops - cotton, oranges or coffee - or the expansion of areas under existing crops - coconuts or sugarcane. Thus there emerged a modified village agriculture system which included both a subsistence segment and a cash crop segment. This pattern is the most widespread today. The crucial question is, can this mixed subsistence-commercial village agriculture continue to meet the rising aspirations of rural people and the revenue demands which governments place on the rural sector? Before considering factors which bear on this question I must note some key points about the other system which emerged in the nineteenth century.

Plantation agriculture

The entry of colonial powers followed (or in a few cases preceded) the arrival of European settlers, intent on establishing farms, plantations, or businesses in this area where, it was commonly believed, the native population would die out in the face of so-called "civilisation". Land was acquired (by fair or unfair means) for plantations and these alienated areas were usually readily accessible by sea (or river), and often included some of the best land for cultivation. Plantations were concerned solely with production for export, required a commercial structure, and (after initially experimenting with a wide range of crops) were usually monocultural. Contract, indentured or wage labour was employed - all mobilized on a commercial basis and paid in cash or rations. The scale of plantations increased and their operations were often integrated with those in metropolitan countries where inputs were obtained, with shipping services, with processing, and with marketing organizations in the overseas countries. The scale and integration of the enterprise allowed such plantations to withstand many of the fluctuations in prices and returns which plague primary producers dependent on world markets.

In recent years the independence of island states has made the status of foreign-owned plantations problematical. Some countries have policies of taking over foreign-owned holdings and reallocating the land to citizens or traditional land owners. But the export production of the plantations, and the revenue it provides, has proved important to governments. State or provincial-owned plantations, community holdings managed by a corporation, or variants which apply an overlay of plantation-type management to small holder producers, are seen as offering alternatives to foreign owned estates. The important point is that all are attempts to retain some at least of the economic advantages of larger scale in marketing and related operations. This may indicate something of the marketing and management contexts within which Pacific Island agriculture may develop in future.

Mixed subsistence-commercial village agriculture systems

Let me return to the crucial question of the future of the mixed subsistence-commercial village agriculture systems. It is important to stress that the changes in these systems have not proceeded at the same pace in all areas. However, I would argue that the general direction has been, essentially, the same and the differences we now see often reflect the stage reached, rather than a different process.

I believe that the changes in village agricultural systems have three immediate causes: the conditions which the commercial market imposes on production systems; the fact that purchased food (or aid from overseas) has replaced traditional methods of guarding against food shortage resulting from environmental hazards; and the trend away from reciprocal labour mobilization towards wage labour. The market, as it becomes more developed, whether for fresh food supply or food processing, demands regularity of supply, and adherence to some set of product specifications. The latter usually require a degree of specialization and larger scale production of the particular line on the part of the grower. Delivery deadlines are inimical to a system of labour mobilization based on reciprocity in which obligations are incurred, and must be met, outside the agricultural production system. Inevitably social and market obligations clash - if the social obligations are given precedence the farmer's market arrangements may well collapse; if the market demands take precedence and the farmer's social obligations are not met, his general welfare - his social security - may suffer. The villager trying to maintain this balancing act is in a no-win position and neither set of obligations can be sustained satisfactorily.

Similar conflicts arise in other farming operations and the marked increase in use of wage labour within villages in Fiji, and other more commercially oriented areas, is in part a reflection of these conflicts. Of course the withdrawal of agricultural work from the reciprocity system affects other elements of the social structure - for example it may no longer be satisfactory to leave house construction, or the care of the aged, to the traditional system. Increasingly specialization of labour is becoming the norm in rural areas.

The commercial market (wholesalers, retailers and consumers) demands a standardized line of bananas, taro or other crop. Uniform size, stage of ripeness, colour and shape are preferred. The grower is therefore encouraged to change from multicrop gardens to monocrop fields - from multivariety plots to fields of the one, commercial variety. The pressure on his and his family's time often means the disappearance of minor crops, the garnishes in the diet and important nutritional items. Yams or taro give way to the less labour demanding cassava. The crops grown for times of risk are also dropped. With larger monocrop gardens the relative attraction of first class soils on near-flat land increases and the steep land, suitable for swidden but not for permanent arable use, declines in relative value. Areas without first-class land are disadvantaged.

Access to a road (or good sea access) to a market becomes of crucial importance. Throughout the Pacific Islands rural to rural migration has been taking place for many decades - towards the coast, towards roads, towards areas with reserves of land better suited for long-term commercial farming, and especially to such areas in the vicinity of urban markets. Areas which 50 or even 20 years ago were perfectly able to sustain people in a dominantly self-production self-consumption economy are no longer attractive to many and people drift away to what are seen as better located areas. Isolation, distance from market, or small size (and hence lack of commercial prospects) all reduce the relative attraction.

The trends which I have described have been evident in countries like Fiji and Western Samoa for 30 or more years. Elsewhere they are not as fully developed. It is possible that they could be reversed in some areas, but I doubt if they will be. I believe that the incorporation of the Pacific Islands into the world's economic system has gone so far in most island countries that the trends will not be slowed or reversed - especially because it is not in the shorter term interests of many, including the leadership, to do so. Under precontact economic systems the short- and the long-term interests of individuals and community - the private and the public good - generally coincided in the maintenance of socio-economic systems. This is no longer the case - short-term interest for individuals and government often lies in moving into the dominantly commercial sector even if this is inimical to the long-term interest of the community or the environment.

Can the village mixed subsistence-cash crop agriculture system be maintained? As a long-term strategy this seems a desirable goal. It would provide the security derived from growing most of one's own food and also the cash required for necessities and luxuries which must be purchased. Personally I doubt if this mixed system will be favoured in the larger island states in the medium term. This is not only because of the conflicts within it, between wages and reciprocity, but also because of the alternatives which many islanders have.

To be successful mixed subsistence-cash crop agriculture must offer returns in cash, security and welfare which are perceived as comparable to those of wage employment in government service, or in the urban private sector. With a few exceptions, the majority of village farmers do not achieve cash incomes which are seen as comparable. Even if the value of goods produced for own consumption is calculated realistically, the fact that cash can be used for 101 purchases, not just food, discounts the subsistence production in the minds of many. Furthermore, export crop prices fluctuate widely. Pacific Island producers cannot influence the world prices - they are inevitably price takers. Small producers of copra, coffee or cocoa are very aware of the insecurity of their markets and cash income. Urban, and especially government jobs, are seen as more secure - and certainly involve less hard manual labour in the hot sun. Labour and wage legislation tends to increase the relative security of wage employment. Another alternative for Cook Islanders, Samoans, Niueans and, to a degree, Tongans, is migration to and employment in New Zealand, the United States and, for a few, Australia. The cash earnings there (or even unemployment benefits), the educational opportunities for children and the other attractions of metropolitan life mean that the opportunity cost of village agriculture is often high. I believe village and smallholder agriculture will become steadily more commercial, the structure of society will continue to change, and change more rapidly, and internal and international migration to towns increase.

Small-holder production systems

None of this means that plantations need become the main form of production. There are strategies which will permit a smallholder production system to provide reasonable cash incomes, plus the opportunity for some subsistence production if the farmer chooses to engage in this as well. The Fiji sugar industry provides one model. This smallholder system has been remarkably successful for over 50 years even though it is geared to a demanding market. The key to this success lies not in the smallholder production system, but rather in the manner in which the provision of essential inputs, and the harvesting and marketing of the crop, are managed. The millers control the cutting, transport, and processing of the cane. They import fertilizer in bulk and distribute it to farmers at near cost. They undertake research to develop new high yielding cane varieties, tolerant of infertile soils, and disease resistant. The bulking up and distribution of the new varieties is also a miller's task. The end result is that many of the advantages of large scale in operations which a plantation can internalize, are made available to the smallholder.

Other examples of this form of management can be found in the Pacific. In its heyday the Western Samoa banana industry had many of these features, as does the reviving Cook Islands industry. Many forms of organization can be used for the superstructure - producer cooperatives (as in the New Zealand dairy industry); nucleus estates with associated smallholders; commercial firms; or government services. The principle can be applied to many crops, destined for local or export markets. But clearly it requires a degree of entrepreneurship and integration which has often been lacking in the region.

It is my belief that, with some inevitable false starts and failures, the next decade or two will see the emergence of this type of agricultural organization in many more parts of the Pacific Islands. The trend has gone furthest in Fiji where, in addition to the sugar industry, the new citrus industry is planned on similar lines, the recent attempt to resuscitate the cocoa industry shares some of the features and a new farm management scheme in dairying is operating.

Other trends

A number of other trends are likely to continue, or become evident. Individual holdings will become larger wherever rural-urban migration allows. Farming will become more technically complex. Traditional land tenure systems will be modified de facto, if not de jure, and land will be held by individuals, or nuclear families, for much longer than under swidden systems. Swidden cultivation will become less common as long-term tree crops or continuous arable cropping on the better land become dominant. Steep land or less accessible land will be used less frequently except for grazing, forestry or other extensive uses. Intensive commercial agriculture will concentrate more and more in the core area of each country. As implied earlier, the more remote and smaller islands (and the smaller states), will tend to be less and less involved in mainstream commercial agriculture.

The extreme archipelagic nature of the South Pacific Islands will accentuate these trends. The Cook Islands is probably the most widely dispersed country in the world in relation to its population - 18,000 people occupying as much of the earth's surface as Afghanistan, Pakistan and Thailand together. The Pacific Islands are often compared with the islands of the Caribbean but it is worth remembering that the whole of the area from Cuba and Jamaica to Trinidad and Guadeloupe would fit easily within French Polynesia, or Kiribati alone. Furthermore most of the South Pacific states are at least 2,000 kilometres from their nearest significant market, and half the world away from their major copra market. The Caribbean states nestle close the world's largest economy.

Transportation factors

Distance from markets is being accentuated by the rising cost of interisland shipping and technical trends in the shipping industry. Rising crew and fuel costs have encouraged ship owners to use larger vessels and containerization. Both developments offer little to the smaller states. Individual consignments are often less than container size and thus few benefits accrue from reduced handling as, in fact, an extra handling stage is added. Larger vessels call less frequently - and the interval between calls is important in the export of agricultural produce. The number of ports of entry has been reduced in several island countries in recent years, thereby increasing import and export costs to the outer islands deprived of direct overseas connections at main port tariffs. Internal costs within the Pacific are sometimes as high as those between Europe and the Pacific. Similar trends have transformed the patterns of international air transport in the last decade. The advent of wide-bodied jets to the region initially provided an increase in freight capacity to larger airports. But these advantages did not extend to most of the small countries which could not provide sufficient traffic for the larger planes. A break of bulk handling stage was added. As the practice of overflying the islands on the Australasia-North America routes increased, some of the benefits were lost, even in the main air traffic nodes. The withdrawal (now partial withdrawal) of wide-bodied aircraft from the Cook Islands - New Zealand service was a serious blow to Cook Island exporters. The use of more narrow-bodied jets on the regional air routes in place of propeller aircraft, has increased passenger comfort and convenience but these aircraft do not allow the islands to benefit from the lower ton-mile or passenger-mile costs of the big jets. And the small size of the market means that this will continue to be the case.

In interisland transport similar trends have occurred. Interisland vessels are larger and call less often. The amount of cargo to be delivered or uplifted is often too small to cover en route costs. Higher standards of safety regulations, desirable in themselves, have led to the withdrawal of older, smaller vessels whose capital costs had been depreciated. The causes of the interisland shipping problems are in fact varied, and often specific to particular countries. But the upshot is that the smaller and more distant islands often have a poorer service now than 20 or even 80 years ago. Internal passenger air services have often improved - but, by capturing much of the inter-island passenger traffic, they have made the viability of shipping links more problematic. Meanwhile on the larger islands road construction has given increasing proportions of the rural population easy access to towns and ports for marketing and have lowered the costs of consumer goods, just when the equivalent costs on outer islands are increasing. Retail prices of consumer goods are 35 to 40 per cent higher in the Lau Islands than in Suva. The Lauan copra grower has to produce a third more than would a counterpart close to Suva in order to achieve the same real income. Not only are the outer islands too small to produce sufficient agricultural produce (for export or urban consumption) to warrant frequent shipping services. They are too small to benefit from bulk wholesale purchasing. And the need to carry large stocks to compensate for infrequent deliveries is costly to retailers. Infrequent services also limit the range of products which can be grown for sale. Copra, being storable (though at a cost of weight and income loss), remains one of the few options, but is notorious for its price fluctuations.

The need, for political reasons, to maintain some degree of service despite the lack of direct economic justification often encourages direct government participation through use of a government fleet. Yet this is often half-hearted. I would argue that it is essential if the small remote islands are to be sustained as a viable part of the state, to re-examine the basis on which the costs and benefits of shipping services are evaluated. For example a study in Papua New Guinea showed that in the setting of charges for users, "the recovery rate for government road and air transport costs was considerably less than 20 per cent while the rate imposed on maritime transport was almost 70 per cent" (Proctor, 1980: 173). The hidden subsidies to road users are usually much higher than to ship users. In Fiji, current rural road construction costs are between $F50,000 and $F80,000 per kilometre, and annual maintenance costs about $F1,200 per kilometre. An absolutely minimum route shipping network would cover about 2,000 kms. This length of road would cost the government about $2,4 million per annum to maintain, quite apart from the cost of servicing the capital. In comparison the current budget allocates some $320,000 to shipping subsidies. I recognize of course that shipping services only generate traffic at the ports of call, not along their whole length as roads may (but not necessarily) do. Thus the direct comparison between $0.3 and $2,4 million is not valid. Neither are the populations served of equal size. But the anti-shipping bias is clear. Until such time as some more equitable means are found for evaluating government contributions to shipping vis-a-vis road transport, the small and the remote islands will remain as backwaters as far as their agricultural potential is concerned. Perhaps the concept of 'notional' or 'shadow' roads has something to offer. Perhaps an index based on road maintenance costs per kilometre might give a measure of reasonable shipping subsidy levels. Perhaps ships should be made available to users free of direct capital charges, as roads tend to be. Certainly some new approach is needed.

Agricultural directions for the next few decades

Let me sum up by indicating what I believe will be the general trends in agriculture over the next 20 years or so, and by noting the particular needs of the atolls for a new consideration of their agricultural systems. Small size and distance from markets will continue to make it difficult, if not impossible, for Pacific Island states to influence world prices for their export products. Special trade arrangements with Australia or New Zealand, or the EEC through the Lome Agreement will continue to be vital. For many of the outer islands in the larger countries, coconut based products will continue to be the only exportable agricultural produce. Improved internal air transport is unlikely to change this situation significantly. Attention and initiatives for new crops and expansion of existing types of commercial agriculture will focus increasingly on the larger islands, on those with an export port, and on those areas with better soils. The village mixed subsistence-cash crop system will continue in a state of malaise as pressures on the whole society from the commercial world increase. Governments and farmers' groups will put increasing emphasis on providing commercially-oriented management in production, provision of inputs and marketing. The type of organization which the Asian Development Bank's South Pacific Agricultural Survey called the "plantation mode of management" (not, I stress, "production", but "management") will become more common. Large-scale production will also find favour once again in some areas, and for some crops, especially as the rural labour shortage which some countries already experience become more marked. But systems of smallholders working under a larger management superstructure will spread.

The needs of the atolls warrant special consideration. Their environmental constraints, when combined with their location and small size, prevent them from following the course which I foresee for the Melanesian and larger Polynesian countries. Kiribati, Tuvalu and the Tokelaus simply do not have sufficient land area to support their existing populations on the basis of commercial coconut farming. It is extremely doubtful if they can support even their existing populations without an indefinite flow of remittances and overseas aid. With the end of phosphate mining of Banaba, Kiribati has recently lost the source of 85 per cent of its exports. Where the atoll regions are part of a larger polity I believe the man-land balance on the atolls will be kept by outmigration, as it has been in the Cooks and the Tokelaus (with movement to New Zealand), and in French Polynesia. But unless new international migration arrangements are made for Kiribati and Tuvalu they will not have this option. The subsistence component of their agriculture and fishing must be intensified. This cannot be done by standard agricultural practices but will require the extension of traditional systems; the search for and introduction of new fruit and nut trees, tolerant of sandy soils and periods of water stress; the wider adoption of soil-forming techniques; the upgrading of coconut productivity, perhaps with hybrids developed specially for atoll conditions; and the genetic improvement and wider use of those few root crops which can be grown in this environment. All this calls for a particular form of scientific application to existing agricultural systems. Such applications are normally concerned only with cash crops which give the prospect of financial returns. Here the returns will not be monetary, but will be no less important to human welfare, and the benefits will help the non-atolls as well. But the countries themselves are too small to carry the cost, and do not have the manpower or facilities to do the work. It is a task which those metropolitan countries with interests in the region should address as a matter of great urgency. The results may not solve entirely the dependency of those atolls states, but at least they should reduce the level of mendicity.

ACKNOWLEDGEMENTS

I am most grateful to my colleagues in the ADB's South Pacific Agricultural Survey team for many of the ideas expressed in this paper. I am also indebted to B.J. Allen, W.C. Clarke, D.R. Howlett, D.A.M. Lea, M.W. Ward and D.E. Yen for comments on an earlier draft. Their help does not imply they agree with my opinions.

REFERENCES

Banks, J. 1963. The Endeavour journal 1768-1771. J.C. Beaglehole (ed.), Vol. II. Public Library of New South Wales in association with Angus and Robertson, Sydney.

de Ricci, J.H. 1875. Fiji: our new province in the South Seas. Edward Stanford, London.

Grange, L.I. and J.P. Fox. 1953. Soils of the lower Cook group. N.Z. Department of Scientific and Industrial Research, Soil Bulletin No. 8, Wellington.

Hansell, J.R.F. and J.R.D. Wall. 1976. Land resources of the Solomon Islands, Vol. 1. Land Resources Division, Ministry of Overseas Development, Surbiton.

Latham, M. 1981. Pedologie, planche 14. In Atlas de la Nouvelle Caledonie et Dependances. Editions de l'Office de la Recherche Scientifique et Technique d'Outre Mer, Paris.

Lea, D.A.M. 1969. Some non-nutritive functions of food in New Guinea. In F. Gale and G.H. Lawton (ed.), Settlement and Encounter. Oxford University Press, Melbourne.

Proctor, A. 1980. Transport and agricultural development, p. 157-180. In R.G. Ward and A. Proctor (ed.), South Pacific agriculture: choices and constraints. Asian Development Bank and Australian National University Press, Canberra.

Twyford, I.T. and A.C.S. Wright. 1965. The soil resources of the Fiji Islands. Government Printer, Suva.

Wright, A.C.S. 1963. Soils and land use of Western Samoa. N.Z. Department of Scientific and Industrial Research, Soil Bulletin No. 22, Wellington.

PEOPLE POTENTIALS IN THE PACIFIC

Mere Pulea
Mere Pulea & Associates
Fiji

ABSTRACT

Population patterns in the Pacific show rapid population growth, tempered in some countries by out-migration, family planning programmes and rising age at marriage. A reduction in population growth rates is crucial to achieving development goals. With children making up 40 to 50 per cent of the population, education and training need to be planned with care and adapted to the changing needs and future of Pacific people.

Are development theories and strategies derived from foreign ideas and values really relevant to Pacific countries? Aid often perpetuates economic and political dependency, creating employment for international experts to the detriment of Pacific Islander personnel. Pacific women are still disadvantaged in their participation in development.

From a colonial or international perspective, Pacific customs and social systems have been interpreted as obstacles to development, but the critical issues in Pacific development are not technological or economic, but psychological, social, cultural and political. Social systems and occupational continuities are potentials that could be utilized for the development of Pacific people. Pacific Islanders should be allowed to develop "naturally" by defining their own needs and wants. Regulations for peoples' participation in development can improve equality, but may retard innovation.

The most valuable resource any country possesses is its people. Indeed some of the Pacific Island countries have little else. Every once in a while we are asked to stop, and think about the deep and problematic truths of our lives in the Pacific. I would like to take a broad view of some of the factors that have a bearing on people potentials in the Pacific and the attempts being made at developing resources as I understand them, and raise a few questions for your consideration. The framework in which we attempt to examine Pacific Islander potentials covers the development of human resources, development theories in a Pacific Island context, methods of assessing resource and human potential, the kinds of opportunities which exist, health factors and so forth.

Underpinning most of these topics is an implied if not an expressed interpretation that the development of human resources is consonant with maintaining a healthy population and providing educational opportunities and training for the development of skills in the various industries and for the potential users of Pacific Islander skills. We then move not only towards work-forces that are efficient and productive but towards maintaining a quality of life Pacific Islanders perceive for themselves. Concomitant with these developments are the socio-cultural constraints and potentials that are likely to inhibit or realize Pacific Islander potentials. I will confine my discussions to the framework of these topics.

Population Trends

In order to discuss people potentials it is necessary to give a broad overview of population patterns in the Pacific as population increases have far reaching implications in the development and the utilization of potentials. It was only in the 1960's that the relationship between high population growth and economic and social development became a significant issue within Pacific governments. Only two generations earlier many of them had been at least equally concerned about the population decline of the 19th century.

Bearing in mind the geographical features of the Pacific Islands, low levels of natural resources in some of the countries and limitations on usable lands, some countries have been viewing the population situation of the last two decades with concern.

Associated with the high rate of population growth is unemployment, high levels of dependency on the state, poverty, malnutrition, high density living, inadequate housing and problems affecting health and education.

Annual growth rates in most Pacific countries are high, but there are a few exceptions. Niue, Tokelau and the Cook Islands have expressed a negative growth rate due to out-migration. See Table 1.

TABLE 1 - Estimated Population (1981-1983)
and Annual Growth Rate (1975-1980*)

Country	Population (000's)	%	Country	Population (000's)	%
American Samoa	33.2	1.5	Pitcairn	0.1	
Cook Islands	17.7	-0.7	Solomon Islands	235.0	3.1
Fiji	646.2	1.8	Tokelau	1.6	0
French Polynesia	49.8	2.2	Tonga	98.4	1.7
Guam	106.4	0.6	TTPI	123.7	2.3
Kiribati	59.9	1.6	Tuvalu	7.6	4.6
Nauru	7.3	0.8	Vanuatu	120.0	4.4
New Caledonia	142.5	1.2	Wallis & Futuna	11.2	3.2
Niue	3.2	-2.1	Western Samoa	157.0	0.8
Northern Mariana Is.	17.6		TOTAL	5004.4	1.9
Papua New Guinea	3066.0	1.9	TOTAL excluding PNG	1938.4	1.9

SOURCE: South Pacific Economies 1981; SPC Demographic Unit
*Approximate five year period; Fairbairn 1982.

The United Nations predicts that the population in the Pacific region is expected to reach nearly eight million by the turn of the century with the annual growth rate of nearly 2%. See Table 2.

Although there is a projected decline in the growth rates for each of the major sub-regions, the growth rate is still high, particularly in Melanesia and Micronesia.

A completely different picture applies to death rates. Death rates in the Pacific declined rapidly immediately after 1920 and the end of the influenza epidemic in Polynesia, except in the Solomon Islands where the decline began after the 1930's. The expectation of life at birth for most Pacific Islanders was under 50 at the beginning of the century, but improved health services and improved socio-economic conditions have led to an increase to about 60 years in most countries. Recent findings indicate that the expectation of life at birth in Fiji is around 61 years; Western Samoa 63 years; Tonga under 60 years; Niue 63 years; Cook Islands 61 years; Kiribati and Solomon Islands 54 years.

It was not until the 1960's that some of the Pacific countries developed policies geared towards lowering the population growth rates. Programmes labelled Family Planning were seen and are seen as the direct means to implement governmental policy to lower the birth rates. Most of the National Development plans recognize the problems of rapid population growth and try to incorporate the Family Planning programme within the broad framework of socio-economic development. However, in practice, family planning is not integrated into the various sectors of development, and it is treated separately, usually as part of the health programme, with little relationship to the rest of the socio-economic development programme.

TABLE 2 - Projected increase in population

Region/Country	Population (000's) 1975-78	Population (000's) 2000-03	% increase 25 years	Average annual rate of growth 1975-78 to 1980-83	Average annual rate of growth 1995-98 to 2000-03
Melanesia	3702	6600	78.3	2.4	2.0
Melanesia excl. Papua New Guinea	986	1614	63.7	2.4	1.4
Micronesia	307	575	87.3	2.8	2.1
Polynesia	435	656	50.8	1.9	1.2
Pacific	4444	7831	76.2	2.3	1.9
Pacific excl. Papua New Guinea	1728	2845	64.6	2.3	1.6

SOURCES: UN 1980; Bedford 1982; Fairbairn 1982.

Family planning programmes are not alone in affecting the decline in the population growth rates; in some countries the rising age at marriage could also have this effect. For example, in Fiji in the early 1950's, the average age at marriage for female Indians was 16 years. Today, female Indians tend to marry in their early twenties. With increasing urbanization, better communication and transport systems, and modern technology, policies affecting migration indicate governmental concern because of the impact of out-migration on the composition and growth of an active population. In some countries population policies in National Development Plans aim not only to reduce out-migration but to minimize the skill drain not only from rural areas to towns but to other countries. However, the small countries in the Pacific cannot solve their population problems by out-migration, as countries to which Pacific Islanders could migrate have become more restrictive in their policies towards accepting Pacific Islander migrants. For example, New Zealand is not likely to accept Pacific Islanders as migrants except from countries with which it still has constitutional ties.

The Kiribati National Development Plan 1 states that:

> "In the past, population pressures have been partially relieved by migration and re-settlement in other countries, for example, Solomon Islands. It is not expected that further opportunities of this type will arise."

The impact of migration on fertility is not fully measured in any country in the Pacific, nor are its magnitude and nature precisely known. As it is more common for Pacific Island men to migrate, there is likely to be a shortage of men so that it is difficult for women to establish unions. However, where unions are established, the untimely emigration of men before the women complete their child bearing period could have an effect on the birth rates, although judging from the figures produced in Table 1, the effect of out-migration is not significant except in Niue, Tokelau and Cook Islands.

It has only been in the last twenty five years that population growth has been perceived as a threat to development goals. No single factor can achieve fundamental changes in the population structure. The reduction in the population growth rates is not dependant entirely on family planning programmes, out-migration, improved health, the influence of education or the increased participation of women in paid employment, but an interaction of all these variables could contribute to downward population trends.

The demographic characteristics of the Pacific Islands, high fertility rates, low death rates, a very young population (40 - 50% under the age of 15 years), high population density on some islands, the economic structure based mainly on agriculture with limited trade potentials at present, the size of the labour force relative to land and other resources, dictate the necessity to consider the potentials the Pacific Islands have for development in order to keep pace with population trends. Island populations could suffer all the miseries associated with poverty if population continues to increase at the present rate.

The problem of providing jobs can better be appreciated when one considers the changes that are occurring and are likely to occur in the composition of employment that accompanies the process of urbanization and industrialization and a movement away from agriculture where a large proportion of the Pacific labour force is absorbed. Pacific countries cannot provide vast increases in non-agricultural employment opportunities as the resources are limited, but there is capacity for the provision of employment opportunities in agriculturally-related fields through marketing, inter-regional and international trade, processing, transport and services. It would be sufficient to say that the reduction in the population growth rates would be crucial not only in attaining the goals for adequate and productive employment, and universal education, but also in providing equal opportunities for both men and women in the development process.

Development of Skills and Training

As referred to earlier, the high fertility rates in some of the countries reflect a large proportion of the population in the under 15 age group. Table 3 indicates a high proportion of the population also in the 15-59 age group and an extremely low proportion in the 60+ age group.

TABLE 3 - Population structure: a summary

Country	Year	Percent of population age 0-14	15-59	60+
MELANESIA				
Fiji	1976	41.1	54.7	4.0
New Caledonia	1976	38.6	55.3	2.9
Papua New Guinea	1971	45.2	51.9	2.9
Solomon Islands	1976	47.8	47.1	4.8
Vanuatu	1979	45.4	50.2	4.4
MICRONESIA				
Guam	1970	39.7	57.3	3.0
Kiribati	1978	41.1	53.1	5.8
Nauru	1977	44.2	53.0	2.9
TTPI	1973	46.2	47.6	5.9
POLYNESIA				
American Samoa	1974	44.5	50.7	4.4
Cook Islands	1976	49.8	44.2	6.0
French Polynesia	1977	42.0	53.1	4.9
Niue	1976	46.1	45.4	8.3
Tokelau	1976	46.3	43.4	10.2
Tonga	1976	44.5	50.5	5.1
Tuvalu	1979	31.8	60.1	8.1
Wallis & Futuna	1976	46.6	47.5	5.9
Western Samoa	1974	48.2	47.3	4.5
PACIFIC	1976+	44.4	52.0	3.6

SOURCES: SPC 1979; Bedford 1982; Fairbairn 1982.

According to Fairbairn (mss.), a notable feature of the Pacific region's population is the large number of children as a proportion of the total population:

> "For most island countries, children (i.e. 0-14 age group) comprise well over 40 per cent of the total ... for the central Polynesian countries they comprise typically around 50 per cent."

Such population patterns not only pose problems for the natural resources and the economic and social development of small Pacific islands, but they also bear on the development of people potentials. The population will continue to expand as this young group enters the child bearing age. If the rate of population growth continues in this pattern it could have serious implications on employment opportunities, education, training, health and other public services, and the participation of women in development. It will also affect the adequacy of existing resources to support growing populations not simply by providing bare subsistence but by maintaining adequate levels of social and economic well-being.

Some of the Pacific countries such as Tuvalu and Kiribati have limited land potential to support a growing population. A glance at countries such as Fiji, New Caledonia, Vanuatu and Solomon Islands reveals large areas of uncultivated land which might suggest substantial scope for development and support of a growing population, but in fact a good percentage of the land is infertile, steep and offers little scope to support large numbers of people. As population becomes more dense the problems of the usage of land resources, and of employment opportunities on the land or in the commercial or white collar sectors are likely to become more serious.

This realization of potential associated with the development of human resources is dependent on many factors. An area for consideration is the development of skills, particularly through education and training of the growing population, as related to the saturated and diminishing opportunities in the labour markets. To what extent are education and training programmes adapted to the changing needs and the future of Pacific people ?

To keep pace with these changes the attempt to develop human resources will require forecasting manpower needs, selection, training, and supervision. Hopefully the workers will be satisfied and productive, leading to an effective and efficient work-force. Although the development of human resources is consonant with providing higher levels of education or more extensive and intensive training usually focussed on skills and techniques, what results, in my view, is the concentration of efforts on the few to serve the many. This is inevitable as we quantify our successes in the development of our human resource potential by displaying data to reveal how many people with different levels of qualification have been produced. However, if this is used as a major index for the development of human potential, then some serious questions need to be asked about its applicability to Pacific societies.

It is fashionable to talk about the development of middle level manpower. All development plans insist on this.

> "In short, it seems that having developed some human resources we then develop the resources of some other humans albeit at a lower level to support the efforts of the first lot, in the hope that the human resources development will take place as our trained and educated and equipped human resource developers descend on other humans whose resources need to be developed." (Maraj, 1977).

The Pacific region requires deliberate planning to focus on training and education if it is to utilize fully the potentials of its greatest asset - its people.

It is also fashionable in the Pacific to talk about rural development, as between 60% to 80% of the Pacific people live in rural areas, and could be the major source of skills and resources for the economy. Following independence in many countries, the rising expectations in nation building, education and training in all sectors of the community are seen as one of the major instruments for progress: more jobs, more social mobility and more investment for generating economic development. These expectations are also encouraged by international agencies who make considerable investments on this front.

Are such development theories and strategies, with particular emphasis on market orientation, specializations and the complexities involved really relevant to Pacific countries? More than 80% of the Pacific people derive their livelihood from agriculture and to a great extent our economy is dependant on agrarian production. Although agriculture is the foundation of the Pacific economy, technological changes have a significant effect on training skills and employment opportunities. To go further, some jobs can be lost to technology which will only be in part be absorbed by employment created by the new technologies.

The pace of economic and technological changes differs from one Pacific country to another, and the question as to whether these changes have been of material benefit to the majority of Pacific people is yet unknown. Is development so geared and entrenched in foreign ideas and values that little note is taken of the real life situation of Pacific countries? Do we continue in order to be developed along with the outside world?

International agencies and metropolitan governments who aid Pacific countries do so in cash, equipment, and the provision of experts and consultants. Although we appreciate these efforts, my impression is that the regulations for aid imposed upon Pacific societies are geared towards the perpetuation of economic and political dependency. At first glance, aid procedures and regulations may not have implications for the development of human resources in the Pacific, but if one notes the number of aid agencies operating in the Pacific today, there is a notable increase in the last ten years which does have some implications for economic and social development and the realization of potentials in the Pacific. Aid agencies in fact play a key role in the development and realization of people potential in the Pacific, although with the exception of only one or two countries in the Pacific there are small indigenous concentrations of capital and resources sufficiently large to operate nationally, regionally, and internationally. The growth of international agencies has also provided a market for international labour. There is no suggestion at this stage that this cadre of personnel will be replaced by local expertise as agencies' demands for minimum viability standards for aid programmes will continue to give international personnel employment and tend to hinder the development of potential Pacific Islander expertise.

The system is also perpetuated by a small group of elites at national level who show little confidence in the skills and innovations of their own people. If Pacific Islander expertise is used, it is usually at a lower level. Above them is the layer of international personnel which does not give Pacific countries independence or equality in the operation of their own development. Although aid agencies have a primary economic function they do play an influential role in the life of Pacific communities. Perhaps a review to the approaches towards the utilization of local manpower potential by both aid agencies and Pacific countries would result in a better partnership towards realistic and attainable programmes. Pacific countries could then match their political freedom with economic and social independence and not be subjected to restrictive aid provisions which turn out to be no aid at all. What in fact does happen is that Pacific islands become a labour market for international personnel.

Before leaving this issue, the last aspect I would like to deal with is the participation of women in development. The participation of women is seen by some as the fundamental process for the realization of certain values and goals tied to society's values themselves. Their level of participation in the development process can also be seen as a useful guide in order to understand the kinds of changes taking place in society. Pacific countries differ in their attitude towards women and this in turn affects the extent to which women are given opportunities for education, training and employment.

For example, a small local study carried out at the University of the South Pacific's Extension Services reveals interesting sex ratio figures for Extension enrollments for 1981 semester II. See Table 4.

TABLE 4 - Sex ratio of USP extension enrollments

	Male		Female	
	No.	%	No.	%
Cook Islands	58	56	45	44
Fiji	510	68	244	32
Kiribati	72	62	45	38
Nauru	6	40	9	60
Niue	22	40	33	60
Solomon Islands	119	84	22	16
Tonga	76	54	66	46
Tuvalu	28	61	18	39
Vanuatu	76	75	25	25
Western Samoa	50	51	48	49
TOTAL	1017	65	555	35

SOURCE: Dr. R. Treyvaud, USP, 1981.

A number of features appear to emerge from these figures, namely:

- Overall there is a low rate of female enrollment in higher education.

- The lowest rates in female enrollments are seen in more recently independent countries such as Solomon Islands and Vanuatu. Is this a reflection of colonial/customary attitudes towards females?

- Is there a difference in attitudes towards female participation in Melanesia, Polynesia and Micronesia? Is there an increase in some countries of the retention rates of females in schools and if so, what factors influence this pattern?

- Are those females who continue to advance in education and training is concentrated into stereotyped traditional occupations such as nursing and home economics?

If females are not equally represented in other fields of study, could it be that they are being discriminated against, or that the problem really lies with those who guide females into "female type" stereotyped traditional occupations?

Socio-cultural Constraints and Potential

A number of writers have stated or implied that the major problems facing the people of the Pacific today arise from the processes of social, economic and political change. Some writers go further and state that Pacific people can solve many of their problems if they adapt their culture to the needs of modern times. Pacific countries are urged to modernize or abandon their traditional land tenure systems, communal obligations, rituals and customs in order to compete with the outside world and progress towards a richer commercial economy.

According to Lasaqa (1973) these statements are not new, nor are they difficult to say. What is more difficult to spell out are their implications in detail, especially as they affect groups and inter-personal relations, social structure and value systems, use of time and resources, local leadership, and the peoples views of themselves and the world around them. Customs, communal living, and traditional land tenure systems are seen as serious threats to development. Since Pacific Islanders have no development theory related to their own environment, development is only encouraged towards a monetarized economy, but this does not develop the full bases for the people to attain a good and satisfying quality of life.

Social units such as the aiga and the matai systems of Western Samoa, the mataqali in Fiji, the unimane system of Kiribati have been interpreted as obstacles to development by colonial and international perspectives in such a way that we feel the need to apologize for these dynamic systems. Preoccupation with western cultural heritage could lead to the abandonment of Pacific traditions and culture in order to advance technologically, but this would not promote the socio-cultural progress of the nation. Surely excellence in culture is just as important as economic progress.

The crucial issues in Pacific development are not technological or economic, but psychological, social, cultural and political: the areas in which cultural conditioning constitutes a pervasive and often vital influence. When such factors are not taken into account it could constrain much meaningful understanding of development in a Pacific context. Crocombe (mss.) states that a major issue is not only motivational patterns of people's work behaviour, but also the differences in the use of time, where long drawn out rituals, ceremonies and meetings in the Pacific are labelled by 'O' and 'M' [Organization and Methods] as 'wasting time'. Some studies have shown that most Pacific societies before contact with industrialized societies used only between twelve and twenty hours a week in the whole range of things called 'work' to maintain a reasonably comfortable existence. Although this is low by world standards, it was possible because of the richness of the environment. Other studies also show that people who are used to working relatively short hours, put into a new context would also work short hours, but this has been disproved when one sees Pacific Islander migrants living in the United States, Canada, Australia and New Zealand. Crocombe, in this article, goes on to discuss the extent of occupational continuity in the Pacific, traditions that go back long before contact with Europeans and industrial technology. He makes reference to the seafaring traditions of the Tongans and especially to the Tongan seafaring captains, where for the past 500 years almost all have come from a very select group of families in Ha'apai. Similarly, wood-carving is the speciality of the people of the tiny islands of Kabara and Fulaga in the Fiji group. Even though these are very small islands the carvers come mainly from the Jiafau clan within them and although many changes have occurred in Fiji the best carvers are still produced to this day from the Jiafau clan. Such examples can be found all over the Pacific. Changes and development in the Pacific have not phased out these skills and in some cases they have remained very strong.

These are the strengths in Pacific communities that we ought to be aware of if we are to utilize the potentials and understand the constraints in a socio-cultural context, as such patterns can have a major bearing on Pacific Islander development. The dynamics of the social systems such as the aiga, the matai, the mataqali and the unimane to name a few, and the occupational continuities in some of the arts and crafts that have continued for the past 400 to 500 years are potentials that could be fully utilized for the development of the Pacific people.

Possible Guidelines

The recognition and utilization of people potential in the Pacific brings me to discuss two main themes. One theme concerns the 'natural' development of Pacific Islander potential and the other theme deals with defining bodies of laws and administrative regulations especially for the people to open up the opportunities and the responsibilities for Pacific islanders in all aspects of their own development.

There is no question about the importance of the role that Pacific Islanders and their institutions play in the development of their own countries. The important question appears to be "what kind of Pacific Islander are we trying to develop ?"

The theme of "natural" development for Pacific Islanders involves in the first instance giving the people the opportunity to define their own needs and wants for themselves, their families and their environment. The "natural" development concept will allow the people to satisfy their needs based on cultural patterns and needs that are attainable and satisfying so that they are not made to cope with development processes that are far beyond their skills, capabilities and environment. The "natural" development process enables Pacific Islanders to identify their own problems and participate fully in the development of their own programmes to meet their needs.

The other theme of the development process is to define the peoples' role through directions, regulations, and legislation, in order to utilize fully their potential and the potential of their traditional institutions. Specifically defining their role and their participation and involvement in development programmes could bring about greater equality and better access to education, training and employment. However, this in effect would result in Pacific Islanders not defining for themselves their own needs and development in a fluid and innovative way where their own development goals and strategies could be adjusted to their changing circumstances. Pacific Islander development would be institutionalized in bodies of laws and administrative directions and this could perhaps have negative effects on the utilization and the development of people potential in the Pacific.

REFERENCES

Crocombe, R. G. (mss.) Culture and development in the South Pacific.

Fairbairn, I. (mss.) Population (unpublished paper, 1982).

Kiribati National Development Plan 1979-1982, p. 45.

Lasaqa, I. 1973. Geography and geographers in the changing Pacific: an islander's view. In H. Brookfield [ed.] The Pacific in Transition. Edward Arnold. p. 306-307.

Maraj, J. 1977. Human resources development and regional co-operation. University of the South Pacific, Suva, Fiji. p. 3

A PERSPECTIVE ON HUMAN HEALTH AND ITS IMPLICATIONS FOR THE POTENTIAL OF THE PACIFIC REGION

Ian Prior
Director, Epidemiology Unit
Wellington Hospital
Wellington, New Zealand

ABSTRACT

The Island populations in the Pacific are made up of people of differing ethnic background - Polynesian, Melanesian, Micronesian, who live in physical environments which vary from small atolls with limited resources to high islands where bounteous supplies of soil and food have been available for hundreds of years.

The patterns of health and disease in these populations are now showing many changes which can be associated with urbanization, migration and altering life styles. Health patterns and population growth have been greatly influenced by improvements in control of the acute infectious diseases, chronic disorders such as tuberculosis and filariasis, and in the areas of maternal and child health. Studies in the Pacific over the past twenty years have demonstrated a wide gradient of risk of conditions which in Western Societies are the principal causes of mortality such as cardiovascular diseases, hypertension, stroke and coronary heart disease.

These conditions are now emerging as important health hazards in some more developed Pacific societies such as Fiji, Samoa, Tonga, and the Cook Islands and involve some ethnic groups more than others. At the same time migration from the South Pacific to industrialized urban societies such as New Zealand is providing a still greater change in environment, life style and health patterns. Multidisciplinary epidemiological studies such as the Tokelau Island Migrant Study established in 1967 are providing evidence of factors which influence the development of "Western diseases" following migration and urbanization which now provide a sound basis for intervention studies that could lessen or prevent the emergence of disorders such as hypertension, diabetes and coronary heart disease.

WHO has set a goal of health for all by the year 2000, based on improved primary health care, use of appropriate technology, greater involvement of individuals and communities in their own health and setting prevention as a primary goal based on strategies that have been tested and are supported by the people and their governments. The Pacific Island populations have many favourable opportunities to pursue such goals.

Introduction

This paper will review some of the major health problems that have existed in the past in the Pacific region as part of the process of developing a perspective on health in the Pacific Islands for the 1980s and leading up to the year 2000. The hypotheses which will be tested and developed into a model for the immediate future can be set out as follows:

(a) The provision of adequate clean water, and facilities for personal and community hygiene and sanitation will result in further major improvement in individual and community health and in the control of certain conditions at present endemic in some Pacific societies.

(b) Prevention of diseases of affluence associated with increase in standard of living and alteration of lifestyle will involve major emphasis on individual and community decision making.

The perspective will be developed by looking backwards and highlighting certain problem conditions that give an understanding of the extent of ill health and its causes and insights into methods developed for dealing with these. Some of the changes that have become important - migration, urbanization, social change and health consequences will be described together with factors relating to the future. Finally the question will be asked whether the World Health Organization goal, "Health for All by the year 2000", is likely to be achieved.

The past

S.M. Lambert, author of "A Doctor in Paradise", commenced working for the Rockefeller Foundation on their programme of hookworm eradication in Papua New Guinea from 1918 to 1921 and then between 1922 and 1935 in other parts of the Pacific including Fiji, the Gilbert and Ellis Islands, Tonga, Western Samoa, the Cook Islands and the Solomon Islands (Lambert, 1941). This book contains a wealth of knowledge concerning the people of these countries and their health status and how effective community based treatment programmes were undertaken with Chaulmoogra oil and a laxative for hookworm infections (Ankylostoma duodenale) and also for yaws using intravenous salvarsen.

Dr Lambert put forward and tested an important hypothesis that related to the devastating effect which visitors from outside had in production of virgin and first encounter epidemics and their intensity. This can be well illustrated from two extracts from this book.

He was in Papua in 1921, visiting a Catholic Mission Station where Kuri were the indigenous people. Father Chabot said: "before the mission came this district had dwindled to less than two thousand. The Kuris would have disappeared if we had not discouraged cannibalism, infanticide and abortion." "I wondered if the good priests were not fooling themselves. Abortion and infanticide may reduce a population, but cannibalism and continued tribal warfare may be blessings in hideous disguise. They keep the tribes apart. Warfare is a sort of rough quarantine. In times of peace strangers wander in and out, and bring infections with them. Native races die off not through their own suicidal customs, but through diseases introduced from the outside world."

In New Guinea he was in charge of the Rabaul Hospital for a period in 1921 and the following extract illustrates how his knowledge of the fear of mutilation which the New Guinea natives had was used by him to help control the treatment of influenza epidemic patients.

"I had returned from field work and found the native hospital filled with flu cases; many were dying in the collapse from pneumonia. The sudden deaths among seemingly mild cases puzzled me, until I probed the cause. Our native attendants hated to lose sleep; as soon as they were snoring, the sick men, hot with fever, would sneak out from a side door and go down to lie in the sea and cool off under the stars. They would sneak back to bed and die of shock.

I put a stop to all that. Native attendants had told them how I slit open dead men's bellies. (I had performed thirty post mortems to determine the average native content of whip-worms). My ogreish fame had spread among a simple folk who would far rather lose a life than a leg. To them I was master of life and death - and the post-mortem table.

Therefore I profited by my foul reputation and marched through the ward brandishing a large amputation knife, and as I passed along rows of quaking cots I shouted: 'Suppose you no stop along bed, you sons of bitches, suppose you no takim medicine good feller, now you die finish, me cuttim belly belong altogether, me cuttim heart, me cuttim wind, me cuttim gut belong you feller. But suppose you good feller altogether, now you die finish, me no cuttim you.'"

He spoke to them very sternly and his mana was such that no more night wandering occurred. This clearly illustrates the extraordinary "power" of the doctor in such societies and the insights they must have of the people and their customs and beliefs.

The efforts commenced throughout the 1920's and 40's to improve hygiene and sanitation and to deal with conditions such as tuberculosis form an important part of the slow but steady overall improvement in health that was taking lace in many of the Pacific territories large and small.

The present

From the viewpoint of health and disease the perspective on health in the Pacific Region has been influenced by the greatly increased mobility of people in the Pacific - particularly since the end of World War II. The number of Pacific Islanders in New Zealand has increased from 1,500 in 1946 to 65,000 in 1982. This includes migration from rural villages to urban centres, from islands to towns and cities in larger land masses and westernized societies such as Australia, and New Zealand. The process of urbanization with its beneficial and less beneficial consequences are strong and important factors influencing societies and the people in them. The move from subsistence to cash economies and the struggle to meet family, church and community requirements all place a considerable number of new strains on individuals and their families.

The strong sense of community and the interdependence of people and communities that is a part of the culture and social pattern in many Pacific Societies has played a valuable part in the community approach developed to a number of health problems. The control that is being achieved for malaria and filariasis are good examples of conditions where real progress had been made by environmental and community measures related to control of mosquitoes, the important vectors and the carrier state in the human hosts.

An example of community control would be filariasis. A changing pattern of filariasis is being found in Tokelau where community control programmes have been instituted as a way of reducing microfilaria carriage in humans and so lessening the rate of new infections.

The public health measures which have led to greatly improved mosquito control have been important for both malaria and filaria. This includes preventing water accumulation in containers in villages in old coconuts, unprotected tanks and similar sites on uninhabited motus.

One of the explanations for the higher rate of clinical filarias in men than in women in Tokelau has been the men's greater exposure time to mosquitoes on the motus whereas women stay mainly on the living motu. The community treatment programme in Tokelau with Hetrazan which involved all adults and children down to six months was carried out over a period of one year and has resulted in virtual elimination of filariasis.

The need for continuing scientific work on these problems and their community control must be stressed. Vector control has advanced greatly but much still depends on the discipline of controlling breeding places and this is essentially a matter of community discipline.

Important new work dealing with biological control of the vectors is being carried out by Laird and his group at the University of Newfoundland (Laird et al., 1982).

Communication, health and the Pacific way

A philosophy which is concerned with a willingness to listen to one's neighbour, to help deal with problems as far as possible and to do it in a way which maintains respect for the dignity and basic human attributes of those involved and without undue rush, unless this is needed, is sometimes referred to as the Pacific Way. The development of this interdependence in areas of health is best illustrated by the way in which certain recent major epidemics in the Pacific have been dealt with. Firstly a cholera outbreak in Kiribati in 1977 (Kuberski et al., 1979) and secondly an epidemic of Ross River Disease in Fiji in 1979 (Roberts et al., 1979).

Cholera outbreak - Kiribati 1977

On September 8th, 1977 a sudden outbreak of severe explosive diarrhoea with fever occurred in Kiribati that was thought to be cholera. Using the Peacesat satellite network which links more than twenty countries in the Pacific, the health authorities discussed the problem with experts in the N.Z. Health Department. The various immediate needs for diagnosis and treatment including intravenous fluid replacement were decided on and in less than twenty four hours a RNZAF plane with medical team and necessary supplies left New Zealand for Kiribati. In addition an epidemiologist from the Center for Disease Control, U.S. Public Health Service was seconded to assist the Ministry of Health. Communication was maintained on a daily basis using Peacesat and further steps taken as needed to contain the epidemic and to identify the causes of the outbreak and the steps needed to prevent future outbreaks. A total of 585 suspected cases were admitted to the two Tarawa Hospitals in the 64 day period 30 August - 2nd November 1977. 45 percent of 366 stool cultures were positive. A total of eight hospital deaths occurred (Roberts et al., 1979).

Ross River Disease

Ross River Disease is a virus disorder transmitted by mosquitoes which first occurred in Queensland and remained confined there for many years. In Fiji an outbreak of pyrexial illness with joint involvement, definite arthritis with effusions into larger joints such as knees suddenly occurred. The diagnoses was not clear and large numbers were being affected (Miles, 1979). The symptoms and signs suggested either Chikungunya or Ross River viruses.

The epidemic began in the western and northern coastal areas of Viti Levu later spreading to Suva and other areas and involving possibly 30,000 people. Dr J.U. Mataika of the Wellcome Virus Laboratory, Suva using suckling mouse brain inoculation methods, isolated two strains of a virus from the blood of polyarthritis patients. These viruses were subsequently shown to be Ross River virus by Professor Miles and his group in Dunedin and this was confirmed by the Queensland Institute of Medical Research in Brisbane, Australia.

The community control response lay in an effective mosquito control programme. There was again a coordinated approach and offers of help with methods of improved mosquito control by a number of different Pacific countries. It subsequently spread widely, not only in Fiji, where many thousand were affected but also to other parts of the Pacific including Tonga. Cases also occurred in New Zealand by travellers returning from Fiji. Fortunately the condition is essentially self limiting and does not appear to have long term consequences.

The outbreak of Dengue in the Pacific that took place in 1975 is a further example (Palmer and Ram, 1976) of Pacific community collaboration where the Peacesat network was used to maintain regular contact between public health officers, government officials and consultants in Hawaii and New Zealand. The ability to interact in this way supported by offers of government to government help with methods of vector control contributed to the control of this epidemic throughout the Pacific.

These examples ranging from water borne cholera to mosquito spread virus infections illustrate what progress has been made in dealing with acute serious community infections. The collaboration between different countries and contributions of both materials and consultants from the developed countries is also part of this phase and must further be encouraged. The more basic reasons behind the cholera epidemic in Kiribati, high rates of typhoid in Tonga and other water and food borne diseases in the region will require a much greater provision of resources to ensure adequate clean water and improved sewage disposal that cuts down or eliminate chances for water contamination by faeces, or food transmission.

The need for greatly improved mosquito control as a means of controlling or eliminating filariasis, malaria and certain other virus infections will require a continuing effort. The increasing use of foods and other materials in tins and plastic containers provide areas for mosquito breeding along with the very common opened coconut and open water tanks.

The continuing presence of hepatitis A and B in such communities are conditions which have been important in the past, are important in the present and will undoubtedly continue to be important in the future. Vaccination programmes for hepatitis B are being developed. At present the cost is $70 per person. This is clearly unrealistic in the Pacific Island countries where annual per capita amount spent on health may be much less than this. Tonga for example in the period 1969-1979 averaged $11 per capita for health. This did not include large sums coming through aid for particular capital programmes.

Clearly improved hygiene and sanitation developments in island communities with high ambient temperatures and food storage facilities that are often inadequate and yet capable of real improvements must be part of future developments which will have widespread benefits in the control of a number of food, fly and faecal borne conditions.

Maternal and child health

Maternal and child health is one of the areas which has a major affect on population growth and overall fitness of individuals and communities. The beneficial changes that have occurred within a number of the Pacific Island countries in the past twenty years must be taken into account as we gather data on which to base our perspective on health for the 80s and to the year 2000.

Data now available suggests that improvements are taking place in a number of health areas. It is important to realize that there has been a considerable improvement in documentation of mortality statistics based on death certification using international WHO coding classification over the past 20 years and this should improve further. It is important to recognize that in a country such as the Philippines up to 60% of deaths in rural areas may not be certified by a medically trained graduate. In the South Pacific this is not the case and much greater confidence can now be placed in data from countries such as Tonga, Western Samoa, American Samoa, Cook Island, Niue, Fiji, and Tokelau.

Availability of oral salt mixture for use in the early treatment of acute diarrhoea in infants and young children represents one of the most important recent advances in public health and cutting down morbidity and mortality. The fact that they are cheap, freely available, can be kept in the houses and that parents and grandparents can be taught how to use them and to use them early in the illness is an excellent example of how simple measures can be developed if new thinking is applied to problems.

Maternal and child health and their progress provide a good measure of health developments in a community, since they involve the management of complications relating to pregnancy, the mother and the child in the neonatal period (birth to 1 month), and the next period from 1 year to 5 years when adequate vaccination programmes and supervision of childhood chest infections will provide evidence of improved status.

Effective child health care requires considerable understanding of health and illness and its management by parents, particularly the mother, and development of this through effective contacts with well trained health professionals. The tradition of breast feeding has been one of the important mainstays of infant care in the Pacific Island countries. The erosion of this by a desire to move to artificial feeding and so to follow what mothers hear is so common in the developed meccas such as New Zealand and Australia is becoming widespread. This increases the risk of gastrointestinal infections and other upsets particularly where mothers are inadequately trained in milk preparation and bottle sterilization. Some reversal of this trend with moves back to a higher percentage of breast feeding may be occurring .

Vaccinations in infancy including BCG in the first 2 weeks, polio vaccinations, whooping cough, diptheria and measles can be used as measures of the effectiveness of health programmes in the area of infant and child health.

Primary health care

The development of the concept of Primary Health Care may prove to be one of the most important factors in bringing about improved health in many parts of the world, particularly in developing countries. Up to the present these countries have often placed excess reliance on small numbers of medically trained persons which has led to great inequalities in the distribution and quality of medical care.

The WHO/UNICEF Conference at Alma Ata in 1978 was of major importance and gave a lead to the adoption of Primary Health Care programmes. Certain of the important principles in the Declaration of Alma Ata are set out in Annex 1 as they constitute a central part of the changes taking place in ideas on health care (WHO, 1978).

It can be seen from the Declaration that real efforts to develop and implement primary health care by efforts of the world community to support national and international commitment with increased technical and financial support could be of enormous value particularly to the developing countries. Many of the Pacific countries come into this category and this will test the strengths of the Pacific Way as we move towards the year 2000.

Chronic non-infectuous diseases - the diseases of affluence

These conditions are of particular importance in the Pacific because of the wide variation in extent and distribution they demonstrate in different populations. The past and present history of the status within the Pacific region of such conditions as hypertension, diabetes and gout make a fascinating study. This varying pattern in different societies and at different times gives an indication of the potential for their prevention and control which thereby broadens our perspective concerning them.

The perspective on health which we are developing places considerable weight on the extraordinary range or gradient that can be seen within the Pacific region for certain conditions which are both important, very common and a major concern as contributors to both morbidity (sickness) and to mortality in Western developed societies. Hypertension and diabetes will be discussed as examples of conditions of importance.

Hypertension

Hypertension is the most important contributor to stroke and one of principal risk factors for coronary heart disease (CHD) due to atheroma of coronary arteries. Hypertension also causes heart disease in its own right.

Blood pressure patterns range from those areas where blood pressure shows little or no increase with age, such as Pukapuka in the Northern Cooks (Prior et al., 1968), parts of New Guinea (Sinnett and Whyte, 1976) and the Solomons (Page et al., 1974), to places such as Rarotonga (Prior et al., 1968), Western Samoa (Zimmett et al., 1980), and Nauru where blood pressure increases with age in ways similar to Western societies and diabetes rates are among the highest in the world (Zimmett et al., 1977).

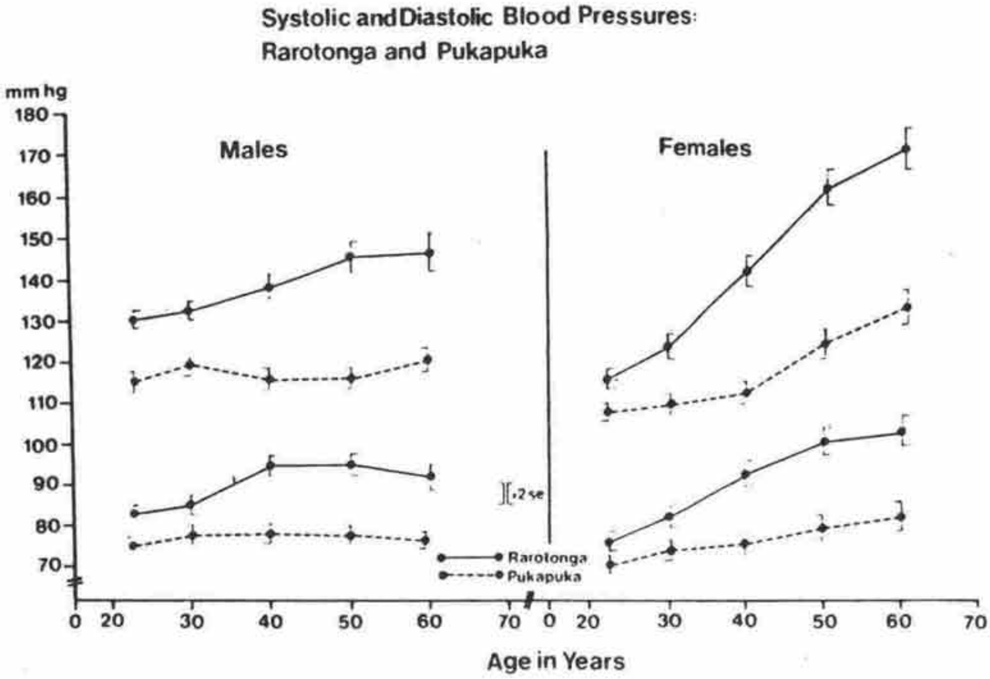
The differing extent of hypertension can be seen in Table 1 where the age adjusted rates of definite hypertension (WHO criteria systolic blood pressure 160 mmHg or greater and or diastolic pressure 95 mmHg or greater) are set out for different Pacific populations studied by the Wellington Hospital Epidemiology Unit (Prior, 1974).

Table 1 : Definite hypertension age standardized rates per 1000 in different Pacific populations

	MALES	FEMALES
N.Z. Maori	287.6	317.6
N.Z. Europeans	265.9	224.9
Rarotonga	343.4	365.7
Pukapuka	46.6	82.3
Tokelau (1968)	79.7	151.2

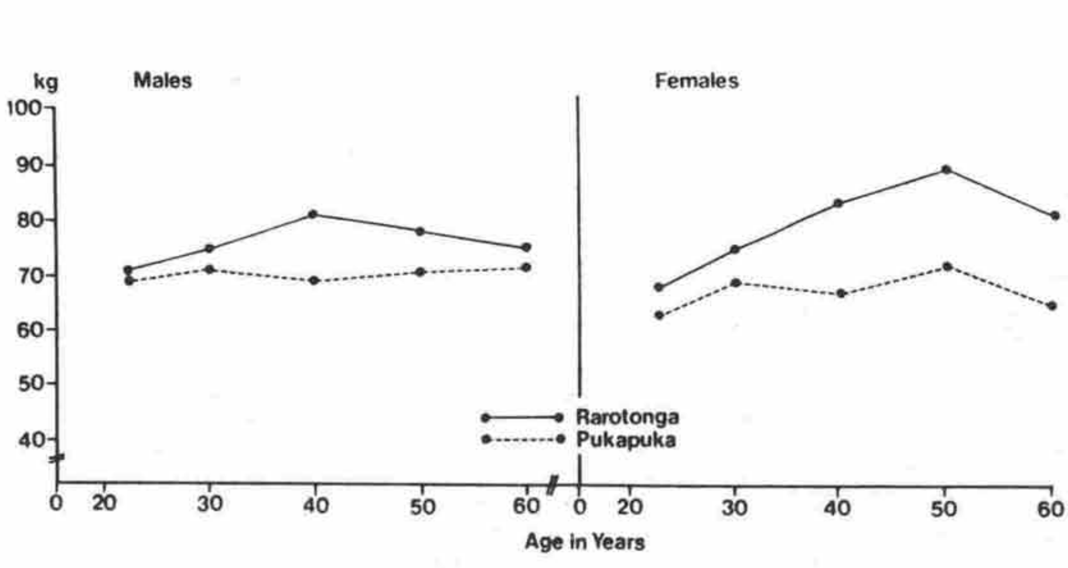
The age specific mean systolic and diastolic pressures for those adults seen in Pukapuka and in Rarotonga are shown in Figure 1. The contrast between the two populations in the rates of rise of blood pressure with age is well shown.

Figure 1 : Mean systolic and diastolic blood pressures by sex
Rarotonga and Pukapuka



The Rarotongans were considerably heavier than the Pukapukans and this is well seen in Figure 2 showing the age specific means for males and females.

Figure 2 : Mean weights in kg by sex, Rarotonga and Pukapuka



A correlation between blood pressure and weight was shown in both populations but this could not account for the extent of the differences observed.

This focussed attention on other possible factors including habitual salt intake and stress. Measurements of stress are difficult to carry out and to quantify and were not pursued at that time. These studies showed significant differences in the habitual salt use between Pukapuka and Rarotonga which gave important insights into the part sodium and potassium intake may play in relation to blood pressure level in communities. The intake was 40mmol/24 hours in Pukapuka and 120-140 mmol/24 hours in Rarotonga (Prior et al., 1968).

Subsequent work by Page and the Harvard group has examined the relationship between salt user and blood pressure in Solomon Island groups (Page et al., 1974). They showed that while all groups had low pressures, the levels were certainly higher in those from the area where cooking methods and catering customs gave them a notably higher sodium intake.

These natural experiments from the Pacific have strengthened the hypothesis of a link between habitual salt use and blood pressure, and has given support to the hypothesis that within a community there are some people and families more sensitive to salt intake than others who, above a certain threshold, will respond by developing hypertension. Below this threshold of around 40-60 mmols blood pressures remain lower and hypertension does not develop.

The data collected by the Epidemiology Unit in Cook Islands, Tonga and Tokelau support this hypothesis in a general way without being able to show a consistent within population relationship of blood pressure to salt intake.

It is now recognized that intake of potassium containing foods may have a protective effect tending to lower blood pressure and a high intake of potassium in many of the low blood pressure populations supports this. The correlation of the urinary sodium to potassium ratio with systolic and diastolic blood pressure shows a definite contribution in some studies, This effect was not apparent in those seen in Tokelau but becomes a definite contributing factor to blood pressure with the increasing time Tokelauans live in New Zealand where they move onto a higher sodium and lower potassium intake.

There is now reasonable evidence to show that a high potassium intake is in fact protective against blood pressure increase and this reinforces the conclusion that any efforts to restrict sodium input should be linked with high potassium intake through a diet rich in vegetables and potassium rich substances (McGregor, 1983).

Other research is seeking to test whether there is a genetic abnormality present in subject who have hypertension and in their children before the condition is apparent in the latter (Garay and Meyer, 1979). The red cell is used as a model to represent how the muscle cell of the wall of the small arterioles or blood vessels may be responding to sodium and potassium. Evidence is suggesting that the membrane of the red cell and white cells do react in an abnormal way indicating some abnormality in sodium pump mechanism whereby sodium content in red and white cells is increased in subjects with essential hypertension and also in their normotensive children. This is considered as a genetic abnormality and could help establish the genetic contribution in subjects developing hypertension. It could also identify subjects at higher risk before hypertension had declared itself.

This represent an exciting development that is very relevant to the perspective we are considering, particularly as there is the opportunity to examine such biological factors in subjects undergoing migration and changes in blood pressure.

This example is set out in some detail to illustrate how epidemiology as a discipline can help in the generation of scientific hypotheses and how the Pacific work had made its contribution to areas that can now be moved forward by detailed basic research at cellular and membrane level. The next phase represents development of intervention programmes at the community level in order to test further the part salt restriction and potassium increase can play in lowering blood pressures and reducing the attributable community risk of hypertension and its complications. We will return to this when considering the future of the Pacific Island regions in the period of the 1980s to 2000.

The changes described above can occur in communities undergoing modernization or as a result of urbanization. These processes can take place within a particular geographic location and society or when people migrate to a new society. These issues and their important consequences will be discussed further in the next section.

Migration, urbanization and health changes

The importance and extent of migration in the Pacific has already been referred to in the Pacific as people move to find work and improved living conditions. The majority are hoping to provide better opportunities for education for their children and a life that can include the "good things" they associate with a cash economy. Younger people migrate for schooling or for trade training or simply to have the chance to see and take part in greater opportunities they have heard about.

The migration may take place from outer island to main island centre, from rural villages to the urban centre or from Pacific Islands to the western industrial societies such as New Zealand and Australia.

The contrast between different groups for conditions such as blood pressure has been referred to and is shown in Figure 1 and Figure 2 for Rarotonga and Pukapuka. Studies of urban and rural groups in Samoa and Tonga have shown that the urban groups have significantly higher blood pressures and are heavier compared with those in the rural villages (Zimmett et al., 1980; Finau et al., 1983).

The factors influencing the changes of blood pressure with age may provide important information concerning hypertension and the way in which it develops and so give more effective leads to its prevention. The opportunity to study subjects moving from a society where blood pressure is not common to one where blood pressure increases with age and contributes to a range of cardiovascular problems has been presented by the Tokelau Island Migrant Study and some of these results will be detailed. The basic hypotheses being tested concerning social change and disease were first put forward by the late John Cassel and their testing has been an important part of the Tokelau Island Migrant Study. The first relates the changes in blood pressure to physical factors including changes in diet, higher calorie intake, an increase in sodium and a decrease in potassium intake, gain in weight and other life style changes; the second involves psychosocial factors such as a stressful life changes, status incongruity, weakening or loss of support systems and coping strategies. It has also to be recognized that both hypotheses may play a part.

The Tokelau Island Migrant study was commenced in 1967 with the support of the Medical Research Council of New Zealand and the World Health Organization, and has been developed as a multidisciplinary longitudinal study (Prior, 1974).

Tokelau is made up of three small atolls, (Fakaofo, Nukunonu and Atafu), lying some 480 km north east of Samoa. Tokelau became a New Zealand dependency in 1925 and the inhabitants were granted N.Z. citizenship in 1948. Tokelauans are of Polynesian origin and constitute a distinct atoll society with many features that are unique compared to other groups in the Pacific.

In 1966 the population was 1980 in Tokelau, around 600 in N.Z., 600 in Western Samoa and 160 in Hawaii. A hurricane in January 1966 caused some devastation with loss of coconut trees and damage to buildings. The N.Z. Government set up a resettlement programme aiming to bring around 1000 of the population to New Zealand over a five year period. The Tokelau Island Migrant Study was established in 1967 and has been maintained since then. There have been major rounds of medical examinations in Tokelau in 1968, 1971, 1976 and 1982 and in N.Z. in 1972-74, 1975-77 and 1980-81. In 1980-81 there were 2570 tokelauans in N.Z. and in 1982, 1650 in Tokelau. The involvement of social anthropologists from the outset and the inclusion of Tokelauans in the study team has helped expand and develop the study and also to maintain a very high participation rate of around 94-95% in New Zealand and 97-99% in Tokelau (Prior, 1974).

The genealogies collected by the anthropologists have been built up into a major pedigree file that is now allowing more critical examination of the part played by genetic and environmental factors in a number of important medical conditions including hypertension, diabetes, coronary heart disease risk factors, asthma and joint disorders (Ward et al., 1980).

There have been a number of publications relating to the different aspects of the Tokelau Island Migrant Study but in this paper the main emphasis will be on the difference in blood pressure, weight and diabetes between those non migrant in Tokelau and the migrants in New Zealand. A bibliography of publications relating to the Tokelau Project is included in the Proceedings of a Seminar on Migration Adaptation and Health in the Pacific (Prior, 1981).

Blood pressure

A comparison of age specific mean systolic and fourth phase diastolic pressure by age and sex for Tokelau in 1976 and New Zealand 1975-77 examinations are set out in Figure 3 for males and Figure 4 for females. The significant differences are indicated. It can be seen that the increases in pressure are greater in male than in female migrants and are evenly distributed among the age groups. The females can be seen to have a steeper increase with age. Adjusting for age and body mass the mean differences in systolic and diastolic pressures between the migrants in N.Z. and those in Tokelau were 7.2 mmHg ($p<0.001$) and 9.1 mmHg ($p<0.001$) respectively for males and 1.0 mmHg (p0.325) and 2.7 mm ($p<0.001$) respectively for females (Joseph et al., 1983).

Figure 3

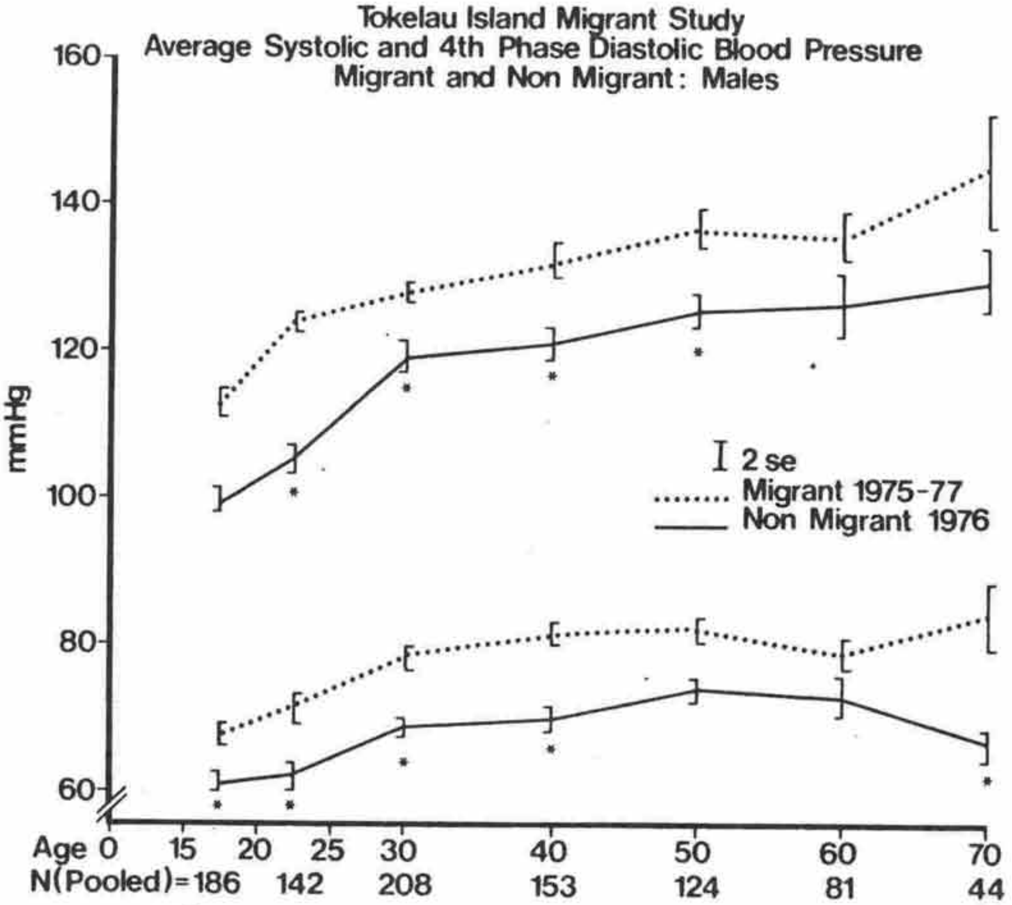
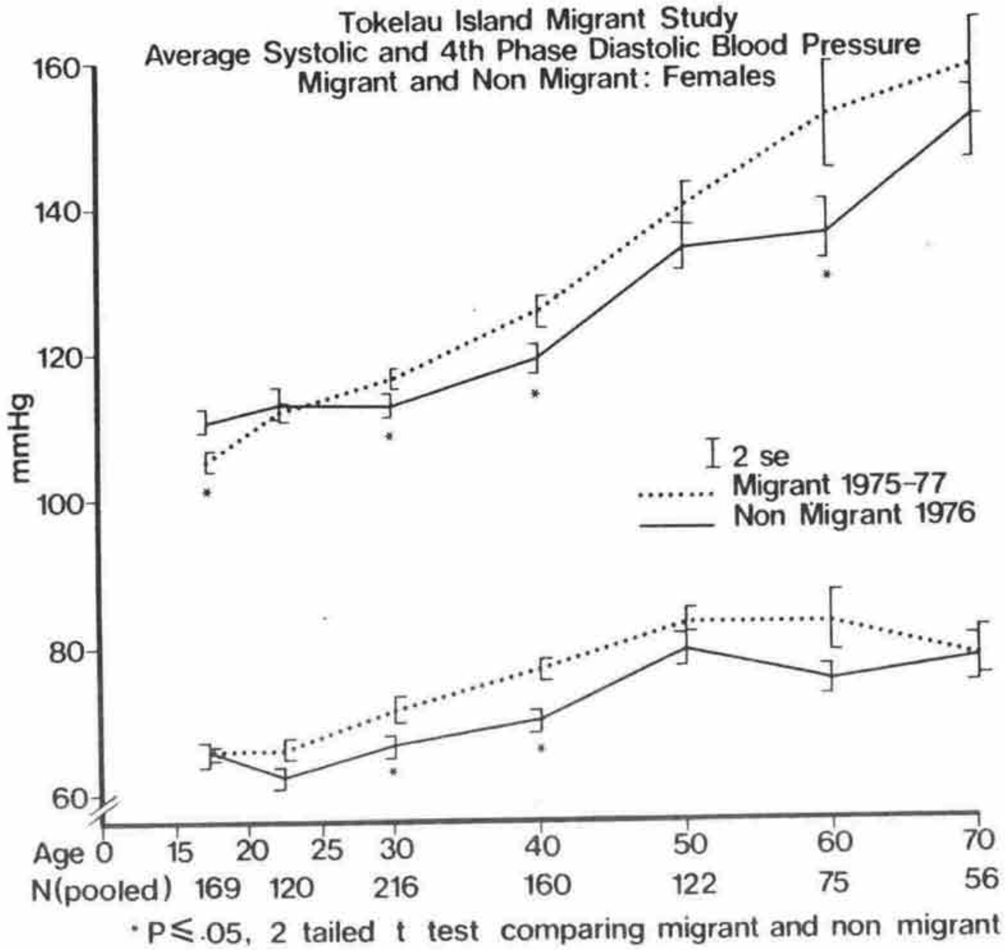


Figure 4



Weight and Body Mass Index (BMI) $\frac{\text{Wt in kg}}{(\text{Ht in cm})^2}$ increases are an important and common finding in migrants and data from Tokelauans in N.Z. confirm this. The BMI by age and sex are set out in Figure 5 for males and Figure 6 for females. Correlational analyses shows a strong correlation of BMI and blood pressure in both sexes. The longitudinal analyses of the same subjects first seen in Tokelau and then either in N.Z. as migrants or still in Tokelau as non migrants has shown similar directional changes with the males in New Zealand showing a greater rate of increase in both systolic and diastolic pressures compared with females in N.Z. These changes support the development of an increased cardiovascular risk status in the migrants in New Zealand.

The changes in blood lipids including cholesterol and the lipoprotein fractions including the protective high density lipoprotein cholesterol are also in the direction of increased risk in New Zealand. It is these combinations of changes in the migrants relating to increased risk that give some insights into how preventive programmes might be developed.

At the same time it can be seen that the health potential of those who remain on their home islands or villages would be best preserved and developed if a rapid move towards western style foods, diet and lifestyle can be contained or slowed down by preservation of their more traditional and healthy foods, patterns of habitual exercise and coping strategies for individual, family and community problems. Diabetes provides a further indicator condition that allows us to examine the effect of urbanization, migration and modernization.

Figure 5

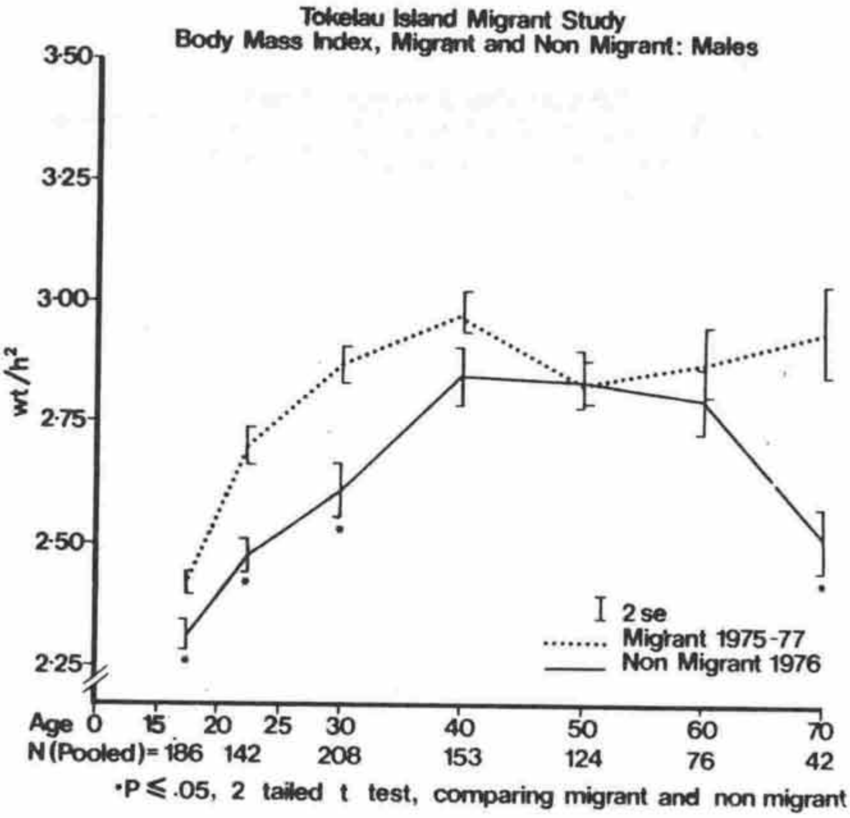
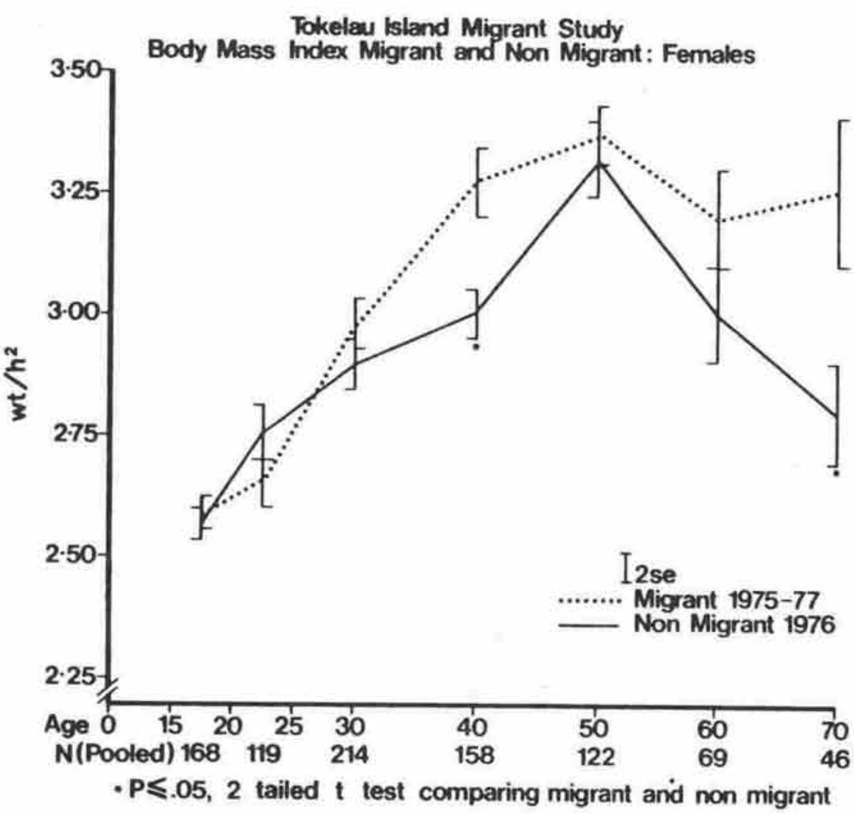


Figure 6



Diabetes

Diabetes is a common condition in Western societies and has some important and unusual features. Involving 2-4% of adults, it has been shown that the condition accelerates arteriosclerosis and its consequences and that diabetic women have a rate of CHD (coronary heart disease) that is similar to men. In non-diabetics, the sex ratio of CHD is around 4 males to 1 female. Diabetes is also associated with hypertension. The pattern in Pacific countries is an important part of the perspective we are considering.

Within the Pacific there is a remarkable range in the extent of diabetes - from population samples where the prevalence and incidence is low (e.g. New Guinea, Pukupuka) to those where it is common and increasing (Table 2). This is seen particularly where groups are undergoing urbanization or migration as in Western Samoa, Tokelau, Fiji and finally Nauru which ranks with the Pima Indians of Arizona as having the highest rates in the world (Zimmett, 1977; Prior and Brauer, 1979; Zimmett, 1982).

Table 2 : Diabetes in the Pacific Region 1975-1981
Age-standardized prevalence rates*

Geo-ethnic group		No. studied (20 years and over)	Diabetes Prevalence (%)
Micronesians	Nauru	456	30.3
	Kiribati** (rural)	1083	2.7
	(urban)	1917	7.5
Polynesians	Tuvalu	397	3.9
	Western Samoa (rural)	745	2.7
	(urban)	744	7.0
	Cook Islands**		
	Rarotonga	1177	6.0
	Manihiki	133	6.6
	Wallis Island**	579	2.7
	Niue**	1192	7.3
Melanesians	Loyalty Islands	535	2.0
	New Caledonia	172	1.5
	Fiji (rural)	477	1.8
	(urban)	861	6.9
	Papua New Guinea (rural)	105	0.8
	(urban)	184	15.4
Indians	Fiji (rural)	452	13.3
	(urban)	848	14.8

* Age standardized to Western Samoa Census (1976)
** Recent survey - data not yet age standardized
Diabetes prevalence according to WHO criteria
Table provided by P. Zimmett, Epidemiology Unit, Royal Southern Memorial Hospital, Melbourne, Australia (includes some results published in Zimmett, 1982)

The Nauruans stand out as suffering from the most severe epidemic of 20th century affluence and this is playing an important role in contributing to the high rate of diabetes. A mean per capita income of around $39,000 for each Nauru man, woman and child has given them extraordinary opportunities for indulgence in many areas including food, alcohol and decreased physical activity.

The genetic predisposition, or genotype, for diabetes is thought to be common in most communities and obesity is the factor which is the most important risk factor for the type now classified by WHO as Non Insulin Dependant Diabetes Mellitus (NIDDM) (WHO, 1980). Obesity is not a new phenomenon in the Pacific and many Pacific people have experienced traditional affluence even though their material resources are limited. Adequate or more than adequate food supplies, bounteous climate and soil, and limited demands for sustained daily exercise have allowed obesity to be common in areas such as Hawaii, Kingdom of Tonga and parts of French Polynesia. Those on atolls with more limited resources and different lifestyles such as on Pukapuka have not had the resources to allow them to become obese. Early explorers described some obese people in different part of the Pacific but no data is available about their health status.

The emergence of diabetes in Tokelau migrants in New Zealand compared with non migrants in Tokelau is providing valuable insights into the risk factors associated with development of diabetes and the part played by diet (Stanhope and Prior, 1980). The duration of time in New Zealand and the emergence of new or incident cases can be compared in the two groups and with results from long term studies carried out among New Zealand Maoris.

The BMI differences between Tokelau migrants and Tokelau non-migrants are clearly shown in Figure 5 and Figure 6 for males and females respectively. The prevalence of diabetes among Tokelauans in Tokelau, in New Zealand and among New Zealand Maori are shown in Table 3.

Table 3 :
Age standardised* prevalence (per hundred) of definite diabetes, by sex, at two points in time in Tokelauans (in Tokelau and in New Zealand) and New Zealand Maoris, aged 24 and over.

	Tokelauans in Tokelau		Tokelauans in New Zealand		New Zealand Maoris	
	1968/71	1976	1972/74	1975/77	1968/69	1974
Male	1.0	3.7	5.6	5.4	10.7	12.4
Female	3.3	8.6	8.0	13.6	11.1	16.4

* Indirect standardisation using pooled groups as reference population.

The increasing rate, particularly in Tokelau women in New Zealand can be seen, while those in men are not significantly different. The notably higher rates in the Maoris can be seen.

The relationship with bodymass using the BMI can be examined further by studying the rates of diabetes in subjects by sex and ethnic group in different tertiles of BMI. These are set out in Table 4.

The rates in the women increase in the second tertile in both Maoris and Tokelauans while the increases are most marked in the third tertile in the males. The overall rates among Maoris are notably higher in both men and women than in Tokelauans in the same tertile. The question whether further increases will take place in the N.Z. Tokelau groups will be examined in the prospective surveys.

The development of incidence cases, that is cases who did not have diabetes when first examined, have been estimated in three groups, the non-migrants, those in Tokelau, the migrants, those seen in Tokelau and then in N.Z. and the post-migrants, those first seen in N.Z. and then followed in N.Z. A number of the latter had spent time in Samoa en route to N.Z., or were in N.Z. prior to first examinations by the Epidemiology Unit.

Among females, post-migrants had the highest incidence, 21.8 per 1000 per year, and non-migrants the lowest, 6.1, while migrants were intermediate, 14.1 (X^2 = 13.486 p = 0.001). Among males, the incidences were: post-migrants 11.0, non migrants 4.5 and migrants 5.2, but the differences were not significant (X^2 = 4.175 p = 0.124).

Table 4 : Age-Standardized Prevalence of Definite Diabetes in Polynesians by Sex and Tertiles of Body Mass Index (W/H^2) (Ages 35-74)

	Body Mass Index		
Males	Low (<2.45)	Medium (2.46-2.77)	High (>2.78)
Maori (New Zealand)	3.9%	4.1%	14.8%
Tokelauans (New Zealand)	1.9%	4.3%	6.3%
Tokelauans (Islands)	2.1%	1.5%	3.6%

	Body Mass Index		
Females	Low (<2.59)	Medium (2.60-3.03)	High (>3.04)
Maori (New Zealand)	3.1%	11.3%	12.8%
Tokelauans (New Zealand)	2.9%	6.7%	8.5%
Tokelauans (Islands)	2.5%	4.3%	9.1%

These are high rates, particularly in the females, and pose a major health risk. This is confirmed by comparisons with incidence rates of 16 per 1000 per year in Maori males and 24.0 per 1000 per year in Maori females and rates of 25 per 1000 per year in Pima Indians.

The work done by Zimmett and others has shown that diabetes constitutes a problem in a number of other populations in the Pacific, and with increasing affluence and development will carry with it the increased extent of atheroma and vascular complications that can cause serious morbidity and mortality (Zimmett et al., 1977).

The challenge being faced now is to find out how best preventive measures can be undertaken in a way that involves the individual and community.

Primordial prevention

The prevention of the development of risk factors associated with particular disorders in societies in whom these particular conditions are occurring frequently has been put forward by WHO as an important goal and is termed Primordial Prevention. It is being considered for such conditions as coronary heart disease (CHD), hypertension and diabetes. It is based on the effect known risk factors have in Western Societies and assumes that to reduce these or prevent them developing will limit the emergence of the condition (WHO, 1982).

In CHD it is hypertension, smoking and raised cholesterol that must be controlled. In hypertension, avoidance of weight gain, salt restriction, and increased potassium intake by dietary manipulation are important. In diabetes, weight control, exercise and diet to ensure high fibre intake are important.

While the concept is excellent, the execution will prove difficult and will require a commitment to health that is far greater than has been shown. The pattern of resources and the inequities of distribution within the region are of utmost importance.

In 1969 the Kingdom of Tonga spent 3.97 dollars per capita of population on health, 11.7 percent of the total budget. In 1979 this had risen to 11.45 dollars, 13.2 percent of total budget, while the same year New Zealand spent 300 dollars per head on health. Australia and N.Z. have a major responsibility to help the Pacific countries in areas relating to health where this has been given a priority by the country concerned. The assistance to strengthening of health services through WHO, the South Pacific Commission and countries such as Australia and N.Z. constitutes a body of important resources that can be used in many ways.

Conclusion

The concept of Primary Health Care, of Primordial Prevention of chronic non-infectious diseases, and of the Pacific Way bring together a valuable triad which has the opportunity of enhancing greatly a number of important areas of health and living in the Pacific.

Health cannot be separated from other aspects of individual and community growth and has to be accepted as one of the areas in which their input is of importance. Increasing responsibility for one's own health and for that of the family and community does not arise de novo and requires provision of carefully collected information as part of the data base. The work already carried out and referred to in this paper illustrates the part that epidemiology has to contribute in defining the extent of disorders such as hypertension and diabetes and the factors which contribute to their development. Programmes in these areas of individual and community health education and health promotion are the next important developments that must be systematically tackled in ways that are suited to the particular people, their customs and their environment (Prior and Tasman-Jones, 1981; Prior and Stanhope, 1980).

"Health for all by the year 2000" is a clarion call put out by WHO but is a goal which will be difficult, if not impossible, to achieve. Our efforts to move towards this in the Pacific countries will be more effective if we note how much progress has been made and make a real investment in our efforts and in the Pacific Way of moving towards the goal.

ACKNOWLEDGMENT

The author wishes to acknowledge the support of the Medical Research Council of New Zealand, the Cardiovascular Disease Unit of WHO, the Wellington Hospital Board and the many members of the Unit staff who have contributed to the Unit Research programme, and the Pacific people and communities who have been involved.

REFERENCES

Finau, S. A. et al. 1983. The Tonga cardiovascular and metabolic study: design, demographic aspects and medical findings. Community Health Studies 7(1):67-77.

Garay, R. P. and P. Meyer. 1979. A new test showing abnormal net Na+ and K+ fluxes in erythrocytes of essential hypertensive patients. Lancet 1:349.

Joseph, J., I. A. M. Prior, C. S. Salmond, and D. Stanley. 1983. Elevation of blood pressure associated with migration. The Tokelau Island Migrant Study. J. Chron. Dis. 36:507-516.

Kuberski. T., T. Flood, T. Tera and the New Zealand Cholera Relief Team. 1979. Cholera in the Gilbert Islands. I. Epidemiological features. Am. J. Trop. Med. Hyg. 28(4):677-684.

Laird, M., J. Mokry, A. Semese and R. Uili. 1982. Field trials of innovative control agents in Tuvalu, South Pacific, towards an integrated methodology against Aedes aegypti. Abstracts, IIIrd International Colloquium on Invertebrate Pathology, Brighton, U.K. p. 138.

Lambert, S. M. 1941. A Doctor in Paradise. J.M. Dent and Sons, Great Britain.

McGregor, G. A. 1983. Nutrition: the changing scene. Dietary sodium and potassium intake and blood pressure. Lancet p. 750.

Miles, J. A. R. 1979. Ross River Fever comes to Fiji. Fiji Med. J. 7:216-217.

Page, L. B., A. Damon, and R. C. Moellering Jr. 1974. Antecedents of cardiovascular disease in six Solomon Island societies. Circulation 49:1132.

Palmer, A. S. and Parshu Ram. 1976. Dengue Fever in Fiji 1975. Fiji Med. J. 14:9.

Prior, I. A. M. 1974. Cardiovascular epidemiology in New Zealand and the Pacific. N. Z. Med. J. 80:245-252.

Prior, I. A. M. 1981. The Tokelau Island migrant study: bibliography, p. 39-43. In C. Fleming and I. A. M. Prior [eds.], Migration, adaptation and health in the Pacific. Peryer Educational Books Ltd, Wellington, NZ.

Prior, I. A. M. et al. 1974. The Tokelau Island migrant study. Int. J. Epid. 3:225.

Prior, I. A. M. and G. Brauer. 1979. Epidemiology of diabetes in the Pacific, p. 63-79. In M. S. S. Ahuia [ed.], Epidemiology in developing countries. Interprint, New Delhi, India.

Prior, I. A. M., J. Grimley Evans, H. P. B. Havrey, F. Davidson and M. Lindsey. 1968. Sodium intake and blood pressure in two Polynesian populations. New Eng. J. of Med. 279:515-520.

Prior, I. A. M. and J. M. Stanhope. 1980. Blood pressure patterns, salt use and migration in the Pacific, p. 243-262. In H. Kesteloot and J. V. Joosen [eds.], Epidemiology of arterial blood pressure. Developments in Cardiovascular Medicine, vol. 8. Martinus Nijhoff Publishers, The Hague.

Prior, I. A. M. and C. Tasman-Jones. 1981. New Zealand Maori and Pacific Polynesians, p. 227-267. In H. C. Trowell and D. P. Burkitt [eds.], The Western diseases: their emergence and prevention. Edward Arnold Publishers Ltd, London.

Roberts, A. B. et al. 1979. Cholera in the Gilbert Islands. II. Chemical and laboratory findings. Am. J. Trop. Med. Hyg. 28(4):685-691.

Sinnett, P. F. and H. M. Whyte. 1976. Epidemiological studies in a total highland population Tu Kenta. J. Chron. Dis. 26:205.

Stanhope, J. M. and I. A. M. Prior. 1980. The Tokelau Island migrant study: prevalence and incidence of diabetes mellitus. N. Z. Med. J. 92:417-421.

Ward, R. H., A. B. Hooper, and J. W. Huntsman. 1980. Pedigree and blood pressure: genetic epidemiology in a migrant isolate, Tokelau. In H. Cairns, J. L. Lyon and M. H. Skolnick [eds.], Cancer incidence in defined populations. Coldspring Laboratory, Coldspring Harbor, USA. p. 351.

WHO. 1978. The Alma Ata Conference on Primary Health Care. WHO Chronicle 32(11):407-458.

WHO. 1980. World Health Organization Expert Committee on Diabetes Mellitus, 2nd Report. Technical Report Series 646. WHO, Geneva.

WHO. 1982. Primordial prevention of cardiovascular disease in developing countries. Report of WHO Task Force, Geneva.

Zimmett, P. et al. 1977. The high prevalence of diabetes mellitus on a central Pacific Island. Diabetologia 13:111.

Zimmett, P. et al. 1980. Blood pressure studies in rural and urban Western Samoa. Med. J. Aust. 2:202.

Zimmett, P. 1982. Type 2 (non insulin-dependent) diabetes - an epidemiological overview. Diabetologia 22:399-411.

ANNEX 1

DECLARATION OF ALMA ATA

I. The conference strongly reaffirms that health, which is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity, is a fundamental human right and that the attainment of the highest possible level of health is a most important worldwide social goal whose realization requires the action of many other social and economic sectors in addition to the health sector.

II. The existing gross inequality in the health status of the people, particularly between developed and developing countries as well as within countries, is politically, socially and economically unacceptable and is, therefore, of common concern to all countries.

III. Economic and social development, based on a New International Economic Order, is of basic importance to the fullest attainment of health for all and to the reduction of the gap between the health status of the developing and developed countries. The promotion and protection of the health of the people is essential to sustained economic and social development and contributes to a better quality of life and to world peace.

IV. The people have the right and duty to participate individually and collectively in the planning and implementation of their health care.

V. Governments have a responsibility for the health of their people which can be fulfilled only by the provision of adequate health and social measures. A main social target of governments, international organizations and the whole world community in the coming decades should be the attainment by all peoples of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life. Primary health care is the key to attaining this target as part of development in the spirit of social justice.

VI. Primary health care is essential health care based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost that the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination. It forms an integral part both of the country's health system, of which it is the central function and main focus, and of the overall social and economic development of the community. It is the first level of contact of individuals, the family and community with the national health system bringing health care as close as possible to where people live and work, and constitutes the first element of a continuing health care process.

VII. (Sets out details of aspects of Primary Health care under 7 headings)

VIII. All governments should formulate national policies, strategies and plans of action to launch and sustain primary health care as part of a comprehensive national health system and in coordination with other sectors. To this end, it will be necessary to exercise political will, to mobilize the country's resources and to use available external resources rationally.

IX. All countries should cooperate in a spirit of partnership and service to ensure primary health care for all people since the attainment of health by people in any one country directly concerns and benefits every other country. In this context the joint WHO/UNICEF report on primary health care constitutes a solid basis for the further development and operation of primary health care throughout the world.

X. An acceptable level of health for all the people of the world by the year 2000 can be attained through a fuller and better use of the world's resources, a considerable part of which is now spent on armaments and military conflicts. A genuine policy of independence, peace, detente and disarmament could and should release additional resources that could well be devoted to peaceful aims and in particular to the acceleration of social and economic development of which primary health care, as an essential part should be allotted its proper share.

PACIFIC ISLANDS' HYDROGEOLOGY AND WATER QUALITY

W.R. Dale* and **B.C. Waterhouse****
Department of Scientific and Industrial Research, Wellington, New Zealand*
and
New Zealand Geological Survey, Otara, New Zealand**

ABSTRACT

Water is the most critical of all resources on oceanic tropical islands. In most cases the ability to carry out detailed studies is limited but technical experience has been gained from practical fieldwork.

Following some six years research on a range of Pacific Islands it is suggested that for practical purposes the Gybern-Herzberg principle be adhered to. Undoubtedly some modification will be made in the future but at present basic information needs to be obtained on the size, shape and thickness of the fresh-water body - the lens in the case of atolls, and subterranean flows on the higher islands.

Monitoring of both the levels of fresh water in drilled or dug wells and of the salinity are also requirements to ensure safe levels of abstraction.

Water quality from limestone bodies is similar from different parts of the Pacific but provides problems for some industrial uses. That from volcanic reservoirs differs noticeably from limestone sources in chemical constituents.

A major knowledge gap about potable waters is the lack of information, especially on a regular basis, about biological contamination.

Introduction

It has long been known or suspected that useful fresh ground-water supplies can be obtained from oceanic islands in the Pacific. Until recently, however, its discovery and subsequent abstraction has largely been a matter of trial and error.

The islands fall into three categories, conveniently termed High Islands, Raised Coral Atolls, and Coral Atolls. Each are briefly described below, together with the findings of a few workers engaged on oceanic-island water-supply studies.

High islands

The term is informally applied to islands with an emergent volcanic core surrounded by narrow coral reefs (Figure 1). The volcanic interior may be rugged or 'mountainous' e.g. Rarotonga, Western Samoa, Hawaii, or domed, or plateau-like, e.g. Mangaia (Cook Islands), Wallis and Futuna.

Geology

The high islands are formed by volcanos rising from the sea floor in a series of spasmodic eruptive events spread over a period of a few tens of million years. A complex history of elevation, subsidence, and fluctuating sea level is indicated by fringing coral reefs which are recorded at various heights on the flanks of the volcanic pile below sea level, and up to 70 m above present day sea level (asl).

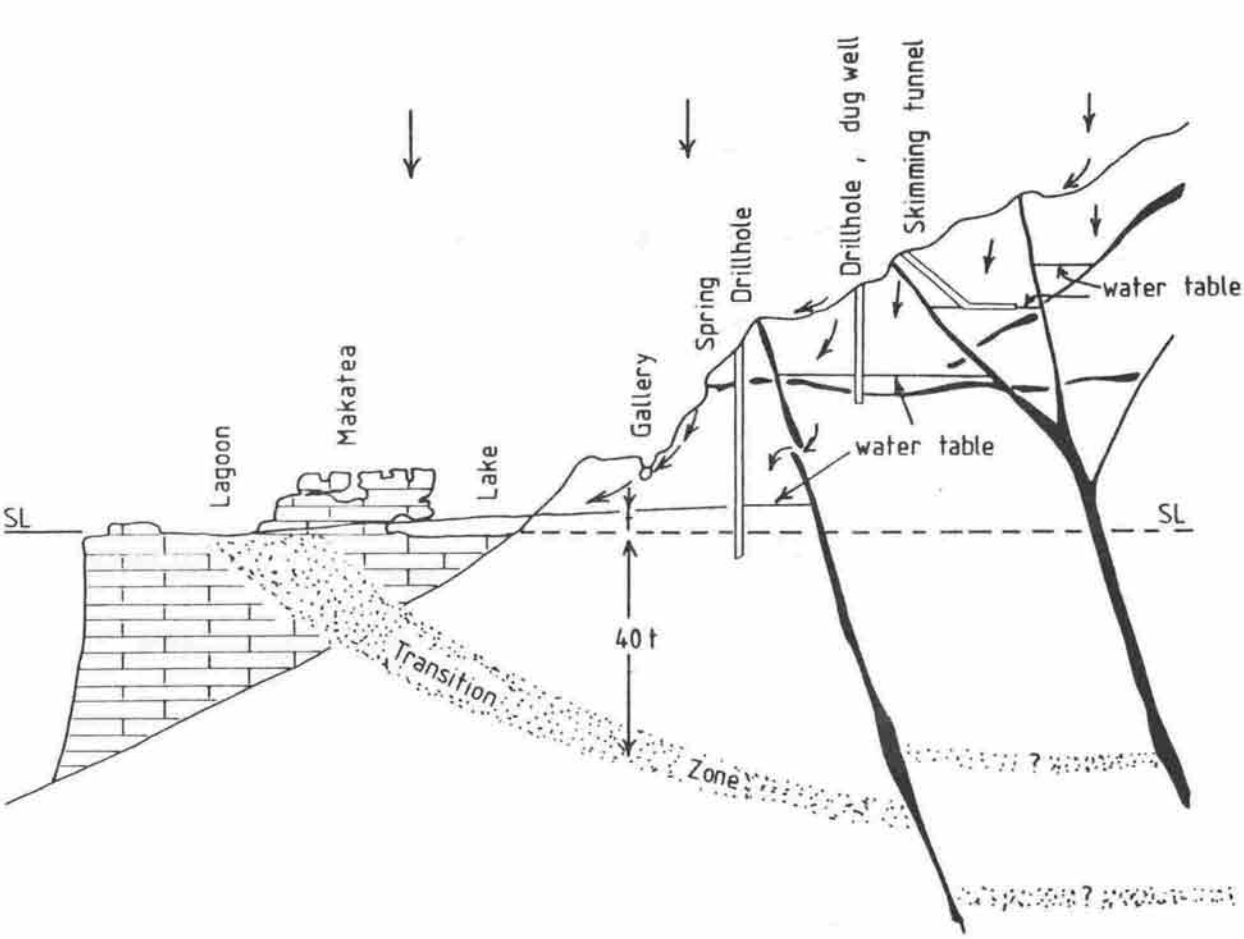


Figure 1 : High island (half width) showing emergent volcano with feeder dikes and sills, and flanking coral reef. Rain water is shed by direct runoff, or percolates to water compartments in the volcanics or to the fresh-water lens.

Hydrology

Oceanic islands' water resources are derived entirely from rainfall. The volcanics of the high islands are relatively impermeable and much of the precipitation is shed as surface runoff via streams. That part which penetrates the rock to the water table can be perched or confined to ground-water compartments formed by dikes, sills, or flows. Leakage from these confining beds allows ground water to percolate vertically or laterally to lower level, and ultimately it replenishes a fresh-water lens (described below), the surface of which might be a few centimetres asl.

The surrounding reef, part of which may be up to 70 m asl, has a karst topography and water falling on its surface, and that shed from the interior volcanics moves rapidly through fissures, caves, solution channels and cracks to the fresh-water lens.

Water Resources

Fresh water is obtained from a number of sources on high islands by:

(1) Roof Catchment. Individual household tanks, or community tanks filled by specially-designed, roof-catchment structures.

(2) Streams. Direct abstraction via water intake in the stream bed and reticulated to villages, or simply by collection in buckets and tins.

(3) Galleries. Trenches dug below the water table in stream valleys, lined with porous pipes and back filled. Ground water seeps through the porous pipes and is reticulated via reservoirs or directly by pipeline to villages.

(4) Maui (skimming) Tunnels. Vertical or inclined shafts or adits dug to about the water table, and one or more horizontal tunnels constructed laterally just below the water level. Highly successful on Hawaii and also used on Tahiti.

(5) Springs. Perched aquifers leaking laterally form springs at various levels around the volcanic slopes. Some of these elevated springs, well inland, and near villages, have been tapped and the water used for drinking, washing, and bathing. At lower levels where they emerge at impermeable dike, sill or flow contacts, spring water is directed into hand-dug rock-lined shallow 'troughs' and used for community purposes. Springs also bubble up through the sand around the foreshore, and holes scooped in loose material are used for washing and bathing.

(6) Dug Wells. Hand-dug wells in weathered volcanic rocks, or in alluvial deposits near the coast provide small supplies for individual families. Their yield is generally small because of the limits imposed by physically digging below the water table.

(7) Drillholes. Generally sited on volcanics and drilled to intersect perched or near sea-level aquifers. Their yield is relatively small but following testing, it can be regulated to sustain a constant flow for an indefinite period. The depth of the hole and pump intake must be indicated before drilling commences, and the collar height surveyed accurately relative to sea level.

In the Southern Cook Group, holes drilled in the volcanics from 13 m to 100 m depth are being developed for community supplies. Pump test analyses indicate that about 1 l/s is available from the better holes, although in all cases transmissivity (an indication of the ability of the aquifer to transmit water) is low at 0.2 m^2/d to 12 m^2/d (Waterhouse and Petty, in press).

Raised coral atolls

Raised atolls comprise a submerged volcanic core surrounded and capped by generally thick coral limestone (Figure 2). The limestone, estimated to be 300 m thick on Niue, is assumed to have formed mainly in response to tectonic elevation and subsidence of the volcanic edifice, and to a lesser degree to eustatic fluctuations of sea level. Tongatapu, Niue, Nauru and Banaba are good examples of raised atolls.

Geology

Some raised atolls show the original atoll topography, as on Niue, with an old, elevated, inland lagoon surrounded by a peripheral reef ridge. Others are relatively flat, or gently sloping, the maximum height generally being between 60 m and 80 m asl., e.g. Tongatapu, Banaba.

Raised atolls are considered to be intermediate in age between the young high islands and old coral atolls because the volcanic base on which the coral became established is now nowhere in evidence but it still represents a significant part of the island's mass. Progressive overall subsidence, during which time the coral continued to grow upwards, may have been in excess of 1 kilometre over the last 30 million years, as the oldest corals recognized are Oligocene to Miocene in age.

Hydrology

The highly-permeable limestone or coral-sand surface on raised atolls allows rainfall to drain rapidly downwards to the fresh-water lens near sea level. In a few instances impermeable clays and small, impermeable depressions pond the rain water locally, but lateral runoff into more porous beds and high-evaporation rates contribute to rapid surface drying.

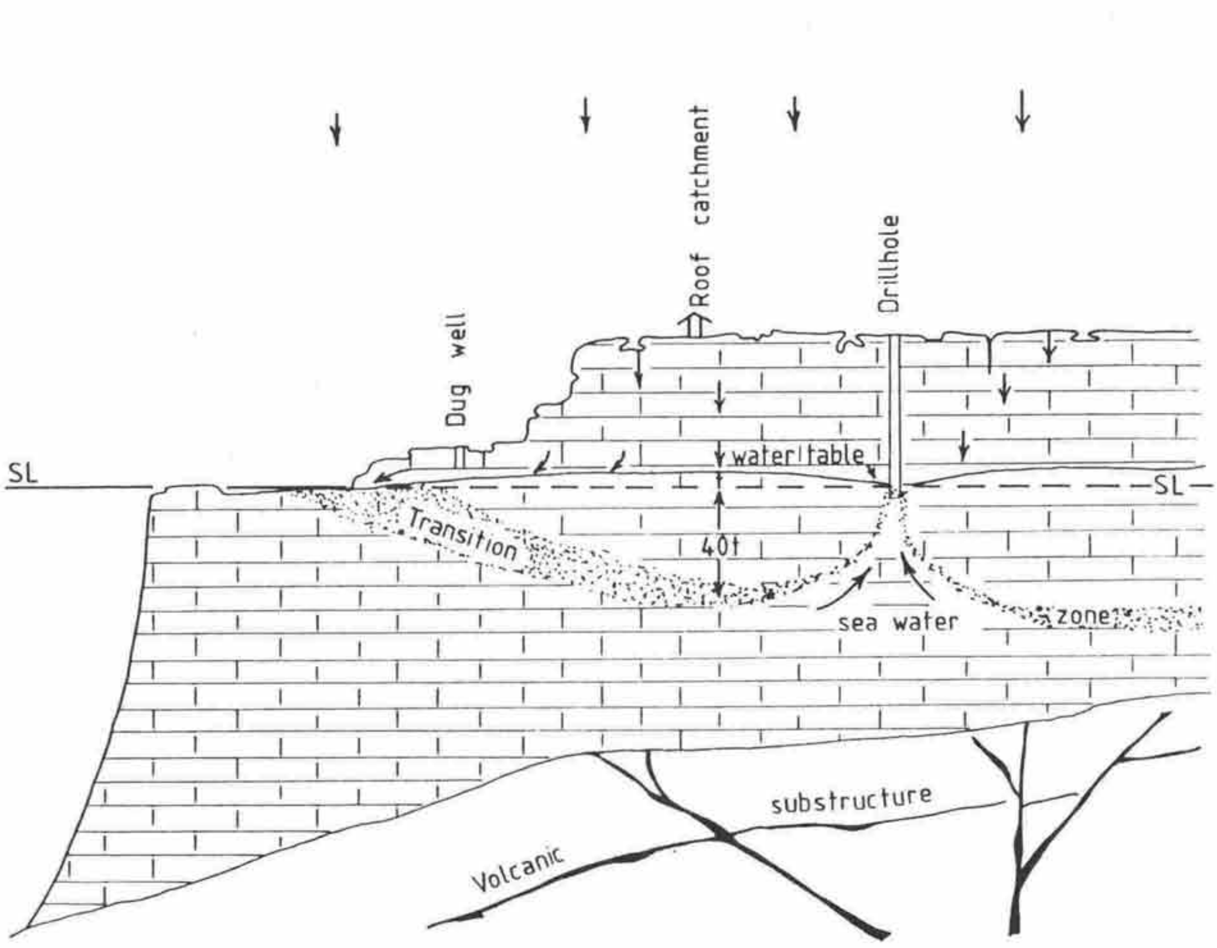


Figure 2 : Raised coral atoll (half width). Submerged volcanic core capped by coral limestone many hundreds of metres thick. No streams are present and rain water penetrates rapidly to the fresh-water lens. Overpumping, with consequent lowering of the lens surface to or below sea level, will yield salt water.

No streams are present on raised atolls and all water for local use is derived from roof catchments, drillholes, dug wells, or brackish ponds and seeps. Of these the most promising for future development are drilled wells for community/horticultural purposes, with roof catchment and shallow dug wells continuing to be used where appropriate.

Investigations of ground water resources by drilling on raised atolls over the past few years has confirmed that a thin layer of fresh water is present 'floating' on sea water. The principle, expressed by the Ghyben-Herzburg formula, is a ratio describing the static relation of fresh ground water and sea water and states that for each unit measurement of fresh water above sea level, the salt water surface will be displaced 40 times that unit measurement below sea level. Thus 0.5 m of fresh water asl is theoretically balanced by 20 m of fresh water bsl, but in practice seldom, if ever is this precise ratio ratio attained. Nevertheless, until further studies in oceanic island ground water dynamics are undertaken, this simple 40:1 ratio is acceptable as an elementary yardstick.

Two islands on which some ground-water work has been done are Niue and Tongatapu .

On Niue, Jacobson and Hill (1980) showed the fresh-water aquifer to be doughnut shaped. In the centre of the island (the old lagoon) the top surface of the aquifer is 1.83 m asl. The thickness of the fresh-water lens, inferred from resistivity data, ranges from 40-80 m in the centre to 50-170 m beneath the former atoll rim, and sea level at the coast. They concluded that the irregular shape of the lens is probably due to variations in permeability within the limestone.

Jacobson and Hill (ibid) calculated that fresh water storage on Niue amounted to about 4.6 km^3, and that pumping and other tests indicated a high permeability in the aquifer (specific capacity of 12.64 l/s/m at one drill site). They suggested a safe yield of 11 m^3/d/ha in their model.

On Tongatapu some 60 dug or drilled wells from a few metres to over 60 m deep penetrated coral limestone. Pfeiffer (1971) estimated that between 5% and 15% of the average annual rainfall of 1750 mm penetrated to the aquifer, and by assuming a recharge of about 10% over the entire island (260 km^2) he estimated that of the 45 x $10^6 m^3$/y replacement, 25000 m^3/d can be extracted from wells.

Waterhouse (1976) established that the lens surface stood 0.5 m to 0.75 m asl in the Tongatapu Water Reserve, and from pump test data calculated a transmissivity at 1200 m^2/d. The pump-test data, and rainfall figures were further analysed by Hunt (1978) who calculated a permeability of 1.5 cm/s, and estimated that 25% to 30% of the average rainfall, or about 75000 m^3, reached the aquifer.

From the above it appears that some 25000 m^3 to 75000 m^3/d might be abstracted from the aquifer underlying Tongatapu.

Coral atolls

These occur as a ring-shaped coral reef appearing as a low, roughly-circular, elliptical, or horseshoe-shaped coral island, or a ring of closely-spaced coral islets encircling or nearly encircling a shallow lagoon. They may vary in diameter from 1 km to over 100 km and are particularly common in the western and central Pacific. The submerged, deeply-buried rock on which the coral limestone originally grew is presumed to be volcanic (Figure 3).

The Gilbert Islands (Kiribati), Tuvalu, Tokelau, Northern Cook Group, and French Polynesia include good examples of true coral atolls.

Geology

Coral atolls are formed by contemporaneous upwards growth of reef coral during gradual subsidence of the volcanic substructure. Baillard (1981) described the birth and growth of an atoll through its different stages of formation from the development of the volcanic edifice on which the coral became established (probably in the mid Tertiary to the present).

Under favourable conditions of climate, temperature, and depth, coral larvae suspended in the sea water form scattered colonies on the volcanic flanks of the submerged or emerging island. They eventually form an encircling reef which itself is raised or lowered by the same tectonic forces controlling the elevation and subsidence of the volcano. The final stages of atoll formation are considered to be subsidence and erosion, and as the volcano sinks to greater depths the coral continues to grow upwards and ultimately completely covers the volcanic substructure. Gradually the fringing barrier reef restricts the circulation of water between the open ocean and the lagoon to the passages in the reef and lagoonal sediments accumulate in the largely shallow, protected basin in which grow a few coral heads. The outer rim at this stage comprises cemented beach rock, coral, sand, conglomerate, storm debris, and thin soil, and rarely attains a height of more than a few metres asl.

By virtue of their sinking to great depths and the long time required to accomplish this, atolls are thought to be among the geologically oldest of oceanic islands. This assumption, however, must be treated with caution because erosional criteria, one of the tools used in dating, (Kear 1957) are impossible to apply when the volcano in question is completely submerged and capped by thick coral (1400 m on Eniwetok in the Marshall Islands) (Menard 1964). In addition, a K/Ar date on a near atoll, Aitutaki, is younger than that for Rarotonga (Dalrymple et al. 1975), a young volcano by any standard.

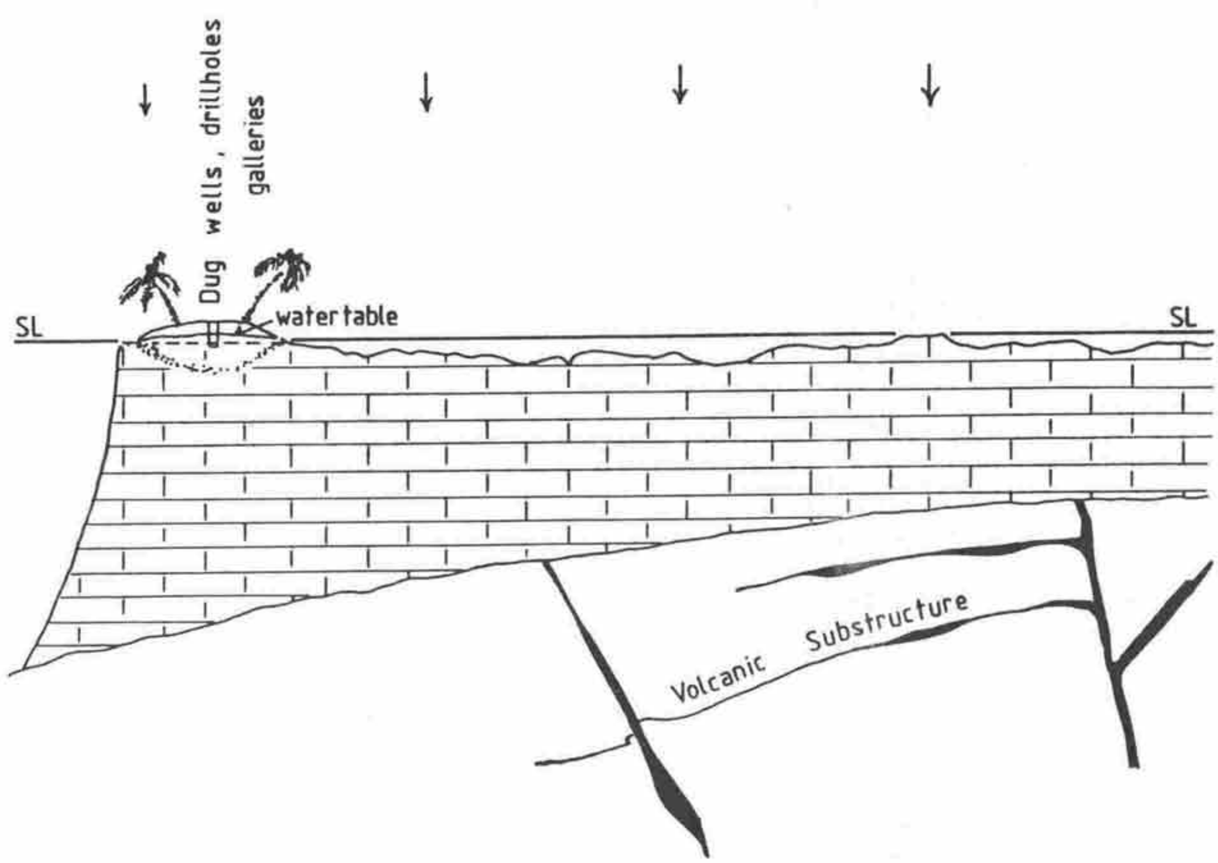


Figure 3 : Coral atoll (half width). Original island almost completely submerged. The peripheral rim rises to a few metres above sea level and comprises cemented beach rock, coral, sand, conglomerate, and storm debris. Thin soil and sparse vegetation are usually present.

Hydrology

Most Pacific island atolls are remote and sparsely populated. Liquid requirements of the inhabitants have traditionally been furnished by coconuts or rain-water tanks. Brackish water, mainly for washing and bathing, is available in some instances from holes dug in beach sand at the fresh-water/salt-water interface. While these sources have proven adequate, at least to sustain life on the atolls, a limited fresh water resource might be exploited from the water lens (Ghyben-Herzburg lens) underlying each atoll, the principle of which is discussed under Raised Atolls (above). Further investigations into developing this resource is necessary as tidal fluctuation, rainfall, and the lateral extent, thickness, and hydraulic characteristics of the lens itself will vary from atoll to atoll.

Mather (1975) established a model for the development of the ground-water resources on atolls in which he assumed that "abstracting ground water from a fresh-water lens is equivalent to reducing vertical recharge, and an estimate of the sustainable yield of the lens can be made".

Jacobson (1976) applied Mather's hypothesis to Cocos (Keeling) atoll in the Indian Ocean, and calculated that an effective recharge to the aquifer of 500 mm/y, and a water table elevation ranging from 0.17 to 0.16 m asl, would produce a sustainable yield of about 200 m^3/d.

The factors governing the shape of fresh-water lens are rainfall periodicity of droughts, tides, seepage, and abstraction rates. To minimize drawdown, Jacobson (ibid) recommends infiltration galleries rather than dug wells. Pumping should be carried out continuously and at a rate such that the thickness of the fresh-water lens is maintained at more than half the original thickness. It follows that abstraction points should be located in places where the lens is thickest.

Because of the delicate hydraulic balance at the fresh-water/salt-water interface, the pumping-water level should be carefully monitored. The pump intake should never be set below mean sea level because when the cone of pumping depression intersects sea-level datum, all the available fresh water is exhausted and upwelling sea water will enter the hole. Once contaminated, the hole may take years before a balance is re-established, although in a few instances it may be possible to accelerate the process by artificial recharge.

Clearly, the ground-water lens configuration will vary from island to island and much investigational work remains to be done. However, it is proven that the fresh-water principle is valid in coral island situations and its abstraction is possible under given conditions.

Water quality

It is clear that we can classify the geological structure of Pacific islands into three broad groups. Both the type of water resource and broad chemical characteristics of water quality also conform to this grouping.

There is little information on the bacteriological quality of water on different islands although unconfirmed accounts by technicians working in hospital laboratories in the region indicate the presence of coliform bacteria in many samples and a general lack of treatment of water supplies.

Our interest has been in providing drinking water of an acceptable standard and the World Health Organization's recommendations have been used to judge water quality from a chemical point of view. Some of these criteria are given in Table 1 (World Health Organization 1971).

Table 1 : WHO quality for drinking water
(except for pH all as g/m^3)

	pH	Ca	Mg	Cl	SO_4	Total Hardness as Ca CO_3	Mn	Fe	Cu	Zn
Highest Desirable	7.0-8.5	75	50	200	200	100	0.05	0.1	0.05	5.0
Maximum Permissible	6.5-9.2	200	150	600	400	500	0.5	1.0	1.5	15.0

Naturally occurring water supplies vary somewhat from these figures. Turbidity (not listed) is a useful measure of alteration to the aquifer, so is the presence of nitrogen compounds. Heavy metal contamination may indicate other variation from good quality. Generally there are aesthetic contaminants which make water less attractive to drink or toxic material which renders it dangerous to drink. Normal rain water has a pH of 5.6.

Overall we have few chemical analyses and are unable to present more than examples of tests from specific sites. There are no data from samples of the same source taken at different times. We can, however, trace the changes which rain water undergoes as it passes into different aquifers.

Rain Water

Samples collected from roofs in Tokelau and Rarotonga typify the expected analyses of rain water (Table 2). Some contamination of wind-blown coral dust and salt-spray as well as material washed from wooden shakes which are used as roofing at the Rarotongan Hotel appear in the Cook Island sample.

Table 2 : Rain water samples from roofs.

	pH	Ca	Mg	Total Alkalinity (bicarbonate)	Cl	SO_4	Total Hardness as Ca CO_3	Mn	Metals Fe	Cu	Zn
a	6.0	<0.1	0.2	2.0	1	<1	0.4	0.01	0.06	0.01	0.04
b	6.5	3.0	0.4	1.2	8	3	11.0	0.01	0.01	0.01	0.01
c	6.1	10.0	0.8	32.0	13	8	28.0	0.05	0.40	ND	ND

(a) Tokelau Islands: roof of Administration Building
(b) Tokelau Islands: roof of Fale Fono
(c) Cook Islands: Rarotongan Hotel roof

These show that normal rain water in the island has very low levels of all constituents with pH lower than "usual" but is entirely satisfactory for use.

Next we examined different water sources on high islands (Table 3). Samples were drawn (a) from a gallery constructed in a stream bed on Aitutaki (Vaitekea); (b) from the Kaavo No. 1 drill hole in volcanic rock on Mangaia; . (c) and from Atiu (coffee grinder) drillhole on Atiu (all Cook Islands). Sample (d) is from the La Colle River in Vanuatu.

Table 3 : Samples of various waters on high islands

	pH	Ca	Mg	Total Alkalinity (bicarbonate)	Cl	SO_4	Total Hardness as Ca CO_3	Mn	Metals Fe	Cu	Zn
a	6.6	ND	ND	38	30	10	42		ND		
b	6.2	1	1.5	8	13	3	ND		ND		
c	6.2	3	3.0	21	16	2	ND		ND		
d	7.4	ND	ND	162	12	12.4	120		ND		

In two cases the pHs are a little low and one, the La Colle river water in Vanuatu, has moderately high total bicarbonate and total hardness figures. In all other aspects these samples were within the WHO standards.

Although these waters on high islands show little modification of rain water, when we looked at samples from the margins of islands in the Southern Cook Islands some differences became obvious. These samples were taken from lakes, caves shallow wells or bores and show departures in most analyses as indicated in Table 4.

In these samples the limestone influence of the makatea is evident with high pH, increased calcium and magnesium levels and elevated hardness. In some cases (samples d, f, g,) the water is brackish and has high sodium chloride values. Analyses for iron and manganese are low.

In the raised coral islands rainfall percolates through the surface soil into the limestone where it is held in the thin lens floating on the sea water. Three samples each from Niue (a, b, c) and Tongatapu (Tonga) (d, e, f) provide examples of this type of water in Table 5.

Table 4 : Samples from margins of high islands
(Southern Cook group)

	pH	Ca	Mg	Total Alkalinity	Cl	SO_4	Total Hardness as Ca CO_3	Metals Fe+Mn
a	7.3	ND	ND	68	29	13	76	low
b	7.4	ND	ND	398	27	16	321	low
c	7.2	66	12	238	107	30	215	low
d	7.9	68	15	210	210	28	ND	low
e	7.8	51	102	246	147	22	548	low
f	7.5	45	37	220	350	48	ND	low
g	9.3	64	101	35	1680	184	576	low

(a) Mauke, makatea drillhole
(b) Rarotonga airport
(c) Mauke, Vaitango cave
(d) Atiu, Te Miro cave
(e) Atiu, Vaiakururu cave
(f) Atiu, Piripuroto cave
(g) Mitiaro, Lake Te Rotonui

Table 5 : Samples from raised coral islands

	pH	Ca	Mg	Total Alkalinity	Cl	SO_4	Total Hardness as Ca CO_3	Mn	Fe	Metals Cu	Zn
a	7.5	47	22.0	245	7	1	209	0.01	0.02	0.01	0.01
b	7.3	47	5.3	148	12	4	135	0.01	2.01	0.07	0.45
c	7.4	60	8.0	219	25	3	194	0.01	0.15	0.05	0.73
d	7.2	104	5.0	350	21	4	290	0.01	0.01	0.01	0.12
e	7.2	100	10.0	339	98	18	305	0.01	0.01	0.01	0.20
f	8.5	105	7.0	355	44	ND	292	0.01	0.01	0.01	0.02

(a) Niue, Tuku'ofe cave
(b) Niue, Vaiola factory bore
(c) Niue, Liku Development Block bore
(d) Tongatapu, Tupou College well
(e) Tongatapu, Hu'atolitoli well
(f) Tongatapu, Vaiola Hospital well

The samples show some similarities within the two sets. Calcium level, total alkalinity, chloride and total hardness are apparently higher in the Tongatapu bore samples than those from Niue. All analyses for metals are low but of interest are the very slightly elevated zinc figures from Niue due probably to galvanized pipes although soils on Niue are all deficient in zinc which is applied as a pasture and crop fertilizer.

Our final group of samples was taken from galleries on an atoll in Kiribati. Water comes from a very thin lens contained within the limestone rock. Highest land elevation is only a few metres asl. Values are given in Table 6 and are similar to those given by Jacobson (1976) for Home Island, Cocos group (Indian Ocean).

Results from atoll waters appear similar to those of raised coral islands. Both samples were high in total alkalinity. Chloride level will be influenced by the sampling site in relation to the thickness of the fresh-water lens.

Table 6 : Samples from an atoll in Kiribati

	pH	Ca	Mn	Total Alkalinity	Cl	SO_4	Total Hardness as Ca CO_3	Metals Mn Fe Cu Zn
a	7.5	107	30	447	35	4.9	390	all low
b	7.5	72	47	382	204	46.0	ND	all low

Well Management

Data from Western Samoa (A. C. McIntosh, personal communication 1981) indicate that many boreholes have been abandoned on account of unacceptably high salinity. He notes that 9 boreholes showed significant increases in salinity - some by a factor of 3 or 4. For example the Taga borehole originally tested at 58 ppm had increased to 228 ppm by 1981 (duration not known). Some borehole analyses now exceed the WHO permissible value of 600 ppm.

Discussion

Chemical analyses for a limited number of key elements illustrate how rain water is modified by the reservoir which contains it. Clearly water contained in aquifers close to sea level may be contaminated by salt and that from limestone will have high hardness levels. Where industrial boilers are used for producing steam, special treatment will be required to overcome scaling problems.

Although the pattern we have illustrated is a simplification of the situation for any particular aquifer, the evidence from Western Samoa of increasing salinity in some wells at lower levels indicates that regular monitoring is essential to ensure that stipulated rates of draw off are adhered to. Unless each island sets up an effective monitoring programme they will be unaware of incipient dangers especially to the fragile fresh-water lens and even to sub-surface flows if overdrawn. In the case of the lens, a long period will probably be required to re-establish the hydraulic equilibrium and shape of the former lens.

Chemical analyses give a good guide to the quality of water supplies from Pacific islands but the limited understanding we have needs to be supplemented by regular bacteriological and salinity checks and regular monitoring of depths to water and pumping rates.

Towards this end DSIR has initiated a co-ordination programme to assist development of new water resources in the Pacific. This involves six steps starting with hydrogeological evaluation, the siting of wells, the supervision of drilling and pump tests, chemical analysis of selected samples, installation of pumps and support for a monitoring programme to ensure safe levels of draw off.

Acknowledgments

All chemical analyses of water samples were carried out by staff of the Water Laboratory, Chemistry Division, DSIR, Wellington. We thank Mr Colin Downes, Chemistry Division for helpful criticism of this paper.

REFERENCES

Baillard, J.P. 1981. Birth and growth of an atoll. South Pacific Bulletin, First Quarter 1981. pp 7-13.

Dalrymple, G.B., R.D. Jarrard, and D.A. Clague. 1975. K/Ar ages of some volcanic rocks from the Cook and Austral Islands. Geological Society of America Bulletin 86:1463-67.

Hunt, B.H. 1978. An analysis of the groundwater resources of Tongatapu Island. Civil Engineering Research Report No. 7815. University of Canterbury, Christchurch, NZ. 20 pp.

Jacobson, G. 1976. The freshwater lens on Home Island in the Cocos (Keeling) Islands. BMR J. of Australian Geol. and Geophys. 1(4):335-343.

Jacobson, G., and P.J. Hill. 1980. Groundwater resources of Niue Island. BMR Record 1980/14.

Kear, D. 1957. Erosional stages of volcanic cones as indicators of age. N.Z. J. Sci. Tech. 38(7):671-82.

Mather, J.D. 1975. Development of the groundwater resources of small limestone islands. Q.J. Eng. Geol. 8:141-150.

Menard, H.W. 1964. Marine geology of the Pacific. McGraw-Hill.

Pfeiffer, D.I. 1971. Outline of the hydrology of the island of Tongatapu (Kingdom of Tonga, South Pacific). Advisory Services Report, U.N. Economic Commission for Asia and the Far East. 16 p.

Waterhouse, B.C. 1976. Nuku'alofa water supply. N.Z. Geological Survey Report, Otara. 8 p.

Waterhouse, B.C., and D.R. Petty. In press. Hydrogeology of the Southern Cook Group, South Pacific. N.Z. Geological Survey Bulletin 98.

World Health Organization. 1971. International standards for drinking water, 3rd Edition. World Health Organization, Geneva.

POLLUTION PROBLEMS IN THE SOUTH PACIFIC: FERTILIZERS, BIOCIDES, WATER SUPPLIES AND URBAN WASTES

R.J. Morrison and **J.E. Brodie**
Institute of Natural Resources
University of the South Pacific
P. O. Box 1168, Suva, Fiji

ABSTRACT

The South Pacific region is fortunate in being relatively free of major pollution problems. However, increasing development and the fragility of some of the regional ecosystems mean that potential dangers exist. Localized problems with pesticides and herbicides have occurred, but at present fertilizer use is limited and thus does not constitute a major hazard. The principal cause for concern is the contamination of water supplies by biocides, human and animal wastes. These problems are particularly acute in atoll environments having a limited fresh-water supply.

There is some evidence of dumping in the South Pacific of agricultural chemicals that have been banned in developed countries. Lack of experienced personnel in monitoring the introduction of these chemicals plus inadequate knowledge of storage methods, disposal problems and safe handling methods constitutes a major problem for many small island communities.

Future developments in the use of agricultural chemicals and in the disposal of human and animal wastes need to be carefully monitored if serious problems are to be avoided. This can only be achieved with the urgent establishment of an appropriate regional environmental monitoring programme.

Introduction

The outsider thinking of the South Pacific visualizes coral sand beaches, palm trees, clear water, etc.; the possibility that the area might be polluted is seldom considered. Fortunately for much of the region this is the case as it is relatively pollution free, but this situation is changing and potential problems do exist.

Development demands of the various countries mean increased industrial activity, increased use of agricultural chemicals, and increased amounts of waste products requiring disposal. This is particularly important given the fragility of South Pacific ecosystems. Concern for ecosystems is mainly in terms of their ability to sustain and maintain themselves, and thus provide food, shelter and water for those life forms present (and we selfish humans consider human life particularly in this context). In terms of their ability to sustain human life, Pacific ecosystems are fragile by the very nature of the region - a large number of small island systems separated by considerable expanses of ocean (except for Papua New Guinea). In the larger continental countries, if one ecosystem or part of a system is damaged by either human of natural activities, then others can be called upon to fill the gap until recovery has occurred. This "fall-back" option is frequently not available in many Pacific countries. It is therefore particularly important that potential pollution problems be identified and the necessary steps taken to minimize them.

Fertilizers

At present it appears that fertilizer use in the region does not present any major problems. The problems that can arise are:

- accumulation of excess fertilizer materials in fresh water or lagoon systems giving rise to algal blooms and the eventual death of aquatic fauna, and

- accumulation of toxic materials such as nitrate or heavy metals in ground water.

Fertilizer use in the region is rather limited with countries like Kiribati and Tuvalu using less than 5 tonnes/yr in total. Even countries like Papua New Guinea, Solomon Islands and Fiji which use 10's of thousands of tons of fertilizer do so at relatively low rates per unit land area. Nitrate levels in ground water supplies are generally low and phosphate is strongly absorbed by many regional soils. Unfortunately, there is no information on the accumulation of heavy metals in soils and ground water but it is unlikely that levels (from fertilizer sources at least) are high enough to cause concern.

Biocides (Pesticides, Herbicides, Insecticides, Fungicides, Weedicides)

Since World War II there has been a marked rise in the number of materials available. Prior to 1940 only a few tons of compounds, usually derivatives of arsenic, copper, lead, mercury, sulphur or chlorine, plus a few plant extracts like nicotine sulphate and pyrethrum, were used. Today well over 1000 products are available. The use of some of these has been the subject of considerable criticism, sometimes unjustified, but it is essential to note many problems have arisen due to improper use of the materials (Mowbray, 1984; Thaman, 1984).

In the Pacific, problems with biocides usually arise only in areas of intensive crop production where the costs of using these materials can be recouped. Demands by governments for increased agricultural production have led and will lead to the extended use of biocides. Problems usually arise as a result of IGNORANCE, CARELESSNESS, NEGLIGENCE, or a combination of these.

Unfortunately, the knowledge necessary for good biocide use cannot be gained overnight. Knowledge on:

- whether or not to use biocides,
- what types to apply,
- what rate to apply,
- how to apply, and
- when to apply,

can be gained only by experience. Information on storage, stock control and compatibility is also required.

The following are some of the problems that do arise.

1. **Storage:** often biocides are collected from stores or shops in unlabelled containers brought in by farmers. This can lead to problems especially when the materials are stored in the home as is often the case. Containers are often labelled in English, not in the indigenous language; perhaps this should be taken up with the manufacturers or distributors. Accidental poisoning occurs frequently. In several countries consumption of paraquat (a herbicide) is a popular method of committing suicide (stenches and emetics can be added to liquid biocides to minimize this problem).

2. **Disposal:** unwanted biocides, such as those left over when too much or the wrong type has been ordered, are frequently difficult to dispose of suitably.

3. **Application:** frequently this must be done in a particular way with the correct equipment. Farmers often have not been educated in the correct way to use the equipment, the equipment is poorly maintained, or not enough sets are available. Protective clothing is sometimes required and in Fiji at least one case of death by poisoning due to absorption of Parathion through the skin has been recorded. Many less serious cases of injury or illness due to inappropriate application methods occur. Only one or two countries have organized training programmes in application techniques and none have any certification scheme.

4. **Persistence and Movement in the Environment:** here the amount of information available is extremely limited. In Guam, paraquat, lindane, and 2,4-D have been detected in the ground water. In American Samoa there is considerable concern that no monitoring of residue levels in the ground water has been done, in spite of the fact that this is the major source of drinking water. Monitoring of persistence and movement is not easy. For example in Hawaii where considerable monitoring does take place, the insecticide heptachlor used in the pineapple industry went undetected in milk for over 1 year (pineapple trash was used as cattle feed).

5. **Legislation:** a few countries have good control over biocide use while others do not; many countries have no legislation and no controls. As a consequence biocides that have been banned from use in various developed countries are sold to and in Pacific countries without controls, e.g. dieldrin in New Caledonia.

Water Supplies

Water resources are the part of the Pacific Islands environment most susceptible to pollution. Rivers, streams, wells and ground water borehole supplies can all be contaminated by chemical, human and animal wastes.

Contamination by chemicals, such as arsenic found in Solomon Island streams from wood treatment operations or biocide residues resulting from excessive use, has so far only been detected in limited areas, but the extent of monitoring has not been great. More extensive use of chemicals is occurring and further problems could be found.

Contamination in less dramatic ways is more common. To illustrate this consider the results of some water quality surveys carried out by the Institute of Natural Resources, University of the South Pacific (Brodie et al., 1983).

Vaitupu (Tuvalu) - a low atoll

Most wells are contaminated to a greater or lesser extent by sea water and can only be used for washing. Wells close to the more inhabited area at the southern end of the island also have high levels of coliform contamination (Total coliforms 1000/100 ml in 6 out of 8 wells; >5000/100 ml in 4 out of 8 wells).

Niue - a raised atoll

The water is very hard with high iron levels and often significant nitrate levels. Seventeen boreholes and 4 rainwater tanks were examined: results indicated water was generally of good quality with little salt, and low coliform counts.

Tongatapu (Kingdom of Tonga) - a raised coral platform covered with ash.

Twelve heavily used boreholes were tested. All indicated high calcium hardness as would be expected. Four showed significant levels of salt water intrusion and 2 showed signs of bacterial contamination.

Savo (Solomon Islands) - a small volcanic island

Savo has surface streams but they cannot be used for drinking purposes as they are very acidic and sulphurous due to volcanic activity. Wells are therefore dug to provide drinking water.

Fifty five wells and three streams were examined. Salt levels in most wells are high and noticeably higher than 1972 values probably as result of Cyclone Bernie in early 1982 (more than half the wells tested had chloride levels >250 mg/l, the WHO drinking standard). It would be interesting to examine the physiological effects on the inhabitants of the continued high salt intake.

All the wells and one stream were contaminated by coliform organisms (total coliform count 20 to >6000/100 ml). The level of contamination in nearly all cases is not high but it is still a matter for concern. The source of contamination is likely to be surface run-off into the wells with pigs (or children) the likely culprits. The wells often have no protective sides and pigs roam unrestrained in the villages. Raised protective sides to the wells and an effort to keep pigs away from the well surroundings would prevent further contamination. On Savo, rainwater catchment may be the only way to supply drinking water meeting WHO standards.

In general village water supplies are more at risk as water is usually untreated. In the major urban centres such as Honiara and Nadi, although coliform levels at source are frequently high, water supplies are treated (including chlorination) before use.

Urban Wastes

Increasing development and the associated changes are causing major problems and the situation may become worse. The "concentration effect" of increased development - bigger harbours and larger ships, bigger processing plants, fish canneries, etc. means greater waste disposal problems are occurring near the major urban centres where the expansion is happening. Frequently wastes are discharged into the marine environment causing considerable pollution around urban centres such as Suva and Port Moresby. This is critical because in many of these areas subsistence fishing is still a major food source.

A second aspect of the "concentration effect" is the human concentration caused by urban drift. Sewerage schemes designed in colonial days are no longer adequate in some places to cope with the increasing population and squatter settlements not connected to any sewage system create further problems. Lack of maintenance of septic tanks can lead to considerable pollution of water supplies.

The Suva urban area has a population of about 150,000 persons and it is estimated that by the year 2000 this will reach 300,000. Up until early 1983 the main Suva sewage works at Kinoya treated sewage from a contributory population of about 12,000 but during 1983 the scheme was expanded to receive sewage from a population of 33,000. Further developments to increase the capacity to cater for sewage from a population of 63,000 and later to 120,000 are now being designed. The effluent from the Kinoya plant and a smaller plant at Raiwaqa all flows into Laucala Bay, which forms part of the estuary of the Rewa River and has an offshore barrier reef. To assess the probable effects on Laucala Bay of the increased effluent flow, a long term monitoring programme was begun in 1979, with major data collection to 1982 and smaller scale monitoring since then (Caldwell Connell Engineers et al., 1982). Results so far interpreted show the growth of algae in the bay to be phosphorus limited - a relatively unusual situation. It is believed, however, that the amount of phosphorus entering the bay from the sewage scheme will not cause blooms as even by the year 2005 Kinoya discharges will only provide a 50% increase in phosphorus loading in the bay and growth will still be phosphorus limited. At present nitrogen/phosphorus ratios for the bay average 180 with average nitrogen levels of 3.3 mg/l and average phosphorus of 0.018 mg/l. Recent bacteriological studies on water and shellfish from the bay have indicated the possibility of serious pollution problems (Brodie et al., 1984).

In Lae, Papua New Guinea, the Bumbu River flows through a number of villages and city suburbs. The Taraka sewage works effluent also discharges into the river. Two self-help settlements which lie on the Bumbu River have been studied to estimate water quality, water usage and the effect on public health (Mallard and Mahoney, 1983). Taraka Self-help Settlement has access to the town water supply and city rubbish collection while Bumbu does not. The Bumbu River and adjacent streams were shown to be highly polluted with faecal coliforms and in most areas not even safe for bathing (46% of samples contained >2000 faecal coliforms/100 ml). Statistical analysis showed that the occurrence of diarrhea, ear and eye infections was higher in Bumbu than in Taraka. 72% of people in Bumbu versus 48% of people in Taraka reported diarrhea, while in Bumbu 29% had ear infections and 36% eye infections and in Taraka the corresponding figures were 16% and 20%. Obvious contamination of wells by pit toilets and of small streams and springs by household rubbish was noticed in Bumbu.

Solid waste disposal is causing less concern. For example Suva and Port Moresby now have well managed landfill operations and it is only in older dumps illegally used that visual and possibly disease vector problems occur.

In Kiribati, however, one example of a reversal of the normal problems has occurred. Dumping does occur but in 1982 it was found that the solid wastes could be put to good use in a particular situation. In the Temaiku Bite on Tarawa, land reclaimed in the early 1970's had been producing very poor coconut palms with chlorosis due to iron, potassium and trace element deficiencies. However, in 1982 it was found that the addition of solid urban waste to the site produced a marked improvement - a message for other atoll inhabitants - do not waste waste (or in the words of Peter Thacher, one man's pollutant is another's resource).

One last feature of the "concentration effect" is the impact of subsistence farming on the hills surrounding the major urban centres like Suva and Lae. Here cultivation on steep slopes together with highly erosive rainfall causes severe erosion; the eroded products are carried down into the sea nearby and damage the reefs which are again a major subsistence food resource.

Industrial wastes

Very few studies have been made into the composition and effects of industrial (non-mining) wastewater discharge in Pacific Island states. Examples have included: fish processing wastes in Pago Pago, American Samoa (Soule and Oguri, 1983); edible oil plant waste in Suva, Fiji and sugar mill effluent in Labasa, Fiji (Lee, 1979, 1981). The Samoan study investigated the fate of the wastes from the two canneries in Pago Pago and their public health implications in early 1982. One of the canneries is now being forced to improve waste disposal while the other had already voluntarily installed anti-pollution measures.

In Fiji the edible oil plant investigation found that the problem of smell and high BOD values in the Qawa River was a consequence not just of the actual dumping of industrial effluent but also of the nature of the river at the discharge point (Lee, 1981). The river is slow moving and meandering with a depression in the river bottom close to the discharge point. The high density, organically-rich effluents sink into this depression, deoxygenating the river at that point and creating a problem for the local inhabitants particularly during the "dry" season when the river flow is particularly sluggish.

Conclusion

There are other problems that could be discussed, such as the impact of mining operations, but it is obvious from the topics covered that in the Pacific Islands the present position of limited pollution problems could change rapidly.

It is essential that we obtain more basic information about our various ecosystems and that they be regularly monitored so that any pollution problems that may occur can be detected early enough to prevent major irreversible damage occurring. Only in this way can we be sure that our presently very hospitable environment is protected.

REFERENCES

Brodie, J. E., G. W. Lee and Regina A. Prasad. 1983. Well-water quality in South Pacific Island states. S. Pac. J. Nat. Sci. 4:14-31.

Brodie, J. E., K. Chand and R. J. Morrison. 1984. Appraisal of the UNEP methods for determining pollutants in coastal waters for use in the Pacific Islands. Institute of Natural Resources, Environmental Studies Report No. 17. University of the South Pacific, Suva, Fiji.

Caldwell Connell Engineers/Commonwealth Department of Transportation and Construction. 1982. Report on receiving water study - Kinoya sewage treatment plant. Prepared for Public Works Department of Ministry of Works and Communications, Suva, Fiji. August 1982.

Lee, G. W. 1979. Report on the discharge by Fiji Foods factory into Walu Bay creek. Institute of Natural Resources, Environmental Studies Report No. 4. University of the South Pacific, Suva, Fiji.

Lee, G. W. 1981. Report on a preliminary investigation into the alleged pollution of the Qawa river. Institute of Natural Resources, Environmental Studies Report No. 8. University of the South Pacific, Suva, Fiji.

Mallard, Ann and D. Mahoney. 1983. Water quality and its effect on public health - a study of water quality in the Bumbu and Taraka Self-Help Settlements, Lae, Northern Province. Department of Chemical Technology, PNG University of Technology, Lae, Papua New Guinea.

Mowbray, D. 1984. A review of pesticide use in the South Pacific. South Pacific Regional Environment Programme, South Pacific Commission, Noumea, New Caledonia.

Soule, D. F. and M. Oguri. 1983. A report on ocean disposal of fish processing wastes off Pago Pago, American Samoa. United States Environmental Protection Agency, Region IX Report.

Thaman, R. R. 1984. Pesticides in the Pacific Islands: panacea or peril. Institute of Natural Resources, Environmental Studies Report No. 19. University of the South Pacific, Suva, Fiji.

FISHERY POTENTIALS IN THE TROPICAL CENTRAL AND WESTERN PACIFIC

R.E. Kearney
South Pacific Commission
Noumea, New Caledonia

ABSTRACT

In defining the topic it is assumed that description of a fishery potential requires more than just identification of a resource, while at the same time acknowledging that there can be no potentials for development without appropriate resource bases. The major fish resources of the tropical central and western Pacific are therefore described and development options for Pacific Island states are discussed in the light of the special problems relevant to this region.

The known fishery resources of the tropical central and western Pacific are divided into four categories: 1) freshwater and shallow coastal resources, including aquaculture; 2) deepwater nearshore resources; 3) deepwater offshore resources; and 4) offshore pelagic resources. Because of the domination of present catches by the highly migratory tuna and billfish species incorporated in category 4, discussion is concentrated on the potential for further development and management of these resources.

Recent assessments of the skipjack resources in only part of the tropical Pacific suggest a standing stock in excess of three million tonnes. Yellowfin, albacore and bigeye tuna, and the numerous billfish species combined represent further highly migratory resources of considerable magnitude.

Recent developments in purse-seine technology have seen the landings by gear type change significantly with a relative decline in the importance of pole-and-line and longline fishing. Distant water fishing nations continue to dominate catches from within the region with catches by the United States of America now being second only to those of Japan.

Pacific Island states presently have only limited ability to participate in the extensive fisheries for tunas in the tropical Pacific. However, recent international acceptance of increased jurisdiction has greatly enhanced the potential for increased involvement in these fisheries.

INTRODUCTION

Bounded in the west by the Philippines, Indonesia and northern Australia, and in the east by approximately 130°W, the tropical central and western Pacific Ocean, encompasses an area of more than 41 million square kilometres, or approximately eight per cent of the surface of the earth. Lying within this area are the 23 developing Island countries and territories for which the South Pacific Commission (SPC) works. The basic similarities amongst the numerous small developing Island states within the 29 million square kilometres of the SPC area and the contrast between these and the larger bordering nations begs differentiation between the two when considering fishery potentials. Only the potentials of the Island states are considered here.

In defining the topic it is assumed that description of a fishery potential requires more than just identification of a fish resource, while at the same time acknowledging that there can be no potentials for development without appropriate resource bases. Only resources presently exploited, or with an identified prospect for exploitation, have been considered as known potentials.

Fish and fisheries have played a central role in the culture, sustenance and recreation of all small island communities. The ability of the traditionally exploited fish resources of the central and western tropical Pacific to continue to provide subsistence protein for island communities is arguably the greatest resource potential of the region, and yet it is one which is commonly overlooked in the quest for more spectacular development options. Not that alternative small scale fishery potentials do not exist, indeed there are many, particularly as improved fish catching techniques increase the potential yield from even traditionally exploited resources, and advanced processing technologies increase the utility of the harvest. Improvements in small scale fisheries technology and fishing techniques have also enabled the exploitation of previously untouched resources, particularly those in deeper waters or further from shore, thereby greatly expanding the horizons of subsistence and artisanal fishermen.

Developments in offshore waters have been pronounced in recent years. International acceptance of the principles of 200-mile zones of extended jurisdiction has highlighted potential for Island states to manage the fisheries resources in more than 29 million square kilometres of the central and western Pacific. Much of this vast oceanic area had been exploited for its extensive tuna resources since the late 1950s by distant-water fishing nations, but enactment of the principles of extended jurisdiction by Island states has seen dramatic change in their involvement in large scale fisheries and has undoubtedly opened up major new avenues for their fisheries development.

THE KNOWN RESOURCES AND THEIR POTENTIAL FOR DEVELOPMENT

Although there is some overlap amongst the various groups, the known fishery resources of the Pacific Island states can be classified as one of four categories:

1. Freshwater and shallow water coastal resources (including aquaculture and mariculture)

Freshwater resources

Only the largest of the Pacific Islands (Papua New Guinea, Solomon Islands, New Caledonia, Fiji and Vanuatu) have freshwater river or lake systems of sufficient size to support extensive freshwater fish resources. Papua New Guinea's tilapia (Tilapia mosambica) resources are by far the largest. They offer considerable promise for increased yields, primarily for local consumption, while the barramundi (Lates calcarifer), which is dependent for part of its life cycle on the freshwater reaches of Papuan rivers, should continue to support commercial fisheries (Kearney 1976). Freshwater fishery resources in the other above-mentioned countries and the smaller Pacific Island states are of more limited value being primarily the target of subsistence, small scale artisanal or recreational fishermen. One exception is the freshwater clam (Batissa violacea) fishery in Fiji which produces approximately 700 tonnes per annum.

Even though the known freshwater resources are limited and the size of the available freshwater habitat is unlikely to increase significantly, the potential for increasing yields from these waterways by improved fish husbandry techniques, including introduction and enhancement of selected species, should not be overlooked. The socio-economic return from increased yields in these fisheries, particularly in places such as the highlands of Papua New Guinea where animal protein is scarce, could well be relatively much greater than the benefits from similar increases in yields in coastal fisheries where production is relatively higher.

Shallow water coastal resources

The small developing states of the tropical central and western Pacific are, in general, isolated islands or archipelagos. In most cases there is little, if any, continental shelf and the transition into depths exceeding 2,000 metres is normally precipitous. The smallness of the land masses greatly restricts the nutrient run-off available to enrich the surrounding ocean. Therefore, the waters surrounding them are typically clear and blue and, compared to continental coastal areas, of low productivity. As a result of this lack of extensive continental shelf or coastal enrichment, small Island states have limited inshore fish resources and hence restricted new inshore fishery potentials. On the other hand, the existing inshore fish resources have provided the bulk of the animal protein consumed by Pacific Islanders since the islands were first settled. In most cases modern gear developments should enable total catches to be increased, thereby realizing a potential. With minimal appropriate management this invaluable potential should remain in perpetuity so long as total human populations remain within reasonable bounds. Management will, however, not be without its problems, some of which have been previously discussed (Kearney 1980).

Aquaculture potentials

There have been numerous attempts to establish aquaculture on a commercial basis in the islands of the Pacific; these have in general been notable for their lack of success. Closed system aquaculture in developing countries has, in the main, only been successful in the larger countries where incomes are very low, population densities are high and natural protein resources are restricted (i.e. in areas such as southeast Asia). In general, continuous access to a relatively high priced luxury market is required for most commercial aquaculture projects to be viable and these conditions are rare in the countries of the tropical central and western Pacific. Markets for specific items, such as live bait for tuna fishing, have been created in countries in which pole-and-line fisheries for tuna have been established, and yet aquaculture has still proven difficult to develop to a commercial level; reasons for this are given by Kearney and Rivkin (1981). Economic implications of developing aquaculture in the Island states of the region were considered by the SPC's Eighth Regional Technical Meeting on Fisheries. This meeting concluded that very few previous aquaculture projects in the Commission's area were at all successful and recommended "that detailed economic surveys should be carried out before any commercial scale aquaculture projects are initiated" and pointed out that such "surveys should include the economics of alternative use of both the land to be developed and the investment capital" (Anon 1975). Equally important is the need to consider the implications to existing fisheries resources from the conversion of so called "swamp land" for aquaculture purposes. Too often coastal mangrove or inter-tidal zones, which are natural breeding, or nursery, areas for coastal fish species, are converted without due consideration of the impact on existing fisheries. Therefore, while it would be foolish to disregard the potential of aquaculture for fisheries development in the central and western tropical Pacific, I feel that in the short-term this potential is restricted and proposed aquaculture projects should be given careful scrutiny.

2. Deepwater nearshore resources

At the periphery of the limited continental shelves of Pacific Islands, the reef slopes harbour resources of deepwater snappers (predominantly Pristipomoides spp. and Etelis spp.) which have only begun to be exploited since the exploratory work of the SPC in the early 1970s (Crossland and Grandperrin 1980) and which offer exciting new potentials for fisheries development. Catch rates, far in excess of those normally taken in shallow water handline fisheries, have been achieved throughout the central and western tropical Pacific with gear little more sophisticated than that required in traditional fisheries. In many countries commercial, exploitation of these resources has proven viable using inexpensive hand-reels and, to a lesser extent, small bottom longlines. While little is known of the magnitude of the available resource, or of the biology and behaviour of the species commonly exploited, the snapper resources of the reef slope are thought to represent one of the best potentials for fisheries development in this region and one of the very few resources suitable for exploitation by existing artisanal fishermen without enormous capital input. These deepwater resources have the additional advantages of being predominantly excellent quality food fish and free from ciguatera poisoning. They therefore command high prices on most markets.

Resources of deep water shrimps (Heterocarpus spp.) and precious corals represent other possible potentials, but the economic feasibility of exploiting these resources in most Pacific Island states is still disputed.

3. Deepwater offshore resources

In the tropical central and western Pacific, areas suitable for large-scale harvesting of bottom-fish resources by conventional means are limited. However, recently developed fisheries for deep water species in other regions of the Pacific Ocean indicate that possibilities for development of fisheries for non-conventional species, or using non-conventional techniques, do need to be considered as fisheries potentials. In recent years fisheries for alfonsin (Beryx splendens) and pelagic armourhead (Pentaceros richardsoni) have been developed on the seamount chain to the northwest of Hawaii. In this area catch rates of pelagic armourhead by experimental Russian trawlers have been as high as 30 tonnes in 10 minutes and commonly of the order of 20-30 tonnes per 10 to 20 minute tow (Sakiura 1972). Other surveys and commercial fishing using bottom longlines and trawling gear have confirmed the resources of both pelagic armourhead and alfonsin the north central Pacific (JAMARC 1973, Anon 1976). The prospects for developing similar fisheries in the more equatorial regions warrant investigation, particularly as the pelagic armourhead has already been proven to be a wide-ranging species (Sasaki 1974).

In addition, the recent spectacular catches of orange roughy (Hoplostethus atlanticus) by large trawlers in waters off New Zealand increases interest in the prospects of finding trawlable deepwater resources in more tropical areas of the Pacific, even though it is doubtful if commercial concentrations of this particular species (orange roughy) extend into this area. Furthermore, preliminary reports of favourable catches of deepwater species, especially the red snapper, Etelis carbunculus, in seamount areas in the waters adjacent to Solomon Islands, and the occurrence of numerous presently unfished seamounts and ocean plateaus in the central and western tropical Pacific, further suggest potentials for future fisheries. It does, however, appear likely that deepwater fish resources are less in tropical regions than in association with the larger oceanic plateaus in higher latitudes.

Exploitation of deepwater resources, even if proven economically viable in the tropical Pacific, would probably require very large vessels, possibly larger than 1,000 tonnes, and hence massive capital inflow plus input from many qualified and experienced personnel. Direct involvement of nationals of the region would therefore be anticipated to be minimal, at least in the short term. This does not mean that the potentials will, or should, therefore be ignored, or that Pacific Island states could not benefit from their exploitation. As later discussed, the increased rights of coastal states associated with changing attitudes to the Law of the Sea has opened up considerable potential for coastal states to become more involved in the exploitation of offshore resources.

4. Offshore pelagic resources

Fish catches from the tropical central and western Pacific in recent years have been completely dominated by the highly migratory tunas and billfish. In 1976, the last year for which complete statistics are available, 253,830 tonnes (88 per cent) of a total recorded fish catch from the region of 289,196 tonnes was tuna or billfish (Table 1). The comparative magnitude of these tuna catches, and their significance to any discussion of fishery potentials, warrants separate consideration of, firstly, the status of the resources and, secondly, the potentials for developing fisheries on these resources.

The resources

From the 1950s through to the end of the 1960s, tuna fishing in the region was dominated by longlining. In the early 1970s pole-and-line catches exceeded those of other gear types. While the Japanese distant-water pole-and-line fleet accounted for almost all of the catch in this fishery in 1970, locally based joint ventures increased quickly and by 1978 reached a peak in annual production of more than 70,000 tonnes. Total tuna catches by locally based pole-and-line vessels have declined considerably since this time, largely as a result of the cessation of the fishery in Papua New Guinea.

In recent years, catches by the Japan based pole-and-line fleet and the longline fleets of most nationalities have declined as a result of serious economic difficulties in the tuna industry. However, at the same time a tremendous increase in purse-seining by predominantly Japanese and United States vessels (Kearney 1981a) has maintained the relative magnitude of tuna landings from the region. Total catches of tuna by purse-seiners in the area considered here were probably of the order of 180,000 tonnes in 1982, more than four times the catch

TABLE 1: LOCAL CATCHES AND CATCHES BY DISTANT-WATER FLEETS IN THE WATERS OF THE COUNTRIES OF THE SOUTH PACIFIC COMMISSION
(after Kearney 1979b)

Country	Local Total Fish Catch (tonnes)	Local Tuna Catch (tonnes)	Longline Catch[8] in 200-Mile Zone by Foreign Fleets in 1976 (tonnes)	Pole-and-Line[8] Catch by Japanese Fleet in 200-Mile Zone in 1976 (tonnes)
American Samoa	220 ('78)[1,2]	20 ('78)[2]	387	29
Cook Islands	-	-	2,866	10
Fiji	11,594 ('77)[1,3]	7,262 ('77)[1,3]	1,553	233
French Polynesia	2,386 ('74)[4]	1,293 ('74)[5]	7,264	0
Guam	-[6]	-[6]	-[6]	-[6]
Kiribati	1,344 ('77)[1]	786 ('77)[1]	11,349	16,570
Nauru	0	0	1,845	8,224
New Caledonia	499 ('77)[1,3]	186 ('77)[1,3]	1,800	58
Niue	20 ('78)[1]	10 ('78)[5]	289	4
Norfolk Island	-	-	700	2
Papua New Guinea	68,000 ('78)[1]	47,720 ('78)[8]	6,312	10,533
Pitcairn Island	-	-	1,090	0
Solomon Islands	17,444 ('76)[5]	15,787 ('76)[8]	2,709	17,248
Tokelau	-	-	450	1,645
Tonga	1,117 ('77)[1]	300 ('77)[5]	816	18
Trust Territory of the Pacific Islands	10,000 ('76)[5]	5,284 ('76)[8]	20,601	38,360
Tuvalu	80 ('78)[1]	40 ('78)[1]	1,886	7,611
Vanuatu	10,500 ('76)[7]	10,000 ('76)[7]	1,012	93
Wallis and Futuna	-	-	386	155
Western Samoa	1,700 ('76)[1]	850 ('76)[1]	160	24
TOTAL	124,904	89,538	63,475	100,817

1 Figures from Crossland and Grandperrin (1979).
2 Excluding unloadings to the Pago Pago canneries.
3 This includes only the catches which passed through markets.
4 From Kearney (1977).
5 Estimated by the author.
6 Catches included under Trust Territory of the Pacific Islands.
7 Mainly longline catches transhipped at Santo.
8 From Kearney (1979a).

by the same fleet in 1978. Further major expansion in the fleet is anticipated, principally by the United States, Japan and Korea. The last thirty years have therefore seen the rapid expansion and, at least partial, collapse of three major tuna fisheries in this region (i.e. the longline, distant-water pole-and-line, and locally based pole-and-line fisheries) and the rapid increase in a fourth, the purse-seine fishery, which appears likely to produce total yields that exceed even the highest of earlier years. The decline in earlier fisheries does not appear to have been related to any short-comings in the tuna resources exploited by the various gear types. Failures appear to have been due largely to greater efficiency in production of other tuna fisheries competing for the same limited international tuna market. In fact, the available evidence suggests that most of the major tuna resources of the central and western tropical Pacific have remained underexploited.

Tuna fisheries in the tropical central and western Pacific target primarily on skipjack (Katsuwonus pelamis), yellowfin tuna (Thunnus albacares), albacore (Thunnus alalunga) and bigeye tuna (Thunnus obesus). Skipjack accounted for well over 50 per cent of the total tuna harvest in recent years with annual landings of this one species exceeding 250,000 tonnes on several occasions (Kearney 1981b). Results from tag release and recovery experiments conducted by the SPC's recently completed Skipjack Survey and Assessment Programme indicate that the standing stock of skipjack in the area of the SPC is of the order of 3,000,000 tonnes. These same results have been used to estimate the turnover rate of this resource at 16 per cent per month which suggests that the total annual throughput of skipjack through the region approaches 6,000,000 tonnes (Skipjack Programme 1982). The catch of this species in recent years of about 250,000 tonnes annually would therefore be much less than the resource could reasonably be expected to sustain. Skipjack Programme scientists, however, stressed that yields could only approach the maximum possible if fishing effort is distributed across this vast region in proportion to the distribution of the resource. They also demonstrated from tagging results that skipjack in this area are capable of extensive migrations and that fisheries scattered throughout the region will interact, particularly as fisheries of different nationalities or different gear types expand and overlap in time and space (Skipjack Programme 1981; 1982).

Yellowfin tuna traditionally have provided the bulk of catches of longline vessels operating in equatorial areas. Two recent estimates of the magnitude of the yellowfin resource exploited by the longline fishery have suggested maximum sustainable yields of 60,000 to 70,000 tonnes annually (Far Seas Fisheries Research Laboratory 1978), and 80,000 to 90,000 tonnes annually (Anon 1980). In both cases levels of effort were considered to be at, or slightly above, the optimal level and an increase in effort was unlikely to result in increased catches. The recent expansion in the purse-seine fishery in the western Pacific has resulted in significant catches of yellowfin (approximately 50 per cent of catches by United States purse-seiners in 1981 were yellowfin tuna), not previously significantly exploited by surface fisheries. In a previous report (Kearney 1981b), I have outlined the problems of trying to evaluate the potential for increasing the total yield of yellowfin from this region by increasing the surface catch and concluded that "it is possible that the yellowfin resources of the western Pacific are at present not maximally exploited, but it is by no means certain that substantial development in the purse-seine fishery will increase the yellowfin yield without detriment to the longline fishery". Unpublished information from the Skipjack Programme presented to the SPC's Fourteenth Regional Technical Meeting on Fisheries suggested that, based on limited tag release and recapture information, the standing stock of yellowfin tuna in the SPC's area was perhaps of the order of 600,000 tonnes, with a turnover rate of approximately 17 per cent per month. A standing stock of this magnitude should indeed support total catches greater than previous estimates of the maximum sustainable.

Albacore has been commercially exploited in the tropical central and western Pacific only by longlining. The species does not normally occur in this area as surface schools. The only available index of the status of the stocks of albacore in the tropical south Pacific is that provided by catch and effort figures from vessels based in American Samoa. Catches by this fleet increased steadily from 1954 to 1967 before fluctuating widely, achieving an all time high in 1973. Relative abundance, as indexed by the catch rate per vessel, fell consistently from 1954 to 1975 and total landings were maintained only by substantial increases in total effort. Although precise figures are not available, there was a recovery in relative abundance in 1976, 1977 and 1978 (Kearney 1981b). The most recent general appraisal of the status of the stocks of albacore exploited by vessels based in the equatorial central and western Pacific is that resulting from a workshop on tuna resources in Shimizu, Japan in June 1979 - "The conclusion of workshop participants was that current fishing levels do not appear to be adversely affecting the (South Pacific albacore) stock. Further increases in longline fishing effort would result in only a slight increase in yield, if any. The impact of the development of major surface fisheries on the stock is unclear and consequently the development of such fisheries should be closely monitored" (Anon 1980).

Statistics on catches of bigeye tuna are even more limited than those of other tuna species exploited in the western Pacific. The present status of the stocks cannot be accurately assessed, however, the species is generally considered underexploited.

Other species of tuna and numerous species of billfish are taken commercially in the central and western tropical Pacific, but mostly as incidental catches in fisheries for other tuna species. In their own right they represent very limited known potential for future development of commercial fisheries. However some species, particularly blue marlin (Makaira nigracans) and black marlin (Makaira indica) do constitute resources which could well support significant sport fisheries.

The potentials for tuna fisheries development, particularly by the coastal states of the region

In the preceding section it has been suggested that the resources of the major tuna species exploited in the central and western Pacific are, to varying extents, underexploited. Bearing in mind the significance of tuna to total regional fisheries, the major potential for increasing the total yield of fish from the region therefore lies in increasing the tuna catch, particularly that of skipjack. Increase in total catches in the near future appear most likely to result from expansion of the purse-seine fishery, which, with proper management, might well achieve total catches at least several times greater than at present. Furthermore, as present daily catch rates by purse-seiners in the western Pacific of approximately 20 tonnes per day (Tuna and Billfish Assessment Programme, unpublished data) are approximately twice those in the more mature eastern Pacific fishery, further rapid increases in total fishing effort in this region can be anticipated. In the longer term it would also appear more economical to process much of this fish in the western Pacific rather than ship it frozen to the world's major markets. The future for the tuna fishery in the tropical central and western Pacific therefore appears bright, provided reasonable management procedures can be agreed upon.

Even though the potential for increasing total tuna landings might be great, the potential for increased participation by the Island states of the region is not without problems. There is no doubt that the increased control by coastal states over the resources of their 200-mile zones, embodied in the new principles of the Law of the Sea, greatly increases the potential for Island states to become involved, and even to control policy in those fisheries. A whole range of possibilities for increased involvement exists, from the development of wholly owned, operated and controlled local fisheries, through the spectrum of joint venture alternatives, to the generation of revenue from totally foreign fleets. Of course, no one of these need be pursued exclusively and some balance of local and foreign enterprise could well be the most rewarding.

If coastal states do pursue the option of developing their own tuna fisheries, the major problems they encounter will include (modified from Kearney 1981c):

(i) **Fluctuations in the abundance of the resource.** Even though the area of ocean under the control of individual coastal states has increased dramatically as a result of 200-mile zones of extended jurisdiction, these areas represent only a part of the habitat of the highly migratory species. The abundance of these resources in any one 200-mile zone fluctuates markedly with season, particularly in the higher latitudes. It may, therefore, be impossible for most small Island states to maintain a fleet year-round, particularly as most of them have no other suitable fisheries in which to employ vessels and crew during off-peak seasons. Co-operation with neighbouring states, preferably on a broad regional basis, would help to alleviate this problem.

Highly migratory resources often show marked year to year variations in abundance in addition to seasonal variability. Companies or countries with limited financial resources find it very difficult to withstand successive poor seasons, or even a single very bad one.

(ii) **The requirement for large expensive vessels.** An average (300 tonne) pole-and-line or longline vessel, used in the distant-water fisheries of the central and western Pacific, now has a replacement value of approximately US$2,000,000; an average United States tuna purse-seiner of 1,100 tons costs approximately US$11,000,000 to build and almost $3,000,000 per annum to run. Few developing island nations can afford such expenses.

Small states generally do not have suitable slipping and docking facilities for larger fishing vessels, nor do they carry extensive stocks of spare parts and ancillary equipment.

(iii) **Cost and availability of fuel.** In 1976, it cost approximately A$140,000 per annum for fuel for a 350 tonne pole-and-line vessel, A$100,000 for a 276 tonne longliner and A$240,000 for a 1,100 ton purse-seiner. The fuel costs for any one of these vessels exceed the entire national fuel bill for 1977 for each of two of the Island states of the South Pacific (Tuvalu and Niue) and represent a substantial fraction of the fuel consumption of several others. Fuel prices have increased dramatically since 1976. Fuel is not only becoming more expensive, but is also difficult to obtain in exactly the quantities required to supply a small number of vessels, which are refuelled on an irregular basis, making it difficult for any non-oil producing country to plan the development of fisheries which will necessitate substantial increases in fuel consumption.

Fuel is also far more expensive in remote areas. This makes it disadvantageous for foreign flag vessels to bunker there and hence difficult for small states to encourage these vessels to call and unload their catch. It also means that Island states have an extra economic disadvantage to contend with when catching fish to sell on an internationally competitive market.

(iv) **Problems of smallness and economies of scale.** There are many problems of smallness and economies of scale relevant to fisheries development in the Pacific Islands. These have been covered in previous publications, e.g. Kearney 1980.

The inability of at least some small Island states to cope with these and other problems might suggest pessimism for their future in tuna fisheries. This is certainly not intended. The magnitude of the problems does suggest that some Island states will find it impossible to develop wholly owned, large scale tuna enterprises, but it does not at all detract from the countries' potential to develop small scale tuna fisheries, or joint venture operations in which they have limited equity, or to generate considerable revenue from the activities of foreign vessels in their fishing zones.

As the tuna resources are generally underexploited, there is obviously potential for increasing catches by subsistence or artisanal fishermen. This potential is being further increased throughout the region by adapting modern technology, such as fish aggregation devices, to small scale fisheries. The success of joint venture or co-operative tuna fishing ventures, such as those in Solomon Islands and Fiji, endorses the potential such arrangements have for further developments. Finally, the magnitude of the value of catches by distant-water fishing fleets in the 200-mile zones of coastal states, in some cases having fresh fish values greater than the gross national product of the country from whose waters they are taken (Kearney 1981a), coupled with the increased rights of coastal states in the new regime of the Law of the Sea, clearly demonstrate the potential for Island states to generate significant revenue from foreign fishing interests, particularly if realistic access fees can be negotiated.

REFERENCES

ANONYMOUS. 1975. Report of the Eighth Regional Technical Meeting on Fisheries. South Pacific Commission, Noumea, New Caledonia.

ANONYMOUS. 1976. The present status of the alfonsin, Beryx splendens, fishery in the Midway fishing grounds. Excerpt from Suisan Sekai, 25(8):28-32, August 1976. Translated from the Japanese by Tamio Otsu, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. Translation No.18. NOAA, Honolulu, Hawaii, January 1977.

ANONYMOUS. 1980. State of selected stocks of tuna and billfish in the Pacific and Indian Oceans. Summary Report of Workshop, Shimizu, Japan, 13-22 June 1979. FAO Fisheries Technical Paper (200). 89 p.

CROSSLAND, J. and R. GRANDPERRIN. 1979. Fisheries directory of the South Pacific Commission region. South Pacific Commission, Noumea, New Caledonia.

CROSSLAND, J. and R. GRANDPERRIN. 1980. The development of deep bottom fishing in the tropical Pacific. Occasional Paper No. 17, South Pacific Commission, Noumea, New Caledonia. 12 p.

FAR SEAS FISHERIES RESEARCH LABORATORY. 1978. The recent status of yellowfin and bigeye tuna stocks in the Pacific Ocean. (Background document). IOFC/IOPC Tuna Management Committee Meeting, Manila.

JAMARC. 1973. Surveys of trawling grounds in the north central Pacific Ocean, 1972 season. JAMARC Report No.7, March 1973. Translated from the Japanese by Tamio Otsu, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. Translation No. 19. NOAA, Honolulu, Hawaii, February 1977.

KEARNEY, R.E. 1976. The expansion of fisheries in Papua New Guinea: prospects and problems. Paper presented at Waigani Seminar, 3-7 May 1976, Lae, Papua New Guinea.

KEARNEY, R.E. 1977. The law of the sea and regional fisheries policy: the impact of extended jurisdiction on fisheries management in the central and western tropical Pacific Ocean and the need for a regional fisheries agency. Occasional Paper No.2, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. 1979a. An overview of recent changes in the fisheries for highly migratory species in the western Pacific Ocean and projections for future developments. SPEC(79) 17. South Pacific Bureau for Economic Co-operation, Suva, Fiji.

KEARNEY, R.E. 1979b. Some problems of developing and managing fisheries in small island states. Occasional Paper No. 16, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. 1980. Some problems of developing and managing fisheries in small Island states. In R. T. Shand [ed.], The island states of the Pacific and Indian Oceans: anatomy of development. Development Studies Centre Monograph No. 23, Australian National University, Canberra, Australia.

KEARNEY, R.E. 1981a. The development of tuna fisheries and the future for their management in the tropical, central and western Pacific. Paper presented at the 15th Annual Meeting of the Law of the Sea Institute, 5-8 October, Honolulu, Hawaii (to be published in Proceedings of this meeting).

KEARNEY, R.E. 1981b. A brief review of the state of the stocks of highly migratory species of fish in the central and western Pacific. Paper presented at Forum Fisheries Agency Regional Research and Development Programme Meeting, 4-8 May 1981, Honiara, Solomon Islands.

KEARNEY, R.E. 1981c. Some economic aspects of the development and management of fisheries in the central and western Pacific. South Pacific Commission Fisheries Newsletter 22:6-15.

KEARNEY, R.E. and M.L. RIVKIN. 1981. An examination of the feasibility of baitfish culture for skipjack pole-and-line fishing in the South Pacific Commission area. Skipjack Survey and Assessment Programme Technical Report No.4, South Pacific Commission, Noumea, New Caledonia.

SAKIURA, H. 1972. The pelagic armourhead, Pentaceros richardsoni, fishing grounds off the Hawaiian Islands, as viewed by the Soviets. Suisan Shuko, No.658:28-31 (June 15, 1972). [The article was a translation of an uncited Russian article.] Translated from the Japanese by Tamio Otsu, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. Translation No.17, NOAA, Honolulu, Hawaii, January 1977.

SASAKI, T. 1974. The pelagic armourhead, Pentaceros richardsoni Smith, in the north Pacific. Bulletin of Japanese Society of Fishes and Oceanography 24:156-165. Translated from the Japanese by Tamio Otsu, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. Translation No.16, NOAA, Honolulu, Hawaii, January 1977.

SKIPJACK PROGRAMME. 1981. Skipjack migration, mortality and fishery interactions. 13th Regional Technical Meeting on Fisheries 1981, Working Paper No. 9. South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME. 1982. An assessment of baitfish resources in the South Pacific Commission area. 14th Regional Technical Meeting on Fisheries 1982, Working Paper No. 11. South Pacific Commission, Noumea, New Caledonia.

THE CHALLENGE OF CONSERVING AND MANAGING CORAL REEF ECOSYSTEMS

Arthur Lyon Dahl
B.P. 1146, Noumea, New Caledonia

ABSTRACT

Coral reef ecosystems are noted for their diversity and complexity. While they demonstrate a certain resilience under natural conditions, they have proven highly vulnerable and easily degraded under man's influence.

The integrated nature of many reef ecosystems and their interaction with terrestrial and oceanic influences limits the possibilities for resource management. The inadequate scientific understanding of the ecosystem also hampers the development of management strategies. The traditional resource management techniques of Pacific Island cultures may prove to be the best guide to methods of sustainable resource use on coral reefs.

A start has been made in conserving coral reefs in several South Pacific countries, using a variety of approaches. Unfortunately, local means have not permitted any study of the effectiveness of these efforts, and the protection of the region's reef resources is still far from adequate. Regional initiatives such as the South Pacific Regional Environment Programme are helping to advance coral reef resource management and conservation in the region.

The coral reef ecosystem occurs commonly along the coastlines and around the islands of tropical developing countries, where it is an important resource for subsistence, coastal protection, and economic development. The increasing use and misuse of resources throughout the world presents man with the challenge of conserving and managing coral reefs so that they can continue to provide benefits on into the future.

The conservation and management of coral reef ecosystems is a particularly difficult task for a number of reasons: the inherent characteristics of the ecosystem itself; its vulnerability under man's influence; and the inadequacy of the present scientific understanding of the ecosystem and how it functions.

The coral reef ecosystem is well known for its complexity and diversity, with perhaps more species within a small area than any other ecosystem known. Its long evolutionary history has allowed it to develop high levels of interaction between its components in both space and time, and on small and large scales. The result is an ecosystem noted for its high productivity even in a resource-poor environment, and for its efficiency in the utilization and recycling of energy and nutrients. There is increasing evidence of the dynamism and resilience of coral reefs under natural conditions, with a successional development of reef structures, a relative stability of reef ecosystems at large scales, and a large capacity for regeneration after damaging extremes at smaller scales.

It was long assumed that these characteristics in an ecosystem would make it more resistant and thus easier to manage, but the tropical environment of coral reefs has been one of the most stable over geological time, and when man pushes environmental factors beyond accustomed limits, or introduces new ones, the coral reef ecosystem has proven particularly vulnerable.

The direct destruction of coral reefs by dredging, construction or other activities can have effects far beyond the immediate area concerned. For instance, the migration routes of fish and other organisms can be upset; damage to reproduction areas can reduce populations far beyond; food chains and the transfer of detritus can be interfered with; nutrient cycles can be interrupted; and the balance of construction and erosion of the reef framework can be altered.

The breaking or removal of corals is a serious problem in some areas. The effect is equivalent to cutting the trees in a forest; only a depauperate community is left behind.

Human activities frequently alter the water quality in coastal waters and affect reef-land interactions. As land is developed, terrestrial runoff changes, often with drastic effects on the turbidity, salinity, temperature, and sedimentation in the waters surrounding coral reefs.

Man also alters the chemical environment of coral reefs. Pesticide spills and the drainage of pesticide residues can have catastrophic or chronic effects. Nutrient inputs from fertilizers and urban wastes can upset delicate population balances, as can inputs of organic materials.

Fishermen find it hard to resist "just one more" or to grab at any opportunity that presents itself, and improved transport has reduced the number of areas protected by their inaccessibility, leading to increasing problems of overfishing on all coral reefs near significant population centers. Human ingenuity combined with modern technology have greatly increased the number of ways of killing fish, many of which (explosives and poisons in particular) are also highly destructive of other coral reef resources.

Furthermore, it is difficult or impossible to isolate a coral reef, as one might a park or reserve on land. Traditional park and reserve concepts and conservation approaches do not work as well in the sea, where the reef ecosystem is still subject to, and perhaps dependent on, oceanic and terrestrial influences.

The management of coral reef resources is further handicapped by the present inadequate scientific understanding of such complex systems. Johannes (1981) doubted that the scientific management of coral reef fisheries would be possible in this century. Predicting reef behavior under human stresses, or planning the restoration of a damaged area, are still well beyond current knowledge.

Unfortunately, with the present rapid rate of reef degradation, actions for the conservation and management of coral reef ecosystems cannot wait for adequate scientific knowledge to accumulate. A pragmatic approach based on educated guesses and common sense extrapolations from present understanding will have to serve until more information is available. Management guidelines will have to be worked out on a trial and error basis.

Efforts to conserve significant coral reef areas in the South Pacific have already begun. Early marine reserves in the region include the Ngerukewid (Seventy) Islands reserve in Palau (1958), the Yves Merlet Marine Reserve in New Caledonia (1970), Scilly Lagoon (1971) and Taiaro Atoll (1972) in French Polynesia, and Rose Atoll in American Samoa (1973). More recently, five coral reef reserves have been created in Tonga (1979), as well as the Palolo Deep Marine Reserve in Western Samoa (1979), Suwarrow Atoll Marine Park in the Cook Islands (1978), and Horseshoe Reef Park in Papua New Guinea (1981). New Caledonia has also recently created a rotating marine reserve on three major sections of barrier reef. Unfortunately, the enforcement of these reserves is often difficult, and the scientific resources in the region are too limited to study the effectiveness of these approaches to marine conservation.

Some regional efforts at coral reef management have started under the Regional Seas Action Plans. The South Pacific Regional Environment Programme (SPREP) has considered approaches to mapping coastal resources to permit more effective siting of developments and reserve areas. It is also planning guidelines for the management of coral reefs, following up on its earlier Coral Reef Monitoring Handbook (Dahl, 1981). In addition, it is supporting a project to strengthen the local management of coral reefs and other resources in rural areas by the users themselves.

In the absence of a strong scientific foundation for reef management, it is possible to look for guidelines in the traditional resource management techniques developed over generations by various Pacific Island cultures. Proper management of limited resources was essential to these peoples' survival, and they developed many approaches of proven effectiveness. The following general guidelines are derived from these practices.

Access to a particular reef fishery or area should be limited to the number of fishermen able to fish the area efficiently on a sustainable basis.

The widest range of reef fishery resources (fish, shellfish, invertebrates, algae, etc.) should be used, rather than just the most desirable species. A broad but light pressure on resources will better preserve the balance of species.

There should be some permanent reserves, and other areas periodically closed to permit the regeneration of resources.

Resource use should be adjusted to protect the breeding cycle or capacity of each species, including limits on the consumption of rare resources. Such information is often part of local traditional knowledge.

Management of a coral reef can often be undertaken best by local people who have the most complete local knowledge of the status of the resource and its evolution over time.

Commercial fisheries development should be limited to areas where subsistence use leaves sustainable resources untapped. Too often in the past, commercial reef fisheries development has been at the expense of subsistence users, who in many cases already make full sustainable use of available resources.

The above approach to coral reef fisheries management, together with the better control of terrestrial influences (particularly those affecting critical habitats) and more integrated planning in the coastal zone, will help to meet the challenge of conserving and managing coral reef ecosystems in the years immediately ahead.

REFERENCES

Dahl, Arthur Lyon. 1981. Coral Reef Monitoring Handbook. South Pacific Commission, Noumea, New Caledonia. 21 p.

Johannes, Robert. 1981. Making better use of existing knowledge in managing Pacific Island reef and lagoon ecosystems. South Pacific Regional Environment Programme, Topic Review No. 4. South Pacific Commission, Noumea, New Caledonia. 18 p.

CORAL REEFS IN THE PACIFIC - THEIR POTENTIALS AND THEIR LIMITATIONS

E. D. Gomez and **H. T. Yap**
Marine Sciences Center, University of the Philippines
Diliman, Quezon City, Philippines

ABSTRACT

The high productivity of coral reefs is generally recognized. Available data indicate appreciable yields in terms of fish biomass, although significant quantities of seaweeds, molluscs, crustaceans and echinoderms are also harvested. Coral reefs are a principal ecological zone in virtually all islands of the tropical Pacific. In characterizing the potentials and limitations of these resources, the uniqueness and physical variability of island systems must be recognized. Of particular relevance is the fragility of small island systems due to isolation, size, and the semi-enclosed character of the reefs. Human populations are a primary factor to consider. Up till the early twentieth century, subsistence economies were the rule in most Pacific island communities which depended on reef resources to varying degrees. In the island economy as a whole, however, the latter were only secondary relative to produce from the land. Even then, marine resources displayed their vulnerability and their inadequacy to sustain exploitation on a commercial scale. At present, new problems arise mainly from the transformation of subsistence economies to cash economies. These problems are associated with increasing human population, shifts in the major spheres of economic activity, the loss of traditional management and conservation systems, the development of new reef uses such as tourism, improvements in harvesting technology, and degradation of coral reefs due to human activities. The carrying capacity of reef resources thus becomes a pivotal issue. A recent promising development related to the question of Pacific reef potentials lies in the field of mariculture.

INTRODUCTION

Pacific island populations have traditionally depended on coral reefs to a great extent for their survival and livelihood. Modern developments have significantly altered the relationships between man and reef in an increasing number of localities, and even extremely remote areas have not been spared. The fundamental dependence of human populations in the Pacific on their reef resources, however, remains.

The present paper attempts to explore a number of factors relevant to these issues. Discussion focusses on the countries and territories of the South Pacific, specifically, those within the jurisdiction of the South Pacific Commission.

NATURAL PRODUCTIVITY OF CORAL REEFS

Coral reefs are recognized to be among the most productive natural ecosystems in the world (Grigg, 1979; Marsh, 1976; Salvat, 1981). Rates of primary productivity range from 300 to 5000 $gC/m^2/yr$, which are as high as in the most fertile waters (Lewis, 1977). Values from different ecosystems are shown in Table 1. Productivity in the various reef habitats is not uniform, however. Some reef ecosystems exhibit relatively low productivities, such as certain atolls in the tropical South Pacific (Ricard and Delesalle, 1981). Important primary producers in coral reefs are the macroalgae, the symbiotic zooxanthellae, and the fine filamentous forms inhabiting the substrate (Marsh, 1976).

Table 1 : Primary production values for pelagic, benthic and terrestrial ecosystems

Habitat	Biomass (gC/m^2)	Production (gC/m^2/year)	Author
Pelagic			
Marine			
North Sea	3.5	100	Steele (1956)
English Channel	2	135	Harvey (1950)
Long Island Sound	8	470	Riley (1956)
Sargasso Sea (Oligotrophic)	0.87	134	Menzel & Ryther (1961)
Peru Current (Eutrophic)	14	3650	Menzel et al.(1971)
Freshwater			
Oligotrophic lakes	--	7-25	Lund (1970)
Eutrophic lakes	--	75-250	Lund (1970)
Sewage treatment ponds, California	24	1800	Goulake et al. (1960)
Benthic, littoral, and shallow water			
Marine			
Algal beds, Nova Scotia	1600	920	MacFarlane (1952)
Algal community, Canary Isles	630	3836	Johnston (1969)
Kelp community Nova Scotia	265	1750	Mann (1972)
Tropical marine grass beds	2260	4650	Odum H.T. (1956), Burkholder et al. (1959)
	196	2100	Qasim & Bhattashiri (1971), Moore et al. (1968)
Coral reef	280	4200	Odum & Odum (1955)
	--	2900	Kohn & Helfrich (1957)
Estuarine and brackish water	--	1320	Odum, E.P. (1961)
Spartina marsh, Georgia	--	520	Smalley (1960)
	840	1600	After Westlake (1963)
	435	430	McFadyen (1964)
Terrestrial			
Field grass, Minnesota	740	500	Golley (1960)
	640	140	Bray et al. (1959)
Sugar cane, Java	1700	3450	Giltay (1898)
Woodland deciduous			
Birch	1760	425	Ovington & Madgewick (1959)
Alder	3400	785	Ovington (1956)
Woodland coniferous	1840	800	Ovington (1957)

Source: Crisp, 1975 in Lewis, 1977.

High productivity values are also evident in the higher trophic levels, such as in the case of the coral animals themselves (Lewis, 1981). High rates of production for the latter are extremely significant because there are grounds for considering them to be the "key industry" forms in coral reefs, i.e., the most important channels through which matter and energy flow. Lewis discovered certain common reef corals in the Atlantic to have productivities of just over 1000 kcal/m^2/yr. Since this value is representative of only 39% coral cover, then productivity rates may be expected to be much higher in reef areas of greater coverage, such as the numerous well-developed reefs in the Pacific. Productivities of all species examined by Lewis appeared to be higher than those of many other benthic invertebrates. An important implication of this study is that there exists a considerable resource of food energy available for higher trophic levels.

A good example of how the naturally high productivity of coral reefs is translated into economically important harvestable biomass is the production of various other invertebrates and of fish. Invertebrate groups harvested for subsistence, commercial, or recreational purposes are gastropods, bivalves, shrimps, lobsters, squid, octopus, sea urchins, and sea cucumbers. A number of studies exist that determine the potential productivity of these different groups, such as that of Richard (1981) who focused his investigation on mollusc species in French Polynesia of potential commercial value. He determined annual potential productivities of Tridacna maxima, Cardium fragum, and Tectarius grandinatus to be 12 kg/ha, 460 kg/ha and 11 kg/ha, respectively. Similar studies conducted also in French Polynesia are outlined in Ricard et al. (1977).

Estimates of fish production vary, but all indicate that significant amounts may be harvested from coral reefs. Numbers of fish on reefs may be 5 to 15 times the number in representative North Atlantic fishing grounds, and twice the average in typical temperate lakes (Lewis, 1977). After briefly evaluating the different approaches to the study of coral reef productivity in terms of fisheries yield, Marshall (1979) arrived at a figure of 3-5 tons of finfish harvested annually per square kilometre. This estimate has now been questioned as being low in view of a number of more recent studies.

Employing a variety of methods, different authors (Alcala, 1979; Carpenter, 1977; Murdy and Ferraris, 1980) have drawn up figures for the fisheries potential of Philippine coral reefs. Contributions of coral reef fishes were estimated to range from 8 to over 20% of the total fisheries catch of the country. In some localities in the central Visayan islands, catch estimates have been determined to be as high as 14-27 tons/km^2/yr (Alcala 1979). As a comparison, coral reef fisheries in seven tropical Pacific islands were found to have productivities ranging from 0.09 to 18 tons/km^2/yr (Marten and Polovina, 1982). The reef fishery contributes a significant percentage (30%) to total fish landed on the west coast of Sabah (Langham and Mathias, 1977). On the east coast of Malaysia, some 35% of all fish landed can be regarded as "reef-associated" (Rashid, 1980). Reef fish in Palau appear to have a potential harvest of 2,000-11,000 tons per year, which is of the same magnitude as the offshore tuna harvest. This relation appears to hold true for Micronesia as a whole (Johannes, 1977). Country data for reef and lagoon fish indicate that these constitute 29% of the commercialized local fishery in the South Pacific (Salvat, 1980), although this estimate does not incorporate contributions to the fishery from subsistence fishing. Salvat estimates a yield of 100,000 tons/yr for the South Pacific. The importance of coral reef fisheries on a world scale was evaluated by Smith (1978). After extrapolating data for Caribbean and western North Atlantic fisheries to the world's reefs, he estimated the potential yield of reef-related fisheries to be near 9% of total commercial fish landings. In view of the more recent studies, this figure probably needs to be adjusted upwards.

DISTRIBUTION OF REEFS IN THE PACIFIC

The distribution of coral reefs in the tropical Pacific is limited by the 20°C isotherms north and south of the equator, and extends from East Asia to the Pacific coast of the Americas. This is a vast expanse of ocean, covering approximately 110 million square kilometres (Wells, 1969), in which the thinly scattered islands are but mere specks. That these islands are able to support a diversity, and often an abundance, of life is due to a fortuitous combination of factors, among which coral reefs figure prominently. The coral reef is a principal ecological zone of both high and low islands (Mason, 1969), and in many cases constitutes their primary building block. The combined area of reefs in the South Pacific has been estimated to be around 77,000 square kilometres (Smith 1978). The North Pacific has a similar figure (76,000 km^2) while Southeast Asia (including northern Australia) accounts for 182,000 km^2.

Coral thus makes up a great portion of Pacific islands, either by active growth of the reef itself, or by the accumulation of reef debris by mechanical forces such as waves and currents.

Biogeographic provinces in the South Pacific and the reef types that occur in each are shown in Table 2. Summary descriptive information on each island in the different biogeographic provinces (excluding New Guinea, the Bismarck Archipelago and the Solomon Islands) is provided in the Draft Check List of Pacific Oceanic Islands by Douglas (1969) based on the work by E.H. Bryan.

Table 2 : Occurrence of reef types in the biogeographic provinces of the South Pacific (from Dahl, 1980)

Biogeographic Provinces \ Biomes/Habitats		Algal reef	Windward atoll reef	Leeward atoll reef	Barrier reef	Fringing reef	Lagoon reef	Non-growing reef	Submerged reef
I	New Guinea	*	*	*	*	*	*	*	
II	Bismark Archipelago				*	*	*		
III	Solomon Islands	*			*	*	*		
IV	New Caledonia - Loyalty	*	*	*	*	*	*		
V	New Hebrides - Santa Cruz		*	*		*	*		*
VI	Norfolk - Lord Howe - Kermadec					*			
VII	Fiji	*	*	*	*	*	*		
VIII	Tonga - Niue	*			*	*	*		
IX	Samoa - Wallis	*	*	*	*	*	*	*	*
X	Tuvalu - Tokelau	*	*	*			*		*
XI	Kiribati - Nauru		*	*		*	*		*
XII	Mariana Islands				*	*	*	*	
XIII	Caroline Islands	*	*	*	*	*	*	*	*
XIV	Marshall Islands	*	*	*			*		
XV	Phoenix - Line - Northern Cook	*	*	*			*		
XVI	Cook - Austral	*	*	*	*	*	*		
XVII	Society Islands		*	*	*	*	*		
XVIII	Tuamotu	*	*	*		*	*		*
XIX	Marquesas					*			
XX	Pitcairn - Gambier - Rapa		*	*	*	*	*		

CHARACTERISTICS OF PACIFIC ISLAND ECOSYSTEMS

Uniqueness of islands

Pacific islands may fall under any of the following structural types (descriptions after Dahl, 1980; Thomas, 1963 in Anon. 1969):

Continental type - composed of sedimentary, metamorphic, igneous or other rocks of continental origin (occurring west of the Andesite Line), and of soils derived therefrom; generally islands of large size with complex landforms.

Volcanic type - islands built by volcanic activity and therefore with substrates derived from lava (usually basalt) and volcanic ash.

Elevated reefs - islands or parts of islands composed of raised coral platforms or limestone.

Low islands - composed of sand and coral rubble accumulated on a reef platform at or near sea-level. This is the typical type on atolls and barrier reefs, and also frequently occurs as coastal or beach areas on other island types.

The islands in turn may be flanked by one or a combination of several reef structures. Following Dahl (1980), these may be described as follows. An algal reef is a calcareous structure in which coralline algae are principal contributors to reef construction and surface cover. A coral reef, on the other hand, is a structure actively constructed by the skeletal deposition of hermatypic corals and associated organisms. Coral reefs in turn take the form of:

Atoll reefs - annular reefs generally with an internal lagoon unassociated with any major landmass.

Barrier reefs - reefs offshore from a major land mass and separated from it by a deep lagoon or navigable channel.

Fringing reefs - reefs growing directly out from the coastline and not separated from it by more than a shallow depression.

Lagoon reefs or patch reefs - reef structures developing in the sheltered waters of a lagoon.

A "non-growing" reef is a calcareous structure now covered with organisms not contributing significantly to skeletal accumulation or reef growth. Submerged reefs are those "drowned" by subsidence to depths below which reef growth has been insufficient to regain the surface.

Similarly, the marine environment may be characterized by different structural criteria (Dahl, 1980). Substrates in different areas may be rocky (calcareous or non-calcareous) or unconsolidated. In addition, reef community structure would depend on whether the island is submerging, emerging or apparently stationary relative to sea level, and whether the setting is exposed or protected with respect to the physical forces of the sea. These factors are all part of the variability of the physical and chemical environment of island ecosystems (which will be discussed in the following section), and which contribute significantly to the uniqueness of each island.

Descriptions of reef structure and morphology in the tropical Pacific are relatively few. Some studies that may be mentioned are those on the Cook Islands (Gibbs et al., 1971; Stoddart and Pillai, 1973); Fanning Island (Maragos, 1974a and b; Roy and Smith, 1971); French Polynesia (Chevalier, 1973b; Ricard et al., 1977); the Lau Islands in Fiji (Phipps and Preobrazhensky, 1976); the Marshall Islands (Ladd, 1973; MacNeil, 1972); the New Hebrides (now Vanuatu) in Melanesia (Guilcher, 1974); New Caledonia (Chevalier, 1973a); Papua New Guinea (Weber, 1973b; Whitehouse, 1973); Samoa (Mayor, 1924); and the Solomon Islands (Jones, 1977; Morton, 1974; Weber, 1973a).

The physical structure of an island is a major determinant of the types of ecosystems present (Dahl, 1980). A clear example may be found in the case of islands with exposed and protected sides, such as atolls. Coral reefs tend to be more robust and better developed on the exposed sides due to more adequate water circulation and greater availability of nutrients. In addition, reef forms and lagoon types are determined by the structure and history of the island substrate (Dahl, 1980). In general, therefore, a broad distinction can be made among continental islands, high volcanic islands, elevated reefs, and low coral islands, but it is also necessary to consider the detailed origin and structure of each, and its geographic location in terms of the origin and evolution of flora and fauna (Elliott, 1973). Dasmann (1973) attributes the uniqueness of island ecosystems to their relative isolation which induces peculiar evolutionary patterns in each separate setting. Differences among similarly situated reef habitats are manifested, for example, in the differing rates of productivity of atoll lagoons in the South Pacific (Ricard and Delesalle, 1981).

Variability in the physical, chemical, and biological environment

Variability in the environment plays a key role in the development of islands and their characteristic reef systems. On the whole, islands may be considered as being unstable ecosystems. Factors in the physical and chemical environment are discussed by McLean (1980b). These are divided into factors of the land, the sea, and the atmosphere. In the first category falls the immense variety of island types already discussed. Also considered here is the plate tectonic setting of most islands in the tropical Pacific which is responsible for long-term instability in the form of vertical and horizontal movements, and present perturbations such as earthquakes and vulcanism.

Of the factors associated with the sea, perhaps the most severe effect exerted on island ecosystems has been that of the rise in sea level in recent geologic time. This phenomenon has resulted in changes in island distribution, size, and type. Small oceanic islands were particularly vulnerable, being drastically altered or disappearing altogether. Reefs either grew proportionately, or were drowned (McLean, 1980a). Present evidence suggests that sea level is continuing to rise (McLean, 1980b). A second factor that has shaped much of coastal morphology and that is responsible for the formation of a number of islands are ocean waves. Of particularly great impact over the short term are tsunamis, storm surges, and hurricane waves. Effects of hurricane waves on reef structures in the Pacific have been documented by Baines et al. (1974), Baines and McLean (1976), and Randall and Eldredge (1977). Fortunately, reefs afford a measure of protection for island shores against the destructive effects of the sea. Altogether, it should be emphasized that there exists an intimate linkage between reefs, marine processes, and the subaerial coastal land in the building and alteration of coastal features (McLean, 1980a). The latter is known to have occurred rapidly throughout prehistoric times.

Factors of the atmosphere are wind, rainfall, and storms. These are closely linked with currents and the oceanographic processes described above, as well as relevant chemical parameters such as salinity and nutrient loading.

Perhaps the most significant biological factor affecting Pacific reefs on a large scale, and hence worth mentioning here, is predation by the crown-of-thorns starfish *Acanthaster planci* (Cheney, 1974; Nishihira and Yamazato, 1974). Repeated population explosions of this organism have occurred in a number of localities and are believed to be cyclic, though probably aggravated by human interference in the environment. These have been reported to cause extreme damage to reefs, as much as 90% in a single area. Serious concern has thus been generated (e.g. Chesher, 1969), including speculations on severe economic loss and the possible extinction of scleractinian corals in some areas. Additional studies indicate, however, that this coral-eating starfish may be a normal component of tropical Pacific coral reef communities, and that the publicized population explosions in areas such as Guam and Palau may be isolated, local infestations of an unknown cause (Weber and Woodhead, 1970). At present, it does not appear to pose a serious threat in any part of the region (Marsh and Tsuda, 1973; Alcala, 1976).

Fragility of small island ecosystems

As a result of physical and biological instability generated by the factors discussed above, and because of the significant role of isolation (Dasmann, 1973; Grigg, 1979), island ecosystems have evolved to be extremely fragile and vulnerable to disturbance. This vulnerability extends even to disruptions of local flora and fauna by the introduction of new species because of the high degrees of specialization that the former have achieved through evolutionary time. Other sources of vulnerability are restricted land and reef areas, and limited carrying capacities for human settlement (Mason, 1979).

Small islands tend to be more densely populated than larger ones, and hence approach more closely the limits of the environment to support the population (Bayliss-Smith, 1978). A more extended discussion of the carrying capacities of islands with respect to human populations is provided by Bayliss-Smith (1980).

MAN'S RELATION TO THE REEF

Inadequacy of reefs to sustain large-scale exploitation

In spite of their high rates of productivity, coral reefs appear to be unable to sustain exploitation on a significantly large scale such as a commercial fishery. This may be attributed to the physical setting of reefs in the Pacific, as well as to the nature of the coral reef ecosystem.

Many islands are actually the tips of submerged mountains, so that the productive shallow waters are limited to the narrow band which is the coral reef (Johannes, 1978). Offshore waters tend to be hazardous and even less productive. In the case of atolls, sheltered lagoons which are more accessible to local fishermen are less productive than the more exposed reefs. This is in striking contrast with the continental situation where wide continental shelves lend themselves to the harvesting of considerable biomass.

The nature of the coral reef ecosystem is such that it is fragile and easily disturbed when pushed beyond its limits (Dahl and Baumgart, 1982). In addition, it is felt that coral reefs have low standing crops of exploitable species (Smith and Stimson, 1979). This may be due to the cryptic nature of much of the reef fauna, and the lack of extensive beds of filter feeders that are amenable to currently employed harvesting techniques. In addition, the exceptionally high diversities characteristic of coral reefs preclude the development of single, dominant species stands which are easily harvested. It would therefore appear that reef species may sustain local (i.e. subsistence) consumption, but not consumption greatly exceeding this level. Subsistence exploitation of reef resources may thus be near the carrying capacity of the ecosystem, having taken millenia to adjust.

Grigg (1979) takes a somewhat different view of the limitations of reef resources but arrives at much the same conclusion. He maintains that reef processes favor the accumulation of biomass which results in an apparent abundance of resources, but certain characteristics of the ecosystem render the latter vulnerable to over-exploitation. These characteristics are summarized as follows:

1) Since a majority of the nutrients in the system are present in the form of biomass, a large fraction is exposed to removal by exploitation;

2) Removal of nutrients from the system reduces the amount that can otherwise be recycled, and thereby reduces potential or future production;

3) Great longevity exposes many year classes to exploitation; and

4) Long-lived species are characterized by low rates of turn-over.

In island settings, additional factors contribute to the easy depletion of reef resources. These are the small size of many islands, and the semi-enclosed character of reef ecosystems (Grigg, 1979). Grigg postulates that sustained harvests may not be much greater than 10% of standing crops.

Varying degrees of dependence on reef resources

No data are available at present on the fraction of the world population living close to and dependent on coral reefs. Salvat (1981a) estimates it to be well below 100 million. Among the Pacific islands at present, there exists a spectrum from subsistence economies to those that are highly urbanized and industrialized. There may be found a contrast, therefore, between self-sufficiency or a close relationship with existing terrestrial and marine resources, and varying degrees of dependence on imports and world markets (Mason, 1979). Except for the larger islands of Melanesia, however, reefs and lagoons may be considered the traditional sources of protein food (Elliott, 1973). In Guam, marine resources have traditionally been of great economic significance though the subsistence base in the past has been agriculture rather than fishing (Nolan, 1979). It may be surmised that most of these marine resources are drawn from the reef and related areas, in Guam and elsewhere, because the knowledge and technology to harvest reef resources is well within the current capabilities of Micronesian fishermen, which is not the case for pelagic fisheries (Johannes, 1977).

Salvat (1980), on the other hand, maintains that the exploitation of marine resources is not central to the island economies in the South Pacific. In the case of certain small islands such as in Fiji, reef and lagoon resources are of greater relative importance than on larger islands (Brookfield, 1978a). Still, there is no truly heavy dependence for subsistence or cash because resources are limited and patchy.

An overview of the utilization of reef resources in the Pacific indicates that most plant and animal groups are still relatively under-exploited (Salvat, 1980). This is true for crustaceans and echinoderms such as sea cucumbers. The latter are of greater relative importance than crustaceans or molluscs in the tropical South Pacific. Trade in these organisms flourished in the 19th and early 20th centuries, then declined. Algae are limited mainly to domestic use. Molluscs are used as food. There are indications that present populations may not be able to support commercial exploitation on any scale, and that these are already heavily taxed on the present subsistence basis. Fishes on the outer reef slopes are underexploited. Limitations to large-scale exploitation of reef fishes are their diversity, relatively small size, occasional toxicity, and existing harvesting technology. Other problems arise with respect to preservation, transport and marketing. Aside from food, these organisms have great potential for use as live bait. Other vertebrates such as sea turtles and dugongs, on the other hand, are threatened with serious depletion of stocks.

Subsistence Populations

As may be gleaned from the discussion above, subsistence populations are still a pervasive and important element in the tropical Pacific. Island peoples have traditionally obtained the bulk of their protein from the sea, up to 90% in some cases (Johannes, 1978). This may be attributed to terrestrial food supplies being limited due to the poor soil quality on most islands, as well as being precarious due to the frequent onslaught of natural catastrophes such as hurricanes. Reefs may thus be seen as being an important element in subsistence economies. This is so in spite of the fact that many islands have to support large population densities, from several hundred individuals to over a thousand per square mile. It would seem that a close relationship has evolved between subsistence populations and the reefs on which they depend, with exploitation being closely attuned to the carrying capacity of the resource.

Detailed profiles of some islands within the Fiji group have been generated by projects under Unesco's Man and the Biosphere Programme (MAB). Descriptions of physical setting and socio-economic structures are available for islands such as Batiki (Bayliss-Smith, 1978), Kabara (Bedford et al., 1978), other islands of the Lau group (Salvat et al., 1978), and Taveuni (Brookfield, 1978b). Certain characteristics of these islands may be considered representative of the wider Pacific region, such as general demographic, economic, and cultural trends (to be discussed later). In contrast to other reports of a great dependence of Pacific island economies on reef resources, however, some of these islands, such as the Lau group, appear to be characterized by a lesser degree of dependence. There, terrestrial resources are accorded a central role in the economy. This may be a result of a paucity of marine resources, or simply their underdeveloped state. In some islands the harshness of the natural environment as a whole produces a dependence of populations on the wider Fijian society and economy for survival.

Also noteworthy are the different scales of exploitation of reef resources in different islands. In Lakeba in the Lau group, for example, reef fish are underexploited, but giant clams are exploited to the extent that they are now in danger of extinction (Salvat et al., 1977). Other groups such as crustaceans, echinoderms, medusae, and the alga Caulerpa are eaten, but are only secondary to fish and giant clams. In the island of Futuna most of the protein consumed is derived from the sea in the form of shellfish, crabs, crayfish, turtles, and echinoderms (Richard et al., 1981). The majority of these species appear to be exploited to the point of exhaustion because of non-selective and harmful fishing practices, and the morphology of the reef substrate which renders the benthos particularly vulnerable to present harvesting techniques.

Transformation from subsistence to cash economies

The impact of westernization, as this historical phenomenon is commonly referred to, resulted in unprecedented disruptions in the economic, social, and cultural fabric of island populations which had taken millenia to develop. Salient features of this development include the introduction of money economies, the imposition of new laws and practices by colonial powers, and the breakdown of traditional authority (Johannes, 1978). All these had important implications for the utilization of natural resources. A significant corollary of the changes wrought in Pacific island settings particularly at the turn of the century was the phenomenal rise in human population, the trend of which continues up to the present day. This in turn has led to new and increasing demands on island resources such as coral reefs. The resultant degradation and depletion of these resources has proven inevitable in many cases, and currently is a widespread and urgent problem to be tackled.

The advent of cash economies

The introduction of money economies by foreigners into Pacific island subsistence societies implied the operation of an entirely new set of factors determining the general course of livelihood of these peoples. Important examples are the development of distant markets and the growth of the profit motive (Johannes, 1978). The latter factor is especially significant because it meant the effective annihilation of the conservation ethic (see discussion in Johannes, 1977; 1978), so that considerable waste of reef resources became widespread. In addition, conflicts over resource use arose between subsistence fishermen and those promoting new commercial fisheries (Gawel, 1981).

In general, the drive for increased cash income meant the decline of subsistence activities (Finney, 1965), with the latter being supplanted by cash-crop production or full-time wage labor. Among other things, this meant the decrease in availability of products traditionally gathered from the reef, and the increasing reliance on imported commodities.

Loss of traditional management and conservation systems

Mention was made earlier of the conservation ethic in subsistence societies. Evidence indicates that this has been a guiding principle in the utilization of reef resources by most island communities. The current breakdown of traditional conservation practices is attributed to the advent of European and Oriental contact (Johannes, 1978; Owen, 1969). This has been accompanied in many areas by a decrease or disappearance of unprotected reef stocks (Gawel, 1981; Johannes, 1978). There are indications that Western approaches to resource management are not applicable in the tropical Pacific (Gawel, 1981), so that the accumulated wisdom of tradition may prove irreplaceable. Examples of traditional management practices are given in Table 3.

Not mentioned in Table 3 is the practice of reef and lagoon tenure (Johannes, 1977; 1978). The latter in effect is a system wherein the right to fish in a particular area is allotted to a clan, chief or family. Regulation of exploitation to achieve sustainable yields was thus pursued as a matter of course because it was perceived to be in the best interest of the controlling party. This practice prevents the tragedy of the commons now prevalent in modern societies.

Traditional management practices were either related to some religious or superstitious beliefs, or were clearly intended to conserve resources. A number were developed to minimize waste associated with periodic and predictable gluts, such as during spawning seasons. It appears that almost every basic fisheries conservation measure devised in the West was in use in the tropical Pacific for centuries (Johannes, 1978).

Problems of increased human population

A number of Pacific islands remain uninhabited, but in those that are inhabited, the growth of populations and their economies is a pervasive phenomenon (Elliott, 1973). Average annual rates of population growth for Oceania have been documented as follows (UN, 1981 in Holdgate et al., 1982):

1960-1965	2.08%
1970-1975	1.85%
1975-1980	1.47%

Percentage change in rate of growth from 1960-65 to 1975-80: -29.3%

Table 3 : Intentional marine conservation measures employed traditionally by tropical Pacific islanders (excluding marine tenure systems) (after Johannes, 1978)

Method	Locality
Closing of fishing or crabbing areas	Pukapuka; Marquesas; Truk; Tahiti; Satawal; Yap; Niue; Samoa; Tonga; Gilbert Islands; Hawaii; Solomon Islands; Marshall Islands; Cook Islands; Losap
Closed seasons or banning of fishing during spawning periods	Hawaii; Tahiti; Palau; Tonga; Tokelau; Samoa; Mangaia
Allowing a portion of the catch to escape or deliberately not catching all readily available fish or turtles	Tonga; Micronesia; Hawaii; Enewetak
Holding excess catch in enclosures until needed	Pukapuka; Tuamotus; Marshall Islands; Palau; Fiji; Huahine
Ban on taking small individuals	Pukapuka-crabs; Palau-giant clams
Fishing in inland lagoons or for certain easily accessible species restricted to times of poor fishing conditions	Nauru; Palau; Gilbert Islands; Pukapuka; Lau Islands, Fiji; Mokil
Restrictions on taking seabirds and/or their eggs	Tobi; Pukapuka; Enewetak
Restricting the number of fish traps in an area	Woleai
Ban on taking turtle eggs	Tobi; New Hebrides
Ban on taking turtles on the beach	Gilbert Islands
Ban on frequenting favorite spots on turtle nesting beach	Samoa

It may thus be seen that populations in the Pacific have continued to grow within the last two decades, although the rate of growth has slowed down perceptibly.

A typical pattern of population growth within documented history is that of the Mariana Islands (Underwood, 1973). The population history of the latter may be divided into four periods spanning the years 1521 to 1950: a period of population stability (1521-1668) immediately after initial European contact; a period of population decline and contraction (1669-1786) following the onset of hostilities and the disastrous impacts of newly introduced diseases; a period of population recovery and integration (1787-1898); and finally, a period of population growth and expansion (1899-1950), a major contributory factor to the latter being immigration. Trends for the island of Guam are graphically illustrated in Figure 1. Current demographic information for islands in the South Pacific is given in Table 4.

The major problem associated with rapid population growth is a limited resource base (Mason, 1979). Economic development would normally be enhanced by population growth when the latter occurs in a setting of abundant contiguous space and natural resources combined with a tradition of managerial and technical skill (Elliott, 1973). In the Pacific, however, contiguous spaces are small, natural resources often limited, and skilled managers and technicians in short supply. Thus in many places each population increment tends to burden the social services, reduce per capita income, and increase the time required to gain investment capital and train managers and technicians. It would therefore seem that population growth would continue to burden the island economy unless the latter is restructured, along with the relevant social and political systems.

Figure 1 : Population trends in Guam, 1521-1950
(based on data from Underwood, 1973)

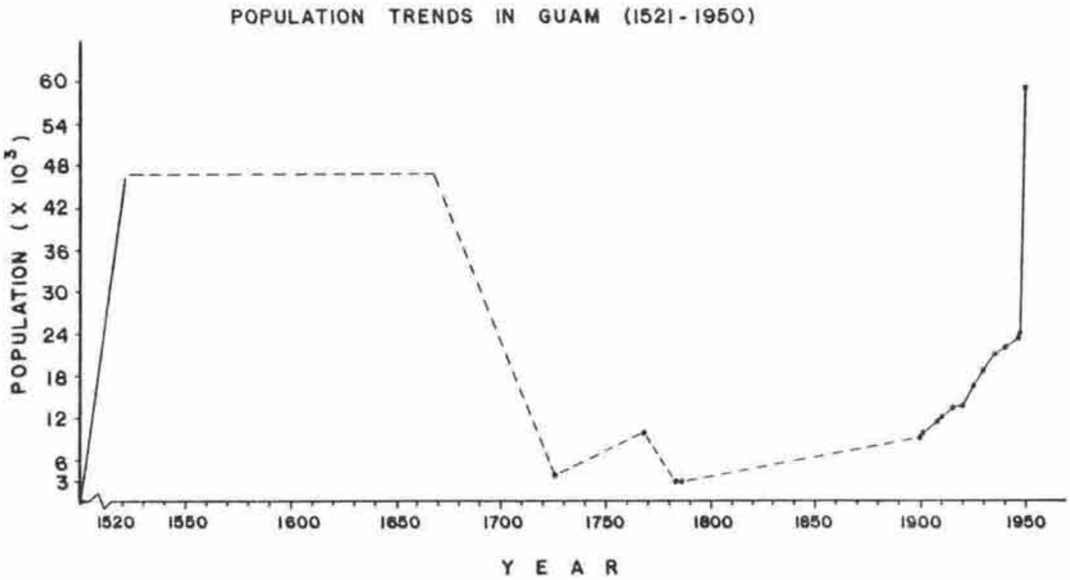


Table 4 : Population trends and land areas in the South Pacific
(South Pacific Commission, SPConf. 22/WP. 8, Page 13).

	Estimated Population (mid-1980)	Estimated Annual Growth Rate	Land Area (sq.km)	Population Density (persons/sq.km)
American Samoa	32,400	1.8	197	164
Cook Islands	17,900	-0.9	240	75
Federated States of Micronesia	74,400		700	106
Fiji	634,100	1.9	18,272	34
French Polynesia	148,100	2.2	3,265	45
Guam	105,800	2.0	540	196
Kiribati	58,600	2.0	690	85
Marshall Islands	31,000		170	182
Nauru	7,300	0.6	21	348
New Caledonia	140,500	0.9	19,103	7
Niue	3,400	-3.2	259	13
Northern Marianas	16,800	4.4	470	36
Palau	12,150		490	25
Papua New Guinea	3,006,800	2.2	462,243	7
Pitcairn Island	60	-5.0	5	15
Solomon Islands	225,200	3.1	28,530	8
Tokelau	1,600	0.0	10	160
Tonga	97,400	2.1	700	139
Tuvalu	7,500	2.0	26	288
Vanuatu	117,500	3.7	11,800	10
Wallis and Futuna	10,800	4.0	255	42
Western Samoa	156,800	0.8	2,935	53
TOTAL	4,906,110			

Improved harvesting technologies

The increasing demand of growing populations on coral reefs for food and other amenities has spurred the development or importation of new and better technology to facilitate the harvest of reef resources, often exceeding the capacity of these resources for renewal or replenishment. Thus, most native fishing equipment, for example, has been replaced by metal hooks and lures, nylon lines and throw nets, spear guns, diving gear, plastic boats, and gasoline-powered engines. The advent of the Second World War, in addition, has introduced Pacific islanders to the use of explosives and chemicals for catching fish (Mason, 1979).

In a sense,the following issues are also an offshoot of the general problem of increased human populations on Pacific islands.

Development of new reef uses

There has occurred over time a decline in the use of food of reef origin. The latter has been supplanted by other reef uses, such as handicraft industries based on products from the reefs, and pearl culture (Salvat, 1981b). Trade in reef products has grown to be a major commercial activity (Salvat, 1980; Wells, 1981). This has resulted in the depletion of stocks of many reef organisms such as mother-of-pearl, Trochus, Turbo marmoratus, other decorative shells, and various scleractinian corals. The coral trade and its implications for management have been discussed elsewhere (Gomez, 1983).

Tourism has grown to be the most important industry on many Pacific islands (Mason, 1979). Because they are small in scale, fragile, and easily degraded, tropical island environments are particularly threatened (Dahl, 1982; Salvat, 1973). With careful planning, however, much of the impact from tourism may be offset (Ryland, 1981).

In the face of the new and mostly unforeseen stresses inflicted on coral reefs with the onset of modernization, efforts have been made to develop reef resources on a planned and controlled basis, but on a larger scale than has hitherto been carried out. Unfortunately, there are indications that the fisheries development efforts currently underway are not appropriate to the natural and human environments of the tropical Pacific (Gawel, 1981). Among others, problems in marine resource development involve manpower, infrastructure, marketing, processing, business management, financing, and fuel costs. It is anticipated that these problems will continue to preoccupy resource managers for a long time to come.

Resource degradation

Perhaps one of the most serious problems to arise with respect to reef resources is that of degradation from human activities. A list of current causes of reef degradation is presented in Table 5. Salvat (1981a) notes that all of the items listed in this table have been originally absent in subsistence settings, except for the use of poisons for fishing. A general discussion of destructive human activities is provided by Salvat (1978, 1981a). Of these, the most serious damage appears to be caused by collection of the reef biota, sedimentation, and dredging. In an overview of reef degradation in the Pacific, Dahl and Baumgart (1982) report blasting, the use of poisons in fishing, pollution, and siltation to be major causative factors. Murrell (1982) reports at least three-quarters of Pacific countries as now having marine pollution problems, although these are mostly concentrated in the coastal zones. An additional source of degradation in the Pacific is the use of several Pacific islands as sites for the construction of military installations, so that a number of reefs are contaminated by radioactive pollution (Yonge, 1969). Mining on coral reefs occurs in Fiji, Papua New Guinea, the Solomon Islands, the Trust Territories, and Western Samoa (Cruickshank, 1981), mainly for coral sand and other construction materials. Causes of reef degradation in Micronesia as a whole are documented by Owen (1969), Nolan (1979) and Tsuda (1981). Short discussions on the specific problems of each island or country are available for American Samoa (Swerdloff, 1973), the Cook Islands (Hambuechen, 1973), Fiji (Richmond, 1981), Guam (Jones and Randall, 1973), Moorea in French Polynesia (Naim, 1981), New Caledonia (Parrat, 1973), the Trust Territory of the Pacific Islands (Division of Lands, 1981; Owen, 1973), and Western Samoa (Hewson et al., 1981). Reef degradation in Southeast Asia is discussed elsewhere in this volume (Yap and Gomez, 1984). Among other things, the above factors have resulted in serious depletion of reef organisms such as fish (Randall, 1979).

Table 5 : Causes of reef degradation
(after Salvat)

A. Collecting and fishing in excess or illegally

1. Collecting of shells and corals by tourists or commercially
2. Collecting of reef fish for aquariums
3. Collecting of coral-reef resources for local populations
4. Spear-fishing
5. Commercial fishing in reef areas
6. Dynamite used for fishing and for public works
7. Poison and other toxic chemicals used for fishing
8. Other destructive fishing methods (e.g. muro-ami)

B. Pollution

1. Pesticides and detergents
2. Sediments from soil
3. Sewage and eutrophication
4. Oil
5. Thermal effluents
6. Industrial wastes
7. Heavy metals
8. Radioactivity

C. Disturbance

1. Dredging activities
2. Constructional activities contiguous to reefs
3. Recreational impacts (scuba and snorkel activities, boating, anchor damage)
4. Introduction of alien or exotic species
5. Acanthaster problems
6. Mining of coral rock, sand, and shellgrit
7. Oil and gas drilling, mineral prospecting

Mariculture potentials

Mariculture as a commercial activity to augment natural harvest from reefs is not widespread in the tropical Pacific. A possible reason is that most islanders are simply unaware of its potentials. A few inroads have been made, however, such as the cultivation of oysters in French Polynesia (Salvat, 1980). In Hawaii and Palau, experimental projects in mariculture appear promising, but have not yet been developed to any stage of commercial importance (Mason, 1979). Pearl cultivation in islands such as the Tuamotus shows potentials of being developed into a major and fairly secure export activity (Salvat, 1980). What are called for now are baseline studies on the different species of possible commercial value, such as those of Munro and Gwyther (1981) on tridacnid clams. To ensure adequate gains from any mariculture venture, however, appropriate marketing strategies must be developed.

REFERENCES

Alcala, A.C. 1976. Population densities of the crown-of-thorns starfish in two Philippines reefs. Silliman J. 23(4):279-285.

Alcala, A. C. 1979. Fish yield of Sumilon Island reserve: implications for coral reef resources management in the Philippines. Paper presented at the 14th Pacific Science Congress, Khabarovsk, U.S.S.R., 20 August - 5 September 1979.

Anonymous. 1969. Report of the International Biological Programme Technical Meeting on Conservation of Pacific Islands, Koror, Palau and Guam, November 1968. Micronesia 5(2):223-269.

Baines, G.B.K., P.J. Beveridge and J.E. Maragos. 1974. Storms and island building at Funafuti Atoll, Ellice Islands. Proc. 2nd Int. Coral Reef Symp. 2:485-496.

Baines, G.B.K. and R.F. McLean. 1976. Re-surveys of 1972 hurricane rampart of Funafuti Atoll, Ellice Islands. Search 7(1/2):36-37.

Bayliss-Smith, T.P. 1978. Batiki in the 1970s: satellite of Suva. In H.C. Brookfield (ed.). The Small Islands and the Reefs. Unesco/UNFPA Fiji Island Reports No. 4 (Canberra, ANU for Unesco), p. 67-128.

Bayliss-Smith, T. P. 1980. Population pressure, resources and welfare: towards a more realistic measure of carrying capacity. In H.C. Brookfield [ed.]. Population - Environment Relations in Tropical Islands: The case of Eastern Fiji. Unesco, MAB Technical Notes 13:61-93.

Bedford, R.D., R.F. McLean and J.Macpherson. 1978. Kabara in the 1970s: home in spite of hazards. In H.C. Brookfield [ed.]. The Small Islands and the Reefs. Unesco/UNFPA Fiji Island Reports No. 4 (Canberra, ANU for Unesco), p. 9-65.

Brookfield, H.C. 1978a. Small is beautiful? In H.C. Brookfield [ed.]. The Small Islands and the Reefs. Unesco/UNFPA Fiji Island Reports No. 4 (Canberra, ANU for Unesco), p. 1-8.

Brookfield, H.C. [ed.]. 1978b. Taveuni: land, population and production. Unesco/UNFPA Fiji Island Reports No. 3. (Canberra: ANU for Unesco) 309 p.

Carpenter, K.E. 1977. Philippine coral reef fisheries resources. Philipp. J. Fish. 15(1):95-114.

Cheney, D.P. 1974. Spawning and aggregation of Acanthaster planci in Micronesia. Proc. 2nd Int. Coral Reef Symp. 1:591-594.

Chesher, R.H. 1969. Destruction of Pacific corals by the sea star Acanthaster planci. Science 165:280-283.

Chevalier, J.P. 1973a. Coral reefs of New Caledonia. In O.A. Jones and R. Endean [eds.]. Biology and Geology of Coral Reefs. Vol. I, p. 143-167. Academic Press, New York.

Chevalier, J. P. 1973b. Geomorphology and geology of coral reefs in French Polynesia. In O.A. Jones and R. Endean [eds.]. Biology and Geology of Coral Reefs. Vol. I, p. 113-141. Academic Press, New York.

Cruickshank, M.J. 1981. Offshore and onshore mining overview. In M.J. Valencia (ed.). Proceedings of the Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979, p. 27-31. University Press of Hawaii, Honolulu.

Dahl, A.L. 1980. Regional ecosystems survey of the South Pacific area. Technical Paper No. 179. South Pacific Commission, Noumea, New Caledonia. 99 p.

Dahl, A. L. 1982. Conservation planning and environmental monitoring for tourism development. S. Pacif. Comm. Environ. Newsl. 4:22-26.

Dahl, A.L. and I.L. Baumgart. 1982. The state of the environment in the South Pacific. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982, p. 47-71. South Pacific Commission, Noumea, New Caledonia.

Dasmann, R.F. 1973. Island values and island use. In H.F.I. Elliott [ed.]. Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 1-5. South Pacific Commission, Noumea.

Division of Lands. 1981. Coastal resources and environment: Trust Territory of the Pacific Islands. In M.J. Valencia [ed.]. Proceedings of the Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979, p. 77-81. University Press of Hawaii, Honolulu.

Douglas, G. 1969. Draft check list of Pacific oceanic islands. Micronesica 5(2):327-463.

Elliott, H.F.I. [ed.]. 1973. Proceedings of the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971. South Pacific Commission, Noumea. 156 p.

Finney, B.R. 1965. Economic change and dietary consequences among the Tahitians. Micronesica 2(1):1-14.

Gawel, Michael. 1981. Marine resources development planning for tropical Pacific islands. Proc. 4th Int. Coral Reef Symp. 1:247-251.

Gibbs, P.E., D.R. Stoddart and M.G. Vevers. 1971. Coral reefs and associated communities in the Cook Islands. Roy. Soc. N.Z. Bull. 8:91-105, 3pls.

Gomez, E.D. 1983. Perspectives on coral reef research and management in the Pacific. Opening address at the Coral Reef Section, 15th Pacific Science Congress, Dunedin, New Zealand, 1-11 February 1983. Ocean Mgt. 8:281-295.

Grigg, R.W. 1979. Coral reef ecosystems of the Pacific islands: issues and problems for future management and planning. In J.E. Byrne [ed.]. Literature Review and Synthesis of Information on Pacific Island Ecosystems. FWS/OBS-79/35. p. 6-1 to 6-17. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C.

Guilcher, A. 1974. Coral reefs of the New Hebrides, Melanesia, with particular reference to open-sea, not fringing, reefs. Proc. 2nd Int. Coral Reef Symp. 2:523-535.

Hambuechen, W.H. 1973. Cook Islands. In H.F.I. Elliott [ed.]. Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 29-33. South Pacific Commission, Noumea.

Hewson, C.A.Y., F. Malele and P.D. Muller. 1981. Coastal area management in Western Samoa. In M.J. Valencia [ed.]. Proceedings of the Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979. University Press of Hawaii, Honolulu.

Holdgate, M..W., M. Kansas and G.F. White. 1982. World environmental trends between 1972 and 1982. Environ. Conserv. 9(1):11-29.

Johannes, R.E. 1977. Traditional law of the sea in Micronesia. Micronesica 13(2):121-127.

Johannes, R. E. 1978. Traditional marine conservation methods in Oceania and their demise. Ann. Rev. Ecol. Syst. 9:349-364.

Jones, O.A. 1977. Some notes on the coral reefs of the Solomon Islands together with a reference to New Guinea. In O.A. Jones and R. Endean [eds.]. Biology and Geology of Coral Reefs. Vol. IV, p. 201-203. Academic Press, New York.

Jones, R.S. and R.H. Randall. 1973. A study of biological impact caused by natural and man-induced changes on a tropical reef. Univ. Guam Marine Lab. Tech. Rep. No. 7. 184 p.

Ladd, H.S. 1973. Bikini and Eniwetok Atolls, Marshall Islands. In O.A. Jones and R. Endean [eds.]. Biology and Geology of Coral Reefs. Vol. I, p. 93-112. Academic Press, New York.

Langham, N.P.E. and J.A. Mathias. 1977. The problems of conservation of coral reefs in northwest Sabah. Mar. Res. Indon. No. 17:53-58.

Lewis, J.B. 1977. Processes of organic production on coral reefs. Biol. Rev. 52:305-347.

Lewis, J. B. 1981. Estimates of secondary production of reef corals. Proc. 4th Int. Coral Reef Symp. 2:369-374.

Mac Neil, F.S. 1972. Physical and biological aspects of atolls in the northern Marshalls. Proc. Symp. Corals and Coral Reefs. p. 507-567. Mar. Biol. Ass. India, Cochin, India.

Maragos, J.E. 1974a. Coral communities on a seaward reef slope, Fanning Island. Pac. Sci. 28(3):257-278.

Maragos, J. E. 1974b. Reef corals of Fanning Island. Pac. Sci. 28(3):247-255.

Marsh, J.A., Jr. 1976. Energetic role of algae in reef ecosystems. Micronesica 12(1):13-21.

Marsh, J.A., Jr. and R.T. Tsuda. 1973. Population levels of Acanthaster planci in the Mariana and Caroline Islands, 1969-1972. Micronesica 9(2):165 (Abstract).

Marshall, N. 1979. Fishery yields of coral reefs and adjacent shallow water environments. In S.B. Saila and P.M. Roedel [eds.]. Stock Assessment for Tropical Small Scale Fisheries. Proc. of an International Workshop, 19-21 September 1979, Univ. Rhode Is., Kingston, R.I. International Center for Marine Resource Development, University of Rhode Island.

Marten, G.G. and J.J. Polovina. 1982. A comparative study of fish yields from various tropical ecosystems, p. 255-289. In D. Pauly and G.I. Murphy [eds.] Theory and management of tropical fisheries. ICLARM Conference Proceedings 9, 360 p. International Center for Living Aquatic Resources Management, Manila, Philippines and Division of Fisheries Research, CSIRO, Cronulla, Australia.

Mason, L. 1979. Socioeconomic development and ecosystem integrity in American-controlled Pacific island locations. In J.E. Byrne [ed.]. Literature Review and Synthesis of Information on Pacific Island Ecosystems. FWS/OBS-79/35, p. 10-1 to 10-29. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C.

Mayor, A.G. 1924. Structure and ecology of Samoan reefs. Carnegie Inst. Wash. Publ. 19(340):1-25.

McLean, R.F. 1980a. The land-sea interface of small tropical islands: morphodynamics and man. In H.C. Brookfield [ed.]. Population-Environment Relations in Tropical Islands: The Case of Eastern Fiji. Unesco, MAB Technical Notes 13:125-130.

McLean, R. F. 1980b. Spatial and temporal variability of external controls on small island ecosystems. In H.C. Brookfield [ed.]. Population-Environment Relations in Tropical Islands: The Case of Eastern Fiji. Unesco, MAB Technical Notes 13:149-175.

Morton, J. 1974. The coral reefs of the British Solomon Islands: a comparative study of their composition and ecology. Proc. 2nd Int. Coral Reef Symp. 2:31-53.

Munro, J.L. and J. Gwyther. 1981. Growth rates and maricultural potential of tridacnid clams. Proc. 4th Int. Coral Reef Symp. 2:633-636.

Murdy, E.O. and C.J. Ferraris, Jr. 1980. The contribution of coral reef fisheries to Philippine fisheries production. ICLARM Newsl. 3:21-22.

Murrell, S. 1982. Marine pollution in the South Pacific. S. Pacif. Comm. Environ. Newsl. 4:10.

Naim, O. 1981. Effect of coral sand extractions on the small mobile fauna associated with the algae of a fringing reef (Moorea-French Polynesia). Proc. 4th Int. Coral Reef Symp. 1:123-127.

Nishihira, M. and K. Yamazato. 1974. Human interference with the coral reef community and Acanthaster infestation of Okinawa. Proc. 2nd Int. Coral Reef Symp. 1:577-590.

Nolan, J.J. 1979. Guam: changing patterns of coastal and marine exploitation. University of Guam Marine Laboratory Tech. Rep. No. 59, 62 p.

Owen, R.P. 1969. The status of conservation in the Trust Territory of the Pacific Islands. Micronesica 5(2):303-306.

Owen, R. P. 1973. A conservation program for the Trust Territory. In H. F. I. Elliott [ed.]. Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 69-83. South Pacific Commission, Noumea.

Parrat, J. 1973. La protection de la nature en Nouvelle-Caledonie. In H.F.I. Elliott (ed.). Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 41-48. South Pacific Commission, Noumea.

Phipps, C.V.G. and B.V. Preobrazhensky. 1976. Morphology, development and general coral distribution of some reefs of the Lau Islands, Fiji. Proc. 2nd Int. Symp on Fossil Corals and Coral Reefs, Paris, 1976. p. 440-455.

Randall, J.E. 1979. Reef and shore fishes of the Hawaiian Archipelago, Guam, American Samoa and the U.S. Trust Territory. In J.E. Byrne [ed.]. Literature Review and Synthesis of Information on Pacific Island Ecosystems. FSW/OBS-79/35, p. 8-1 to 8-32. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C.

Randall, R.H. and L.G. Eldredge. 1977. Effects of Typhoon Pamela on the coral reefs of Guam. Proc. 3rd Int. Coral Reef Symp. 2:525-531

Rashid, R. 1980. Coral reefs - the case for conservation. Sekitar 2(2/3):40-46.

Ricard, M. and B. Delesalle. 1981. Phytoplankton and primary production of the Scilly Lagoon waters. Proc. 4th Int. Coral Reef Symp. 1:425-429.

Ricard, M., G. Richard, B. Salvat and J.L. Toffart. 1977. Coral reef and lagoon research in French Polynesia: 123 publications with abstracts. Rev. Algol. Fasc. Hors. Ser. No. 1. 44 p.

Richard, G. 1981. A first evaluation of the findings on the growth and production of lagoon and reef molluscs in French Polynesia. Proc. 4th Int. Coral Reef Symp. 2:637-641.

Richard, G., R. Galzin, B. Salvat, R. Bagnis, J. Bennett, M. Denizot and M. Ricard. 1981. Geomorphology, ecology and socio-economy of the Futuna marine ecosystem (Horn Archipelago - Polynesia). Proc. 4th Int. Coral Reef Symp. 1:269-274.

Richmond, R.N. 1981. Fiji. In M.J. Valencia [ed.]. Proceedings of the Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979, p. 59-60. University Press of Hawaii, Honolulu.

Roy, K.J. and S.V. Smith. 1971. Sedimentation and coral reef development in turbid water: Fanning Lagoon. Pac. Sci. 25:234-248.

Ryland, J.S. 1981. Reefs of southwest Viti Levu and their tourism potential. Proc. 4th Int. Coral Reef Symp. 1:293-298.

Salvat, B. 1973. The preservation of Polynesian atolls. In H.F.I. Elliott [ed.]. Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 19-21. South Pacific Commission, Noumea.

Salvat, B. 1978. Trouble in paradise. Part 1: Assault on coral reefs and lagoons. Parks 3(2):1-4.

Salvat, B. 1980. The living marine resources of the South Pacific - past, present and future. In H.C. Brookfield [ed.]. Population - Environment Relations in Tropical Islands: The Case of Eastern Fiji. Unesco, MAB Technical Notes 13:131-148.

Salvat, B. 1981a. Preservation of coral reefs: scientific whim or economic necessity? Past, present and future. Proc. 4th Int. Coral Reef Symp. 1:225-229.

Salvat, B. 1981b. Utilization and trade of coral reef molluscs in French Polynesia, past and present. Proc. 4th Int. Coral Reef Symp. 1:331 (Abstract).

Salvat, B., M. Ricard, G. Richard, R. Galzin and J. Toffart. 1978. A summary review of the ecology and reef-lagoon economy of Lau. In H.C. Brookfield [ed.]. The Small Islands and the Reefs. Unesco/UNFPA Fiji Island Reports No. 4 (Canberra,ANU for Unesco), p. 129-145.

Salvat, B., G. Richard, J.L. Toffart, M. Ricard and R. Galzin. 1977. Reef lagoon complex of Lakeba Island (Lau Group, Fiji) - geomorphology, biotic associations and socio-ecology. Proc. 3rd Int. Coral Reef Symp. 2:297-303.

Smith, S.V. 1978. Coral reef area and the contributions of reefs to processes and resources of the world's oceans. Nature 273:225-226.

Smith, T. and J. Stimson. 1979. Status of harvested marine resources in the Hawaiian Islands and the Pacific Trust Territory. In J.E. Byrne [ed.]. Literature Review and Synthesis of Information on Pacific Island Ecosystems. FWS/OBS-79/35, p. 9-1 to 9-15. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C.

South Pacific Commission. 1982. South Pacific economies 1979: statistical summary. South Pacific Commission, Noumea. 36 p.

Stoddart, D.R. and C.S.G. Pillai. 1973. Coral reefs and reef corals in the Cook Islands, South Pacific. In R. Fraser [ed.]. Oceanography of the South Pacific, 1972, p. 475-483. New Zealand National Commission for Unesco, Wellington.

Swerdloff, S.N. 1973. The status of marine conservation in American Samoa - 1971. In H.F.I. Elliott [ed.]. Papers presented to the Regional Symposium on Conservation of Nature - Reefs and Lagoons, Noumea, New Caledonia, 5-14 August 1971, p. 23-27. South Pacific Commission, Noumea.

Tsuda, R.T. 1981. Coral reefs in Micronesia. IUCN Coral Reef Newsletter No. 3:25-27.

Underwood, J.H. 1973. Population history of Guam: context of micro-evolution. Micronesica 9(1):11-44.

Weber, J. N. 1973a. Generic diversity of scleractinian reef corals in the central Solomon Islands. Pac. Sci. 27(4):391-398.

Weber, J. N. 1973b. Reef corals and coral reefs in the vicinity of Port Moresby, Papua New Guinea. Pac. Sci. 27(4):377-390.

Weber, J.N. and P.M.J. Woodhead. 1970. Ecological studies of the coral predator Acanthaster planci in the South Pacific. Mar. Biol. 6:12-17.

Wells, J.W. 1969. Aspects of Pacific coral reefs. Micronesica 5(2):317-322.

Wells, S.M. 1981. International trade in ornamental corals and shells. Proc. 4th Int. Coral Reef Symp. 1:323-330.

Whitehouse, F.W. 1973. Coral reefs of the New Guinea region. In O.A. Jones and R. Endean [eds.]. Biology and Geology of Coral Reefs. Vol.I, p. 169-186. Academic Press, New York.

Yap, H.T. and E.D. Gomez. 1984. Coral reef degradation and pollution in the East Asian Seas region. In A. L. Dahl and J. Carew-Reid [eds.]. Environment and resources in the Pacific: a regional approach. UNEP Regional Seas, Geneva.

Yonge, C.M. 1969. Conservation of coral reefs. Micronesica 5(2):307-310.

FORESTRY IN THE SOUTH PACIFIC: HOW AND FOR WHOM ?

Dennis Richardson
Forestry Council, P.O. Box 5052, Lambton Quay
Wellington, New Zealand

ABSTRACT

The Asian Development Bank has classified the forest economies of its South Pacific Member Countries as follows: industrialized economies with significant forest resources (Australia and New Zealand); island economies with abundant resources at a low level of industrialization (Papua New Guinea); developing island economies with significant forest resources (Fiji, Western Samoa, Solomon Islands); and developing island economies with limited forest resources (Kiribati, Tonga, Cook Islands).

Following a review of projected global and regional demand for wood, the constraints and opportunities for forestry development in these different environments are discussed. The ecological hazards - and economic myopia - of unrestrained logging are emphasized. The goods and services which forestry can undoubtedly provide will not be realised by exploitative ventures or by casting island economies in the role of raw material suppliers to the industrialized nations.

Professional arrogance and blinkered vision among land-use pundits (including environmentalists) are as damaging to fragile ecosystems as the juggernauts of exploitative logging and large scale monocultural reforestation. This paper highlights the need for safeguards to mitigate the effects of dangerous technologies, at the same time enabling a sustainable supply of goods and services from forestry. It calls for a reduction in the export of unprocessed logs, the adoption of light capital technologies and appropriate operational scales, and the expansion of agriculture-supportive, multi-purpose, forestry.

Some implications of adopting a "human chauvinist" approach to ecosystem utilization are considered.

Introduction

In this paper, I propose to draw your attention to what I perceive to be significant recent changes in the regional forest economy (including some of the ecological hazards associated with those changes) and to suggest possible safeguards to ensure a sustainable supply of goods and services from forestry in the Pacific Islands.

I shall argue the case against the twin juggernauts of exploitative logging and large-scale industrial plantations in the smaller islands, and I shall attempt to reconcile global and regional needs for forest products with the conservation of our diminishing resource. My arguments are not new: indeed, the gist of what I have to say I have previously discussed at a Waigani seminar and in a presentation to a gathering of environmentalists (Richardson, 1981). But I believe the theme has particular relevance because of the Pacific Island potential to teach the rest of the world a lesson in the art and science of biological self-sufficiency which ultimately we shall all need to learn.

Industrial Wood Demand and Supply

The ecological hazards to which I have referred stem primarily from a massive increase during the last few years in exploitative logging in the South Pacific. It has followed the resolve of the traditional log-exporting countries in Asia and Africa to reduce the export of unprocessed raw material.

A decade ago, Indonesia exported 19 million cubic metres (m^3) of logs, Malaysia 14 million m^3, and the Philippines 8 million m^3. Six years later these volumes had dropped by 25% and in 1981 by a further 30%. Over the same period, however, log exports from Papua New Guinea rose by 100% and from the Solomon Islands by 200%. To contain logging costs, producers are now searching out flat, easy terrain in sparsely populated areas - where there will be no inconvenient demands for environmental impact statements and where they may import cheap labour without arousing too much opposition. This is taking them to the smaller islands (in Papua New Guinea, for example, to Woodlark and Umboi Islands, to Erromanga in Vanuatu, to Kolombangara and South New Georgia in the Solomons) where their impact is infinitely greater and the benefits more restricted than on the bigger, more densely populated, land masses, and where we simply do not know what effects may result from ecological change on this scale in a confined environment .

Changes in the regional forest economy must be viewed in the context of burgeoning increases in global demands for the products of the forests and, too, for the land which sustains them.

Moreover, in place of the dearth of reliable information about forest resources which frustrated the early supply and demand forecasts of the FAO, we nowadays suffer almost an "embarrassment of riches" of prognoses. Technology changes more rapidly than trees grow, and faster than economists think - but slower (it seems) than data accumulate! A smorgasbord of satellite technology and electronic data processing equipment currently enables us to monitor area and volume changes in the world's forests with a greater precision than ever before; for most countries, the results of such investigations have been frightening and, for all of us, they are sobering.

The world in 1975 contained 2.8 billion hectares (ha) of closed forest capable of being managed for a sustained yield - 40% coniferous (softwood), 60% broadleaved (hardwood). These forests carry more than 300 billion m^3 of wood - of which 200 billion m^3 is of hardwood and concentrated in the tropical and sub-tropical areas of Latin America, Africa and the Asia-Pacific region. From this resource, we remove 2.5 billion m^3 p.a. - but although this is less than 1% of the growing stock, the removals are not balanced over the resource base. As to species, the conifers are intensively exploited, the hardwoods are under-utilized.

To put these values into perspective, only 40% of the world's forests are managed (even superficially) to sustained yield standards (the rest are "mined"), while almost half the forest removals are not used industrially at all (especially in Latin America and the Asia-Pacific).

Several questions arise.

Firstly, how have we reached this position?

Over the last 60 years, our world has experienced an increase in wood use from 1 billion m^3 p.a. (log equivalent measure) to 2.5 billion m^3 p.a. - of which about 50% has been used industrially. If these trends continued, the projected global demand would reach 4.5 billion m^3 by the end of the century. (In fact, this picture is misleading, because the trends on which the projections are based were established prior to the so-called energy crisis, triggered in 1973).

Secondly, where is this industrial wood traded?

The industrialized nations consume some 82% of the total world supply (North America, 34%, the USSR and E. Europe 27%, W. Europe 12%), and the less developed countries use 18%. These figures illustrate the massive dependence of world trade on the demands of the developed countries.

Of interest, too, is the fact that nearly 50% of the world's trade in unprocessed logs is to supply Japan, while 55-60% of trade in sawn wood and pulp and paper is handled by

Western Europe. And despite the huge demands of Japan, that nation has a bigger proportion of its land surface under forests (67%) than any Pacific country other than Papua New Guinea.

Thirdly, can this trade be maintained?

Forecasts of future global needs for wood derive from models incorporating econometric parameters such as gross domestic product (GDP), population growth rate, and literacy, and demand projections are only as accurate as the forecasts of changes in these parameters. Inasmuch as they take into consideration previous studies - and the results of satellite surveillance - the estimates for "Global 2000" (prepared for a US presidential committee in 1980; Barney, 1980) and those made by the Centre for Agricultural Strategy in 1981, are the most convincing. Assuming high income growth and high GDP per capita, projected annual roundwood consumption is 6 billion m^3 by the year 2000 and 11 billion m^3 25 years later (respectively 2.4 and 4.4 times the 1976 consumption). The high growth scenario is, of course, unrealistic. Assuming no growth at all, demand will be 4 billion m^3 (in 2000) and 6 billion m^3 (in 2025) - 1.6 and 2.4 times the 1976 figures.

Fourthly, how do these estimates compare with future supply forecasts?

If we consider our existing forest resources and assume the "no growth" scenario, we shall be cutting 1.3% p.a. of the growing stock by 2000 and nearly 2% p.a. by 2025. This implies a 50 year forest rotation - which may be feasible in coniferous forest (even in the northern hemisphere) but is highly unlikely in most tropical forests.

Fifthly, will technology enable us to extend supplies?

The answer to this question is, of course, "Yes, in theory". G. K. Elliott (personal communication, 1982) has estimated a sustainable increase in supply of 1.4 billion m^3, of which 49% derives from more extensive exploitation and closer utilization of the world's coniferous forest and 23% from closer harvesting of the tropical forests: the remainder is made up of increases in plantations (7%), improved silviculture (6%), reduced losses from fire and pathogens (8%), increased use of wood residues (7%), and improved pulping yields (6%). Most of these achievements will be costly and few of them offer much help to the Pacific Islands. And even these increases are predicated upon sweeping changes in the acceptability of species.

Moreover, the maintenance of supply assumes that reductions in natural forest yields and areas are balanced by increases from plantations. We are told by the Global 2000 report (Barney, 1980), however, that the world's forests are disappearing at the rate of 18-20 million ha p.a. - mostly from the humid tropics - "Growing stocks of commercial size timber are projected to decline 50% per capita (over the next 20 years)... The projections indicate that by 2000, some 40% of the remaining forest cover in least developed countries will be gone".There are few signs that plantation production will replace this lost yield. The FAO (1982) projects an increase from 5 million ha to 16 million ha in tropical plantations by the year 2000 with industrial wood production reaching some 100 million m^3 p.a. (This does not include a possible contribution from China, whose afforestation programme - largely temperate - is enormous but for which information on long-term production possibilities is not available).

Sixthly, how does the potential supply match the likely demand?

Evidently, not too well. Significant tightening in world supply is inevitable by the end of the century, with a serious shortfall by 2025. This situation presages continuing increases in real prices for wood products and a rapid rise in the value of natural forests as their area diminishes. There is no need to spell out the commercial implications of these changes or to identify the likely beneficiaries. More serious are the non-commercial implications. The countries of our region stand in as much need of the goods and services which forests can provide as any; and there is more to Pacific Islands forestry than industrial wood production.

The role of forests as a climatic buffer has yet to be analysed in detail, but it is undoubtedly important; more readily evident in the larger and mountainous islands is their crucial protective role in agriculture and water supplies. The distinctive physiognomy of forest ecotypes - in certain critical areas and in certain types of watershed - effectively controls the siltation of rivers and reservoirs, prevents flooding and denudation, and enables the survival of agriculture. Forests also contribute a wide range of goods for which demand in the island economies is growing. Increasing attention is focusing upon forest production of fuelwood (both domestic and industrial), charcoal, artifacts, medicinal products and biocides, foods (fruits, nuts, berries, tubers, fungi and honey), wildlife (especially pigs and birds), fodder, dyes, cloth fibres, gums (copal, damar, etc.), rattan, oils (sandalwood, massoy, cinnamon, candlenut), silk, cutch, orchids and a host of other useful products. Several of these non-wood products enter commercial production and some promise to form the bases of new, small-scale industries (e.g., silk and shiitake mushroom production). Trees can also play a recreational role in the alleviation of mental and physical stress and in creating the illusion of privacy which is necessary to all people, no matter how gregarious their cultures may depict them. Moreover, trees have a role - increasing in importance unfortunately - in hiding the scars of open-cast mining.

Finally, does not the answer to our dilemma lie in massive reforestation?

Already New Zealand and Australia have espoused this alternative and there appears to be no shortage of low-interest loan money (from, e.g., the World Bank, the Asian Development Bank, bilateral aid agencies, etc.), to enable the less-developed Pacific Islands to follow suit. The trans-national corporations, too, (especially the oil companies) are becoming involved with reforestation and, in several countries, the availability of financial concessions for forestry is adding a new dimension to the avoidance of tax.

A common feature of these various ventures is their large scale and the use of monocultures of species (usually exotic) chosen for a high rate of uniform fibre production. Because of the concessionary financing element in reforestation , there is an opportunity cost to be borne and at this point it is pertinent to ask who will be the beneficiary. If the present pattern of forest utilization in our region continues, the answer is Japan. And to suggest that the less developed countries - after exporting their resources to Japan - should undertake large-scale reforestation for the primary benefit of that country would be less than tactful. Yet if concessionary finance is not made available, there is unlikely to be any re-planting.

Alternative Forestry

The ADB (1978) classifies the forest economies of its South Pacific member countries as follows: island economies with abundant resources at a low level of industrialization (e.g., Papua New Guinea); developing economies with significant resources (Fiji, Western Samoa, Solomon Islands); developing economies with very limited resources (Kiribati, Tonga, Cook Islands); and industrialized economies with significant forest resources. Their diversity is uniform. Equally paradoxically, the kind of forestry appropriate to their economies varies greatly (with respect to policies and practices) but derives from an essentially similar ethic - giving priority to the needs of indigenous people.

Papua New Guinea exemplifies the dangers of exploitative logging. In promoting foreign investment successive governments have repeatedly cited a total forest area of 40 million ha (15 million operable) capable of sustaining an annual cut of 19 000 ha for the next 500 years. Throughout the 1970s the log-yield was steady at rather less than 1 million m^3 and from this base the National Public Expenditure Plan (NPEP) projected a 5-fold increase in log exports over the decade 1978-1988 - thus reducing the resource life to a little more than 100 years. It was assumed that over 100 years the natural resource could be replaced by high-yielding plantations.

In fact, log exports in 1981 were double the NPEP projection. Applying the NPEP projected growth rate to this new base, therefore, reduces the life of the resource to 50 years - less than a lifetime even in Papua New Guinea and (since there is virtually no re-planting) offering a very different prospect from that based on the original assumptions. Moreover, Papua New Guinea forest development policies must be judged in the light of documented evidence of malpractices (transfer pricing, under invoicing, etc.), in the expatriate-dominated log trade which (according to the Crown Law Office) are siphoning off some US$15 million revenue annually! Clearly, then, if the people of Papua New Guinea are to benefit realistically from their forest resources, there is an urgent need to control exploitative logging and to invest in some kind of sustained yield forest management.

Constraints on conventional reforestation are the high silvicultural costs (when compounded to the end of the rotation) and the fact that the finance agencies (whether

Government, international agencies or private interests) are unwilling to invest in tree planting without unquestionable security of land tenure: in Papua New Guinea - as indeed throughout most of the Pacific - there can be no such thing. Elsewhere I have suggested that a possible solution may lie in the identification of tree species which are natural "survivors" (which, no matter how slowly they may grow, will survive without any tending) and their planting in the immediate wake of logging (literally within 2-3 days and with no burning) (Richardson, in press). The costs would then be set against the proceeds from logging and not compounded forward. Such replanting must imply no claim to land tenure or to ownership of the future crop but has to be regarded as the forestry equivalent of the now widespread requirement in open-cast mining that the top-soil be replaced before handing the land back to the owners.

The second category of country (exemplified by Fiji, Western Samoa and Solomon Islands) have some natural forests but are already committed to their replacement by plantations - almost entirely of exotics. Species have been selected according to their projected growth rates and with a view to utilization for energy generation as well as conventional purposes.

It is probably too late for governments of these countries to achieve anything through closer control of natural forest logging (except, perhaps, in the case of the Solomon Islands), though much could be done, I believe, to bring about more realistic returns from timber sales through the revision of royalties and other taxes. (It has been estimated that the total tax on Solomon Island logs ranges from US\$10/m^3 to US\$30/m^3, compared with a range in West Africa for species with similar end uses of US\$20/m^3 to US\$130/m^3).

Plantation establishment is far-sighted and, in the case of Fiji, already yielding some returns, as well as providing employment in rural areas (where most needed) and using otherwise derelict land. In future, it may be necessary to monitor the nutrient status of soils under fast-grown plantation species subject to ultra-close spacing and short-rotation harvesting. The biomass road to energy self reliance is an option under consideration in many Pacific islands; recent evidence from South America, however, suggests that short-rotation intensive culture (SRIC) systems may result in rapid depletion of potassium (and perhaps other nutrients). In general, the soils of the lowland tropics available for reforestation are relatively infertile; it is no coincidence that their most successful tree crops are those from which only small quantities of nutrients are removed in harvesting (rubber, oil-palm, cocoa, etc) - a far cry from SRIC systems. Recent reports on the Jari river project (the most ambitious plantation scheme ever) underline the need for caution.

The island groups of Tonga, Kiribati and the Cooks exemplify the thousands of small, isolated and necessarily self-contained economies in the Pacific Ocean which are extremely vulnerable to external economic forces and have no prospect of developing significantly beyond subsistence. They have learned to live with adversity and have much to teach the rest of us about self-reliance (Richardson and Richardson, 1984).

In these islands, the utilization of coconut is highly developed - the stems for construction, furniture, roof tiles, cladding, tools, utensils, charcoal, fuel, etc.; the fibre and leaves for cloth, packaging, matting and roofing; the sap for soft drinks, sugar, alcohol and toddy; the nuts for foods, oil, charcoal, etc.; and the roots for rope and twine. Logs may be preservative treated by immersion in salt water. There are a few other trees available (e.g., breadfruit, Calophyllum, Terminalia, Cordia, Pandanus, Inocarpus, Canarium, etc.) but all are grown within an agro-forestry system and all are used for multiple purposes. The isolation of the islands, their tiny size and fragile ecosystems put a premium on cultivable soil. For the atolls and islets there is no alternative forestry.

The forest economies of Australia and New Zealand serve rather different objectives and face different problems. New Zealand in particular is committed to a major export role and has one of the most advanced forest production economies in the world. (Our processing economies, by contrast, are with few exceptions, primitive.) Australia has been described as a vast continent, the fringes of which are littered with eucalypts and Australians. Both countries are characterized by small, scattered domestic markets, high labour and transport costs, and an increasing proportion of forest production coming from small producers. Our challenge, I believe, is to adapt advanced processing technology to the point where scale economies become irrelevant and we can maximize grade outturn (irrespective of product) at acceptable costs. Comparative advantages we possess vis-a-vis other industrialized countries are low wood costs, cheap power and - above all - a reputation for pioneering ingenuity and adaptability. If that capacity for innovation could be married to the island ethic of self-reliance, we would have little to worry about.

The important difficulties we face are two-fold: firstly, we have not yet come to terms with the ultimate need for a low-growth economy (and the achievement of social stability within such an economy); secondly, we have yet to learn how to manage our resources sensibly, equitably and in national rather than sectional interests.

Since returning to New Zealand six months ago, the biggest change I have noticed is in attitudes to the forest environment. I recall my astonishment when I first arrived here in the early 1960s at what appeared to be nothing short of a misanthropic obsession of New Zealand foresters - the padlocks on forest access gates, the huge notices along the tourist routes south of Rotorua proclaiming that "It is illegal to enter these forests"! There were no provisions under the Forests Act for setting apart State forest parks and recreation areas in State forests until 1965 - and we were spending enormous sums of money annually poisoning wildlife!

Inevitably, I then contrasted these attitudes with Denmark - where every forest over 5 hectares in area, State or private, is legally and freely accessible to public recreationists; where deer in State forests are artificially fed so that people may watch them; where urban facilities (hotels, pubs, restaurants, racetracks, golf courses - even amusement parks) are provided to attract people into forest areas; and where the forester is as much concerned with the management of a resort as a resource!

What made for difficulties in coping with NZ forestry attitudes in the 1960s was the patent sincerity of foresters. The idea that there might be general and free access to State production forests - let alone those in private ownership - was regarded at that time as an astonishing concept - as was the notion that there might be widespread public consultation and debate about forest policies and practices. The subsequent change in attitudes has been revolutionary; present-day foresters are infinitely more concerned about the needs and aspirations of ordinary people (and much more knowledgeable about how those needs may be satisfied) than was that generation - and is, I believe, every bit as sincere. Few of us, 20 years ago, could have imagined a Landscape Section in the NZ Forest Service and the publication of Guidelines for Creative Forestry; or the wealth of information now freely available about our forest and environmental heritage. Who, then, could have envisaged a Commission for the Environment - let alone a Government prepared to pay $7 million in compensation to preserve part of Pureora?

Not surprisingly there is a much greater public awareness of forest land values than there was in the 1960s - and throughout the region more people than ever before care more than ever before about the environment in which they live and work. For the sake of our children - and their children - we should be thankful that this is so.

Considerably less comforting, however, is a disturbing parallel development - the increasing, though subtle, exploitation of people's concern. There have always, I suppose, been prophets of doom but they have exploited primarily the selfishness of a few ignorant souls; our latter-day profiteers of doom exploit the finer feelings of many more people. Moreover, they do so under the guise of scientific omniscience. Again, there have always been scientific charlatans - but they have usually deceived only each other. A small but vociferous minority of mountebanks purporting to represent our environmental movements, however, mislead vast numbers of concerned citizens who are honest enough to acknowledge that they do not know the answer to the Faustian dilemma we face with respect to the use of our resources.

There is a real need, I believe, for environmental leadership which does not over-represent particular issues at the expense of real problems. In Australia, for example, preoccupation with rain forests diverts attention from the Mediterranean ecosystems - which have no conservation status. In New Zealand a similar preoccupation with Government-held land results in an almost total absence of environmentalist pressures upon private owners of land to manage it purposefully for multiple use and in the national interest. And where is the environmentalist concern for the traditional (and appropriate) food resources and their management in the Pacific Islands?

It is perhaps timely to expound the splendidly sensible case for human chauvinism argued by John Passmore in his masterly account of "Man's responsibility for Nature" (1974) -

the view that nature should subserve the interests of mankind. Thus conservation must be selective; there is merit in preserving the crown pigeon - because it is edible; and the New Zealand black robin - because it is beautiful. There is common sense in maintaining a wide range of gene pools because we are woefully ignorant of the economic potentials of many plant and animal species; but there is none whatever (unless we believe in transmigration of souls) in preventing the extinction of mosquitos or sandflies. Moreover, there is little point in preserving any natural resource unless people are able to enjoy its fruits. And the challenge to management is to develop methods which ensure that those fruits remain to be enjoyed by all who so wish.

I would not, of course, argue that all foresters are beyond reproach when it comes to concern for humanity: there are still many who are happier in a Procrustean pine plantation than among people (and of course there are commercial timber interests who rank company profits before the national interest). But, as in all things, there is a golden mean - a balance which we need to find before it is too late. We shall not reach it through distortion, half-truths and arrogance. Nor, I am afraid, shall we find it through the determined objectivity to which our scientists aspire. Let us remember the legend of Occam's ass - the beast tethered equidistantly between two equally desirable bundles of hay; because of its strict objectivity , it (inevitably) starved to death!

More important is a humanist commitment to future generations. In conclusion, may I apply the famous Nigerian credo concerning land to our Pacific environment? It "belongs to a vast family of which many are dead, a few are living and countless numbers are still unborn." It does not belong to foresters, or sawmillers or blinkered environmentalists. Let all of us endeavour to manage it with honesty, awareness and humility.

REFERENCES

ADB. 1978. Sector paper on forestry and forest industries. Asian Development Bank, Manila, Philippines. 78 p.

FAO. 1982. World forest products, demand and supply, 1990 and 2000. FAO Forestry Paper 29. Food and Agriculture Organization, Rome, Italy.

Barney, Gerald O. (Study Director). 1980. The Global 2000 Report to the President, Entering the Twenty-First Century. Government Printing Office, Washington, D. C.

Passmore, John. 1974. Man's responsibility for nature. Duckworth.

Richardson, S. D. 1981. Forestry and the environment in the South Pacific. SPREP Topic Review 8. South Pacific Commission, Noumea, New Caledonia. 13 p.

Richardson, S. D. (In press). Unnatural practices. World Wood.

Richardson, S. D. and J. Richardson. 1984. Agroforestry and the Pacific Islands. Journal of Pacific Studies (in press).

TROPICAL FORESTRY IN MELANESIA AND SOME PACIFIC ISLANDS

K. D. Marten
J. G. Groome and Associates, P.O. Box 169
Taupo, New Zealand

ABSTRACT

Most of the material used in this paper is based on work in the Solomon Islands, but supplementary data are derived from Fiji, Western Samoa and Enga Province, Papua New Guinea. The reduction in vegetative complexity east of the Wallace Line is illustrated partly by comparison of the principal timber species in the various countries. Some indication is given of the structure of the forest biomass, the implications of various forest phases, and species grouping using Solomon Island data. Variations in forest structure with increasing distance from the coast and increasing altitude on Pacific Islands are discussed, as well as the effect of wind, logging and agricultural development which are the main instruments of forest disturbance.

Both natural and artificial aspects of forest regeneration are covered, with particular reference to close and line planting techniques. Monocultures and vegetational mixtures are considered as they relate to pests, diseases and soil fertility.

Finally some major factors affecting optimal land use on small Pacific Islands in the 21st Century are outlined.

Introduction

Sandal wood was exported from the Western Pacific islands in the nineteenth century, but large scale and scientific forestry did not really start until after the Second World War. In the first few years poor communications and scarce funds generally meant that little impact was made. Most knowledge and data have been gained during the past two decades.

The author spent much of that time in the Solomon Islands with short term assignments to Fiji, Western Samoa, Enga Province in Papua New Guinea, and Tonga. In the Solomon Islands the author was closely involved in most branches of the Forest Service work.

At the present time research into various aspects of forestry is most advanced in Papua New Guinea, while in other countries the Forest Services have devoted most of their efforts to replanting: predominantly Pinus caribaea in Fiji, and tropical hardwoods in the Solomon Islands. Vanuatu has been developing forestry extension services. The French-speaking territories have had the benefits of research conducted by a branch of the Centre Technique Forestier Tropical in New Caledonia. The United States Forest Service operates in Hawaii and in recent years small scale forestry has been started in Micronesia, with staff usually from the Peace Corps.

In 1978, a Pacific Regional Meeting on Forest Management and Development was held in Suva, Fiji, which indicated both the diversity and the common ground in forestry development on the islands of the Pacific and stressed the need for a greater interchange of data between countries, for co-ordination of training, and for a full time forestry adviser to the Pacific. The New Zealand Government has recently appointed a Forestry Adviser to the Pacific region under its aid scheme.

TABLE 1 - MAJOR PACIFIC TIMBER SPECIES

Generic names	Papua New Guinea	Solomon Islands	Fiji	Vanuatu	Western Samoa
A. Specialist - furniture and veneer					
Amoora	A. cucullata	A. cucullata			
Aglaia	A. spp.				A. spp.
Castanopsis	C. acuminatissima				
Dracontomelum	D. puberlum				
Dysoxylum	D. spp.	D. spp		D. spp.	D. samoense
Elmerrillia	E. papuana				
Nothofagus	N. spp.				
Pterocarpus	P. indicus		P. indicus		
Schizomeria	S. serrata	S. serrata			
Toona	T. sureni				
Flindersia	F. spp.				
Burckella	B. obovata	B. obovata			
Palaquium	P. spp.	P. spp.	P. fidgiensis		
B. Heavy construction and decking					
Heritiera	H. littoralis				
Homalium	H. foetidum				
Hopea	H. iriana				
Intsia	I. bijuga	I. bijuga		I. bijuga	I. bijuga
Manilkara	M. kanosiensis				
Mastixiodendron	M. pachyclados				
Neonauclea	N. hagenii	N. spp.			
Vitex	V. cofassus	V. cofassus			
Palaquium			P. hornei		
Eugenia/Syzygium	S. buettnerianum	E. spp.	E. spp.		S. inophylloides
Serianthes			S. myriadenia	S. vitiensis	
Dysoxylum					D. hunti
C. General construction					
Anisoptera	A. thurifera				
Calophyllum	C. papuanum	C. kajewskii	C. vitiensis		C. samoense
Eucalyptus	E. deglupta				
Hopea	H. papuana				
Maniltoa	M. psilogyne				
Planchonia	P. papuana				
Pometia	P. pinnata	P. pinnata		P. pinnata	P. pinnata
Sloanea	S. spp				
Tristiropsis	T. acutangula	(T. acutangula)			
Dillenia		D. salomonensis			
Endospermum			E. macrophyllum		
Bischofia				B. javanica	
Piliocalyx				P. concinnus	
Dysoxylum					D. samoense
Garuga					G. pacifica
D. Light construction, internal, utility					
Alstonia	A. scholaris	A. scholaris			
Anthocephalus	A. chinensis				
Campnosperma	C. brevipetiolata	C. brevipetiolata			
Canarium	C. spp.	C. spp	C. spp.		
Celtis	C. nymanii	C. spp.			
Cryptocarya	C. spp.	C. spp.			
Endospermum	E. medullosum	E. medullosum			
Gmelina	G. moluccana	G. moluccana			
Mangifera	M. minor				
Myristica			M. spp	M. fatua	
Octomeles	O. sumatrana				
Panchonella	P. spp.	P. spp.		P. spp	P. torricellensis
Polyalthia	P. oblongifolia				
Pterocymbium	P. beccarii				
Pterygota	P. horsfieldii				
Spondias	S. dulcis				
Sterculia	S. shillinglawii				
Terminalia	T. brassii	T. brassii	T. spp.		T. richii
Terminalia	T. complanata	T. calamansanai			
Terminalia	T. kaernbachii				
Xanthophyllum	X. papuanum				
Elaeocarpus		E. spp.	E. kaubii		
Garcinia		G. macrophyllus	G. spp.		
E. Poles, village uses, carving					
Maranthes	M. corymbosa				
Geijera	G. salicifolia				
Diospyros	D. ferrea	D. spp.			
Glutea	G. spp.				
Fagraea	F. spp.	F. gracilepes	F. gracilepes		
Securinga		S. flexuosa	S. samoana		S. samoana
Casuarina	C. oligodon				
F. Conifers					
Agathis	A. alba (dammara)	A. macrophylla	A. vitiensis	A. obtusa	
Araucaria	A. hunsteinii				
Araucaria	A. cunninghamii				
Podocarpus	P. amarus				
Papuacedrus	P. papuanus		P. vitiesis		
Dacrydium	D. spp.				
Decussocarpus	D. spp.		D. elatum		
Dacrycarpus	D. spp.				

Natural forest cover

Even now most Pacific Islands are predominantly tree covered; though an increasing proportion of that tree cover has been significantly modified by the requirements of rapidly growing populations.

Within the tropical zone the rain forest of the islands of Borneo, Indonesia and the Philippines and Peninsular Malaysia have the richest vegetation associations, followed by the rain forests of South America; particularly in the Amazon Basin. Though the species-rich rain forests of Indonesia lie west of Papua New Guinea there is a significant reduction in the number of species in total and per unit area east of the Wallace line.

There is a progressive loss of species as one travels eastwards from Irian Jaya to Fiji, Vanuatu and beyond.

This trend is illustrated in Table 1 which lists the more common trees in various countries that have economic potential. These are arranged in four categories of end use; while the listings under the fifth category of conifers illustrates, in part, the much greater altitudinal range of the mountain forest in Papua New Guinea.

Loggers with experience both in Borneo and the larger Pacific Islands note how minor genera in Borneo like Calophyllum and Pometia become major species in the Pacific Islands. The large number of commercial species in the Dipterocarpaceae in Borneo and the Philippines are reduced to three genera in Papua New Guinea and absent from other islands to the east. There are also typical Australian genera like Eucalyptus, Toona, and Flindersia in Papua New Guinea and West Irian that do not occur further east. As the proportion of sea to land increases significantly this must have influenced the spread of species. Distribution patterns cannot always easily be explained. In more western islands of the Solomons, relatively common species like Campnosperma brevipetiolata and Gonystylus macrocarpus, are absent from Guadalcanal and Makira. Further east, Terminalia brassii and Calophyllum kajewskii are absent from the Santa Cruz group, though unaccountably Campnosperma reappears, while Pometia pinnata occurs with much poorer form and contrastingly larger fruit.

Relatively little study has been carried out in the region on the structure of the forest and its biomass. One such study was carried out in 1971/1972 in the Solomons, felling all trees on four plots. This is summarized in Table 2. Total stem and branch biomass to a minimum 10 centimetres small end diameter under bark varied between 235 and 507 cubic metres per hectare (m^3/ha). Land with over 500 m^3/ha would be approaching the maximum carrying capacity of this type of forest, while 250 m^3/ha represents forest closer to the average for these islands. Total basal area in the forest sampled varied between 20 and 43 m^2/ha, which is much less than for temperate conifer plantations. Some indication of variation in tree form is given by dividing total volume by total basal area; this gives factors lying between 5.0 and 14.

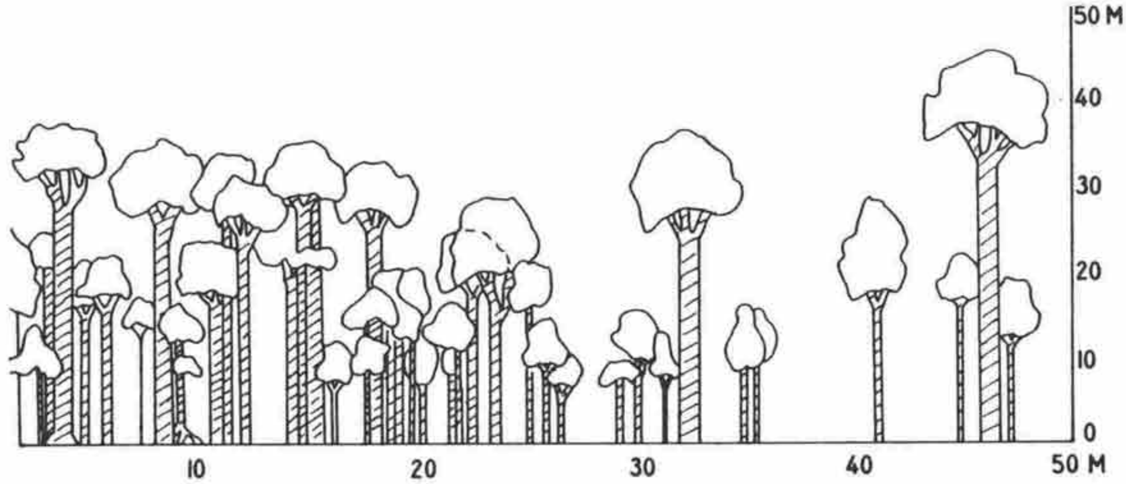
Such records as there are relating inventory data with actual volumes extracted indicates that, though small areas can yield more, yields of 30 to 50 m^3/ha of logs over 55 cm mid-diameter can be anticipated over large blocks. These are much lower than with yields from forest in Borneo, Philippines and Malaysia.

Tropical high forests are a very complex matrix containing individual elements which can be isolated in small units, but seldom on a large scale. It is common practice to distinguish an upper canopy 30 to 45 m above ground; a middle canopy 15 to 30 m above ground level; and a lower canopy 5 to 15 m above ground level. This excludes herbaceous ground vegetation and is usually illustrated by a profile diagram similar to that in Figure 1. Another useful device is to distinguish a gap phase of regeneration; a building phase with maximum rate of height growth; and a mature phase. Classification of crown exposure and crown closure of individual trees further describe the condition of the forest together with details of the physical factors of altitude, aspect, topography, soil, drainage and previous history.

TABLE 2 : SOLOMON ISLANDS BIOMASS POTENTIAL
Minimum 10cm small end diameter
Volumes in cubic metres/ha (under bark)

	KOLOMBANGARA		VIRU	
	Plot 1 0.4 ha	Plot 2 0.4 ha	Plot 1 0.4 ha	Plot 3 0.33 ha
Export Log Volume	205.6	55.0	129.4	61.3
Provent Pulpwood spp	28.7	32.9	24.3	23.5
Potential Pulpwood (PNG)	1.2	6.4	8.0	1.3
Potential Pulpwood (SI)	17.4	6.5	11.9	0.0
Other Stems	21.8	18.7	129.1	18.1
TOTAL STEM VOLUME PER HECTARE	274.7	119.5	302.7	104.2
Export Log Trees/Other Logs	134.0	21.8	65.6	23.3
Waste from export Logs	-	1.0	13.2	-
Stumps	0.4	2.0	11.3	-
Smaller Branchwood	24.4	3.3	5.2	4.8
SUB TOTAL	158.8	28.2	95.4	28.2
Other Trees				
Second Logs	-	14.0	-	1.0
Stumps	-	-	-	-
Smaller Branchwood	7.8	3.7	11.1	3.1
Creeper	3.2	0.4	-	-
SUB TOTAL	11.0	18.2	11.1	5.1
STEMS UNDER 90CMS	61.8	69.5	98.1	105.6
TOTAL STEM/BRANCH BIOMASS	505.5	235.4	507.3	243.1
TOTAL BASAL AREA M^2/ha	36.5	20.2	42.8	23.0
BASAL AREA EXPORT LOGS M^2/ha	20.5	6.3	25.0	9.1
Conversion Factor for form M^3/M^2				
All Stems/Branches	13.8	11.7	11.8	10.6
Export Logs Only	10.0	8.7	5.1	6.7

FIGURE 1 : FOREST PROFILE DIAGRAM



Ecologists and silviculturalists have spent much time trying to understand and explain the species patterns and associations in tropical rain forests. An association analysis by computer of data where no distinction is made between trees of the upper canopy, and those smaller trees of the middle canopy (which are underlined) is given in Table 3. Table 3 shows the contrast between Campnosperma, Calophyllum and Dillenia dominated forest of New Georgia and Kolombangara; with Campnosperma, Pometia forest on a limited area at Alladyce, Santa Isabel; and with Pometia, Calophyllum and Vitex forest on Guadalcanal. The first two forest types are more suitable for producing logs for export while the last type is more suitable for sawmilling.

TABLE 3 : FOREST GROUPS IN THE SOLOMON ISLANDS
TIMBER SURVEY DATA AFTER ASSOCIATION ANALYSIS

Location	Area Surveyed	Forest Group	Species 1 (st/ha)	Species 2 (st/ha)	Species 3 (st/ha)	Species 4 (st/ha)	Species 5 (st/ha)	Species 6 (st/ha)
Kolombangara Ecological Survey	13.7ha (30cm min girth)	I	TEYA (88.9)	DILS (29.6)	CAMB (10.1)	PARS (6.9)	CALK (6.9)	SCHS & GMEM (2.2)
		II	TEYA (38.0)	CAMB (21.4)	PARS (11.1)	CALK (8.1)	DILS (6.6)	MARC & TERCAL (3.2)
		III	TEYA (104.5)	CAMB (14.8)	DILS (8.1)	EUG (6.1)	PARS (4.2)	SCHS (3.7)
		IV	CALV (13.5)	CALK (13.5)	CAMB (11.1)	PARS (8.8)	MARC (5.9)	TERCAL (5.9)
		V	TERC (12.1)	PARS (9.6)	CALK (8.6)	ENDM (6.6)	CALV (2.9)	POMP (2.7)
		VI	TERC (15.8)	CALV (8.8)	SCHS (6.4)	PARS (5.6)	ENDM (5.1)	CAMB (4.4)
North East New Georgia Enumeration	154.5ha (180cm min girth)	I	CAMB (5.6)	SCHS (3.7)	EUG (2.9)	DILS (2.4)	GONM (1.4)	PARS (1.2)
		A	POMP (2.2)	PARS (2.2)	SCHS (1.9)	CALK (1.7)	EUG (1.2)	GONM & GMEM (0.7)
		J	CAMB (6.4)	DILS (5.4)	EUG (2.2)	CALK (1.9)	PARS (1.4)	GONM (1.2)
		D	CAMB (5.1)	CALK (2.7)	POMP (2.7)	DILS (1.9)	PARS (1.2)	GONM (0.9)
Allardyce Santa Isabel Sample Enumeration	3.2 ha (90cm min girth)		CAMB (28.4)	TEYA (13.8)	POMP (5.9)	GMEM (3.2)	NEOF (2.4)	DILS (2.2)
White River Guadalcanal Enumeration	8.6 ha (90cm min girth)	A	CANH (29.6)	POMP (24.7)	PIMA (16.0)	BURO (10.6)	CALV (9.1)	CALK (1.7)
		B	POMP (24.7)	ALAJ (16.5)	NEOF (6.1)	VITC (4.9)	CALK (1.7)	BURO (1.2)

Source: Whitmore (1974) Tables 2.4 & 3.2

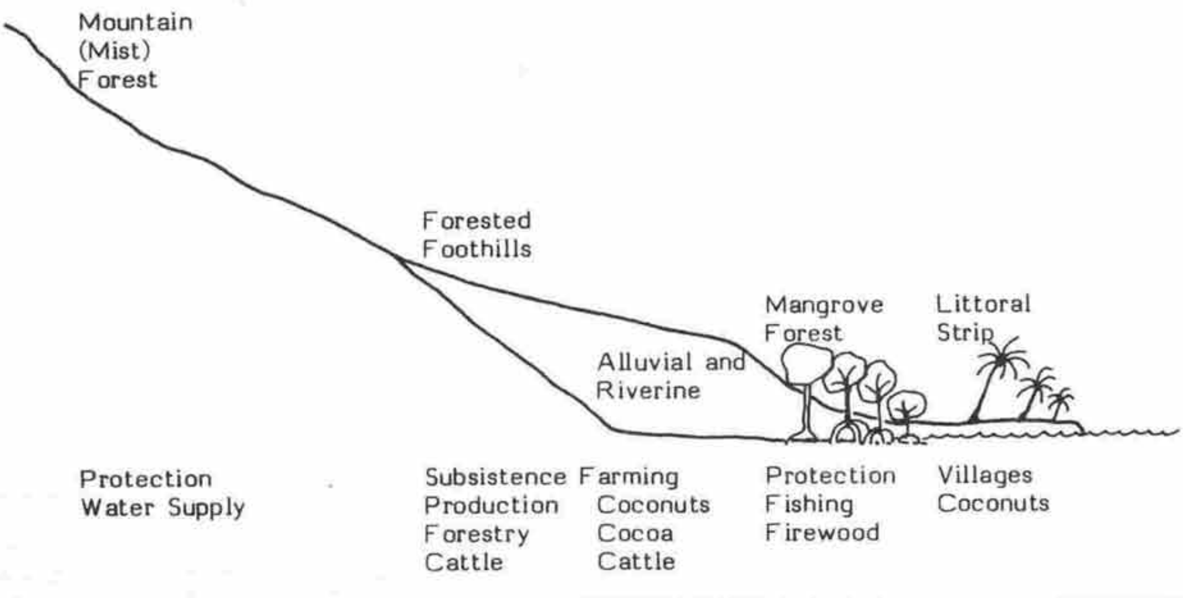
Notes: Species underlined TEYA, BURO etc. seldom grow larger than 180 cm girth, and so do not influence North New Georgia analysis.

Examples of botanical names: ALAJ = Alanjium javanicum; BURO = Burekella obovata; CALK = Calophyllum kajewskii; CALV = Calophyllum vitiense GONM = Gonystylus macrophyllus

Forest zonation

In broad terms there are two types of island in the Pacific region. Low lying coral atolls have vegetation that has generally been wholly modified by local populations, and now consists largely of trees with local uses, of which coconut and Pandanus are the most obvious. These low lying coral islands have no forestry potential. The inhabitants are generally short of building timbers and fruit trees, and these can be planted in and around villages and food gardens. The larger islands nearly all have a rugged volcanic core fringed by coral reefs which may have been uplifted on more than one occasion. The volcanic core may range from relatively low altitudes to the snow capped mountains of West Irian and Papua New Guinea. The larger islands east of Papua New Guinea seldom exceed 2,000 m in altitude. On the geologically youngest and active volcanic islands like Tinakula in the Santa Cruz group there may be no fringing reef. On older islands on the tectonic interface between the Australia and Pacific plates, land building is still continuing and successive coral and limestone platforms have been uplifted to altitudes in excess of 300 m above sea level. Such formations can be seen on Malaita, Guadalcanal and elsewhere, with the oldest of these platforms being now considerably eroded, and dissected. Forest composition is influenced by increasing altitude, by increasing distance from the sea, and by the underlying soil. Figure 2 gives a simplified vegetation zonation common in the Solomon Islands.

FIGURE 2 : DIAGRAMATIC VEGETATION ZONATION
Typical of the Solomon Islands



Mangrove swamps are limited to sheltered water, often protected by reefs. Despite limited rise and fall of the tides, species vegetational zonation is precise. Large areas of mangroves only occur in West Irian and Papua New Guinea. Elsewhere they are generally of limited extent and are too valuable as sources of local building material, fruits and seafood to be allocated to commercial exploitation.

In most of the coastal zones the natural littoral vegetation on beaches, with its ability to provide coast protection, has largely been removed to make way for coconut plantations and villages. Reintroduction of the protective screen of native littoral species would retain a measure of protection from erosion by the sea.

The vegetation developed on the low-lying raised platforms is generally lime-tolerant in nature, with Pometia pinnata a prominent timber and fruit species. The species mixture found on the low lying terraces is generally very similar to that found on successively higher terraces with soils of varying depth developed over limestone, which by the standards of tropical soils contain modest reserves of nutrient. These sites have often been heavily used in the past by shifting cultivators, and more recently are those to which Agricultural Officers direct their extension programmes.

Behind the low-lying raised coral platforms, lie alluvial terraces and swamps, which receive runoff water and detritus from inland areas and have richer soils with agricultural potential. Fire-maintained grasslands in a number of islands almost certainly result from past over-population where there is a rain shadow effect. Examples can be cited from Papua New Guinea, the Solomons and Fiji. In many cases these fire-maintained grasslands have spread to adjacent ridges which may be of sedimentary origin.

A zone of dissected sedimentary foothills is typical of the geologically older islands, characteristically with red-coloured, weathered, deep and apparently freely-drained soils. Tree rooting patterns indicate that only the upper 30 centimetres of soil is tapped either due to imperfect drainage, imperfect aeration or a combination of both factors. The most economic forest usually occurs on these sites and the profusion of vegetation leads many to expect an adequate to high level of fertility. Absence of evidence of occupation from archaeological sites and recent experience growing food crops by forest workers reveals that for all intents and purposes long bush fallows are required between cropping if modest fertility is to be retained. Traditional knowledge usually reinforces this view.

In Western Samoa very recent lava flows occur on the foothills. The young rocks are often very fertile provided plants can survive long enough to put roots down into crevices. A crowbar is required for planting tree seedlings, and cocoa or timber trees should be raised in large containers to ensure survival.

The volcanic core of the larger islands is usually steep, the soils skeletal and often unstable because of torrential rain and frequent earthquakes. This reduces effective rooting volume, and the forest that develops is often much disturbed and has limited commercial potential above 500 m in most islands other than Papua New Guinea.

In Papua New Guinea large areas of mountain forest occur and cultivation is carried out in deep, often glacial, valleys. Cooler ambient temperatures and frosts mean that tropical root crops like kumera and taro are near their limits; and temperate vegetables can be successfully raised and introduced into local diets. The exploitable mountain forests are generally confined to the higher ridges but there is growing pressure to cultivate higher up the slopes where agricultural rotations lengthen and yields are reduced. Conifers are locally abundant, but species with temperate characteristics like Castanopsis, Elmerrillia and Nothofagus cover much larger areas. In places Nothofagus stands are dying off and being replaced by abundant natural regeneration.

Agathis species are the main conifers in mountain forest in parts of the islands to the east of Papua New Guinea; often with Calophyllum species as a main component of the matrix. New Caledonia is atypical in having a large number of Araucaria species in the forest; while Dacrydium and Podocarpus are relatively common in Fijian mountain forests. Moss forest is found at higher altitudes.

A noticeable feature is that the generalized zonation is compressed on isolated smaller mountainous islands. A good example is the contrast between moss forest occurring at over 2,000 m above sea level, with a maximum altitude of about 2,500 m, on the large island of Guadalcanal; on Vanikolo, with maximum altitude of about 1,000 m, moss forest occurs at about 800 m; while on Santa Cruz Island which is larger than Vanikolo, localized patches of moss forest occur at about 500 m on the crest of the spinal ridge.

Forest disturbance

Two major factors causing disturbance of forest cover south and east of Papua New Guinea are wind and earth movement; but throughout the region conversion to cash cropping, subsistence agriculture and logging are also extremely important, particularly on the smaller islands. Urban development is most noticeable on some atolls, but relatively insignificant elsewhere.

Between November and April the south easterly trade wind belt moves south, and intense tropical storms develop from time to time mainly in zones between 5 and 10 degrees south. These tropical storms increase in intensity as they move south, but until they pass about 15 degrees meridian wind speeds seldom exceed 100 km per hour.

The low pressure areas associated with the storms for 24 hours or so before they strike bring torrential rains which saturate the ground. These tropical storms are locally called cyclones, and when they strike major canopy damage can be caused almost as much by uprooting on sedimentary clay ridges, as by trees snapping.

Major damage to exploitable forest has been caused by cyclones Annie (1967), Ida (1972), and Bearnie (1982) in the Solomons, and on the Fiji south coast in 1980. Interpretation of current vegetation patterns in the Solomons indicates that catastrophic wind disturbance has occurred on a wide scale from time to time over the past 150 years or so.

On Makira, Guadalcanal, and Malaita most of the remaining forest shows evidence of wind damage. This damage can be seen by the existence of climber towers, damage seen under the canopy, and compression failure in lumber of certain species, notably Pometia. In the New Hebrides where cyclones are more intense very little primeval forest is left except where Agathis dominates.

Considerable areas of topsoil may be lost by earth movements following both cyclones and earthquakes. Examples of the former can be seen in southeastern Fiji, and on Santa Isabel in the Solomons, while the earthquake in April 1977 caused almost 40% of the topsoil and forest to slip on parts of Guadalcanal.

In the islands, usually near the coast, considerable areas of forest have been converted to cash crops. The most common cash crop is coconut. During the last 30 years or so cocoa and oil palm estates have been developed, noticeably in Papua New Guinea and Guadalcanal and to a lesser extent in Western Samoa.

The land commonly selected for these crops is either low coral limestone terraces or alluvial soils. Conversion of forest to cattle pasture has been increasing during the last decade or so often on the better quality soils, but usually has low carrying capacity.

When indigenous populations were low, shifting cultivation was carried out with bush fallows that must have ranged up to 50 or more years. Even in the past there is evidence that what are now fire-maintained grasslands were originally converted by excessive pressure of shifting cultivation. Spanish records from 1565 for Guadalcanal and Ngella record "meadows" visible from the sea, with village cultivators using irrigated taro terraces. The "meadows" are still there and are now extending as modern population pressures increase in this rain shadow area. The taro terraces have long since disappeared, as have the high populations recorded by the Spanish visitors here and elsewhere in the Solomons. The large expanse of grassland on western Viti Levu and parts of Vanua Levu, also in rain shadow areas, are probably of similar origin.

During the past century or so, cessation of warfare, increased availability of health care, and movements of tribes towards lines of communication and economic opportunities by sea, land and air have all led to changes of traditional ways and high rates of population growth. Most tribal boundaries, formerly alterable by warfare, are now fixed. Land holding groups unfortunate enough to have large populations and small land areas, have had to reduce shifting cultivation cycles to as little as 6 to 9 months. Rapid, and in places irreversible soil degradation follows. This is compounded by local people clinging to traditional farming techniques based on a much longer bush fallow which formerly allowed humus and microfauna regeneration to follow in a natural cycle.

Logging damage

In Vanikolo in the Solomons extraction of kauri started nearly 60 years ago; elsewhere large scale mechanical logging seldom dates back more than about 15 years.

Timber trees in the natural forest are scattered both as individuals and groves, and therefore damage to the canopy and to the soil is also irregular. Maximum damage generally occurs 50 m or so on either side of access roads. On islands which are relatively uniform volcanoes, there is generally a main metalled logging road close to the coast with metalled spur roads running up the major ridges; so soil damage naturally falls in the middle of the broadest ridges. On steep topography with deep sedimentary soils, road layouts are more irregular and cut into hillsides; so soil damage can be extensive. Studies in the Solomons on the patterns and extent of damage following mechanical logging in five areas showed that a combination of metalled logging roads, extraction tracks and loading areas with "high lead" logging destroyed 7% of top soil in well stocked forest. A higher figure of 22% was for extraction by small crawler tractors in similar forest. Overall, for forest yielding 30 to 50 m^3/ha of logs, 10% to 15% topsoil damage can be anticipated. The damage will generally be most noticeable near access roads and also on either side of creek crossings. On steeper ground there are generally more scattered extraction tracks. Measurements showed that crawler tractor tracks mostly were less than 5 m wide, and that compaction and removal of topsoil was always severe after two or more turns of logs were extracted. On flat ground little topsoil compaction or removal occurred when only one or two logs were removed, provided the tractor did not have to bulldoze a path through trees. Once vegetation, usually in the form of climber, covers the compacted ground, there is a slow buildup of vegetable detritus and later colonization by trees. After 25 to 40 years the tracks can still be seen, but quite large trees can have established on the compacted soil with their roots spreading on either side to more favourable areas.

Assessments of canopy damage have been carried out in a number of localities in the Solomons within the 18,000 ha of logged forest that have been line planted. These show that even with heavy logging taking out small trees with diameters down to about 45 cm diameter above buttress, 25% to 30% of the original canopy is relatively untouched, largely on the steeper hillsides and in valleys. About 35% of the original canopy is completely destroyed and the rest suffers severe damage in some form or another.

Natural forest regeneration

Relatively few studies of natural regeneration following logging in tropical rain forests have been carried out in the Pacific Islands. The patterns of natural forest development on Kolombangara in the Solomons were studied in detail between 1964 and 1971, with some areas studied for a longer period. In 1967 Cyclone Annie struck part of the island, so that subsequent assessments gave an indication of natural regeneration patterns that followed the cyclone. Provided the forest is in the mature phase, and only a relatively small proportion has been destroyed by a cyclone, increment more or less balances losses. Species like Endospermum, Campnosperma and Elaeocarpus are capable of 2-5 centimetres diameter increment per year when in the upper canopy; while more dense species like Schizomeria, Dillenia and Pometia grow more slowly and with greater variability according to their place in the canopy. Calophyllum however has remarkable uniform increments of about 1 cm per year regardless of size.

A number of studies were carried out in the Solomons starting about 20 years ago in logged forest. Natural regeneration in Kauri forests was studied separately. The first hardwood forests logged were predominantly of Pometia and Calophyllum and the most prolific early regeneration was from these species. After a series of assessments it soon became obvious that there was an extremely rapid loss of seedlings due to weeds, lack of light and competition. After a short while it became apparent that operations to successfully enhance the development of slower growing more valuable species would be very tricky.

At about this time logging operations transferred to forest of markedly different types in which Campnosperma and Dillenia were dominant, except in swamps which carried Terminalia brassii stands.

Four quotations from Solomon Islands Forestry Division Research Reports on the silvics of species have been adapted to illustrate the likely pattern of natural regeneration:

> "The traditional idea of growing shade tolerant species by manipulation of the upper canopy has serious drawbacks. Natural regeneration of Kauri is scattered, particularly in areas nearer to the coast where the original stocking was low. On Vanikolo, areas that had been logged 20 years or so before, were treated by poisoning and weeding designed to release saplings and poles over 2 metres height from within a matrix of older and taller weed species. After treatment only 30% to 45% of 0.01 hectare sample units were stocked with Kauri of all sizes of which only 10% of the sample units contained Kauri poles over 10 centimetres diameter which were sufficiently vigorous to stand a chance of developing to maturity. In areas that were logged more recently, poisoning was more drastic, especially where the Kauri regeneration was small and there was more thorough weeding. It is likely that the original stocking of Kauri

regeneration was higher and over 70% of 0.01 hectare plots were stocked and 35% of the sample units contained Kauri poles over 10 centimetres diameter likely to develop to maturity. As the distribution of Kauri in the forest before logging was very patchy, the distribution of Kauri seedling both before and after logging is likely to be irregular; with perhaps 50% to 50% devoid of Kauri regeneration." (Research Report S/5/80)

"The largest numbers of Campnosperma and Endospermum seedlings occur when the original canopy is most disturbed and where there is quite a lot of soil disturbance. Only a few seedlings are found in shaded areas and small gaps and these grow slowly. Initial natural vegetation of Campnosperma and Endospermum is often prolific, with over 1,000 and 2,000 seedlings per hectare respectively. Endospermum suffers heavier losses in the first three years or so as a lot of young trees are shaded out or smothered by climbers. After 3 years only about 100 Campnosperma and 50 Endospermum are left per hectare, and only about half the survivors are growing fast enough to compete with other weed trees." (Adapted from Research Reports S/2/80 and S/6/80)

"It has not been possible to study natural regeneration of Terminalia calamansanai in detail. Observations mostly on North Kolombangara, where it is a major component of the original forest, indicate that seed is spread fairly freely from scattered mother trees, and germinates quite well. The young seedlings are easily shaded out, and only relatively few, often near disturbed ground, grow fast enough to compete with the weed trees." (Research Report S/3/80)

"There can be prolific regeneration of Terminalia brassii after a stand has been felled; with the best regeneration occurring where the soil has been disturbed rather than in moister areas where the humus is more or less intact. Recent observations indicate that it can also generate naturally quite well on disturbed clay soils on hillsides and on dryer coralline sites provided wind blown seed is available. Where natural regeneration develops very strongly the resulting stands contain a high proportion of very slender trees. These are rather susceptible to strong winds, but after about 10 years the most vigorous individuals will have dominated the others and formed solid poles with long clear boles and well balanced crowns." (Research Report S/4/80)

Replanting

The oldest and most mature areas of close planted industrial plantations are mainly in Papua New Guinea. They include teak at Brown River and Mount Lawes, Agathis species at Bulolo, and Eucalyptus deglupta and Terminalia brassii at Kerevat. The writer unfortunately has not visited any of these areas; but does have limited experience of the Fiji Pine Commission Plantations on Viti Levu. The most promising close planted industrial plantations in the region are generally those developed on degraded soils with dense Pennisetum and Themeda grass vegetation where Pinus caribaea is the most successful species, though it is likely to be replaced by Pinus patula at higher altitudes in Papua New Guinea. The Centre Technique Forestier Tropical is testing P. caribaea in New Caledonia, and this work is likely to be extended to other French-speaking territories. Conversion of logged Tropical Rain Forest to close planted industrial plantations presents many problems in the region. The most notable of these are: irregular topography that precludes use of heavy machinery for land clearing; lack of a pronounced or predictable drying season that precludes successful burning; and extremely vigorous weed regrowth, particularly of climbers that require up to 10 or 12 tending operations a year to be even modestly successful. A number of close planted industrial plantations have been proposed, for example in Gogol, but few have been successful. Even the much publicized Jari Forestal project in the Amazon has eventually become problematical. Noticeable degradation of the understorey vegetation may also be associated with problems. Experience in the Solomons, Fiji and Western Samoa has suggested that greater understanding is required of the limitations of those sites most likely to be replanted. When these limitations are compared with some of the criteria required to ensure the success of line planting, there is remarkable compatibility throughout the region. These features are:

- Soils are generally highly weathered with few or no nutrient reserves.

- The vegetation matrix is not easy to burn.

- Mechanical land clearing is uneconomic.

- Browsing animals should be few or absent altogether.

- Weed regrowth in cleared areas is generally more vigorous than on average in less disturbed areas.

- Overhead shade from big trees must be removed early.

In the region the largest areas of line planting are in Fiji, the Solomons and Western Samoa.

All areas exhibit a range from failure to success. Most species growing successful in line planting do not occur as monocultures in nature in the tropics. Where monocultures do occur in tropical forest the site is often specialized as with Terminalia brassii swamps, Casuarina groves on ultramafic rocks, Agathis on basalt ridges, and mangrove areas. Elsewhere monocultures are generally a limited seral stage. Widespread observations indicate that retention of a reasonably complex vegetative mix contributes to success. Where there is little damage to the relict natural vegetation, especially of former understorey components, line planting is often successful.

In the Solomons, measurements on mature trees over a range of sizes on 20 to 25 years rotations indicated that crown diameters of final crop trees were of the order of 10 metres. Until recently most line planting has been carried out at about this spacing. When a strip about two metres wide is cleared, 80% of the relict vegetation need not be disturbed. Where the canopy has been destroyed by logging, weed regrowth, particularly by Merremia and Mikania species, has been rampant.

This causes severe losses to planted trees. Heavily logged areas seldom exceed 20% to 25% of the total; so that special techniques involving closer planting will have to be evolved to combat the problem of rampant climbing weeds. Final crops of around 100 stems per ha are anticipated for trees with 50 to 60 cm average diameter. Anticipated average merchantable bole length varies from about 5 m to 12 m for hardwoods on 15 to 25 year rotations. Few line planted areas have yet reached maturity and conservative estimates would put yields of sawlogs in the range of 75 to 200 m^3/ha, with a small end diameter limit of 30 cm. Total wood yield based on an interpolation from Table 2 is likely to be of the range of 350 to 500 m^3/ha. Additional sawlog volumes could be harvested if the merchantable small end diameter limit were reduced to about 20 cm. In all cases a considerable proportion of the total yield could be used as pulpwood or for energy.

The wisdom of continuing line planting has been questioned because of two recent events. The first was the discovery of Ambrosia beetle attack and associated problems with the fungi Armellaria and Fomes on Sweitenia macrophylla plantations in Fiji in 1971. Secondly, inventories of the line planting in the Solomons in 1980 revealed much lower stockings of potential final crop trees in all ages than was anticipated. In both cases the authorities curtailed their replanting programmes and instituted a radical change of emphasis in their replanting work. In Fiji a wider range of species were introduced that had not then been proven on a wide scale in line planting. In the Solomons the line planting technique was changed by reducing the spacing between lines to 5 m. In Fiji the areas subsequently replanted to mixed hardwoods were extremely variable and no large area of fully stocked plantations has yet been successfully established. In the Solomons the reduction of spacing between lines has lead not only to removal of the relict understorey between lines, but also to the increased incidence of rampant climbers, early and heavy branching on species like Campnosperma, attack by insects like Ambleypelta on Campnosperma, and potential danger of attack by Hypsipylla on Swietenia which had virtually been absent in wider spaced line planting. Had there not been such a radical reaction to the problems, it ought to have been possible to have maintained the momentum of the planting programmes. Field management and financing in Fiji and the Solomons then lost momentum.

Research has showed that the radical corrective techniques had their own serious problems. Closer control and adaptation of former procedures also had a substantial place in retaining cost effectiveness.

When the objective is to create industrial plantations, the following criteria should be used when selecting species:

- Local seeding at a relatively early age, say before 15 years; or seed easily obtainable in bulk from a nearby territory.

- Seed easy to collect and handle in the nursery.

- Height growth of at least 4 m in the first three years after planting.

- Development of a potential log, free of major forks or faults, of a least 6 m length by the fifth year after planting.

- A mean crop diameter at breast height of 10 cm over bark; a mean crop height of 10 m 5 years after planting.

- A main crop with a stocking of 100 logs of 8 to 10 m length with top-diameters of 30 cm under bark, or 35 cm over bark, in 25 years for furniture and construction species, or in less than 20 years for utility species.

- For utility species development of logs with small end diameter of at least 15 cm and log lengths of over 6 m on at least 100 stems per ha by 10 years after planting.

- Yields of about 140 - 150 m^3/ha of sawlogs.

In temperate climates, mixtures are seldom successful and tree form is usually enhanced by close spacing. In New Zealand the form of final crop trees is often improved by pruning. A number of tropical species, including Campnosperma, Swietenia, Tectona, Pometia, Calophyllum, and Cedrela grow unbranched in the first few years provided there is overhead light. Others like Terminalia, Eucalyptus, and Gmelina arborea need both overhead and lateral illumination, and relative freedom from competition before full vigour is developed. In the former group the interrow matrix can be manipulated to give a narrow corridor within which full vigour and adequate unbranched stems lengths are developed. Later a heavy crown should develop above the interrow matrix. Where land pressures are low the interrow matrix in line planting can be the former understorey, or regeneration of weed trees like Trema and Macaranga.

Where competition for land is higher on the smaller islands, silvicultural techniques need to be modified. The scale of operations can generally be smaller since the plantations mainly supply the local population with sawlogs. Examples of proposed species selections in parts of the Solomons, Papua New Guinea, Fiji and Western Samoa are given in Table 4.

Optimum land use

On most of the smaller islands, population growth will increase so rapidly that, within the next generation or two, relatively little forest will remain unmodified. Already there are clear examples that the pressures of indigenous agriculture are leading not only to degradation of vegetation complexity, but also to severe reduction of the productive potential of hill soils. This can easily be seen in western and central Viti Levu in Fiji, Malaita in the Solomon Islands and Upolo, Western Samoa. Within two more decades the position could be critical unless traditional agricultural techniques are modified to give more intensive production from the better sites by mulching and crop rotations. Already in Tonga and Western Samoa lines of Securinega trees are planted between houses and along paths to provide building materials. These trends are likely to increase and be introduced to other island groups.

Large areas of land have been allocated to cocoa, oil palm and cattle on many small islands, and this is likely to be questioned in the longer term. On Malaita, large areas are degrading because of the bush fallow cycles being reduced in places to less than a year. On north Guadalcanal, where there is a "rain shadow", increasing pressure of use is resulting in a rapid spread of Themeda dominated grassland with increasing soil erosion and soil degradation. These trends must be checked and if possible reversed.

TABLE 4 : SPECIES SELECTION FOR REPLANTING

Papua New Guinea (Enga)	**Solomon Islands**	**Fiji**	**Western Samoa**
Construction and Furniture species			
Eucalyptus robusta E. grandis	Swietenia Tectona	Swietenia	Swietenia Tectona Toona sureni
Utility Species			
Pinus patula	Campnosperma Terminalia brassii T. calamansanai Gmelina arborea Pinus caribaea	Endospermum Maesopis eminii Anthocephalus chinensis Cordia alliodora	Cedrela odorata Anthocephalus T. calamansanai E. deglupta Octomeles sumatrana
Wood Energy			
Casuarina obligodon	Acacia auriculeiformus Acacia mangium Leucaena leucocephela		
Village Uses			
Casuarina obligodon Pandanus spp. Dodonaea viscosa	Securinega sp. Eucalyptus tereticornis Fruit trees Cordia subcordata		Securinega samoana

Both logging and shifting cultivation destroy or at the very least, greatly upset, the dynamic balance of the moist tropical forest ecosystem. The tropical soils on the sites most likely to be allocated to long term timber production have poor or virtually non-existant nutrient reserves and only maintain vegetative productivity by rapid recycling of litter from a wide variety of species. Substitution of any monoculture can have very severe effects on the understorey. At one extreme, Teak plantations will have bare ground covered with large dry teak leaves; while 10 year old line planted Terminalia calamansanai or Campnosperma may have a very rich interrow matrix with a major component of the understory from the original forest. Close planted Campnosperma plantations which develop an understorey of Glychenia ferns may prove to be less thrifty. Conifer plantations may develop fern or grass understoreys and be very susceptible to fire danger.

The writer believes that experience to date indicates that as much complexity of vegetation as possible must be maintained to ensure that soil productivity is retained. Where land pressures are not high this suggests that if possible the relict natural interrow of vegetation should not be modified, except where there has been severe damage to the original forest and soil near roads and loading areas.

Where land is in short supply, trees for timber and for village use have to be grown between crops for food. After food crops are harvested the vegetation matrix has to be planted and, to get variety, a range of species is needed. The shorter the natural bush fallows become, the more they loose their legume element; there is not enough time in which to rebuild the nitrogen and micro-fauna cycles. A range of legumes should then be planted partly to provide nitrogen and partly as a filler with limited canopy height which will improve the form of timber species planted to provide poles and sawlogs.

Some special consideration is needed in many islands in planning to provide plants for defence against coast erosion on the seaward side of coconut plantations and villages where the natural coast vegetation has been removed.

Two aspects remain to be covered. Protection of water supplies, for example, is vital on Upolu and Savaii which have porous lava rock through which water will drain if vegetation is removed and not replaced. Not only village and town water supplies will be affected, but also hydroelectric power projects. In addition, forests have traditionally provided building materials, fruits, hunting, and traditional medicines. If the central and highest portions of islands are left with their primeval vegetation little modified, these vital features of island life will be to some extent preserved.

REFERENCES

Alston, A. S. 1982. Timbers of Fiji: properties and potential uses. Department of Forestry, Suva, Fiji.

Eddowes, P. J. 1977. Commercial timbers of Papua New Guinea, their properties and uses. Office of Forests, Department of Primary Industry, Papua New Guinea.

Gowers, S. 1976. Some common trees of the New Hebrides and their vernacular names.

Marten, K. D., and B. R. Thomson. 1980. Solomon Island Forestry Division Research Reports 1 - 12/80, The silvics of species 1980. (Cyclostyled report) Forestry Division, Ministry of Lands, Energy and Natural Resources, Honiara, Solomon Islands.

Solomon Islands Timber Booklet No. 1: Major Species, and Timber Booklet No. 2: Minor Species. 1979. Forestry Division, Ministry of Lands, Energy and Natural Resources, Honiara, Solomon Islands.

Solomon Islands Tropical Rain Forest Ecology Research Report 5/2/79. 1979. (Cyclostyled report) Forestry Division, Ministry of Lands, Energy and Natural Resources, Honiara, Solomon Islands.

Whitmore, T. C. 1974. Changes with time and the role of cyclones in tropical rain forest on Kolombangara, Solomon Islands. Commonwealth Forestry Institute Paper No. 48. Oxford University.

MINERAL POTENTIAL OF THE SOUTHWEST PACIFIC ISLANDS

H. L. Davies
Bureau of Mineral Resources
GPO Box 378, Canberra, A.C.T. 2601, Australia

ABSTRACT

The islands of the South Pacific produce minerals worth about one billion dollars each year. Chief revenue earners are the large porphyry copper-gold mine at Panguna on Bougainville Island in Papua New Guinea, the nickel mines of New Caledonia, and the phosphate exported from Nauru. Metals which have been produced in the past, from these and other islands, include gold and silver, base metals, antimony, cobalt, chromium, manganese and magnesite; other known metals and minerals include mercury, molybdenum, coal, hydrocarbons and probably uranium.

In the immediate future a second large porphyry copper-gold mine will come into being in Papua New Guinea, at Ok Tedi near the Irian Jaya border. Other likely developments include the discovery of commercial accumulations of hydrocarbons in Papua New Guinea, and possibly in Tonga and Fiji; the discovery and/or development of other gold, silver, base metal, nickel, cobalt, chromium and phosphate deposits, in response to more thorough or sophisticated exploration, or improved metal prices; the better definition and possible commercial development of known deposits of bauxite, coal, mineral sands and metal-rich sea floor nodules; and the possible discovery of mercury and tungsten minerals, platinum group metals, metals of the carbonatite association, sea floor volcanic vent minerals, diamonds, uranium and precious coral.

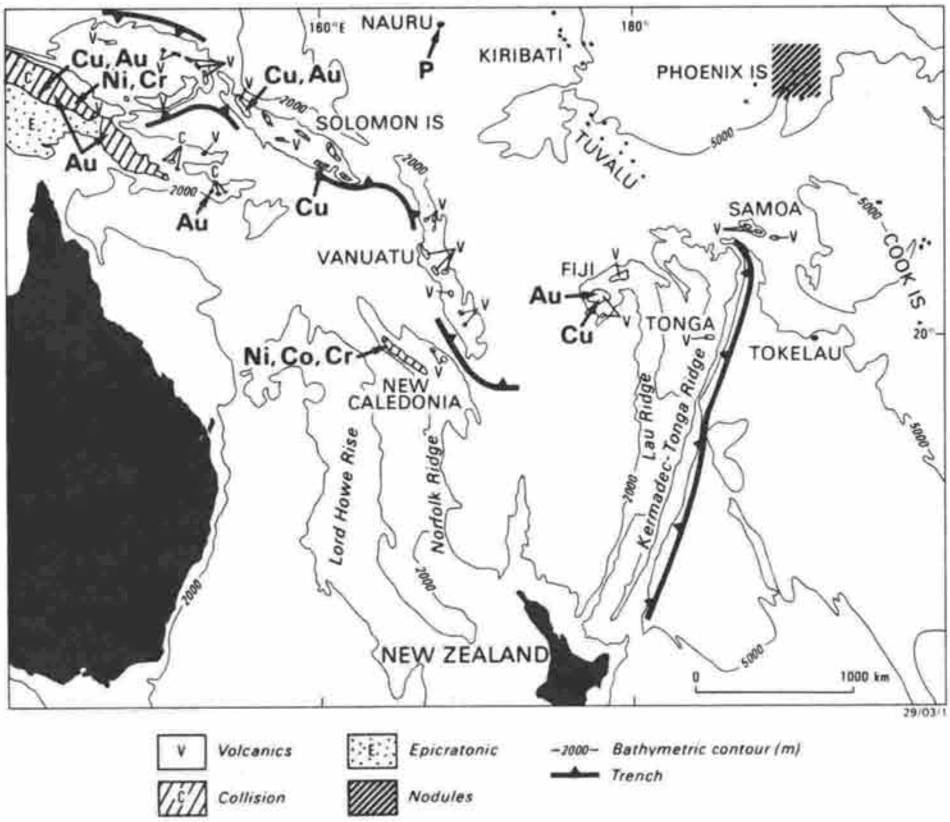
Introduction

The great expanse of the waters of the southwest Pacific conceals a sea floor which is remarkable for its configuration of ridges, trenches, platforms, basins and seamounts (Figure 1). It is these features which indirectly control the distribution of mineral and petroleum wealth amongst the island groups and it is only from an understanding of the nature and origin of these features, coupled with a knowledge of discovered resources, that a reasoned assessment of mineral potential may be drawn.

These geomorphic features have developed by continued interaction between the Australian and Pacific lithospheric plates. Present-day seismicity (Figure 2) indicates that the boundary between the two plates is approximately on the line Kermadec-Tonga-Vanuatu-Solomon Islands-northern New Guinea. In the past the boundary has lain closer to Australia, but has moved away as segments of the Australian craton have broken away by rifting and opening of, for example, the Coral Sea and Tasman basins.

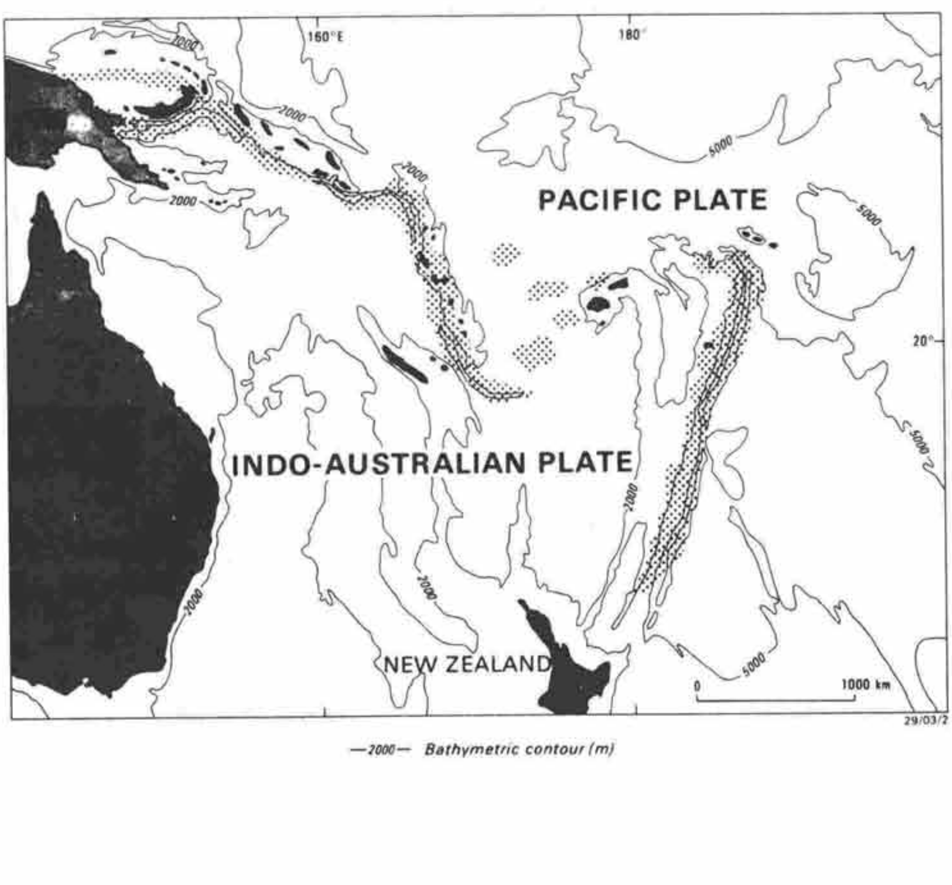
Interaction between the plates has led to the growth of new land masses by volcanism linked with subduction, or by collision (Figure 3). Collision occurs when thick low-density crust enters a subduction system and cannot be drawn down into the lower levels of the earth because of its innate buoyancy. The result is multiple thrusting and the emergence of a complex terrain which includes elements of volcanic, sedimentary, metamorphic, igneous and lower crustal and mantle rocks.

Figure 1 : Simplified geology and sea floor morphology of the southwest Pacific



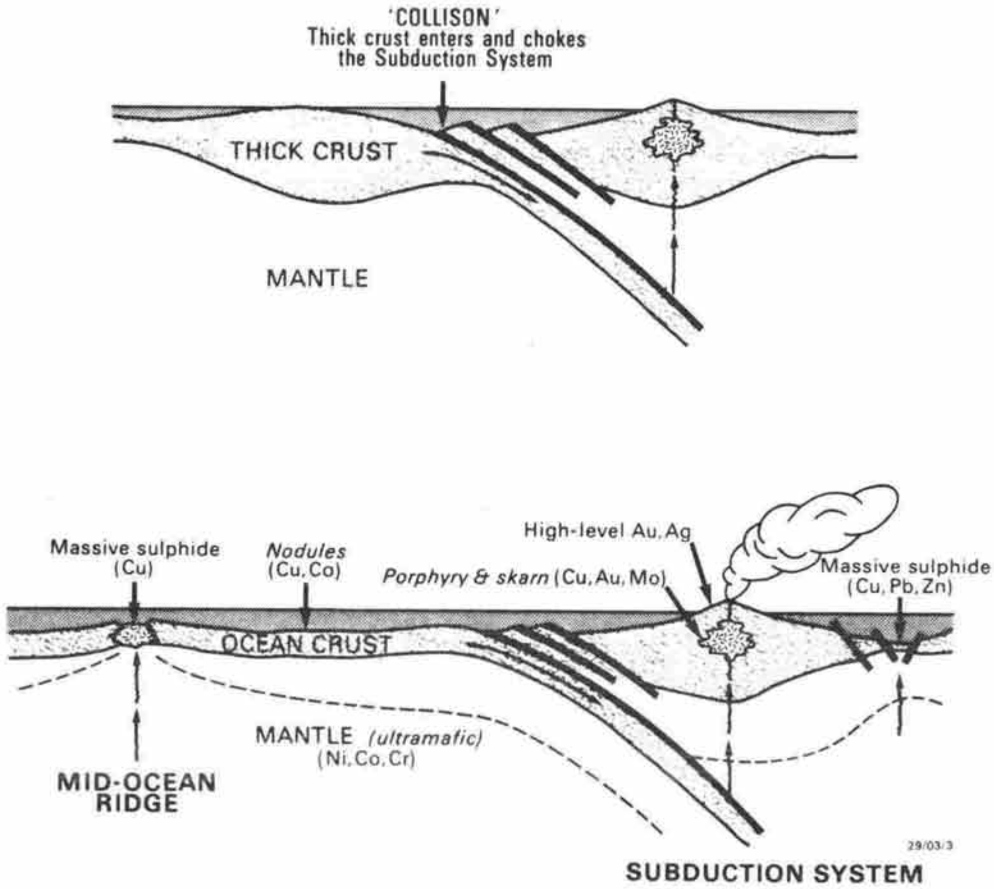
Au = gold
Cr = chromium
Cu = copper
Co = cobalt
Ni = nickel
P = phosphate

Figure 2 : Shallow earthquakes (patterned) indicate the boundary of the Indo-Australian and Pacific plates



—2000— Bathymetric contour (m)

Figure 3 : Diagrams of subduction and collision, with environments of mineralization



Certain mineral deposits are associated with volcanic processes, notably the exhalative base-metal sulphide deposits of the rifts and spreading ridges, and the porphyry and skarn copper and gold and high-level gold and silver of the volcanic islands (Figure 3). These are the types of mineralization found in volcanic terrain.

In collision terrain, which by its nature must include volcanic terrain, the same types of mineralization are found, but to these are added the ores of metals associated with mantle rocks, notably nickel, cobalt and chromium.

Examples of volcanic terrain are the islands of the Fiji and Western Samoa groups, while the classic example of a collision terrain is New Caledonia (Figure 1). In southwestern Papua New Guinea a third type of terrain, epi-cratonic, may be recognized where relatively thin sediments overlie a northerly extension of the Australian craton.

Papua New Guinea

The island group with the largest land area and the greatest mineral wealth is Papua New Guinea (Table 1). The mountainous axis of mainland Papua New Guinea is collisional terrain which contains a considerable mineral wealth and the potential for more discoveries. Notable are the Ok Tedi porphyry copper-gold mine, currently being developed, the Frieda River copper-gold prospect, gold at Porgera and on Misima Island, copper at Yandera, lateritic nickel and chromium at Ramu, and Morobe detrital chromite (Table 2).

Table 1 : Mineral production in Pacific countries (1980)

Country	Population (thousands)	Area (km^2)	Value of annual mineral production ($ million)	Value per km^2 ($)	Value per capita ($)
Australia	15,000	7,686,849	7,429	966	494
Papua New Guinea	3,000	461,690	485	1,050	161
Solomon Islands	173	28,160	0.6	22	3.5
New Caledonia	121	19,099	350	18,326	2,893
Fiji	531	18,274	10	547	19
Vanuatu	89	14,763	-	-	-
Western Samoa	151	2,841	-	-	-
Kiribati	48	718	-	-	-
Tonga	92	696	-	-	-
Tuvalu	8	26	-	-	-
Nauru	7	21	100	4,762,000	14,286

The northeastern mainland and the adjoining islands are volcanic terrain. Typical is Bougainville Island which is constructed of modern volcanoes and uplifted coral reef, on a basement of partly-eroded older volcanoes and their feeder intrusive rocks. The Bougainville porphyry copper-gold mine is the fourth-largest mine of this type in the world; annual production is about 170,000 tonnes copper, 20 tonnes gold and 45 tonnes silver (metal content of concentrate).

The epi-cratonic sediments of Papua New Guinea and sediments of the collision terrain are prospective for petroleum, and a number of as yet uncommercial discoveries have been made (Table 2) including the 1983 discovery of gas and gas condensate in the Juha well. The volcanic terrain of Papua New Guinea includes some thick sedimentary basins and is also considered prospective for hydrocarbons, although no indications have been found to date.

Another energy resource of Papua New Guinea, by virtue of its large land area, mountainous terrain, and relatively high rainfall, is the hydro-electric potential of its rivers. This has been estimated at 12,000 megawatts, of which slightly less than 100 megawatts has been developed.

Table 2 : Mineral Resources of Papua New Guinea*

Panguna Mine (Bougainville Copper Limited): Initial reserves were 944 million tonnes averaging 0.48 percent copper, 0.56 grams/tonne gold and 3 grams/tonne silver. Production peaked in 1978 at 199,000 tonnes copper, 23.4 tonnes gold and 52.5 tonnes silver and has declined subsequently due to declining head grades and harder ore. Current reserves are about 650 million tonnes averaging about 0.43 percent copper and 0.48 grams/tonne gold.

Ok Tedi mine (under development; Ok Tedi consortium): Reserves are 351 million tonnes of 0.7 percent copper, 0.6 grams/tonne gold and 0.011 percent molybdenum, with some supergene enrichment; overlain by 34 million tonnes of oxidized ore which carries 2.87 grams/tonne gold; adjacent skarns contain 25 million tonnes of 1.17 percent copper. Gold production will start in 1984, and full copper production in 1989.

Frieda River copper-gold prospect: Resource is 780 million tonnes of 0.46 percent copper and 0.29 grams/tonne gold (cut-off 0.3 percent copper), with some supergene enrichment, and nearby massive sulphide with more than 1 percent copper and 1 gram/tonne gold. A dissected volcanic complex.

Yandera copper prospect: Resource is 338 million tonnes of 0.42 percent copper and 0.018 percent molybdenum as porphyry-type mineralization, localized within major batholith.

Porgera gold prospect: Resource of 100 million tonnes of 2.3 grams/tonne gold. Gold and associated base-metal sulphides are in veins in high-level intrusive complex and adjacent Mesozoic sediments. Figures from Mount Isa Mines Ltd. Annual Report 1982.

Ramu prospect: Residual soil over ultramafic rock includes 78 million tonnes of 0.86 percent nickel, 0.09 percent cobalt and 3.3 percent chromium; 50 million tonnes of 1.14 percent nickel, 0.16 percent cobalt and 3.2 percent chromium; and 25 million tonnes of 1.46 percent nickel and 0.06 percent cobalt (from Mount Isa Mines Ltd. Annual Report for 1982).

Morobe chromite prospect: Coastal alluvium includes resources of 30 million cubic metres averaging 2 percent chromite, and 6 million cubic metres of 2.5 percent chromite, for estimated total recoverable 1.5 million tonnes chromite.

Misima gold-silver prospect: Resource of 30 million tonnes of 1.3 grams/tonne gold and 18.6 grams/tonne silver (from Placer Development Ltd Annual Report 1982).

Wau: Current reserves at Golden Ridges mine are 960,000 tonnes averaging 2.4 grams/tonne gold, with probable reserves of 670,000 tonnes of 2.3 grams/tonne gold (Australian Financial Review, 21 October, 1983).

Laloki: Resource of 315,000 tonnes of 4.3 percent copper, 6.4 grams/tonne silver and 3.5 grams/tonne gold.

Arie prospect: Resource of 165 million tonnes of 0.32 percent copper (Mining Journal, 7 July, 1978).

Hydrocarbon discoveries: Significant volumes of gas and gas condensates were intersected in Juha, Pasca, Uramu and Bwata wells. Attempted development of the Pasca field in 1983 has resulted in an uncontrolled blowout. Gas was also encountered in Barikewa, Iehi and Kuru wells, and gas, gas condensate and oil in Puri well.

---

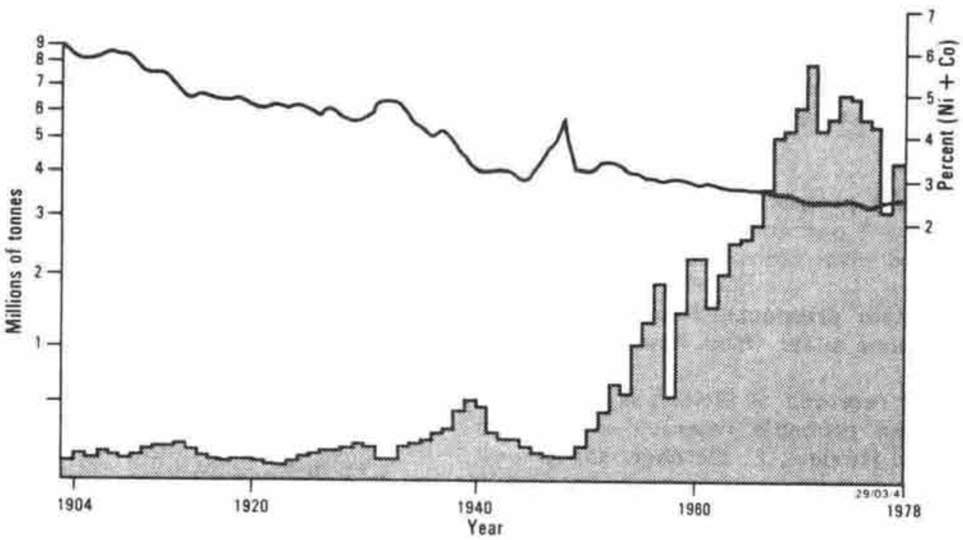
*Based on Doble (1981), up-dated by A. Williamson, personal communication, 1983.

New Caledonia

Second to Papua New Guinea, in terms of total value of minerals produced annually, are the smaller and less populous islands of the New Caledonia group. The main island, which is the source of most of the mineral wealth, is classic collisional terrain, with a vast variety of different rock types of different origins and ages, juxtaposed by faulting. The dominant rock type is ultramafic or olivine-rich rock which has been rafted to the surface during collision, from the earth's mantle. Weathering processes have released from this rock, and concentrated in the overlying soils, a number of bodies of nickel ore which together constitute 25 percent of known world reserves of nickel (Matthews and Sibley, 1980).

The ore is won by surface mining and shipped as crude ore or smelted as nickel matte (75 percent nickel) and ferronickel (25 percent nickel) before export. Production of high grade ore started almost 100 years ago and has reached a cumulative total of 2.4 million tonnes of contained nickel. Since 1950, annual production has increased and grade of ore has declined systematically (Figure 4). More recently production has decreased because of reduced world demand. For example, in 1980 4.5 million tonnes of wet ore were produced, with an average grade of 2.53 percent nickel, and a total metal content of 85,000 tonnes. In 1982, only 3 million tonnes of wet ore was produced, with a nickel content of 35,000 tonnes (figures provided by Service des Mines et de l'Energie, Nouméa, 1983).

Figure 4 : Increasing annual production and declining head grades of New Caledonia nickel ore (Paris, 1981a)



(Reproduced by permission of the Director, Bureau de Recherches Géologiques et Minières, Nouméa)

The ultramafic rocks of New Caledonia are also a source of chromite. Production increased dramatically in 1982 with the development of underground reserves at Tiebaghi and the commissioning of a large concentrator. By year end almost 84,000 tonnes of wet ore and almost 50,000 tonnes of concentrate had been produced, which compares with a total of 2,500 tonnes of lump ore and concentrate in 1980 (figures from Service des Mines et de l'Energie, Nouméa, 1981, 1983).

There is a great variety of other mineral occurrences in New Caledonia, some of which have been worked intermittently. These occurrences include cobalt and iron ore (associated with the nickel ore), copper, lead, zinc, gold and silver, manganese, antimony, mercury, phosphate (on the smaller islands) and coal; oil seeps are known (Paris, 1981c).

Nauru

The third major mineral producer in the region is the island of Nauru which produces phosphate to the value of about US$100 million annually. The phosphate is guano which has developed by reaction between limestone and bird excrement. It occurs within furrows up to 12 m deep between pinnacles of dolomitized limestone (British Sulphur Corporation, 1980). Reserves are said to be sufficient for 10-15 years further production.

Fiji

The Fijian islands are volcanic terrain, in terms of our classification, although there is evidence of a major tectonic event in the younger geologic record (the Tholo orogeny in the late Miocene; Richmond, 1981).

Main mineral production is from the Emperor gold mine which produces silver and gold worth about US$10 million annually, from quartz-telluride veins in a former volcanic caldera (Forsythe, 1971). The largest identified mineral resource is the Waisoi porphyry copper prospect at Namosi, also in the eroded root of a former volcano; this contains 500 million tonnes averaging 0.48 percent copper with minor recoverable gold and molybdenum. Copper-zinc massive sulphide deposits are known on Viti Levu, and gold deposits and Kuroko-type copper-zinc-lead sulphides with some associated gold and silver on Vanua Levu (Greenbaum, 1981).

Thick sediments both onshore and offshore are currently being tested for hydrocarbons.

Solomon Islands

The Solomon Islands are a mixture of volcanic and collision terrain. A variety of mineralization is known, including porphyry copper and lode and alluvial gold on Guadalcanal, volcanogenic sulphides in the Florida group, lateritic nickel on several islands, bauxite on Rennell and phosphate on Bellona islands, and some heavy mineral sands, and intrusive rocks which might be prospective for diamonds, on Malaita (Arthurs, 1979; Coulson, 1981). The only current production is alluvial gold shedding from Gold Ridge on Guadalcanal; total value of production in 1980 was US$600,000.

The largest porphyry copper prospect is Koloua, on Guadalcanal, with 90 million tonnes averaging 0.17 percent copper, .0025 percent molybdenum, 0.06 grams/tonne gold and 0.77 grams/tonne silver (A. Chivas, personal communication, 1982).

Thick sediments in New Georgia Sound (The Slot) may be prospective for hydrocarbons (Katz, 1980).

Vanuatu

The Vanuatu islands are mostly volcanic with the exception of some collisional terrain on Pentecost Island (Macfarlane and Carney, 1981). Manganese was mined on Efate Island until 1978 but there is currently no mineral production. Magnetite beach sands with high titanium are found on most islands, weak porphyry-type copper mineralization on Santo and Malekula, and some copper, nickel and zinc sulphides on Pentecost.

The Slot basin contains up to 3 km of sediments and these may be prospective for hydrocarbons (Carney and Macfarlane, 1980b).

Tonga

The Tongan islands are volcanic terrain; oil seeps are known and exploration for hydrocarbons continues (U Maung et al., 1981).

Offshore Minerals

Reconnaissance sampling of the southwest Pacific sea floor for manganese nodules has indicated best metal values and high concentrations of nodules in the eastern Central Pacific Basin, in the vicinity of the Line and Phoenix islands, between 6° north and 5° south latitude and 155-175° west longitude (Glasby, 1982; Exon, 1983). These are in water depths of 4,500-5,500 metres.

The heaviest concentrations of nodules are up to 31.6 kilograms per square metre, and the best grades are up to 3.55 percent total nickel, copper and cobalt. These are potentially commercial deposits, subject to confirmation by further sampling, and to subsequent mining and treatment feasibility studies.

Other offshore minerals may remain to be discovered in submarine volcanic centers and active rifts (Cronan, 1983). Hydrothermal iron oxides in the summit area of submarine volcanoes off Epi Island, Vanuatu, might indicate sulphide mineralization nearby (Exon and Cronan, 1983).

Undiscovered Mineral Deposits

Most current exploration activity is focused on hydrocarbons and gold, followed by base metals, minerals of ultramafic association, vent minerals, precious coral, rock phosphate, uranium and, possibly, diamonds. Other minerals which are known, and which may be proven commercial, include bauxite, coal, heavy mineral sands and sea floor nodules. Other metals which are likely to be discovered, by analogy with similar geologic terrain elsewhere in the Pacific, are **mercury** and **tungsten**, and, possibly, metals of **carbonatite association.**

The search for **hydrocarbons** has been spurred by discoveries of gas, gas condensate and minor oil on and near the Papua New Guinea mainland (Table 2). Oil seeps on Tonga are proof that hydrocarbons can develop and accumulate in volcanic arc environment, and have led to continuing exploration programmes in Tonga and Fiji. Any hint of success in these two areas will attract attention to other major volcano-sedimentary basins in Vanuatu, the Solomon Islands (Katz, 1980), and off New Ireland (Exon and Tiffin, 1983).

The search for **lode gold** and **silver** continues to be keyed to known alluvial fields, but, increasingly, is being directed towards hydrothermally-altered volcanics and high-level intrusives. This follows the more general recognition of a link between thermal and fumarolic activity and gold-silver mineralization, and of the fact that gold in this environment is commonly too fine to be detected by panning.

Metals of ultramafic association include nickel and chromium, which are currently mined on New Caledonia, and are known in Papua New Guinea and the Solomon Islands. Platinum group metals have been recovered from alluvium in Papua New Guinea and may remain to be discovered in lode.

Precious coral is present at water depths exceeding 100 m throughout much of the southwest Pacific (Grigg and Eade, 1981) and is a significant potential resource, given that the ex-vessel value of precious coral harvested in the north Pacific in 1980 was US$50,000,000.

Concealed **phosphate** deposits, similar to those exposed on Nauru Island, may remain to be discovered on other southwest Pacific islands (Lee, 1980; Sheldon & Burnett, 1980; J. Barrie, Avian Mining, personal communication, 1983).

Uranium mineralization is known in volcanic environments in some of the lands bordering the Pacific (Goodell & Waters, 1981; Gableman, 1982), and may remain to be discovered in the southwest Pacific islands, specifically in volcanics of highly alkaline and silicic character. Indications of uranium and base metals beneath limestone on Niue Island are not yet tested by deep drilling (Barrie, 1981).

Carbonatites have not been discovered in the southwest Pacific, but there are indications of carbonatite-like rock associations, notably in southeastern Papua New Guinea, in the Milne Bay region. Here are alkaline ultramafic rocks and feldspathoidal syenitic intrusions, poorly exposed, but typically with strong expression in both the gravity and magnetic fields - a characteristic of carbonatites elsewhere. The carbonatite mineral association in Africa and the Americas includes ores of the metals niobium, thorium, uranium, phosphorus, strontium, the rare earths, iron, manganese, titanium and copper.

Prospective Areas

If it is accepted that equal areas of comparable geologic terrain should produce approximately equal mineral wealth, then it is clear that the **Solomon Islands** and **Vanuatu** are either anomalously mineral deficient, or have been inadequately explored (Table 1). Both may be compared with Papua New Guinea which has a similar mixture of volcanic and collisional terrain and which annually produces minerals worth more than $1,000 for each square kilometre of land area. By analogy with Papua New Guinea, both the Solomons and Vanuatu should be highly prospective for porphyry copper-gold, porphyry and high-level gold and massive-sulphide base-metal deposits. Possibly exploration has been less effective than in Papua New Guinea because of restricted access to land.

Impact of Mineral Development

Any projected mineral development will have both positive and negative aspects in terms of national development and quality of life. It is now customary for governments and would-be developers to enter into negotiations, prior to development, to ensure that the best interests of all parties are served; the gamut of issues at stake has been discussed elsewhere (e.g. Davies, 1983).

In an earlier time it was generally accepted that mining could proceed with little regard for any damage inflicted on surrounding terrain or traditional life styles. The results may be seen, for example, in the piles of dredged boulders which mark the former alluvial gold fields of the Bulolo Valley in mainland Papua New Guinea, and in the Mother Lode country of California. A more modern example is the flooding of low-lying terrain downstream from the Bougainville mine by rock waste from the mine; this is now the target of a major rehabilitation programme.

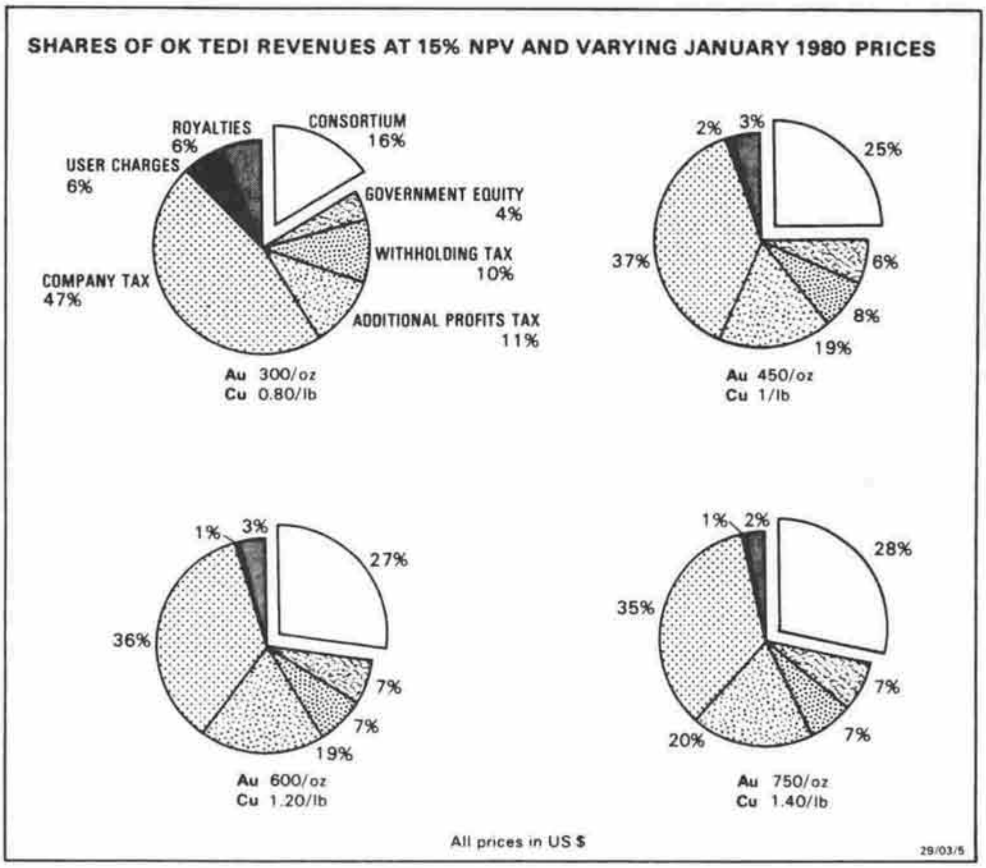
Modern mining agreements seek to ensure that the impact on environment and traditional life styles is minimized. For example, the Ok Tedi Agreement provides for most mine wastes to be stored within the mine area, and for the immediate environment and river systems to be monitored (Jackson et al., 1980).

In terms of the fiscal impact of mineral development, the Pacific nations have successfully negotiated with private sector interests to ensure that both parties receive what is perceived as a fair return from the profitable development of any resource. An example is the Ok Tedi agreement, under the terms of which the developer will spend $1,300 million to establish the mine; normal tax provisions will apply until such stage as the developer has recouped the cost of his investment plus a 20 percent discounted-cash-flow return on the investment; after this stage, additional taxes will apply in years of high profit. The net result is that over the life of the mine about 75 percent of all earnings should flow to government (Figure 5).

ACKNOWLEDGEMENTS

Essential information for this paper was kindly provided by G. P. Glasby of New Zealand Oceanographic Institute, K. W. Doble and A. Williamson of the Geological Survey of Papua New Guinea; A. Macfarlane of the Department of Geology, Mines and Rural Water Supplies, Vila, Vanuatu; J. P. Paris and A. Colleau of Bureau des Recherches Géologiques et Minières, Nouméa, New Caledonia; P. Rodda of the Department of Mineral Resources, Suva, Fiji; and N. F. Exon, C. R. Pratt and D. J. Perkin of the Bureau of Mineral Resources, Canberra. This paper was originally presented at the 15th Congress of the Pacific Science Association, Auckland, February 1983, and has been improved by discussion at the conference, specifically with J. V. Eade of the New Zealand Oceanographic Institution, and by subsequent critical review by Exon, Perkin, Pratt and J. H. C. Bain. Publication is by permission of the Director, Bureau of Mineral Resources, Geology and Geophysics.

Figure 5 : Cash flows to Papua New Guinea Government and Ok Tedi Consortium for different metal prices (1980 budgeted development costs)



Reproduced by permission of the Secretary, Department of Minerals and Energy, Port Moresby

REFERENCES

Arthurs, J. W. 1979. Mineral occurrences in the Solomon Islands. Solomon Islands Geological Survey Bulletin 13.

Barrie, J. 1981. The mineral potential of Niue Island. Avian Mining Pty Ltd, Canberra (unpublished report).

British Sulphur Corporation. 1980. World survey of phosphate deposits, 4th edition. British Sulphur Corporation Limited, London.

Carney, J. N. and A. Macfarlane. 1980b. A sedimentary basin in the central New Hebrides arc. UN ESCAP CCOP/SOPAC Technical Bulletin 3:109-120.

Coulson, F. I. 1981. The economic geology of the Solomon Islands. Solomon Islands Geological Survey, Honiara (unpublished).

Cronan, D. S. 1983. Metalliferous sediments in the CCOP/SOPAC region of the South Pacific, with particular reference to geochemical exploration for the deposits. UN ESCAP CCOP/SOPAC Technical Bulletin 4. 55p.

Davies, H. L. 1983. Evaluation of a mining project in a national development programme. In AGID Guide to Mineral Resources Development. Association of Geoscientists for International Development, Asian Institute of Technology, Bangkok, Report 10:35-46.

Doble, K. W. 1981. Regional geological mapping and mineral exploration activity in Papua New Guinea. Geological Survey of Papua New Guinea, Port Moresby (unpublished manuscript).

Exon, N. F. 1983. Manganese nodule deposits in the central Pacific Ocean, and their variation with latitude. Marine Mining 4:79-107.

Exon, N. F. and D. S. Cronan. 1983. Hydrothermal iron deposits and associated sediments from submarine volcanoes off Vanuatu, southwest Pacific. Marine Geology 52:M43-M52.

Exon, N. F. and D. L. Tiffin. 1983. Geology of offshore New Ireland basin in northern Papua New Guinea, and its petroleum prospects. American Association Petroleum Geologists Studies in Geology (in press).

Forsythe, D. L. 1971. Vertical zoning of gold-silver tellurides in the Emperor Gold Mine, Fiji. Proceedings Australian Institute of Mining and Metallurgy 240:25-31.

Gabelman, J. W. 1982. Uranium on oceanic side of circum-Pacific mobile belt. (Abstr.) Bulletin American Association Petroleum Geologists 66:968.

Glasby, G. P. 1982. Manganese nodules from the south Pacific: an evaluation. Marine Mining 3:231-270.

Goodell, P. C. and A. C. Waters [eds.]. 1981. Uranium in volcanic and volcaniclastic rocks. American Association of Petroleum Geologists Studies in Geology 13.

Greenbaum, D. 1981. Status of mineral exploration and mining in Fiji 1980. Mineral Resources Department, Suva, Report 27.

Grigg, R. and J. V. Eade. 1981. Precious corals. In Inshore and Nearshore Resources Training Workshop Report. UN ESCAP CCOP/SOPAC, p. 13-18.

Jackson, R. T., C. A. Emerson and R. Welsch. 1980. The impact of the Ok Tedi project. Department of Minerals and Energy, Port Moresby.

Katz, H. R. 1980. Basin development in the Solomon Islands and their petroleum potential. UN ESCAP CCOP/SOPAC Technical Bulletin 3:59-75.

Lee, A. I. N. [ed.]. 1980. Fertilizer mineral occurrences in the Asia-Pacific region. East-West Resource Systems Institute, Honolulu.

Macfarlane, A. and J. N. Carney. 1981. Economic minerals in Vanuatu, known and potential resources. Geological Survey of Vanuatu (unpublished manuscript).

Mattews, N. A. and S. F. Sibley. 1980. Nickel. In Mineral facts and problems, 1980 edition. United States Bureau of Mines Bulletin 671:611.

Paris, J. P. 1981a. Géologie de la Nouvelle Calédonie. Mémoire du Bureau de Recherches Géologiques et Minières 113.

Sheldon, R. P. and W. C. Burnett [eds.]. 1980. Fertilizer mineral potential in Asia and the Pacific. East-West Resource Systems Institute, Honolulu.

U Maung, Tun, K. Anscombe and S. L. Tongilava. 1981. Assessment of petroleum potential of the southern and northern parts of the Tonga Platform. UN ESCAP CCOP/SOPAC Technical Paper 18. 57 p. (unpublished).

SELECTED BIBLIOGRAPHY

Regional

Cox, M. E. 1980. Geothermal occurrences in the southwest Pacific. UN ESCAP CCOP/SOPAC Technical Bulletin 3:197-219.

Cronan, D. S. 1983. Metalliferous sediments in the CCOP/SOPAC region of the southwest Pacific, with particular reference to geochemical exploration for the deposits. UN ESCAP CCOP/SOPAC Technical Bulletin 4. 55p.

Exon, N. F. 1983. Manganese nodule deposits in the central Pacific Ocean, and their variation with latitude. Marine Mining 4:79-107.

Gabelman, J. W. 1982. Uranium on oceanic side of circum-Pacific Mobile Belt. (Abstr.) Bulletin American Association Petroleum Geologists 66:968.

Glasby, G. P. 1982. Manganese nodules from the south Pacific: an evaluation. Marine Mining 3:231-270.

Grigg, R. and J. V. Eade. 1981. Precious corals. In Inshore and Nearshore Resources Training Workshop Report. UN ESCAP CCOP/SOPAC. p. 13-18.

Johnson, C. J. 1981. Economics of South Pacific minerals development. East-West Resource Systems Institute, Honolulu (unpublished).

Mining Annual Review. 1981. The Mining Journal Limited, London.

Richmond, R. R. 1981. Geology, tectonics and mineral potential of the southwest Pacific. East-West Resource Systems Institute, Honolulu (unpublished manuscript).

Wyche, C. 1981. The mineral industry of other South Pacific islands. United States Bureau of Mines Minerals Yearbook 1981, 3. Area Reports-International, p. 1399-1413.

Papua New Guinea

Arnold, G. O. and T. J. Griffin. 1978. Intrusions and porphyry copper prospects of the Star Mountains, Papua New Guinea. Economic Geology 73:785-795.

Davies, H. L. 1978. Geology and mineral resources of Papua New Guinea. In Third Regional Conference on Geology and Mineral Resources of Southeast Asia, Asian Institute of Technology, Bangkok, Proceedings, p. 685-699.

Davies, H. L., W. J. S. Howell, R. S. H. Fardon, R. J. Carter, and E. D. Bumstead. 1978. History of the Ok Tedi porphyry copper prospect, Papua New Guinea. Economic Geology 73:796-809.

Doble, K. W. 1981. Regional geological mapping and mineral exploration activity in Papua New Guinea. Geological Survey of Papua New Guinea, Port Moresby (unpublished manuscript).

Exon, N. F. and D. L. Tiffin. 1983. Geology of offshore New Ireland basin in northern Papua New Guinea, and its petroleum prospects. American Association Petroleum Geologists Studies in Geology (in press).

Grainger, D. J. and R. L. Grainger. 1974. Explanatory notes on the 1:2,500,000 mineral deposits map of Papua New Guinea. Bureau of Mineral Resources, Australia, Bulletin 148.

Jackson, R. T., C. A. Emerson and R. Welsch. 1980. The impact of the Ok Tedi Project. Department of Minerals and Energy, Port Moresby.

Lowenstein, P. L. 1982. Economic geology of the Morobe goldfield. Geological Survey of Papua New Guinea Memoir 9.

Whalen, J. B., R. M. Britten and I. McDougall. 1982. Geochronology and geochemistry of the Frieda River prospect area, Papua New Guinea. Economic Geology 77:592-616.

GSPNG. 1983. Catalogue of data files. Geological Survey of Papua New Guinea, Port Moresby.

Solomon Islands

Arthurs, J. W. 1979. Mineral occurrences in the Solomon Islands. Solomon Islands Geological Survey Bulletin 13.

Coulson, F. I. 1981. The economic geology of the Solomon Islands. Solomon Islands Geological Survey (unpublished manuscript).

Hackman, B. D. 1980. The geology of Guadalcanal, Solomon Islands. Institute of Geological Sciences, London, Overseas Memoir 6.

Katz, H. R. 1980. Basin development in the Solomon Islands and their petroleum potential. UN ESCAP CCOP/SOPAC Technical Bulletin 3:59-75.

Landmesser, C. W. 1977. Evaluation of potential hydrocarbon occurrence in the Solomon Islands. South Pacific Marine Geological Notes, UN ESCAP CCOP/SOPAC, Suva. 1:47-54.

Taylor, G. R. 1974. Volcanogenic mineralization in the islands of the Florida group, B.S.I.P. Transactions Institution Mining Metallurgy, Section B Applied Earth Sciences 83(B):120-130.

Vanuatu

Carney, J. N. and A. Macfarlane. 1980a. Mineral resources of the New Hebrides. Report of the Regional Workshop on Mineral Assessment, Evaluation and Calculation, Commonwealth Geological Liaison Office, Proceedings 1:101-112.

Carney, J. N. and A. Macfarlane. 1980b. A sedimentary basin in the central New Hebrides arc. UN ESCAP CCOP/SOPAC Bulletin 3:109-120.

Exon, N. F. and D. S. Cronan. 1983. Hydrothermal iron deposits and associated sediments from submarine volcanoes off Vanuatu, southwest Pacific. Marine Geology, 52:M43-M52.

Macfarlane, A. and J. N. Carney. 1981. Economic minerals in Vanuatu, known and potential resources. Geological Survey of Vanuatu (unpublished manuscript).

Mallick, D. I. J. and G. Neef. 1974. Geology of Pentecost. Geological Survey of New Hebrides Condominium Regional Report.

Pontoise, B., G. V. Latham, J. Daniel, J. Dupont and A. B. Ibrahim. 1980. Seismic refraction studies in the New Hebrides and Tonga area. UN ESCAP CCOP/SOPAC Technical Bulletin 3:47-58.

New Caledonia

Briggs, R. M., H. W. Kobe and P. M. Black. 1977. High Pressure metamorphism of stratiform sulphide deposits from the Diahot region, New Caledonia. Mineralium Deposita 12:263-279.

Equipe de Géologie-Géophysique du Centre ORSTOM de Nouméa. 1982. Les péridotites de Nouvelle-Calédonie dans leur contexte régional: mise en place de la série ophiolitique et évolution des structures. In Contribution à l'étude géodynamique du Sud-Ouest Pacifique. Travaux et Documents de l'ORSTOM 147:479-564.

Guerange, B., J. Lozes and A. Autran. 1976. Mesozoic metamorphism in the New Caledonia central chain and its geodynamic implications in relation to the evolution of the Cretaceous Rangitata orogeny. In Contribution à l'étude géodynamique du Sud-Ouest Pacifique. Travaux et Documents de l'ORSTOM 147:265-277.

Guillon, J. H. 1973. Les massifs péridotiques de Nouvelle-Calédonie. Modèle d'un appareil ultrabasique stratiforme de chaine récente (thèse). Université de Paris VI.

Leblanc, M., D. Cassard, C. Dupuy, J. Moutte, A. Nicholas, A. Prinzhoffer and M. Rabinovitch. 1980. Essai sur la genèse des corps podiformes de chromitite dans les péridotites ophiolitiques: étude des chromites de Nouvelle-Calédonie et comparison avec celles de Méditerranée orientale. International Ophiolite Symposium, Nicosia, Cyprus, 1979. Communications, p. 691-701.

Paris, J. P. 1981a. Géologie de la Nouvelle-Calédonie. Mémoire du Bureau du Recherches Géologiques et Minières 113.

Paris, J. P. 1981b. Géologie, planche 9. In Atlas de la Nouvelle Calédonie. Office de la Recherche Scientifique et Technique Outre-Mer, Paris.

Paris, J. P. 1981c. Gîtes minéraux et substances utiles, planche 40. In Atlas de la Nouvelle Calédonie. Office de la Recherche Scientifique et Technique Outre-Mer, Paris.

Trescases, J. J. 1975. L'évolution supergene des roches ultrabasiques en zone tropicale. Formation des gisements nickelifères de Nouvelle-Calédonie. Mémoire ORSTOM 78.

Fiji

Emperor Mines Limited. 1981. Annual report for 1980-81. Sydney Stock Exchange Research and Statistical Bureau.

Forsythe, D. L. 1971. Vertical zoning of gold-silver tellurides in the Emperor Gold Mine, Fiji. Proceedings Australian Institute Mining and Metallurgy 240:25-31.

Greenbaum, D. 1981. Status of mineral exploration and mining in Fiji 1980. Mineral Resources Department, Suva, Report 27.

Greenbaum, D. and H. G. Plummer. 1981. Minerals development policy and resource classification: Fiji case study. Mineral Resources Department, Suva (unpublished manuscript).

Leggo, M. D. 1977. Contrasting geochemical expressions of copper mineralization at Namosi, Fiji. Journal of Geochemical Exploration 8:431-456.

Plummer, H. G. and R. Holmes. 1981. Fiji: summary of surveys, progress and results in offshore activities - October 1980 to October 1981. Mineral Resources Department, Suva, Report 30.

Siwatibau, S. 1977. Report of the committee appointed to examine the economics of the gold mining industry at Vatakoula. Government Printer, Suva.

Tonga

Pontoise, B., G. V. Latham, J. Daniel, J. Dupont and A. B. Ibrahim. 1980. Seismic refraction studies in the New Hebrides and Tonga area. UN ESCAP CCOP/SOPAC Technical Bulletin 3:47-58.

U Maung, Tun, Karen Anscombe and S. L. Tongilava. 1981. Assessment of petroleum potential of the southern and northern parts of the Tonga Platform. UN ESCAP CCOP/SOPAC Technical Paper 18, 57 p. (unpublished).

U Muang, Tun, Karen Anscombe and S. L. Tongilava. 1982. Petroleum potential of southern part of Tonga Platform (abstr.). Bulletin American Association Petroleum Geologists 66:986.

ENERGY POTENTIALS OF PACIFIC ISLAND NATIONS

C. R. Lloyd* and S. Siwatibau**
University of the South Pacific, Suva, Fiji*
and
Ministry of Energy, Suva, Fiji**

ABSTRACT

This paper gives an overview of the various energy sources that could be used by Pacific Island nations in the future. Emphasis is of course on indigenous sources that could provide some relief from oil import expenses. Particular attention is paid to the need for gathering data on the use of energy in particular sectors, with a view to developing sources for actual needs rather than just developing energy sources. Some information is given in this respect from work done in Fiji by the authors. This relates to surveys of energy use in the rural area, particularly firewood for cooking, and in the urban area where a range of energy sources are used, e. g. firewood, kerosene, gas and electricity. The programmes in the energy field developed by aid agencies are also discussed.

Introduction

This paper gives an overall view of the energy scene in Pacific Island nations. No detailed attempt will be made to discuss the benefits or disadvantages of particular energy alternatives from a technical viewpoint.

The importance of energy potentials to Pacific Island nations has grown at approximately the same rate as the increase in mineral oil prices. After the 1973-74 oil shocks the vulnerability of the countries to reliance on imported petroleum has led to increasing research on the possibility of using alternative sources. This has culminated in the Pacific Energy Programme (P.E.P.). This programme originated from discussions in 1979 and is an attempt by aid agencies to get together and present a co-ordinated plan for the development of energy strategies in the region. For this discussion the region will consist of those countries covered by the Pacific Energy Programme, corresponding to the newly independent island nations of:

Western Samoa	(independent in 1962)
Cook Islands	(" " 1965)
Tonga	(" " 1970)
Fiji	(" " 1970)
Niue	(" " 1974)
Papua New Guinea	(" " 1975)
Solomon Islands	(" " 1978)
Tuvalu	(" " 1978)
Kiribati	(" " 1979)
Vanuatu	(" " 1980)

The Cook Islands and Niue are self governing with ties to New Zealand. All except Papua New Guinea are member countries of the University of the South Pacific.

Before an analysis could be made of energy strategies a data base had to be accumulated to define the present situation. We are fortunate now to have at least a basic picture of the energy scene in each of the programme countries. During early 1982 a team of between one and six persons visited each of the countries to gather data with the object of assessing the best alternatives for aid dispersion. The European Economic Community (E.E.C.), as part of the Lome II Convention, has allocated about US$6 million and the United Nations US$2 million to be used to develop energy potentials in the countries. The data gathering team and the funds are being co-ordinated by the South Pacific Bureau for Economic Co-operation (SPEC) which is based in Suva, Fiji. The first author (Lloyd) was involved in the initial stages of the data gathering doing a pre-survey of the Solomon Islands and Vanuatu. Mrs Siwatibau, the co-author, visited most of the countries as part of the main team which was led by Ken Newcombe. In addition, the East-West Center in Hawaii has been collecting energy data as part of a separate programme and so has the Asian Development Bank and the World Bank. This led to some duplication of effort in data collection; shortly after the first author visited the Solomon Islands, the SPEC team of four persons visited along with two from the E.E.C., and at the same time there was a team from the Asian Development Bank, all after the same information from a country which has no government energy specialist. Other agencies interested or involved in energy matters are the South Pacific Commission (based in Noumea), CRREIS (Australia), ESCAP, I.L.O., UNDAT, UNDP, and of course USP and the regional governments.

The impetus for all this activity comes from two main sources. First the region is fossil fuel poor and is extremely reliant upon imported petroleum products. Secondly the region is small in population and reasonably poor but surrounded by rich countries which have strategic and political motives for organizing aid.

As far as energy data goes, the overall situation is fairly well defined for all the ten countries. There are some gaps, however, in particular areas, e.g. the hydroelectric potential of the Solomon Islands. Some of these gaps will be filled in by the monitoring sections of the Pacific Energy Programme, e.g. solar and wind measurement programmes. Detailed information on sectorial energy use patterns, however, is only available or becoming available for two countries, Fiji and Papua New Guinea. This sectorial information (How much and what kind of energy is needed in the domestic sector for cooking, refrigeration, ironing, etc.? What is needed for industry and commerce?) is vital before deciding on development priorities. The authors' work in this area will be mentioned later.

The problems faced by the countries to secure some relief from reliance on imported oil products vary considerably with differences in size, population and economic condition. Table 1 shows, for example, that Tuvalu has an area of only 26 km^2 whereas Papua New Guinea covers some 460,000 km^2. Population likewise varies from a mere 3,400 in Niue to 3 million in Papua New Guinea. Similarly Table 2 shows that economic status varies. Tuvalu, for example, whose major money earner is stamps, has a G.D.P. of about US$3 million, while Papua New Guinea has a G.D.P. of over US$2,000 million.

Table 1 : Basic Statistics

	Area km^2	Population 1000s	Population Growth Rate	Population Density P/km^2
Tuvalu	26	7.5	0.9%	288
Cook Islands	235	17.5	-0.9%	74
Niue	260	3.4	-3.2%	13
Tonga	670	98	2.1%	146
Kiribati	690	58.6	2.0%	85
Western Samoa	2,934	158	0.8%	54
Vanuatu	12,200	123	4.2%	10
Fiji	18,272	670	1.9%	37
Solomon Islands	27,560	240	3.1%	8
Papua New Guinea	462,240	3000	2.1%	6.5

Table 2 : Economics (1979-80)

Country	C.O.P./capita US$	Growth	Imports US$ millions	Exports US$ millions
Tuvalu	500	19%	3.6	1.4*
Cook Islands	1,100	18%	22.8	4.1
Niue	900	13%	0.3	3.2
Tonga	450	10%	33.7	7.6
Kiribati	400	7%	19	2.7
Western Samoa	400	5%	63	17
Vanuatu	700	10%	71	35
Solomon Islands	600	14%	67.3	66.6
Fiji	1,600	24%	552	368
Papua New Guinea	750	12%	1009	1020

* including stamps

Energy consumption

Energy consumption is similarly variable, with a range from about 100 TJ/yr in Tuvalu and Niue to 40,000 TJ/yr in Papua New Guinea (Table 3). Figures for Australia are shown for comparison. The per capita consumption for the programme countries is roughly 10 times less than Australian per capita consumption.

Table 3 : Energy Consumption (1981)

Country	Renewable TJ	Non-renewable TJ	Total TJ	Total Per Capita GJ/C
Australia (1978-79)	2,784,000	125,000	2,909,000	200
Tuvalu	43	54	97	13
Niue	76	20	96	28
Cook Islands	302	135	437	25
Kiribati	409	425	834	14
Tonga	469	1,056	1,525	16
Western Samoa	1,140	1,743	2,883	18
Vanuatu	758	2,682	3,440	28
Solomon Islands	1,849	3,655	5,504	23
Fiji	11,665	13,639	25,300	38
Papua New Guinea	22,141	18,600	49,741	14
Total for region (%)	48%	52%	100%	

Also for the total region (excluding Australia), renewable energy accounts for a little over one half of the total used. In all cases except Fiji this is due to the high firewood consumption for domestic cooking, in Fiji bagasse is used in large quantities by the sugar industry as well as firewood for cooking.

The non renewable energy which dominates the commercial and industrial sectors is nearly exclusively imported petroleum products.

There are two broad demand sectors in the internal energy requirements of each island nation: the domestic sector and the industrial/commercial sector. There is a third sector, the bunkering sector, which caters for international aircraft and shipping refuelling (perhaps even parts of the tourist industry could be placed in this sector). Bunkering can totally distort the national energy picture and so is best excluded from an internal analysis.

National energy planning tends to concentrate on the industrial/commercial sector as it is this sector which is often seen by the national governments to best serve economic development objectives. In the Pacific Island nations these objectives have tended to follow those of developed countries, e.g. large hydroelectric schemes or fossil fuelled electricity generation, the high technology end. Many aid agencies on the other hand have tended since the early 1970's more towards appropriate indigenous alternatives, e.g. biogas and solar energy, the low technology end. A national energy policy should examine both high and low technology options.

Potential energy is only useful if taken in relation to a countries economic, social and technical infrastructure. Thus the large hydroelectric power potential in Papua New Guinea is only useful to the country if social and political decisions are made to secure its consumption. Solar energy is only useful if people have a need for it. For planning purposes then it is essential to examine these factors and the present and possible future consumption patterns before deciding on which potential energy sources should be given priority. This is not to exclude the possibility of new energy sources generating new consumption patterns.

Domestic sector

In the domestic sector, consumption surveys have been made in Papua New Guinea both in Lae and Port Moresby (Newcombe et al., 1982). In Fiji the work of Mrs Siwatibau on rural energy use has provided much needed data on fuelwood consumption, showing that in rural villages the average wood consumption for domestic cooking amounts to approximately 350 kg (oven dried) per capita per year (Siwatibau, 1978). To complement this work Lloyd and others have completed an extensive survey of energy use in the Nadi-Lautoka area of Fiji (Lloyd, n.d.), and Siwatibau and others are in the process of doing a similar survey for the Suva urban area (Siwatibau, personal communication). The Nadi-Lautoka survey compiled results of questionnaires from nearly 1,000 households of which 43% were classed as urban, 34% peri-urban and 23% as rural. For fuelwood consumption the Nadi-Lautoka results agreed well with the earlier work of Siwatibau finding the consumption to be a little over 300 kg/capita/yr in the rural areas ranging to 120 kg/capita/yr in peri-urban and 50 kg/capita/yr in urban areas. In Lae, Papua New Guinea, the average consumption was around 250 kg/capita/yr (Newcombe, 1982), though there are indications that in wood-rich areas such as the Solomon Islands, 500 kg/capita/yr would be used for domestic cooking. The amount used is vital for planning because it determines the life of present fuelwood supplies and the extent of possible fuelwood plantations.

Also from the Nadi-Lautoka survey, which spanned largely urban and peri-urban areas, we found that the most used source of energy was petrol or motor spirit, which contributed 41% to the total use, followed by wood 22%, kerosene 18%, electricity 8%, LPG 6% and diesel 5%. In terms of end use, cooking and transport each used 43% of the total energy, with lighting using 7%, refrigeration 5% and all other uses 2%. In the rural non-electrified areas, the amount of firewood used was much higher, around 60% of the total, with kerosene for cooking and lighting and motor spirit for lighting making up the bulk of the remainder. The large proportion of energy used for transport nationally (in Fiji transport consumes 54% of the total commercial energy) makes energy substitution difficult.

In terms of potential sources for transport, the most reasonable alternatives come from biomass (unless petroleum is discovered locally). The most tested alternative is alcohol substitution where the alcohol can come from sugar cane, cassava or possibly breadfruit.

Production of such fuel crops is certainly a possibility in most of the countries of the region, but there are considerable economic and some technical problems to be overcome; in Fiji it is at present more profitable to sell the sugar. The other possible source of liquid fuel is coconut oil. Most of the island countries have extensive coconut plantations which, if the economics are right, could be diverted to manufacturing coconut oil for use in diesel engines rather than producing copra. The use of coconut oil in diesels has been tested in the Philippines, Australia, Samoa and at the University of the South Pacific (USP) in Fiji. USP has also studied the ester of coconut oil and alcohol. Further research in this area is necessary and is being sponsored by the Pacific Energy Programme. The present stabilization of oil prices should give some time, perhaps until 1990, to consolidate findings and to choose the best liquid fuel alternative. For the next decade, however, the region will continue to rely on imported petroleum both for transport and for electricity generation.

Realizing this, one of the strongest recommendations of the 1982 Pacific Energy Programme report (Newcombe, 1982) was that countries should improve their knowledge of the oil industry, and in particular the basis on which oil companies negotiates supply and pricing arrangements. It was found, for instance, that in at least five countries (Fiji, Samoa, Tonga, Cook Islands and Kiribati) oil was being priced on the basis of its delivery from Singapore whereas in fact it came from Australia, resulting in a considerable surcharge on freight costs. With other practices, this meant that Pacific Island countries were paying much more than warranted for petroleum imports, and that the best short term savings in the energy sector could be had be re-negotiating such contracts.

In the domestic sector the other major user of energy is cooking, with the main fuels being wood and kerosene. All countries, with the possible exception of Kiribati, have reasonable quantities of firewood for domestic purposes, although replanting with suitable fuelwood species would be advisable to secure future supplies. Cooking in all countries is mostly done over an open fire, even in the Nadi-Lautoka region of Fiji, where we found that, of 773 wood users, 51% cooked over an open fire. Such cooking is very inefficient and a great waste of fuelwood. With this in mind the E.E.C. is sponsoring the design and production of fuel efficient slow combustion stoves and charcoal stoves. For lighting the present sources are electricity (where connected to a grid or village generator), or kerosene and benzine. Electricity will be considered separately later.

Both kerosene and benzine (unleaded motor spirit) pressure lamps are used, although the preference is for the benzine lamp as it is easier to start and requires less maintenance. Kerosene standing lamps are also common, often being lit throughout the night. One potential replacement considered by the Pacific Energy Programme is the photovoltaic system. While it can be shown that such a system can be economically advantageous if evaluated over a 10 year period, it suffers from the disadvantage of initial high capital cost and decreased flexibility. For instance, with the kerosene or benzine lamp, a family that cannot afford the fuel for a short period simply does without the light, whereas the photovoltaic represents a permanent financial commitment.

For refrigeration, electricity is the main source, although kerosene refrigerators are also used. Potential replacements are many as almost any liquid fuel, e.g., alcohol, coconut oil, solid fuel wood or charcoal, could be used in a suitably modified kerosene refrigerator. In the Nadi-Lautoka survey we found that, of all appliances owned, the refrigerator was by far the most popular indicating a (perhaps obvious) need for food cooling. For households connected to grid, about 64% of the electricity budget was used for refrigeration in the survey sample.

Also from the Nadi-Lautoka survey, we found that, except for ironing, other uses of energy such as water heating only became significant in the most affluent households. Since Fiji is the most affluent of the programme countries per capita, this can safely be assumed for the rest.

Commercial-industrial sector

Surveys on energy use in this sector have been completed, but not yet fully analysed, by Lloyd and others at USP again for the Nadi-Lautoka area in Fiji, and by Siwatibau for the Suva area. This sector relies most heavily on imported petroleum products for transport, boilers, and electricity generation. Transport has already been discussed. In Fiji most industrial concerns use oil-fired boilers; the major exception is of course the sugar industry, which uses bagasse. Newcombe (1982) noted that this is general in most Pacific Island countries, even when considerable wood or wood waste products were available. The Fiji Sugar Company burns off large amounts of bagasse that are surplus to its requirements. The timber milling industries in many of the countries produce wood waste which could profitably substitute for imported petroleum. Already there is some move to such substitution. In Papua New Guinea, 32 hot air generators fired by wood or coconut residues had been installed by early 1982, as well as one in the cocoa drying factory in Samoa. In most of the Programme countries the potential for further substitution is great for small industries such as bakeries, laundries and soft drink factories and for larger industries such as copra drying.

In addition to using petroleum fuels directly, industry and commerce are the main users of electrical energy. In Fiji, with 36% of the domestic sector households electrified, 80% of electrical energy generated is used in the industrial/commercial sector (Table 4). By industrialized country standards, the peak demands are very small, with only Fiji and Papua New Guinea needing more than 10 MW peak in 1981. The small demand has meant that until recently almost all electricity generated has been from oil-fired diesel resulting in high generation costs. Though the charges for electricity in the region are also quite high, the 1982 P.E.P. report noted that only two governments recovered costs (Newcombe, 1982). Such a subsidy to electricity consumers obviously does not encourage the implementation of energy saving measures, or allow for economic substitution of alternative energy sources. As in the rest of the world the opportunities for energy savings by efficient use of electrical energy are great. Lloyd (1983) reported that the electrical energy consumption of the School of Natural Resources building at USP could be halved by better use of air conditioning, lighting and hot water heating.

Table 4 : Electricity (1981)

	% Households Electrified (estimates)	Peak Demand M.W.	Tariff US$/kwh
Tuvalu	N.A.	0.13	.30-.38
Cook Islands	75%	1.9	.18-.31
Niue	75%	0.6	.21
Kiribati	15%	0.9	.28
Tonga	40%	2.1	.19-.22
Vanuatu	10%	3.2	.12-.40
Western Samoa	28%	5.9	.24
Solomons	10%	3.4	.19-.28
Papua New Guinea	5%	79.1	.17-.39
Fiji	36%	62.0	.18

Hydroelectricity is the other main source of electricity production at present (Table 5). As can be seen perhaps five of the programme countries have potential for hydroelectric generation, with Papua New Guinea by for the largest. Fiji has just completed the first stage of its hydroelectric scheme at Monosavu.

Table 5 : Hydroelectric potential

	Installed	Potential
Tuvalu	0	0
Cook Islands	0	0
Niue	0	0
Kiribati	0	0
Tonga	0	N.A.
Vanuatu	0	4.5 MW
Western Samoa	0.8-3.5 MW	N.A.
Solomon Islands	0.07 MW	N.A. (730 MW)
Fiji	40 MW	280 MW
Papua New Guinea	10 MW	21,000 MW

Other potential sources are biomass for small steam plants, wood gasification, coconut oil fueled diesels and to a limited extent wind. More exotic alternatives such as ocean thermal energy conversion (O.T.E.C.) or wave systems need further evaluation in developed countries before deployment in the Pacific Islands.

In summary, to realize the full energy potential of the region, it will be necessary to deal with both the oil companies and the open fire.

REFERENCES

Lloyd, C. R. 1983. Electrical energy consumption by SNR building at USP. Internal Report.

Lloyd, C. R., (et al.). n.d. Nandi-Lautoka survey. Internal Report.

Newcombe, K. 1982. Pacific Energy Programme. Internal Report.

Newcombe, K., (et al.). 1982. An analysis of some energy issues in Papua New Guinea 1982. Pacific Energy Programme, Internal Report.

Siwatibau, Suliana. 1978. A survey of domestic rural energy use and potential in Fiji. Centre for Applied Studies in Development, University of the South Pacific, Suva, Fiji. 299 p.

RADIOACTIVITY IN THE SOUTH PACIFIC REGION

M. P. Bacon
Woods Hole Oceanographic Institution
Woods Hole, MA 02543, U. S. A.

G. Lambert
Centre des Faibles Radioactivités
CNRS, B. P. 1, 91190 Gif-sur-Yvette, France

T. A. Rafter
16 Simla Crescent, Khandallah, Wellington, New Zealand

J. I. Samisoni
Fiji School of Medicine
Suva, Fiji

D. J. Stevens
10 Lyric Grove, Camberwell, Victoria 3124, Australia

ABSTRACT

This paper summarizes the main conclusions of the Report of the South Pacific Regional Environment Programme Technical Group on Radioactivity in the South Pacific Region, of which the authors are members. It reviews ionizing radiations and their possible harmful effects, and evaluates exposures to ionizing radiation in the South Pacific region. It then discusses present and proposed activities involving radioactive materials in the region, particularly ocean dumping of radioactive materials and nuclear weapons tests.

Introduction

In November 1982 the Technical Group on Radioactivity in the South Pacific Region was formed and assigned the task of reviewing radioactivity and its regional impact. The project was motivated largely by the concern expressed in the region over existing and proposed activities that might release radioactive materials to the environment. Of particular concern are the nuclear explosions presently being conducted in Polynesia and proposals to use the Pacific Ocean in strategies for radioactive waste management. Formation of the technical group took place following the Conference on the Human Environment in the South Pacific (Rarotonga, Cook Islands, 8-11 March 1982), where concern was expressed over these issues. The subject of radioactivity was given high priority in the Action Plan for the South Pacific Regional Environment Program (SPREP, 1982). The purpose of this paper is to summarize the work of the Technical Group and the main conclusions of the Technical group Report (SPREP, 1983).

The Technical Group held its first meeting at the headquarters of the South Pacific Commission in Noumea, New Caledonia, 17-21 January 1983. At that time an interim report was prepared in the form of a working outline, which was distributed to governments in February for comment. A second and final meeting was held at Noumea, 4-9 July 1983, with the support of the SPREP secretariat. A draft report was completed at that time and was distributed for comment to the SPREP Co-ordinating group and to outside reviewers in the scientific community. The final report (SPREP, 1983) was completed in December.

The report of the Technical Group on Radioactivity in the South Pacific Region has three overall objectives. The first is to provide the general reader with an introduction to some of the concepts and terms used in nuclear science, especially the properties and effects of ionizing radiations, which are basic to an understanding of the scientific issues. The second objective of the Report is to give an overview of the radiation environment in which Pacific people live. Present levels of exposure to natural and artificial sources of ionizing radiation must be known if the impact of possible future releases of radionuclides to the environment is to be properly assessed. The third objective is to provide an evaluation, from the scientific point of view, of some of the issues that are presently of greatest concern in the Region.

Ionizing radiations and their possible harmful effects

In considering the scope of its work the Technical Group decided that for completeness and for achieving a proper perspective it should expand its coverage slightly to include all sources of ionizing radiation to which people are commonly exposed. Thus, in addition to discussing natural and artificial radionuclides, the Report also discusses exposures to cosmic rays and machines that give off X-rays.

Two of the most important basic terms defined in the report are the **absorbed dose**, measured in gray (replacing the older unit rad; 1 gray = 100 rad), and the **dose equivalent**, measured in sievert (replacing the rem; 1 sievert = 100 rem). The absorbed dose is the amount of energy that is absorbed in a substance (for example, a living tissue) as radiation passes through it. The dose equivalent is equal to the absorbed dose multiplied by a factor that takes into account the different properties of the different types of ionizing radiation (alpha, beta, gamma or X radiations).

The concept of the dose equivalent is especially important and is used very extensively throughout the Report. Use of the dose equivalent provides a basis for comparing exposures of people to different sources of ionizing radiation, for comparing exposures received by different groups of people in different geographical areas, and for assessing objectively the impact of radionuclide releases to the environment. It is extremely important to recognize that it is the dose equivalent that is the important consideration in assessing the effects of ionizing radiation, not the origin of the radiation. The potential harm to living things from ionizing radiation depends only on the type of radiation (that is, whether it is alpha, beta, gamma, or X radiation) and its energy. It makes no difference whether the ionizing radiation derives from a natural or artificial source.

The Report provides a general review of what is known about the harmful effects of ionizing radiation on living things and explains the role of various international bodies in the field of radiation protection, most notably the International Commission on Radiological Protection (ICRP). The Technical Group noted the expanding use of X rays for medical diagnosis in the Region, and saw a need for countries in the Region to consider the enactment of radiation control legislation. Similar legislation has been adopted by developed countries and some developing countries so as to establish proper standards of radiation protection for workers and members of the public and acceptable levels of radiation and radiation dose for persons and the environment. In the preparation of such legislation, consideration might be given to setting an upper limit for the contribution which any one source of ionizing radiation might be permitted to make to persons as members of the public. Dose limits adopted in such legislation would provide a basis against which radiation doses to persons in the Region could be monitored and possible harmful effects of the doses assessed. The detailed requirements of such legislation could appropriately be based on the recommendations of the International Commission on Radiological Protection, on codes of practise of other competent international authorities, such as the World Health Organization and the International Atomic Energy Agency, and on the experience gained in this field by other countries.

In discussing the known harmful effects produced in living things by exposure to ionizing radiation, an important distinction is made between what are called **stochastic** and **non-stochastic** effects. For some effects, it has been shown that their severity depends on the size of radiation dose received and that for these effects a minimum threshold dose is required for their occurrence. These are called non-stochastic effects. For other effects, particularly many late effects, the probability that the effects will occur, rather than their severity, depends on the size of the radiation dose. These are called stochastic effects. For these effects it has not been possible to show whether or not a threshold dose exists. However, so as not to underestimate the probability that such effects will occur, current radiation protection practise assumes that no threshold dose exists. The Technical Group adopted this assumption in its Report.

Exposures to ionizing radiation in the South Pacific region

Ionizing radiations originate both in sources that occur naturally and in sources created by human technology. Natural sources of ionizing radiation have been present in the environment since the beginning of the earth's history. They include cosmic rays that come from outer space and natural radionuclides that occur on earth. Barring a nuclear war or major reactor accidents, natural sources are likely always to be the main environmental contributor to human radiation exposure. Artificial sources of ionizing radiation in the environment are due almost exclusively to atmospheric nuclear explosions and nuclear electric power production, the former being by far the most important.

The Technical Group spent a considerable amount of its effort reviewing the information available on human exposure to sources of ionizing radiation in the environment. Much of that information is compiled in the most recent report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1982), which derived global averages for exposure to natural and artificial ionizing radiation. In addition the Group reviewed data relating specifically to the exposures of people living in the South Pacific Region with the aim of determining how the average exposures to ionizing radiation in the Region compare with the global averages.

In the case of natural radiation, the world population as a whole receives an average annual effective dose equivalent* of 2000 microsievert (UNSCEAR, 1982). This is an average figure, and there is a large variation from place to place on earth, depending on a number of environmental factors, and from person to person, depending on living habits. The exposure is received in a variety of ways: by external exposure to cosmic rays and the radiations emitted by radioactive elements (potassium, thorium and uranium) in soils, by the consumption of food containing natural radionuclides, and by the inhalation of radon-222 and other radionuclides that are naturally present in the air. For the South Pacific Region the Technical Group concluded that, on the average, the annual effective dose equivalent from natural sources of ionizing radiation is approximately 1000 microsievert, only half the world average. The lower-than-average exposures in the Region are the result of several factors: (1) the low concentrations of radioactive elements in the coralline soils that occur in much of the region, (2) the lower concentrations of radon-222 in the air over the ocean compared with concentrations over the continents, and (3) the fact that most people in the region live in well-ventilated houses and spend much of their time outdoors, thus avoiding exposure to the elevated levels of radon that often occur in indoor air.

The Technical Group also concluded that exposure to artificial radionuclides, mainly the radionuclides formed during past nuclear weapons tests in the atmosphere, is on the average lower, perhaps two or three times lower, in the South Pacific region than it is for the world as a whole. This is because most of the population in the Region lives in the Southern Hemisphere, whereas the greater part of the fallout from atmospheric testing was delivered in the Northern Hemisphere. In general, the contribution to total radiation exposure due to artificial radionuclides is small and is much less than the variability that exists in exposure to natural sources of radiation.

Although average doses from both natural and artificial ionizing radiation in the Region are substantially lower than in most other parts of the world, there are certain islands in the Region where populations receive unusually high radiation exposures. Niue Island in the South Pacific is a documented example of an area of unusually high natural radioactivity (Fieldes et al., 1970; Marsden, 1974), and there are data suggesting that part of Guam might also be such an area (Nelson, 1979). Unusually high levels of artificial radioactivity are found at some atolls in the Marshall Islands that were contaminated by local fallout from the United States weapons tests (Robison et al., 1982).

---

*The effective dose equivalent expresses non-uniform doses as a uniform whole-body dose which would produce the same harmful effects. The factors used in calculating the effective dose equivalent were assigned by the ICRP (1977).

Exposures to ionizing radiation also arise from the use of radiation in medicine and other activities. In most developed countries the radiation doses to populations from the medical diagnostic uses of ionizing radiation are the largest of all the doses from artificial sources. It is reasonable to assume that there will be an increase, and more diversity, in the use of sources of ionizing radiation for medical purposes in the South Pacific Region as health services develop further. In many countries in the Region the special facilities necessary for these purposes are becoming more readily available in the major population centers, and it is to be expected that, with time, the facilities will be provided in less densely populated areas. As these developments occur, it will be important for the countries of the region to ensure that the resulting radiation doses to their populations are minimized. The Technical Group concluded that there would be value in the development of a regional program through which special technical services to oversee standards with respect to the medical uses of ionizing radiation would be available. The medical uses of ionizing radiation are the area in which countries have the greatest possibility of control over the radiation doses received by their populations.

Present and proposed activities involving radioactive materials in the South Pacific region

After a brief review of radioactivity in the Pacific Ocean, and of the behavior of radionuclides in the marine environment, the Technical Group Report proceeds to a discussion of activities presently conducted in the Region, or proposed for the future, that might result in the release of radionuclides to the environment. The activities that are presently of greatest concern and most likely to influence the setting of environmental policy in the near future are the underground nuclear explosions presently being conducted in the Tuamotu Islands by France, as part of its weapons development program, and the proposed use of the Pacific Ocean for the disposal of radioactive wastes.

Regarding the question of radioactive waste disposal, the Report includes an extended discussion of the ocean dumping of packaged low-level waste, because there has already been considerable development of a scientific basis for setting limits on such disposal and because there exist well-developed international mechanisms for control and surveillance. Furthermore, a specific proposal has been issued by Japan to initiate in the near future a program of low-level waste disposal at a site in the western North Pacific, and this proposal has been the focus of considerable debate in the Region over the general issue of ocean dumping.

Discussion of the scientific issues related to ocean dumping begins with the fact that appreciable amounts of radionuclides are continually delivered to the oceans by natural processes. The question that is open to scientific debate is a quantitative one and the scientific task is to provide a quantitative answer: What additional amounts of radionuclides, if any, can be added to the ocean without a risk to the environment or to human health that exceeds the standards set by society? The answer is based on the results of scientific research, which is a continuing process, so the answer is always (as it should be) subject to revision as improved scientific knowledge warrants. Because of this, a conservative but flexible approach should be taken.

The International Atomic Energy Agency (IAEA, 1978a,b,c) provided a general assessment of the problem of ocean dumping. Its task was to set limits on the release rates of radionuclides on the seafloor so that a definition of high-level waste (not suitable for dumping) could be formulated as required by the London Dumping Convention. In its assessment the IAEA used quantitative predictions of the dose equivalent to people as a measure of the impact of dumping. The IAEA scientists recognized that present scientific knowledge does not allow exact predictions of seawater concentrations resulting from radionuclide releases to be made. They also recognized the possibility that some radioactivity could be transferred from the seafloor to human populations by completely unforeseen pathways. Because of these uncertainties, they adopted a conservative approach based on pessimistic assumptions about what might happen in extreme circumstances, not on realistic assumptions about what would most likely happen under ordinary circumstances. Thus the doses predicted by their calculations are, by intention, most probably overestimated. For this reason the resulting release-rate limits contain built-in safety factors. The Technical Group concluded that a very high level of conservatism was adopted in the IAEA assessment and that the release-rate limits set by IAEA are restrictive enough that dumping carried out within the IAEA guidelines should pose extremely little risk to human health or environmental safety.

The Japanese proposal for dumping low-level waste in the North Pacific is also discussed extensively in the Report. The proposed full-scale operation would involve dumping at a rate no greater than one per cent of the release-rate limit set by the IAEA, and, on the basis of the IAEA work and the confirmatory calculations made by Japanese scientists, the Technical Group concluded that the proposed Japan dumping operation would pose extremely little risk to human or environment health and well-being. This evaluation was made on the basis of a draft Japanese assessment of the proposal (STA/NSB, undated draft). It is understood that a final report on the proposal is in preparation. That report will require careful public review to ensure that the proposal complies with all the principles of the London Dumping Convention and with its associated requirements.

It does not necessarily follow from the above conclusion regarding the safety of the particular Japan dumping proposal that dumping of radioactive waste in the ocean should be advocated generally as a procedure to be preferred over land-based options. This cannot be clearly decided on the basis of present scientific knowledge alone. Continued evaluation of all the alternatives is required. The problem of the management of wastes, both radioactive and non-radioactive, will always exist, and scientific understanding of the environment will always continue to be revised. The Technical Group felt it is important that policies and practises remain flexible enough to respond to changed circumstances and improved scientific knowledge. At any moment in time, policy decisions should be based on the best scientific information then available, but there will always be need in the end for the exercise of good judgement and common sense.

Regarding the program of underground nuclear weapons testing by France, the technical group noted the difficulty of giving an informed evaluation because of the high level of secrecy that surrounds the activity. This is in sharp contrast to civilian activities, such as radioactive waste disposal, which are subject to international surveillance, scientific review, and public scrutiny.

The present procedure of testing underground avoids the previous pollution of the atmosphere by radioactive debris and is considered safer, with regard to human health, than was the former procedure of testing above ground. Crude approximations of the amounts of radionuclides that might be accumulating underground at the test site indicated that they are unlikely to be large enough to be cause for alarm, but neither could they be considered altogether negligible. One should be particularly concerned for the possible long-term effects, such as leakage of radionuclides into the ocean, especially if the testing program and the accumulations of radionuclides underground are to continue into the future. The Technical Group concluded that past environmental safety assessments and publications of results have been inadequate, and it urged prompt publication of results and distribution to concerned governments in the Region.

Overall the Technical Group concluded that the present nuclear weapons testing and the proposed low-level waste disposal involve only a small, quite possibly a non-existent risk to human health and the environment in the South Pacific Region. The group found little scientific basis for judging these activities to be unacceptable. However, this conclusion does not in any way deny that important legal, political, and moral principles might very well be involved in, and dominate the evaluation of them. Through its Report the Technical Group attempted to provide factual scientific information and interpretation that, it is hoped, will contribute to informed debate on these important issues.

ACKNOWLEDGEMENT

It is a pleasure to acknowledge the hospitality of the South Pacific Commission. Special thanks to Dr. Jeremy Carew-Reid, SPREP Co-ordinator, for his encouragement and support for this project.

REFERENCES

Fieldes, M., G. Bealing, G. G. Claridge, N. Wells and N. H. Taylor. 1960. Mineralogy and radioactivity of Niue Island soils. New Zealand J. Sci. 3:658-675.

International Atomic Energy Agency (IAEA). 1978a. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter: the definition required by Annex I, Paragraph 6 to the Convention, and the recommendations required by Annex II, Section D. IAEA Information Circular INFCIRC/205/Add. 1/Rev. 1, Vienna.

International Atomic Energy Agency (IAEA). 1978b. The oceanographic basis of the IAEA revised definition and recommendations concerning high-level radioactive waste unsuitable for dumping at sea. IAEA Technical Document IAEA-210, Vienna.

International Atomic Energy Agency (IAEA). 1978c. The radiological basis of the IAEA revised definition and recommendation concerning high-level radioactive waste unsuitable for dumping at sea. IAEA Technical Document IAEA-211, Vienna.

International Commission on Radiological Protection (ICRP). 1977. Recommendations of the International Commission on Radiological Protection. Annals of the ICRP, ICRP-26, Pergamon Press.

Marsden, E. 1974. Radioactivity of some rocks, soils, plants, and bones, p. 807-824. In J. A. S. Adams and W. M. Lowder [eds.], The natural radiation environment. Univ. of Chicago Press, Chicago.

Nelson, V. A. 1979. Radiological survey of plants, animals, and soil in Micronesia. Report NVO-269-35. Laboratory of Radiation Ecology, University of Washington, Seattle.

Robison, W. L., M. E. Mount, W. A. Phillips, C. A. Conrado, M. L. Stuart and C. E. Stoker. 1982. The Northern Marshall Islands radiological survey: terrestrial food chain and total doses. Lawrence Livermore National Laboratory (USA), Report UCRL-52853 Pt. 4.

Science and Technology Agency/Nuclear Safety Bureau (STA/NSB). Undated draft. Environmental safety assessment on sea disposal of low-level radioactive wastes in the Northwest Pacific.

South Pacific Regional Environment Programme (SPREP). 1982. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia.

South Pacific Regional Environment Programme (SPREP). 1983. Radioactivity in the South Pacific. Topic Review No. 14. South Pacific Commission, Noumea, New Caledonia.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1982. Ionizing radiation: sources and biological effects. Report to the General Assembly, with Annexes.

LEGAL MEASURES FOR IMPLEMENTATION OF ENVIRONMENTAL POLICIES IN THE PACIFIC REGION

Mere Pulea
Mere Pulea & Associates
Fiji

ABSTRACT

In response to a decade of increasing concern for environmental protection and conservation in the Pacific, the governments of the region adopted regional environmental policies at the 1982 Conference on the Human Environment in Rarotonga. Steps are now being taken to prepare regional legal measures to implement these policies, including a Convention on the Protection and Development of the Natural Resources and Environment of the South Pacific Region, and associated protocols.

Background

Under the 1947 Canberra Agreement which sets out the legal framework for the South Pacific Commission (SPC), the SPC has a broad mandate to carry out regional action plans for various economic and social policies, "in matters affecting the economic and social development of the territories within the scope of the commission and the welfare and advancement of their peoples" (SPC, 1980). Under this broad umbrella, concern for environmental protection and conservation of the natural resources of the Pacific has been voiced over a period of more than a decade. Although Pacific traditional culture, through taboos, sanctions and myths, encourages the conservation of natural resources and protection for the natural environment, the past decade has seen a growing environmental awareness within the region. Increases in population, industry and development; the testing of nuclear devices; and the proposed use of the Pacific region as a dumping ground for nuclear wastes have shown that a united and concerted effort on a regional scale is necessary to protect not only the present but also the future resources and the destiny of the people to whom the Pacific is "home".

The heightening awareness of a need for environmental protection on a regional level was brought about by France's testing of nuclear devices on Mururoa Atoll in French Polynesia. This was the catalyst that opened the way to bringing a political issue to the conference table of the South Pacific Commission, as issues of a political nature fell outside its mandate. France in 1970 opposed the discussion of nuclear testing at the South Pacific Conference as the subject came within the realm of politics. Although the discussion was discontinued that year, the issue of French nuclear testing found its way back to the South Pacific Conference every year, and at the Guam conference in 1973:

> "the question of nuclear tests was again introduced. France raised a 'point of order' but the chairman ruled allowing the discussion.... Unlike past conferences discussion did not stop but instead the matter was discussed fully and resolutions passed condemning France for her activities" (Kite, 1974).

According to Kite (1974) the independent anti-nuclear test activities by Australia and New Zealand gave the island leaders the psychological assurance that they would not be deserted by their two immediate metropolitan neighbours in their insistence that the nuclear testing matter be given a full airing.

"The islands are concerned not only for health reasons, but also for the destruction and pollution of the resources from the sea which hitherto has provided much of the livelihood for the island peoples.... Nevertheless, given that the Canberra Agreement came into being to better the lot of the island peoples it is difficult to reconcile such aspirations with the current activities of the French government at the Mururoa Atoll which is undoubtedly hazardous to the health of the Pacific Islands and to the natural resources in their ocean environment" (Kite, 1974).

Since the inception of the SPC and the first conference held in Suva, Fiji in 1950, much has been done to provide economic development and social welfare in the South Pacific region and the SPC has undoubtedly been progressive in accommodating the aspirations of the islands as each territory since 1962 has acquired independence. The work programme of the SPC has increased from a budget of Stg 40,000 in 1948 to about $3,000,000 in 1983.

Apart from the issue of nuclear testing, other environmental concerns were also raised at regional meetings. In 1971, a Regional Symposium on Conservation of Nature - Reefs and Lagoons was organized by the SPC. In 1974, the SPC initiated a special project on Conservation of Nature and appointed a Regional Ecological Adviser. Consultations with the United Nations Environment Programme (UNEP) in 1975 led to the development of a comprehensive programme for environmental management and proposals for a Regional Conference on the Human Environment. 1976 saw the South Pacific Forum's decision for the South Pacific Bureau for Economic Cooperation (SPEC) to consult with SPC with a view to preparing proposals for a co-ordinated regional approach to the problems of environmental management and a comprehensive environmental programme reflecting the environmental interests of all countries and territories in the region. The 34th Session of the Economic and Social Commission for Asia and the Pacific (ESCAP) in 1978 endorsed the idea of convening a South Pacific Conference on the Human Environment and recommended that such a conference be held in co-ordination with SPEC and SPC. Proposals submitted to the Forum and the South Pacific Conference the same year led to the subsequent adoption of the South Pacific Regional Environment Programme (SPREP), and the organization of the Conference on the Human Environment in the South Pacific which took place in Rarotonga, Cook Islands in 1982.

Regional Environmental Policies

Since the matter of nuclear testing and concern for the health of the island people and the degradation of the Pacific's natural resources was first raised at the 1970 SPC Conference, twelve years passed before the Conference on the Human Environment in 1982 brought action responding to the concerns of the Pacific Islanders. At the Conference there was:

"widespread concern expressed at proposals to dump large quantities of low-level nuclear waste in the Pacific Ocean and to use Pacific Islands for high-level waste storage" (SPREP, 1982).

Two of the resolutions passed at the Conference on the Human Environment were as follows:

"The Japanese, United States and other governments should be requested to abandon their studies of specific proposals to store or dispose of nuclear waste in the Pacific regional environment. They should be strongly urged to research alternative methods of disposal outside the region."

and:

"Each country and territory of the region should be requested to accede to the London Dumping Convention. A regional meeting should be held, preferably before the end of 1982 so that these countries and territories can prepare a common regional agreement. This would enable them to invoke the provisions of Article VIII of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also known as the London Dumping Convention [LDC]) and thus ensure that the regulatory framework of the Convention incorporates the prohibition on storage and disposal which has been adopted as a policy of the South Pacific Regional Environment Programme (SPREP)" (SPREP, 1982).

As a result of these resolutions, the **Convention on the Protection and Development of the Natural Resources and Environment of the South Pacific Region**, and two protocols, namely, the **Protocol for the Prevention of Pollution of the South Pacific Region by Dumping;** and the **Protocol for the Co-operation in Combating Oil Pollution Emergencies in the South Pacific Region**, embodying the resolutions passed at the 1982 Human Environment Conference, were drafted to invoke article VIII of the LDC which states:

> "Contracting parties with common interests to protect in the marine environment in a given geographical area, shall endeavor, taking into account characteristic regional features, to enter into regional agreements consistent with this Convention for the prevention of pollution, especially by dumping" (LDC, 1972).

The draft Convention is not limited to pollution control. It includes the general principles of resource development and management in order to reflect the regional policy statement of the Rarotonga Conference which includes:

> "Integrated environmental, economic, social and resource planning and management is essential to ensure sustainable rational use of the land and sea resources of the region and the greatest enhancement of human well-being."

and:

> "Appropriate and enforceable legal instruments and institutional arrangements are a necessary basis for effective integration of environmental concern with the whole of the development process" (SPREP, 1982).

It was pointed out at the second Pacific regional meeting to discuss the Convention and Protocols (Noumea, November 1983), that resource development and management should not be included in an anti-pollution Convention as this goes beyond the obligation to prevent and control pollution. However, the inclusion of these concepts in the Convention is not only in keeping with other regional and international Conventions, but is also in keeping with regional policy in the Pacific. Although obligations to prevent and control pollution are common in other regional Conventions such as the Abidjan, Barcelona and Kuwait Conventions, the Abidjan and Caribbean Conventions also include the principles of environmental management within the scope of the Convention to reflect the broad framework of their regional Action Plans. According to Dahl and Baumgart (1982):

> "Environmental management is not a new concept for Pacific peoples. Wherever natural resource management was needed, the traditional cultures of the region developed practises which protected their essential interests. These included land and reef tenure systems, permanent and temporary taboos on specific species or places, refined and selective fishing techniques, agroforestry, terracing and irrigation, windbreaks, bush fallow, and other agricultural and soil management practises, etc. The cultural heritage of the Pacific is full of examples of sound environmental management equivalent or superior to modern methods. One of the great tragedies of the region is that this heritage is rapidly being lost just as the need for it is increasingly apparent."

Although management issues referred to in the Pacific Regional Action Plan are addressed in the Convention to take care of mining and coastal erosion, specially protected areas, co-operation in combating pollution in cases of emergency, and environmental assessment, these are by no means exhaustive of the concerns of the Pacific Islanders for the Region. The provisions of the Convention, however, reflect priorities for activities envisioned in the Action Plan and other management problems elaborated through specific Protocols.

In a similar manner the draft Convention also reflects the broad scope of the 14 point Declaration agreed to in Rarotonga by the 20 participating countries as a statement of regional policy.

Further, in keeping with the concern to prohibit nuclear testing first raised at a regional forum in 1970, the Conference on the Human Environment endorsed a statement of regional policy that:

> "The storage and release of nuclear wastes in the Pacific regional environment shall be prevented" (Declaration 9),

and:

> "The testing of nuclear devices against the wishes of the majority of the people in the region will not be permitted" (Declaration 10).

Legal Protective Measures

New regional convention

The draft **Convention on the Protection and Development of the National Resources and Environment of the South Pacific Region** broadly makes provisions for preventing, reducing and controlling pollution from: ships, land based sources, seabed activities, radioactive wastes, nuclear testing, dumping and atmospheric sources and makes provision to prevent, reduce and control damage caused by mining and coastal erosion. Because of the unique nature of the Pacific Islands, the Convention makes provision for appropriate measures to be taken to protect and preserve rare and fragile ecosystems as well as the habitat of depleted flora and fauna. Provision is made for co-operative efforts for combating pollution in cases of emergency and imposes a duty to develop and promote contingency plans and a duty to notify other countries if they are likely to be affected by pollution. This follows the policy requirements as stated in Declaration 11 "for the development of national and regional contingency plans and prevention programmes". The Convention further creates a general duty of co-operation amongst the contracting parties and other organizations to share and exchange scientific and technological data and other information and to develop research programmes. This is in keeping with the policy stated in Declaration 12 "requiring the further development of regional co-operation as an effective means of helping the countries and territories of the South Pacific to maintain and improve their shared environment".

In order to assist Pacific Island countries at the scientific, educational and technical levels, the Convention creates a duty for advanced technological countries who become contracting parties to the Convention to assist in programmes for the development and management of the environment. There are further provisions for the exchange of information, for determining liability and compensation for damage caused by pollution and provision for the settlement of disputes.

Apart from the provisions stated above, note has been taken of the policies in Declarations 9 and 10, and Resolution 1 of the Conference on the Human Environment and to this end, provision has been made in the draft Convention to prohibit the testing of nuclear devices and the dumping of radioactive wastes matter.

After two lengthy regional debates in January and November 1983, agreement was reached on a majority of the principles of regional policy articulated in the draft Convention. Considerable discussion, however, was generated on the question of the "Convention Area" as agreement could not be reached on issues involving the high seas, the two hundred mile economic zone and the internal waters of territories within the Convention Area. The other issues which could not be finalized were the provisions prohibiting the testing of nuclear devices and the storing, disposal and dumping of radioactive wastes. These matters have been carried forward to a third regional meeting in 1984.

Protocols

The draft **Protocol for the Prevention of Pollution of the South Pacific Region by Dumping** and the draft **Protocol Concerning Co-operation in Combating Oil Pollution Emergencies in the South Pacific Region** had a "first reading" during the regional meeting in November 1983. The two draft Protocols give detailed treatment to regional policy articulated at the 1982 Human Environment Conference, which declared:

"The storage and release of nuclear wastes in the Pacific regional environment shall be prevented" (Declaration 9),

and:

"The rate and nature of discharges of non-nuclear wastes shall not exceed the capacity of the environment to absorb them without harm to the environment and to the people who live from it" (Declaration 8).

The draft Protocol on Oil Pollution Emergencies for the Pacific follows a global pattern and is similar to those of the Kuwait, Abidjan, Barcelona and Caribbean Protocols on Oil Pollution, but the draft Protocol, having had the benefit of the experiences in other regions of the world, has been broadened to cover other pollutants.

Convention on Conservation of Nature

In June 1976, following World Environment Day, a regional meeting in Apia, Western Samoa on the **Convention on the Conservation of Nature in the South Pacific** was sponsored by the SPC and the International Union for Conservation of Nature and Natural Resources (IUCN). The regional meeting and the draft Convention were largely the result of IUCN initiatives following similar work in other parts of the world and the regional Symposium on Conservation in 1971. The 1976 meeting in Apia was the first attempt in the Pacific to co-operate on environmental matters at a regional level.

Drawing on the Declaration of Environmental Principles adopted by the United Nations Conference on the Human Environment at Stockholm in June 1972, and conscious of the growing dangers that threaten the natural resources and fragile ecosystems of the Pacific, collective action at regional level was thought to be the best means of protecting and safeguarding these assets for the benefit of present and future generations.

Provisions of the Convention on Conservation encourage the creation of protected areas (Art. II) as well as the protection of indigenous flora and fauna (Art. V). Certain acts such as the hunting, killing and capturing of specimens of fauna or collection of specimens of the flora in protected areas are prohibited (Art. III). Co-operation at regional level for the exchange of information, research and training is encouraged (Art. VII).

Although the Convention on Conservation was tabled for information at the South Pacific Conference on National Parks and Reserves held in New Zealand early in 1975, followed by the Convention meeting in Apia in June 1976, only three countries (France, Papua New Guinea, and Western Samoa) have signed the Convention. The Convention requires the ratification of four countries to come into force.

Perhaps the lack of regional support for this Convention lies in the fact that conservation of natural resources is regarded by some countries as a national matter rather than a regional one, as each country's needs are dependent on their own development priorities. The objectives as articulated in the Convention are pursued through national legislation in almost all Pacific countries. For example, Papua New Guinea's Constitution declares that the resources and environment be conserved and used for their collective benefit and replenished for the use of future generations, as their Fourth National Goal. Other examples are the Conservation Areas Act 1978, and the Fauna (Protection and Control) Act 1974 (Papua New Guinea); The Conservation Act 1975 (Cook Islands); The National Parks Act 1974 (Solomon Islands); The Wildlife Conservation and Endangered Species Act (Guam); the Prohibited Areas Ordinance 1971 (Kiribati); the Birds and Game Protection Act 1923 (Fiji); the Fish and Bird Preservation Act (Tonga); the Endangered Species Act (TTPI); to name a few. The protective legislation in some countries dates far back before independence and also before the 1976 regional discussions on the Convention on the Conservation of Nature. Added to this is the Australian arrangement where each State has its own laws, its own system of national parks and reserves and its own administration. Research, training and the exchange of information have been taking place in the region prior to the 1976 discussions and together with traditional conservation methods through rituals and taboos these have been some of the factors that have affected a firm commitment at a regional level.

Forum Fisheries Agency

The Convention establishing the **South Pacific Forum Fisheries Agency** in 1977 culminates the common interest in the Pacific for the conservation and optimum utilization of the living marine resources and particularly those of highly migratory species. Co-operation and co-ordination of fisheries policies at a regional level has become a necessity as it is only at this level that the exchange of information about living marine resources and especially those of highly migratory species can bring about the maximum benefits for the people and the region as a whole.

Conclusion

The three regional Conventions and the two Protocols are indicative of the trends emphasizing the number of environmental concerns affecting the Pacific Region and its people. Some of the provisions such as those prohibiting nuclear testing and dumping, and the geographic area the Convention seeks to cover, have wide political ramifications and have yet to be agreed upon. The changes sought and required by the Conventions and Protocols have been the result of wide consultation and research at national and regional level. The conventions are not only a clear acknowledgement of the policy decisions made to protect the Pacific environment but are also in keeping with trends in other parts of the world.

REFERENCES

Dahl, A. L. and I. G. Baumgart. 1982. The state of the environment in the South Pacific, p. 47-71. In Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia. Reprinted as UNEP Regional Seas Reports and Studies No. 31 (1983).

Kite, Sione. 1974. The microstates of the South Pacific. Unpublished M.A. thesis, University of London. [synopsis published in 1977 in Pacific Perspective 6(1):6-21).

LDC. 1972. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention).

SPC. 1980. Consolidation of agreed provisions and practices relating to the establishment and operation of the South Pacific Commission, including the Canberra Agreement as amended. Third edition. South Pacific Commission, Noumea, New Caledonia.

SPREP. 1982. Report of the Conference on the Human Environment in the South Pacific, Rarotonga, Cook Islands, 8-11 March 1982. South Pacific Commission, Noumea, New Caledonia.

EAST ASIAN SEAS REGION

OVERVIEW OF THE EAST ASIAN SEAS ACTION PLAN

Kasem Snidvongs
Secretary General
National Environment Board of Thailand
and COBSEA Coordinator

ABSTRACT

This paper presents an overview of the East Asian Seas Action Plan. It describes its historical background, and discusses its principal components as well as the institutional and financial arrangements for the implementation of the action plan. Lastly, it identifies administrative delay, financial problems and legal difficulties as problems involved in the implementation of the action plan.

HISTORICAL BACKGROUND

As a focal point for environmental action and co-ordination within the United Nations System, the United Nations Environment Programme (UNEP) realized that environmental action should encompass a comprehensive approach to environmental problems dealing not only with the consequences but also with the causes of environmental degradation. The Governing Council of the United Nations Environment Programme has designated "Oceans" as a priority area for environmental action, in which it will focus efforts to fulfil its catalytic role. It also recognized that environmental problems of the oceans are global in scope and must be dealt with in an integrated way. It thus launched its Regional Seas Programme in 1974, as a regional approach seemed a more realistic way to solve the problems. Action plans were to be formulated for each region. The regional approach allowed UNEP to focus on specific problems of high priority to the States of each region. The UNEP Governing Council has identified the following ten areas as components of the Regional Seas Programme: the Mediterranean, the Kuwait Action Plan Region, The Wider Caribbean, the West and Central African Region, the East African Region, the East Asian Seas, the Red Sea and Gulf of Aden, the South-West Pacific, the South-East Pacific and the South-West Atlantic.

The East Asian Region was recognized by the UNEP Governing Council in 1976 as "concentration area" for the establishment of a regional seas programme in Asia with a scientific programme involving research, prevention and control of marine pollution, and monitoring. During the same year an international workshop on marine pollution was convened in Penang by IOC, FAO's Indo-Pacific Fishery Commission (IPFC) and UNEP. The workshop proposed that the region should be divided into six subregions for the purposes of the UNEP Regional Seas Programme. The East Asian Seas (EAS) was one of the proposed subregions, covering the area of the five member countries of the Association of South East Asian Nations (ASEAN)*. A few years later (1979), a draft regional action plan for the East Asian Seas was prepared by UNEP and was submitted to the Governments of the Region for consideration. Several meetings were held with the assistance of UNEP to consider and revise the draft action plan as follows:

---

* The Association of South East Asian Nations (ASEAN) was established in 1967 for the technical collaboration among its five member countries on the attainment of peace, progress and prosperity of the region. The five members are: Indonesia, Malaysia, Philippines, Singapore and Thailand.

(1) Second Meeting of the ASEAN Experts Group on the Environment, September 1979, Malaysia;

(2) Third Meeting of the ASEAN Experts Group on the Environment, May 1980, Philippines;

(3) First Meeting of Experts to Review the Draft Action Plan for the East Asian Seas, June 1980, Philippines;

(4) Second Meeting of Experts to Review the Draft Action Plan for the East Asian Seas December 1980, Thailand;

(5) Fourth Meeting of the ASEAN Experts Group on the Environment, April 1981 Singapore;

The Action Plan was finally adopted at the Intergovernmental Meeting on the Protection and Development of the Marine Environment and Coastal Area of the East Asian Region, April 1981, Manila, Philippines.

At the Intergovernmental Meeting on the East Asian Seas Action Plan, December 1981, Thailand, agreement was reached concerning which projects of the action plan programme should be implemented during 1982-1983 and which national focal point would be responsible for co-ordinating each project.

The First Meeting of the Co-ordinating Body of the Seas of East Asia (COBSEA) was convened one day after the Fifth Meeting of the ASEAN Experts Group on the Environment, April 1982, Thailand. The meeting finalized the approved priority projects including the financial arrangements for implementation during 1982-1983.

The ASEAN countries then started implementing the approved projects.

OBJECTIVES OF THE EAS ACTION PLAN

The principal objective of the EAS Action Plan is "the development and protection of the marine environment and the coastal areas for the promotion of the health and well-being of present and future generations." The EAS Action Plan is aimed at providing a framework for a comprehensive and environmentally-sound approach to coastal area development particularly appropriate to the needs of the regions.

The EAS Action Plan is composed of three components: environmental assessment, environmental management and co-ordinating measures. The corresponding immediate objectives are:

(1) "assessment of the state of the marine environment, including assessment of the effects of marine, coastal and other land-based activities on environmental quality, so as to assist Governments to cope properly with marine environmental problems;"

(2) "management of those marine and coastal development activities which may have an impact on environmental quality or on the protection and use of renewable marine resources on a sustainable basis;"

(3) "development of suitable co-ordinating measures for the successful implementation of the action plan."

Note that the above immediate objectives do not include one relating to the legal aspects of marine pollution control as has usually been the case in other action plans. The legal component, which is an integral part of the now-standard UNEP four component model, was dropped at the First Intergovernmental Meeting at Manila which adopted the revised EAS Action Plan.

PRINCIPAL COMPONENTS OF THE EAS ACTION PLAN

Environmental Assessment Component

This component is concerned with assessment and evaluation of the causes, magnitudes and consequences of marine pollution problem. Priority will be given to the identification of the present quality of the marine environment and the coastal areas, the factors currently affecting its quality and the projection of future trends. A co-ordinated basic and applied regional marine science programme aiming at co-operative research and assessment of the present situation of the marine environment has been developed in four priority areas: oceanography, oil pollution, non-oil pollutants, and mangrove and coral ecosystems. On going and planned national and regional programmes have been duly taken into consideration during the formulation of the operational details of this programme.

It was also agreed that, for "the possible future expansion" of the above-mentioned programme, the following components "may be considered", at a lower level of priority.

1. Assessment of the environmental impact of offshore seabed exploration and exploitation, including petroleum, mining and dredging.

2. Assessment of thermal pollution in coastal waters and its impact on marine biota.

3. Assessment of the nature and magnitude of pollution reaching the marine environment through the atmosphere.

It is also envisaged that an intensive programme of training and technical support of local scientists and technicians will be developed in order to strengthen the environmental assessment component.

The projects under this component of the EAS Action Plan will be executed primarily through existing national institution within the framework of regional co-operation. For some projects a training programme has been formulated.

Environmental Management Component

Some preparatory activities are necessary to achieve the objectives of the development and environmental management component of the action plan. Such activities comprise:

1. Preparation of a directory of institutions in the region active in fields related to environmental management.

2. Identification of relevant on-going national, regional and internationally supported development projects which demonstrate sound environmental management practices.

Special importance is attached to the training of managers and policy makers in environmentally sound management practices in order to achieve more effective management of environmental affairs and pollution control in coastal areas. Three projects are under this component, namely: oil pollution control, pollution control and waste management, and information and data exchange. Environmental impact assessment and nature conservation are excluded from this component, since they are already included in the ASEAN Environment Programme (ASEP).

Co-ordinating Measures

Support Measures

Since agreement on the legal component as well as on institutional arrangements could not be reached during the First Intergovernmental Meeting, the revised Action Plan was adopted at Manila in April 1981 without these provisions. Only support measures in the draft legal component were retained with slight modifications. No reference was made to relevant international and regional agreements on the protection of the marine environment. The co-ordinating measures relating to legal aspects of marine environment protection are confined only to:

1) maintenance by each State of an up-to-date compilation of its national laws relevant to the protection of the marine environment;

2) technical assistance and co-operation in the drafting and updating of national legislation relevant to the protection of the marine environment.

However, other suitable co-ordinating measures for the implementation of the action plan are possible.

Financing of the Action Plan Programme

The EAS Action PLan simply states that the action plan programme may be financed by:

1) initially, the United Nations System;

2) other sources from within and outside the region.

The EAS Action Plan and its projects

Institutional and financial arrangements were adopted in December 1981 at the second intergovernmental meeting, held in Bangkok, although not as part of the EAS Action Plan. After the Bangkok meeting a trust fund as established with contributions promised for 1982 and 1983 from the ASEAN member countries and UNEP. UNEP will contribute at least the same amount as the ASEAN member countries. The management of the Trust Fund was entrusted to UNEP.

The final version of the EAS Action Plan contains following priority projects:

1. Assessment of oceanographic phenomena through detailed oceanographic surveys;
   - Observation of maritime meteorological phenomena and their influence on water movements;
   - Study of oceanographic features with emphasis on hydrography, water masses and water circulation, and their effects upon pollution dispersion patterns;
   - Oceanographic reference stations.

2. Assessment of oil pollution and its impact on living aquatic resources:
   - Survey of sources and monitoring of oil pollution in the marine and coastal areas;
   - Co-operative research on oil and oil dispersant toxicity.

3. Assessment of non-oil pollutants, especially metals, organics, nutrients and their environmental impact:
   - Survey of rivers and land-based sources of non-oil pollutants ;
   - Study of concentration levels and trends of non-oil pollutants ;
   - Study of the effects of non-oil pollutants on marine environment.

4. Assessment of the impact of pollution on, and habitat degradation of, mangrove and coral ecosystems:
   - Survey of the state of mangroves and coral reefs;
   - Effects of pollutants and destructive factors on mangrove and coral communities and related fisheries.

5. Oil pollution control:
   - Training programme for oil pollution control;
   - Support programme for contingency planning;
   - Operational pollution from ships;
   - Regional advisory services.

6. Pollution control and waste management:
   - Wastes discharges into coastal waters;
   - Marine sites for dumping of hazardous wastes.

7. Information and Data Exchange.

INSTITUTIONAL AND FINANCIAL ARRANGEMENTS FOR THE IMPLEMENTATION OF THE ACTION PLAN

Institutional arrangements

Policy matters and co-ordination

It was agreed in the Intergovernmental Meeting on the EAS Action Plan, Bangkok, December 1981, that the participating countries will form a policy co-ordinating body known as the Co-ordinating Body on the Seas of East Asia (COBSEA) in order to make policy decisions concerning all substantive and financial matters.

COBSEA has the overall authority to determine the content of the action plan, to review its progress and to approve its programme of implementation including the financial implications. COBSEA communicates on policy matters through the interim co-ordinator, who maintains contact both with UNEP and with the national focal points, who in turn communicate policy to the national institutions.

Overall technical co-ordination

In the Intergovernmental Meeting mentioned above, the ASEAN member countries designated UNEP to be responsible for the overall technical co-ordination and continuous supervision of the implementation of the action plan for the year 1982 and 1983. For a channel of communication between UNEP and COBSEA, it was agreed in the meeting that the Interim Co-ordinator of the ASEAN Experts Group on the Environment should be the one who undertakes this function. UNEP then communicates directly on technical matters with the national focal points, and through them with the national institutions.

National focal points

The Bangkok meeting designated the following national focal points:

Indonesia:	The First Assistant Minister Ministry of State for Development Supervision and Environment
Malaysia:	Director General of Environment Environment Division Ministry of Science, Technology and the Environment
Philippines:	Executive Director National Environmental Protection Council Ministry of Human Settlements
Singapore:	Permanent Secretary Ministry of the Environment
Thailand:	Secretary General National Environment Board Ministry of Science, Technology and Energy

The roles of the national focal points are:

(i) To act as the official channel of communication between the Interim Co-ordinator and their respective governments;

(ii) To co-ordinate, as appropriate, the participation of national institutions and agencies in the agreed programmes; and

(iii) To consult with all relevant organizations within their countries on the activities and progress achieved in implementing the action plan.

National institutions

Projects under the action plan are carried out by national institutions, such as research centres, laboratories, government services, and universities, which are designated by the national focal points. In this way, the national institutions will act as the principal executors of the specific work and research under the action plan.

Sub-regional and regional institutions

It is also envisaged that sub-regional and regional institutions will be used to the maximum possible extent for the implementation or co-ordination of the action plan.

Networking

The national institutions, in principle, could become participants in any one activity of the action plan. They could be linked in a network of co-operating institutions if they work on the same activity. The Bangkok meeting also agreed that one member of a network could assume the role of a regional activity centre and be responsible for co-ordinating the activity for which the network as established.

International organizations

UNEP was invited to undertake responsibility for co-ordinating technical and managerial support for specific projects. Participation of international organizations, especially those belonging to the United Nations System, is also welcome. The national focal points serve as the channel for contacts between the international organizations and concerned national institutions.

Financial arrangements

EAS Trust Fund

The EAS Trust Fund was established in response to the request of the participating countries; the authority for its administration was delegated by the UN Secretary General to the Executive Director of UNEP. The Trust Fund, therefore, is administered according to the financial rules of the UN and the terms of reference agreed by the participating countries. The establishment of the EAS Trust Fund is aimed at providing financial support for the action Plan adopted by the Intergovernmental Meetings on the Protection and Development of the Marine Environment and Coastal Areas of the East Asian Region, Manila, 29 April 1981. The Fund comprises mainly the contributions from the participating governments and support from the UNEP Environment Fund, as well as any other source of funding agreed to the participating governments.

At the beginning of the EAS Programme, the Trust Fund was established for two years beginning 1 January 1982 and ending 31 December 1983.

Funding

The participating governments contribute US$ 86,000 annually in both 1982 and 1983 in accordance with the table below:

Indonesia	US$	30,000
Malaysia		17,000
Philippines		19,000
Singapore		1,000
Thailand		19,000
	Total	86,000

The UNEP contribution towards technical co-ordination and programme activities in both 1982 and 1983 amounts to US$ 300,000.

PROBLEMS INVOLVED IN THE IMPLEMENTATION OF THE EAS ACTION PLAN

There are several problems that have occurred during the implementation of the EAS Action Plan such as administrative delay, financial problems, legal difficulties, etc.

Administrative delay

Even though the Trust Fund has been established since 1 January 1982, payments into the Trust Fund had been very slow. Therefore, the Trust Fund could not be utilized for the implementation of the EAS Action Plan until late 1982, because the terms of reference for the management of the Trust Fund stipulate that "no expenditure from the Trust Fund shall be made in advance of the receipt of contributions, and none shall be made before a minimum of US$ 50,000 has been contributed to the Trust Fund ". Consequently, interim period prior to the actual implementation of the plan was prolonged for more than 9 months until sufficient funds could be raised to permit the release of money from the Trust Fund.

Financial problems

UNEP, considering itself not as a funding agency and maintaining its catalytic role, has always stressed that each regional action plan area should progressively become financially self-supporting, predominantly through regional trust funds. UNEP will withdraw its financial support gradually. Here lies the crux of the problems involved in the implementation of the action plan: financial difficulties. To achieve the objectives set in the EAS Action Plan requires a huge amount of money. Many projects need a strong data base, the collection of which involves substantive expenditures that the participating countries can not afford in the long run, should UNEP withdraw its support after a few years. The situation in the East Asian Seas Region is not like the one in the Mediterranean, where most of the 18 participating countries are developed countries which can afford to pay millions of dollars to save the Mediterranean. We, the countries in this region, are developing countries, in which the large part of population is still living in poverty. Therefore, economic planners do not show much concern about the health of the surrounding seas, and little money has been provided so far for the protection of the marine environment, compared with the budgetary allocations to solve poverty in the rural areas. Should UNEP withdraw its support too soon, or not be able to contribute substantially to the implementation of the action plan, the action plan would not be able to achieve its objectives. Moreover, genuine financial commitments on the part of the participating countries are needed. However, such commitments cannot be obtained easily, since those who approve the budget are different from those environmental planners who support the EAS Action Plan. Promotion of an awareness of the importance of protecting the marine environment among such people is therefore necessary. However, to show environmental gains from protecting the marine environment is not an easy task.

Legal difficulties

Effective protection of the marine environment at the regional level requires some form of legal arrangements such as the conclusion of a regional convention on the control of pollution from land-based sources as well as from ships. Such legal arrangements are considered by many as an integral part of an action plan; without such arrangements the effectiveness of the action plan in protecting the marine environment is doubtful. However, the ASEAN countries seem to have a strong aversion to regional legal agreements of any kind. The reasons why this is so are not fully known. It may be that the economic and administrative costs of having such an agreement are prohibitive, whereas the benefits are not yet fully quantified. Another reason may be that existing legislation may be obsolete, and the enactment of internal legislation requires years of preparation. Therefore, most participating countries are reluctant to include in the EAS Action Plan any binding statement which would form an integral part of the legal component. It is still possible that the legal component will be reconsidered by COBSEA at a later stage. In the meantime, the legal component, it was agreed, should be the subject of a consultant's study.

CONCLUSION

The action plan represents a start in technical co-operation in the field marine environment protection among the participating countries, starting with the ASEAN sub-region. If successful, the ASEAN sub-region is expected to act as a nucleus for development of a wider programme for the adjacent regions identified at the Penang Workshop.

REFERENCES

UNEP. 1980. Report of the Meeting of Experts to Review the Draft Action Plan for the East Asian Seas. (UNEP/WG. 41/4, 8 July 1980).

UNEP. 1981. Report of the Intergovernmental Meeting on the Protection and Development of the Marine Environment and Coastal Areas of the East Asian Region. (UNEP/IG. 26/6, April 1981).

UNEP. 1981. Report of the Intergovernmental Meeting on the East Asian Seas Action Plan. (UNEP/IG. 31/6, 11 December 1981).

UNEP. 1982. Achievements and planned development of UNEP's Regional Seas Programmes and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1.

UNEP. 1982. Report of the First Meeting of the Co-ordinating Body on the Seas of East Asia. (UNEP/IC. 37/10, 3 April 1982).

OCEANOGRAPHIC ASSESSMENT OF THE EAST ASIAN SEAS

Aprilani Soegiarto
National Institute of Oceanology
Jakarta, Indonesia

ABSTRACT

This paper reviews oceanographic conditions in South-East Asian waters, in particular highlighting the monsoonal influence on oceanographic features. It gives a general assessment of atmospheric and water circulation and tidal patterns, and summarizes the data on the discontinuity layer, temperature, salinity, dissolved oxygen, and transparency of the waters in the region. Finally it describes the present knowledge of nutrients and primary productivity, and associated phenomena such as upwelling.

Introduction

The East Asian Seas actually cover a very large area in the western Pacific Ocean, bordered by the Bering Sea to the North, the Indian Ocean to the south, the coasts of continental Asia to the West and the Pacific Ocean to the East. However, the East Asian Seas Action Plan of the United Nations Environment Programme (UNEP) is limited to the South-East Asian Region, and this oceanographic assessment concentrates on that region. This assessment is largely based on the work of Wyrtki (1961) and various existing reviews such as Soegiarto and Birowo (1975), Soegiarto (1978) and Soegiarto (1981).

The South-East Asian Waters

The waters and islands between Asia and Australia and between the Pacific and the Indian oceans form a geographical unit because of their special structure and position. In geographical terms, the whole region is a part of Asia and is referred to as South-East Asia. In oceanographic terms, the waters of the region are part of the Pacific Ocean, which is separated from the Indian Ocean by the islands of Sumatra, Java, and the Nusa Tenggara (Lesser Sunda). The seas in the region draw their water from the Pacific, to which they provide access.

The South-East Asian waters comprise the Andaman Sea, the Straits of Mallaca, the Straits of Singapore, the South China Sea, the Java Sea, the Flores Sea, the Banda Sea, the Arafura Sea, the Timor Sea, the Celebes Sea, the Sulu Sea, and the Philippine Sea (Figure 1). The whole body of water covers 8.94 million square kilometres in area, which represents about 2.5 per cent of the world's ocean surface.

The South-East Asian seas form one geographic unit distinct from the Pacific and Indian oceans. The Andaman Sea is part of the Indian Ocean but should be regarded as South-East Asian waters. It is perhaps rather surprising that the Timor and Arafura Seas and Gulf of Carpentaria are often regarded, in oceanographic terms, as part of the Pacific Ocean.

Nearly all types of topographical features are found in South-East Asian waters, such as shallow continental shelves, deep sea basins, troughs, trenches, continental slopes, and volcanic and coral islands. In its distribution of water and land the South-East Asian region is one of the most complex structures on earth. The numerous large and small islands divide the waters into different seas connected by many channels, passages, and straits. The complexity

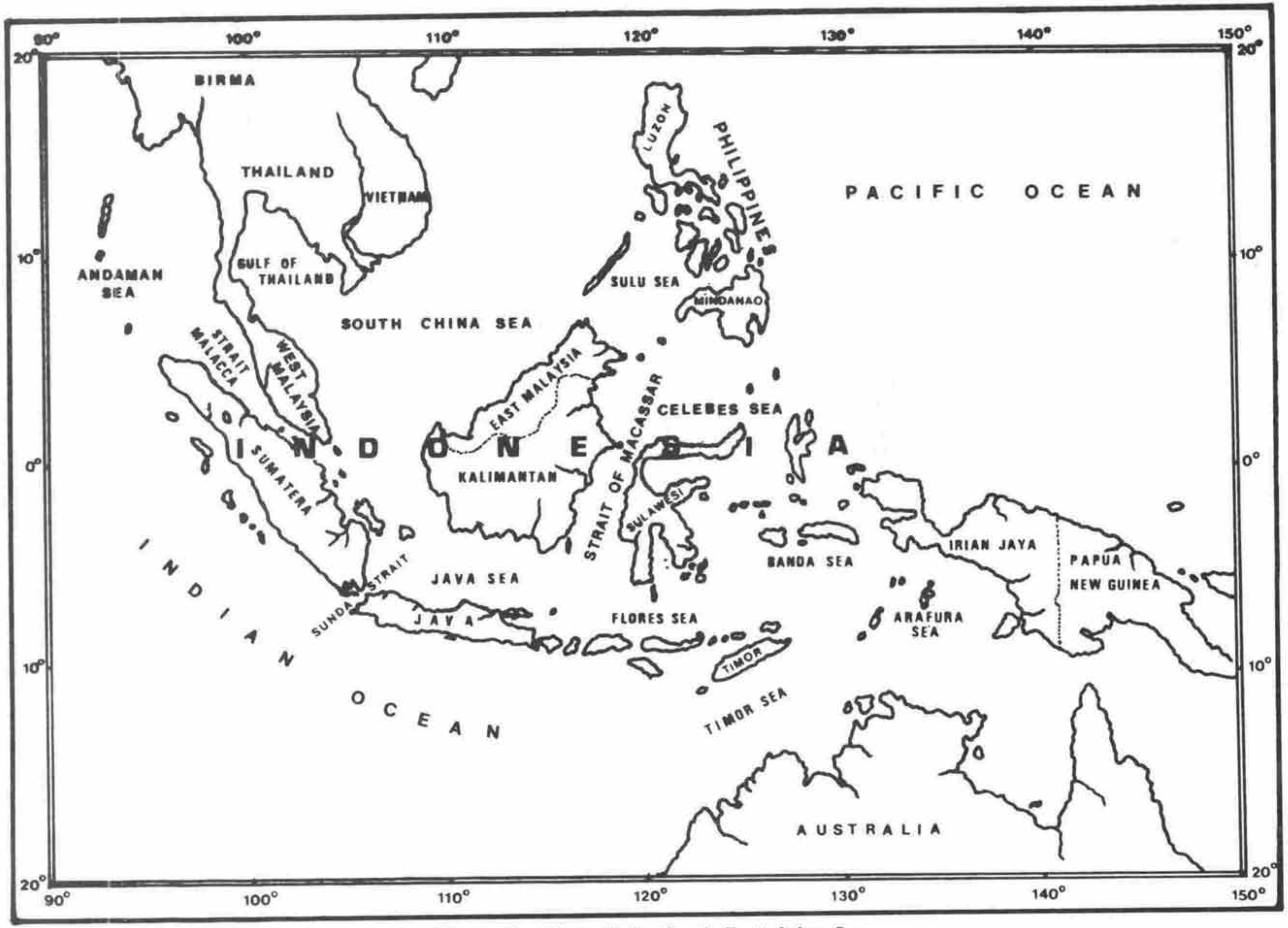


Figure 1 : Map of the South-East Asian Seas

of the region is the reason why it has drawn many major international oceanographic expeditions, such as those of the CHALLENGER (1872-75), the GAZELLE (1875), the VALDIVIA (1899), the SIBOGA (1899-1900), the PLANET (1906-7), the SNELLIUS (1929-30), the ALBATROSS (1948), the SPENCER F. BAIRD (1947-50), and the CALATHEA (1951). In recent years, a few oceanographic cruises have been organized, locally or as part of some cooperative regional studies, such as the Intergovernmental Oceanographic Commission (IOC) Cooperative Study of Kuroshio which also covers the South China Sea, and the International Indian Ocean Expedition (IIOE). We are thus fortunate to have a fairly good picture of the general oceanographic characteristics of these waters (Wyrtki, 1961; Soegiarto and Birowo, 1975).

Monsoonal influence on oceanographic features

Located between the Asian and the Australian continents, the South-East Asian region is strongly influenced by the monsoons. The South-East Asian waters are thus ideal for studying the effects of the monsoons on both water circulation and the seasonal distribution of physical, chemical, and biological properties.

The equatorial pressure trough moves according to the position of the sun, crossing the Equator twice each year. In the northern summer, a low pressure area develops over the Asian continent as an extension of the equatorial pressure trough. In winter, a high pressure area is formed over the continent, forming part of the subtropical high pressure system. The monsoons develop between the winter hemisphere "high" and the "low" in the other hemisphere. Because the pressure distribution is stationary, the winds are rather constant, especially over the sea. The wind forces are, however, generally small. Storms and typhoons are observed only over the northern parts of the South China Sea and the Philippines, over the Andaman Sea, and north of Australia. During the intermonsoon period when the equatorial trough passes over the Equator, the winds over the region are generally extremely variable. During the full monsoon the trough is deviated over land in the direction of the monsoon, owing to thermal influences.

The north monsoon in South-East Asia lasts from December to February and the south monsoon from June to August. The rest of the year represents the transition from the north to the south monsoons (March-May) and from the south to the north monsoons (September-November).

The variation of the atmospheric circulation described above parallels the corresponding variation of the water circulation. Because of the high constancy of the monsoons and the regularity of appearances, the ocean currents show the same characteristics. Just as the monsoons change direction twice a year and are practically reversed at the time of their strongest development, the oceanic circulation is also reversed over large areas. This complete reversal is typical of the circulation in these waters. The following is the description of the surface current systems in South-East Asian waters (FAO/IPFC Secretariat, 1976).

When the south monsoon prevails, northerly monsoon currents are dominant in the middle portions of the South China Sea and the Java Sea. The inflow of oceanic water is strong through the Celebes Sea and the Flores Sea from the Pacific. The water of the South China Sea flows out through the Strait of Taiwan (Formosa) and the Luzon Strait. During the north monsoon a southerly flow of water causes a cyclonic pattern of surface water movement. In this season, the inflow of oceanic water is strong through the Taiwan Strait and Luzon Strait. The outflow from the South China Sea is strong through the Flores Sea and less strong, but with considerable volume, from the Celebes Sea to join the water mass from the South China Sea flowing eastwards. In both monsoons, smaller amounts of water enter the South China Sea through the Philippine Islands from the Pacific and flow out to the Indian Ocean through the Malacca Strait and the Sunda Strait.

As mentioned earlier, the water mass of the South-East Asian region originates from the Pacific Ocean. This is also clearly indicated by surface current patterns in this region (Figures 2 and 3). The North Equatorial current flows westwards and, upon approaching the Philippine Islands, splits into two main branches: the northward branch becomes the Kuroshio, and the southward branch the Mindanao current.

Figure 2 : Surface current patterns of South-East Asian waters during the North monsoon (December-May)

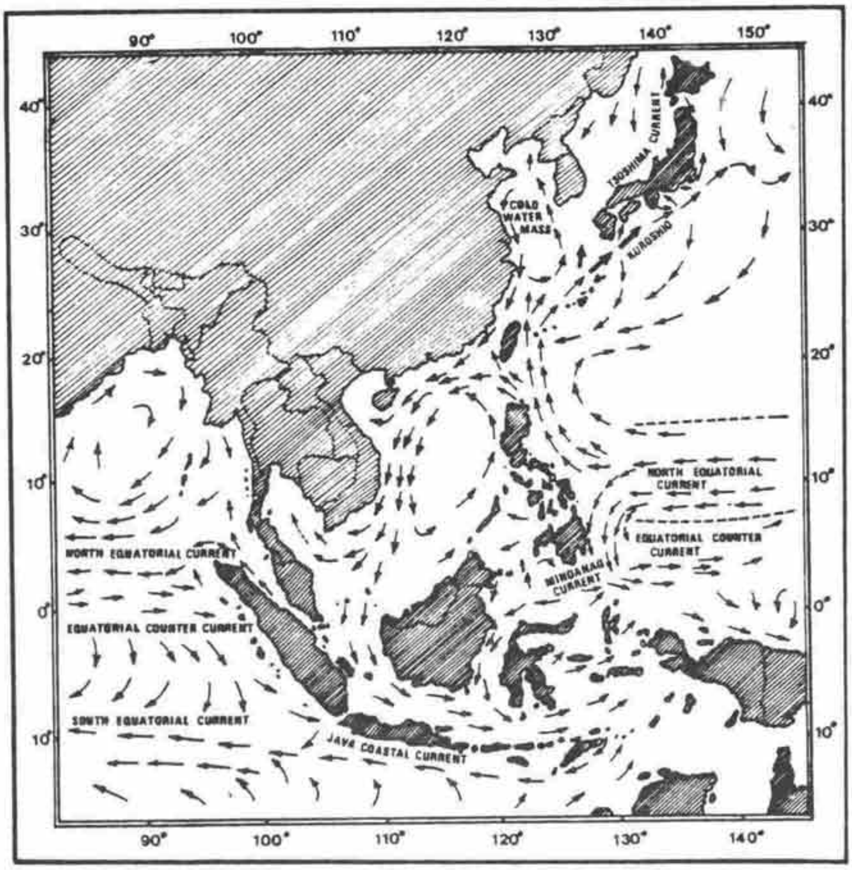
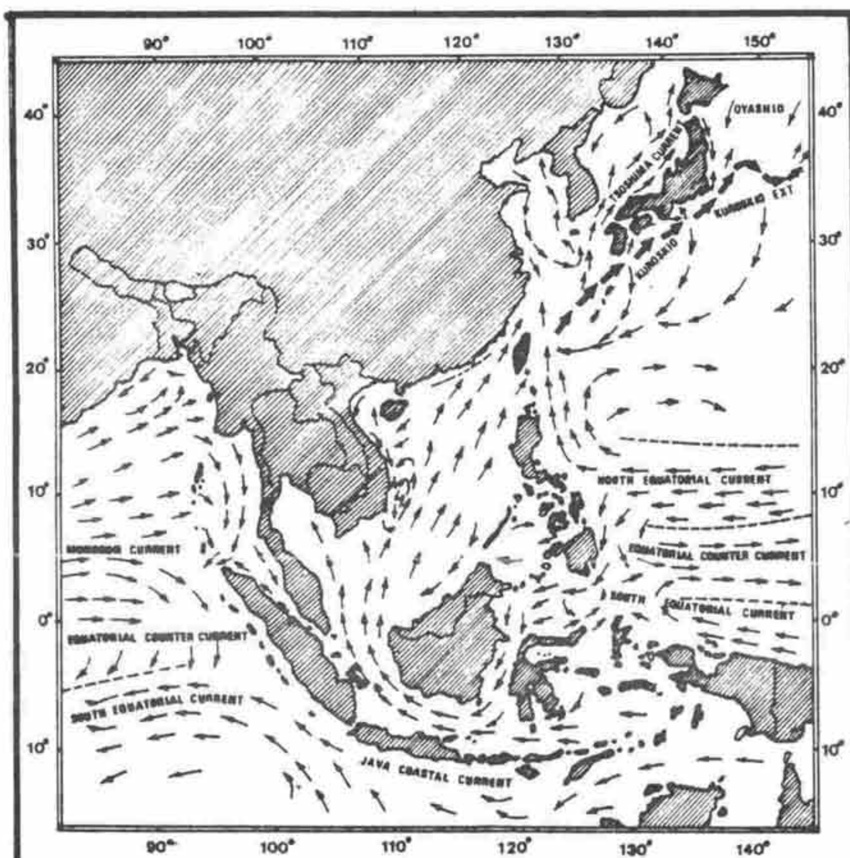


Figure 3 : Surface current patterns of South-East Asian waters during the South monsoon (June-November)



The Kuroshio begins east of northern Luzon as a swift and narrow segment of the western boundary current. It flows close to the east coast of Taiwan and then into the East China Sea and farther north into the Japan Sea. At the height of the north monsoon, a substantial mass of water from the Kuroshio is deflected into the China Sea and then pushed farther south by the prevailing wind into the South China Sea and the Java Sea.

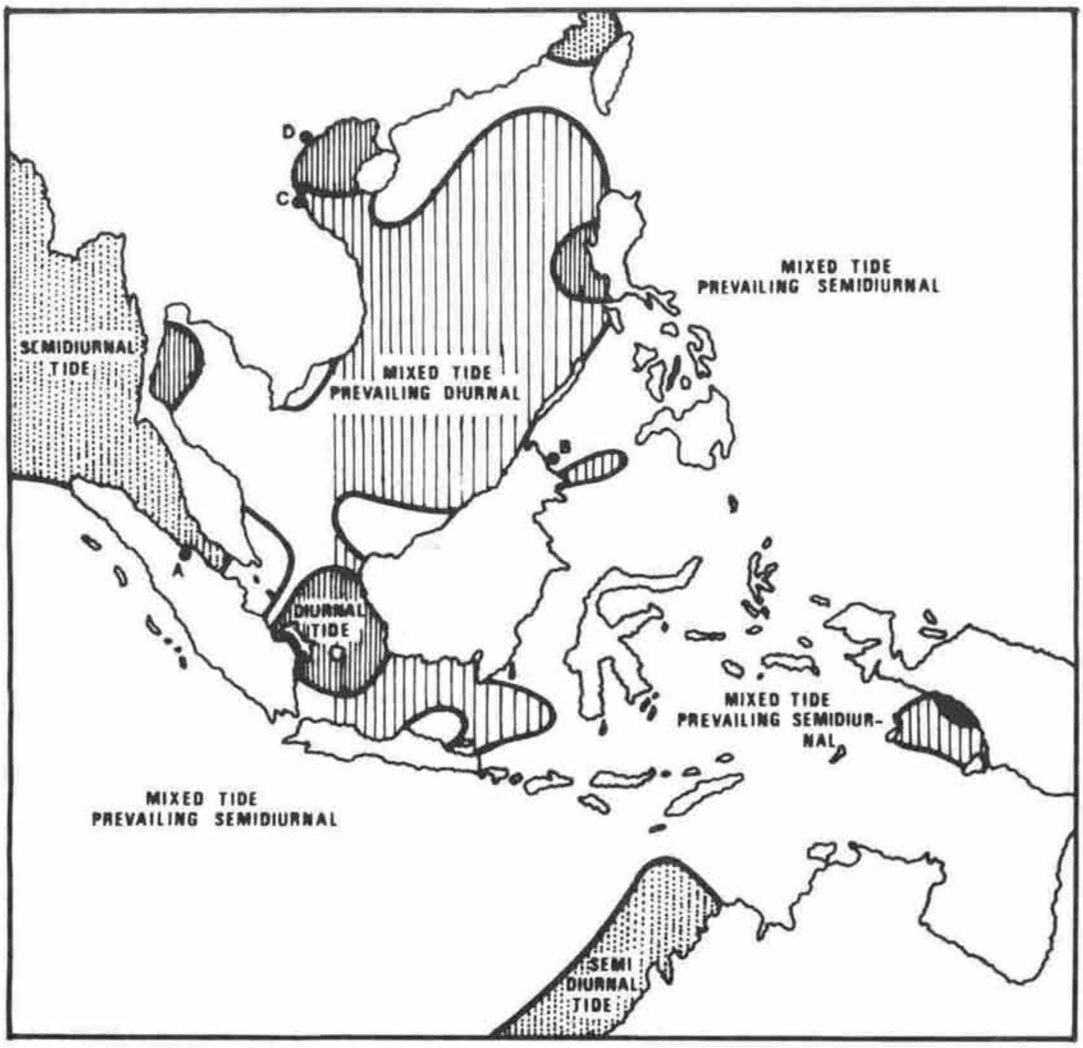
The Mindanao current flows southwards with a speed of 1 or 2 knots along the coast of Mindanao Island. Its main part becomes the Equatorial Counter-Current. A weaker branch of the Mindanao current enters the Celebes Sea through the straits between Mindanao and Sangir and Talaut Islands. Within the Celebes Sea, a major portion of its water is deflected to the south and flows along the north coast of Celebes as a coastal current to the east.

Tidal patterns

Next to waves and currents, tides are the most striking feature of the movements of sea water, and they affect navigation considerably. The vertical movements of sea water can be transformed into tidal currents of high speed in narrow inlets, river mouths, small bays, and entrances to inland seas. Apart from the direct effect on ships, the dredging and silting action in the waterways and harbour basins will affect conditions at the port.

The tides of South-East Asian waters are affected by both the Pacific and the Indian oceans. Thus, diurnal tides predominate in the South China and Java seas, whereas mixed tides prevail in the Eastern Archipelago and in Philippine waters. However, semi-diurnal tides of the Indian Ocean are predominant in the Andaman Sea and the shelf areas northwest of Australia. Wyrtki (1961) characterized the four tidal types in the South-East Asian waters as follows (Figure 4):

Figure 4 : Geographic distribution of tidal types in South-East Asia



(1) Semi-diurnal type: Daily, two high and two low waters of almost equal height, e.g., Bagan Siapi-api (Riau Archipelago) and the Malacca Strait.

(2) Mixed tide, prevailing semi-diurnal: Daily, two high and two low waters, but different both in height and the time of high water; e.g., Sandakan and Sulu Sea.

(3) Mixed tide, prevailing diurnal: Only one high and one low water daily, but there are also regimes with two high and two low waters which differ appreciably in height and in the time of occurrence of the high water; e.g., Hon Nie Nieu, Vietnam.

(4) Diurnal Tide: Only one high and one low water daily; e.g., Gulf of Tonkin.

Since in the Indian Ocean the semi-diurnal type of tide is predominant, the Andaman Sea, the Malacca Strait, and the shelf off northwest Australia have semi-diurnal tides. Other regions, such as the south coast of Sumatra, Java, and the Nusa Tenggara Islands, have mixed tides with prevailing semi-diurnal. In the western Pacific Ocean, the diurnal tide is dominant. However, this changes as soon as the tides enter South-East Asian waters. Almost the entire South China Sea, for example, experience a mixed, prevailing diurnal tide. In other waters, the diurnal tide is strengthened. Thus, in the Gulf of Thailand, the Gulf of Tonkin, the waters between Sumatra and Borneo, and the Java Sea, an almost purely diurnal tide is observed. In contrast, over the eastern parts of the Indonesian Archipelago the mixed, prevailing semi-diurnal tide is dominant.

General properties of the water

Discontinuity layer

Since the South-East Asian region is located near the Equator, the surface water is characterized by high temperatures. This property combined with the influence of low salinity reduces the density of the surface water rather markedly. The large excess of rainfall over evaporation causes an average salinity of less than 34 parts per thousand within a region enclosed by a line running from Sri Lanka, off the islands of Sumatra, Java, Celebes, and Philippines to Taiwan (Wyrtki, 1961). The density of this water always remains below Sigma t 22.0 (or a specific gravity of about 1.022). This light tropical surface water contrasts strongly with the cold water masses in deeper layers with Sigma t of 27.7 to 27.8. The transition between these two water masses, usually called the discontinuity layer, takes place between 100 and 300 metres. This stable discontinuity layer practically prevents any vertical exchange of water. It is only in a few places and in certain seasons that this stable stratification is disturbed, either by extremely strong wind or by upwelling processes.

The properties of the water at the surface normally extend downwards to a certain depth before the transition to colder water takes place. This upper homogeneous layer of water is mixed by the action of winds and, in some cases, by currents and tides. Below this layer, a change of water properties, especially an increase in the density, begins, at first gradually, later rather rapidly until a maximal density gradient is reached at the centre of the discontinuity layer. Below this, the density of the water continues to increase, but rather slowly, until it reaches the deep cold water.

The depth of the homogenous layer is of interest in dynamic oceanography and is of relevance in marine productivity. Over the Sunda and Sahul shelves the homogeneous layer reaches the bottom of the shallow parts. In the deeper parts, high density water is found below the homogeneous layer at a depth of about 40 metres. In the Celebes, Sulu, and Flores seas, the homogeneous layer is at about the same depth throughout the year. However, in the South China Sea and in the Eastern Archipelago, the seasonal variation is more pronounced. In the Banda Sea and the Arafura Sea, the depth of the homogeneous layer is about 20 to 50 metres in October and down to about 100 metres in March. A similar range is recorded for the South China Sea where the homogeneous layer is only about 30 to 40 metres deep in the south monsoon, but increases to 70-90 metres during the strong north monsoon.

The thickness of the discontinuity layer is affected primarily by dynamic processes. In a large eddy, the warm water masses are pressed downwards, causing a thick discontinuity layer. In the eastern archipelago, the discontinuity over the year is of a uniform thickness of about 100 metres. The sharpest discontinuity, at 20 metres depth, is found off the Sumatra coast in October, when the Counter-Current turns along a broad front to the south.

Temperature

One of the features of tropical waters is that the surface layer is warm and the annual temperature variation is small. During the north monsoon, generally high surface temperature of 28-30°C prevail in the west coast of Sumatra and the Eastern Archipelago waters. However, because of the inflow of water masses from higher latitudes, colder water (26-27°C) is found in the South China Sea. The surface temperature distribution of other parts of the South-East Asian waters ranges between these figures. Very different conditions occur during the south monsoon. High surface temperature (29-30°C) are found in the South China and lower temperatures (26-27°C) prevail in the Arafura Sea and the South coast of Java. In other waters, temperatures range between 27°C and 29°C (Figures 5 and 6).

The average annual range of sea surface temperatures in the equatorial region is less than 2°C, but is slightly higher, 3°C to 4°C, in the Banda Sea, the Arafura Sea, and Timor Sea as well as in the waters south of Java. In the South China Sea the annual temperature range increase northwards, owing to the increasing inflow of cold water through the Strait of Formosa during the north monsoon. Over the shallow parts of the Sunda and Sahul shelves the temperature is uniform throughout the water column.

Figure 5 : Surface temperature of South-East Asian waters during December to May (in °C)

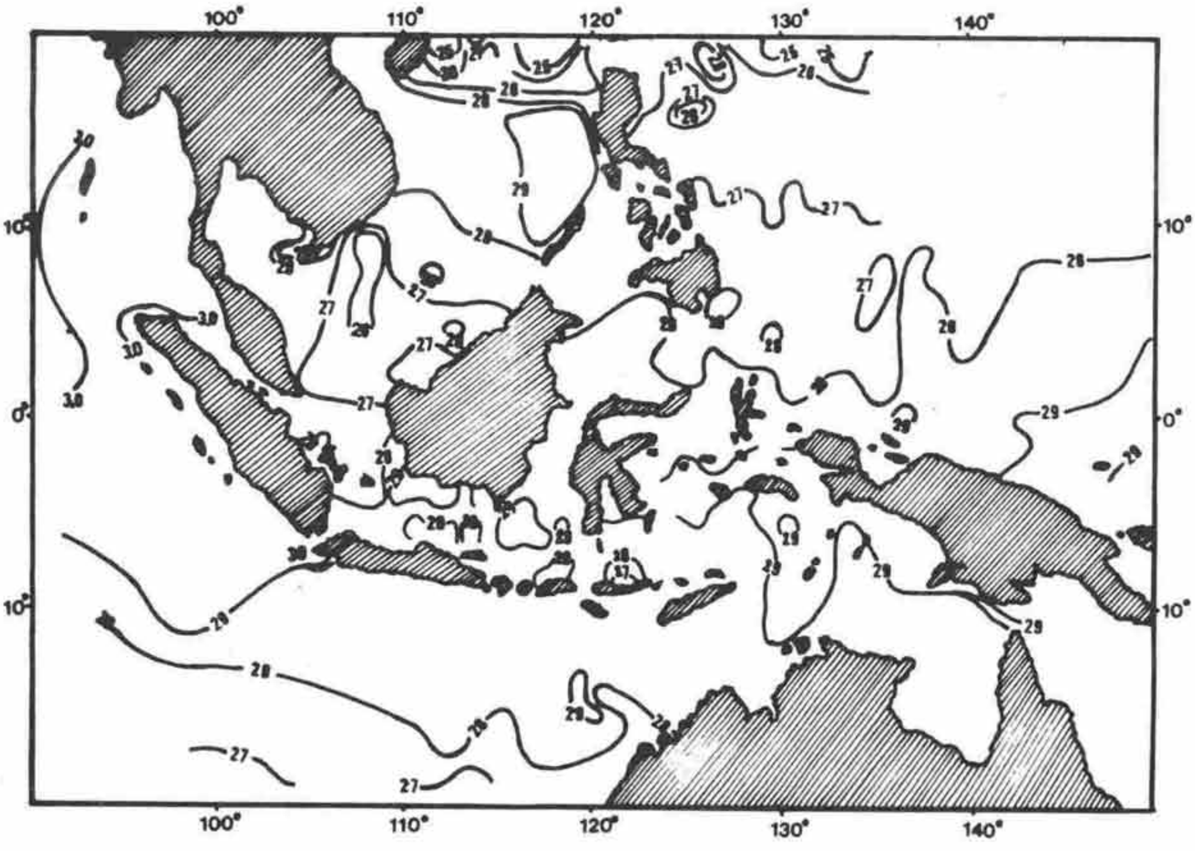
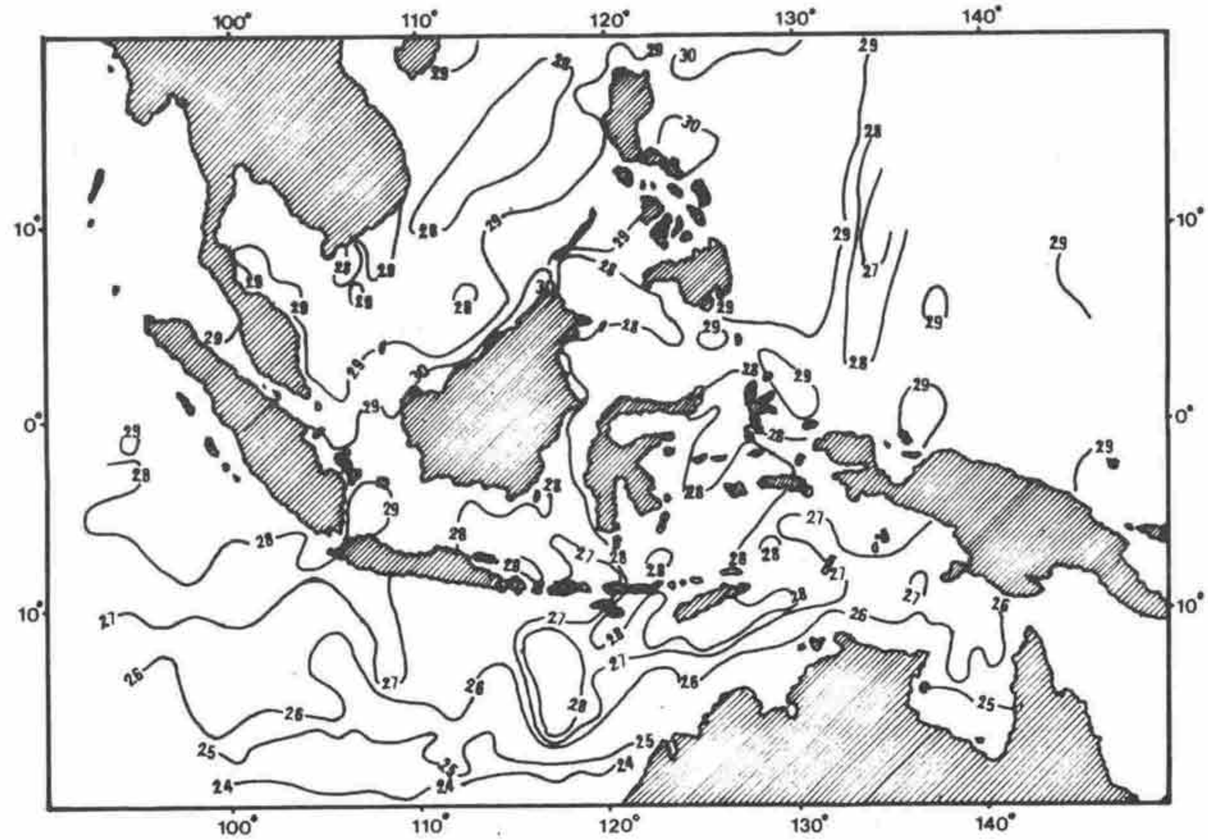


Figure 6 : Surface temperature of South-East Asian waters during June to September (in °C)



Salinity

In contrast to the uniform temperature in South-East Asian waters, the salinity is extremely variable. The high rainfall, the runoff of many large rivers, and the geographical subdivisions of the seas are responsible for this characteristic. The high rainfall lowers the salinity of the surface layer. The distribution of discharges from land and the presence of large bays and channels with little water exchange favour the formation of regions with very low salinity, which contribute to the general lowering of the salinity. The monsoons cause a rainy and a dry season which then affect the annual variation of salinity. But monsoons also govern the seasonal water circulation. These interactions between different factors and influences, the geographical structures, runoff from rivers, evaporation, and circulation result in a highly complex distribution and marked variation of the salinity in these waters.

Figure 7 shows the averaged surface salinity distribution in South-East Asian waters during the north monsoon (December-May). In general, low salinity prevails over the Sunda Shelf and the coastal areas. This low salinity is mostly due to the heavy rainfall and river discharge. During the south monsoon (June-November), however, high salinity prevails in almost all South-East Asian waters (Figure 8). The Java Sea is a good example of how the monsoons affect surface circulation and salinity variation (Doty and Soegiarto, 1970). During the north monsoon, heavy rainfall occurs throughout the western parts of the Indonesian Archipelago. The heavy rainfall, combined with the large runoff of many rivers from Sumatra, Java, and Borneo, results in a general lowering of the salinity level near the shore. Sometimes even the 30 parts per thousand isohaline is pushed far towards the open sea. At the same time, the surface current from the South China brings low salinity water into the western Java Sea and pushes the high salinity water eastwards. With the onset of the south monsoon, this low salinity water is pushed back westwards and replaced by water masses of higher salinity from the Makassar Strait and the Flores Sea. By September, the water masses of high salinity reach their maximal westward penetration.

Figure 7 : Average surface salinity of South-East Asian waters during December to May (in parts per thousand)

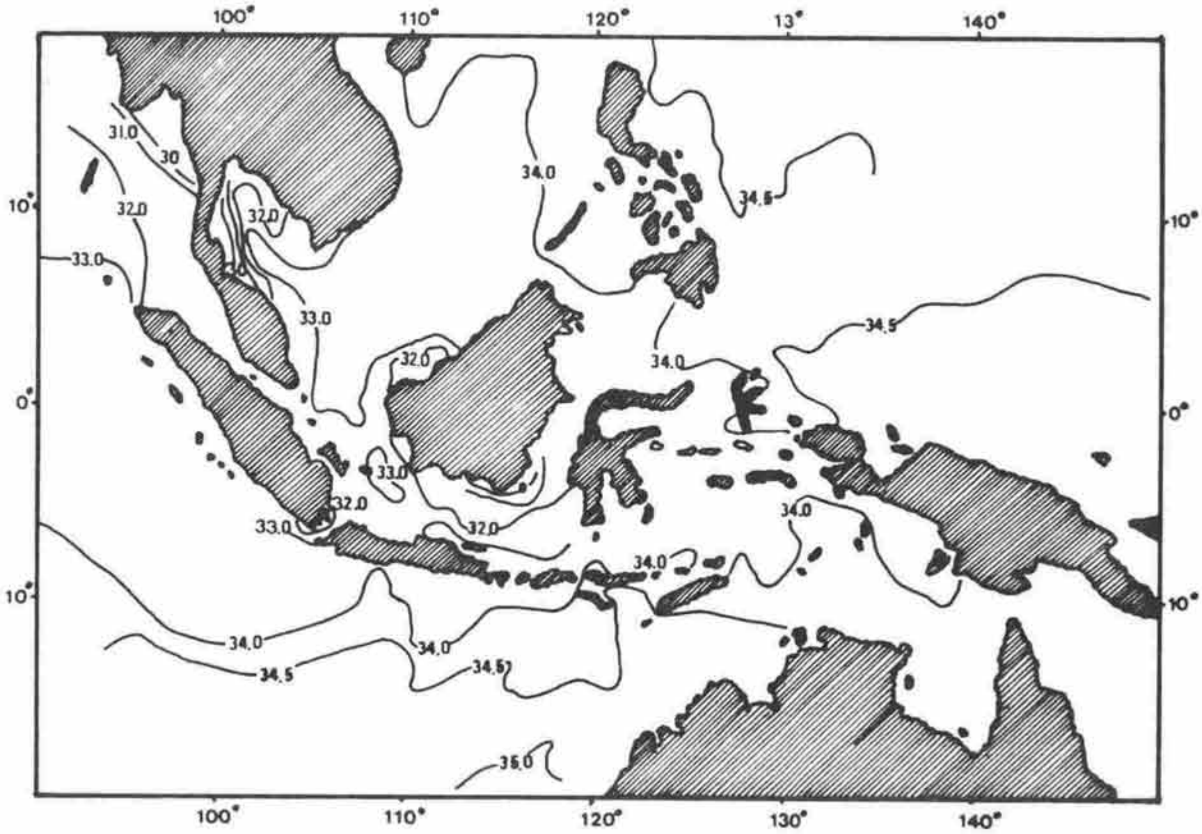
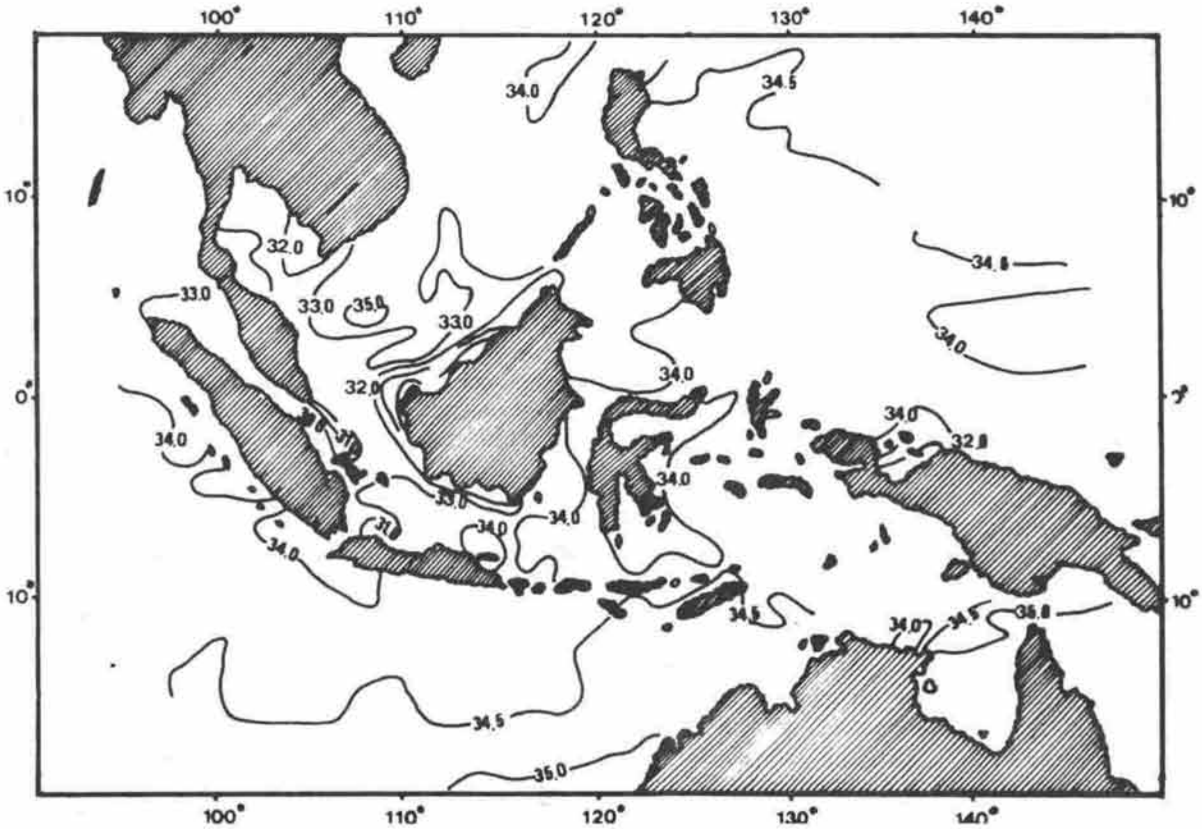


Figure 8 : Average surface salinity of South-East Asian waters during June to September (in parts per thousand)



Dissolved oxygen

In general, the surface distribution of dissolved oxygen (DO) does not show a strong seasonal variation. In the waters of the Eastern Archipelago, the surface distribution of DO varies from 4.0 to 4.5 millilitres per litre (ml/l), whereas on the Sunda Shelf, the value is somewhat lower, varying between 3.5 and 4.0 ml/l. However, at 100 metres depth, the DO distribution shows some interesting features. In Eastern Archipelago waters, the DO is relatively low, between 2.5 and 3.0 ml/l, with no apparent seasonal variation. Towards the Indian and Pacific oceans, the DO increases. In the area of the Mindanao current, DO values of 4.5 ml/l are common. Off the south coast of Java, the DO tends to increase from coastal area (2.5-3.0 ml/l) towards the open water (over 4.0 ml/l). In the South China Sea, the DO concentration varies between 2.5 and 3.0 ml/l, but increases towards the north owing to the influence of the Pacific Ocean water masses.

Water transparency

The transparency of the water generally is measured by lowering a white Secchi disc. The point at which the disc disappears visually is called the depth of the transparency. Many factors influence the water transparency, for example, the silt content and the plankton and other particulate matter in the water. Low water transparencies (less than 10 metres deep) are found in the areas off river mouths and in coastal waters around Sumatra, Borneo, and the Gulf of Thailand. In general, the transparency is high (between 10 and 20 metres) in deep water and in the open seas (20 to 30 metres). Water transparency does not show strong seasonal variation between the north and the south monsoons (Soegiarto and Birowo, 1975).

Nutrients and primary productivity

Basic to and understanding of geographic, seasonal, and other types of biological variation is an understanding of the related variations in primary productivity, the conversion rates of inorganic matter to organic forms. Our knowledge of the South-East Asian waters in this respect is still very meagre, and data have only recently begun to accumulate. A number of authors have summarized our knowledge of the primary productivity and nutrients in this region, particularly for Indonesian waters (Wyrtki, 1961; Soegiarto and Birowo, 1975).

The nutrient content over the deeper portions of the South-East Asian waters shows a distribution pattern typical of tropical waters. The surface layer is extremely poor in nutrients with phosphate content of less than 0.2 micrograms per litre (µg/l). Within the discontinuity layer, it increase rather markedly and reaches 1.5 µg/l at the lower boundary. Phosphate content of 2.5 to 3.0 µg/l is usual in the deeper layer. Over the shelves, the phosphate content varies considerably depending the proximity to the river mouths and the strength of the mixing processes. In the vicinity of river mouths, the water is normally rich in nutrients, particularly during the wet monsoon. In addition, over the shallow waters, vertical mixing can bring the minerals at the bottom to the upper layer. Consequently, there is a continuous supply of nutrients to the water column enabling a high production of organic matter.

The replenishment of the nutrients in the surface layer over deeper water is achieved through different mechanisms. It is caused either by upwelling or by the divergent movements of water at the surface, when more fertile water from the discontinuity layer can ascend and enter the euphotic zone. However, these mechanisms occur only locally and during certain seasons. The presence of such upwelling in Indonesian waters has been summarized elsewhere (Soegiarto and Birowo, 1975). In 1961, Wyrtki reported the occurrence of upwelling in the Arafura Sea and in northwestern Australian waters. In 1962, he gave a detailed account of the upwelling in the water along the south coast of Java up to the entrances of the Savu Sea. The upwelling in this area reaches its full development around September, adding about 2.4 million cubic metres per second to the flow of the South Equatorial current of the Indian Ocean. The upwelling in the Arafura Sea takes place somewhat earlier in August. In both areas, however, upwelling occurs during the winter monsoon. A few smaller upwellings in other waters, such as off the south coast of Celebes, have also been reported (Wyrtki, 1962 and Ilahude, 1970). The region of upwelling is characterized by high plankton biomass, high rates of organic matter production, low water transparency, and a high concentration of inorganic phosphorus, especially at the bottom of the euphotic layer.

In general, the surface phosphate content of the water is slightly higher during the south monsoon than during the north monsoon. There is also a gradual decrease of the content from South-East Asian waters towards the Pacific Ocean. In Eastern Archipelago waters, the average phosphate content varies from 0.2 to 0.3 µg/l in the north monsoon and increase to 0.3 - 0.4 µg/l in the south monsoon, partly owing to upwelling in the Banda Sea. In both the Java Sea and the South China Sea, the average phosphate content is between 0.1 and 0.2 µg/l in the north monsoon and between 0.2 and 0.3 µg/l in the south monsoon.

Figures 9 and 10 show the average surface primary productivity, or the rates of organic carbon production expressed in micrograms per cubic meter per hour, in South-East Asian waters during the north and the south monsoons, respectively. They are constructed from rather limited and unevenly distributed data, and should be considered as preliminary, to be improved when more complete data are available. Generally, the coastal and shallow waters show high rates of organic production (over 1.0 microgram per cubic metre per hour) of organic production, mainly owing to nutrient enrichment from rivers and from the bottom resulting from mixing. In deep seas, high rates can only be attributed to upwelling, such as that occurring during the south monsoon in the Banda Sea and the Arafura Sea, the Indian Ocean south of Java, and the Lesser Sunda Islands.

Conclusion

It is obvious that the above assessment is a very general one. At best it covers only the most general oceanographic features of the South-East Asian waters. There are still many more features that are not assessed in this paper. For more detailed information readers should consult the references below or request data and information directly from the existing regional or international data centres, such as Western Pacific Data Center, c/o Japan National Data Center in Tokyo, Japan, or the World Data Center in Washington, D.C., USA.

REFERENCES

Doty, M.S., and A. Soegiarto. 1970. The development of marine resources in Indonesia, p. 70-89. In H. Beers [ed.] Indonesia: resources and their technological development. University Press of Kentucky, Knoxville.

FAO/IPFC Secretariat. 1976. Preliminary review on the state of marine pollution in East Asian waters. Paper presented to the IOC/FAO/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, Malaysia, 7-13 April 1976. 37 p.

Ilahude, A.G. 1970. On the occurrence of upwelling in the southern Macassar strait. Mar. Res. in Indonesia 10:3-53.

Soegiarto, A. 1978. Introduction to the regional oceanography of the South-East Asian Waters. Lecture presented at the 5th FAO/SIDA Workshop on Aquatic Pollution in Relation to Protection of Living Resources, Manila, Philippines, 17 January-27 February, 1977. p. 1-11.

Soegiarto, A. 1981. The oceanographic features of the South-East Asian waters, p. 20-47. In Chia Lin Sien and C. MacAndrews [ed.] South-East Asian seas: frontiers for development. MacGraw-Hill South-East Asian Series.

Soegiarto, A., and S. Birowo [ed.]. 1975. Atlas Oceanology of the Indonesian and the adjacent waters. Book 1. The present state of knowledge of oceanology in Indonesia. National Institute of Oceanology, Jakarta, Indonesia. 79 p. + 39 maps [in Indonesian].

Soegiarto, A., and A. Nontji. 1966. A seasonal study on primary marine productivity in Indonesian waters. Paper presented at the 11th Pacific Science Congress, Tokyo, Japan. 20 p.

Wyrtki, K. 1961. Physical oceanography of the South-East Asian waters. Naga Report No. 2. Scripps Institute of Oceanography, La Jolla, California. 195 p. + 44 plates.

Wyrtki, K. 1962. The upwelling in the region between Java and Australia during the South-East monsoon. Austr. J. Mar. Fresh. Res. 13(3):217-225.

Figure 9 : Average surface primary productivity of South-East Asian Waters during December to May

(in $\mu g/m^3/hr$)

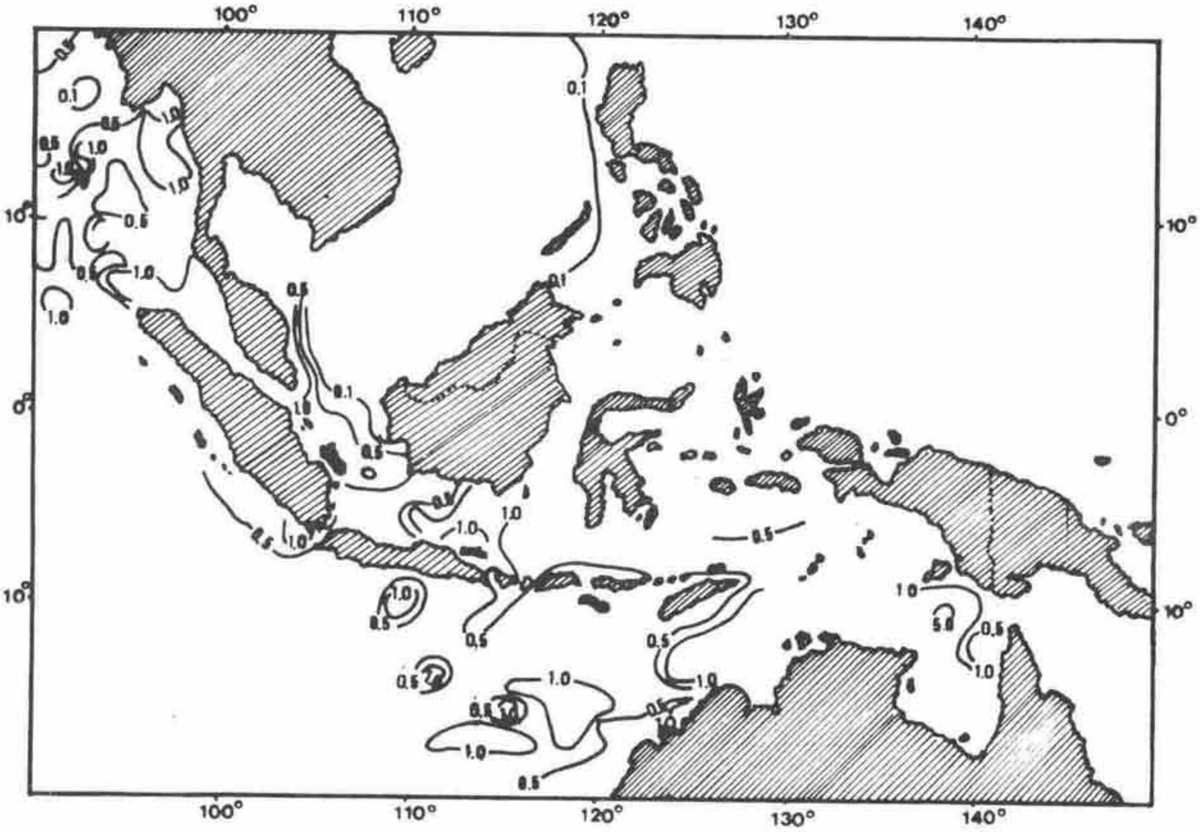
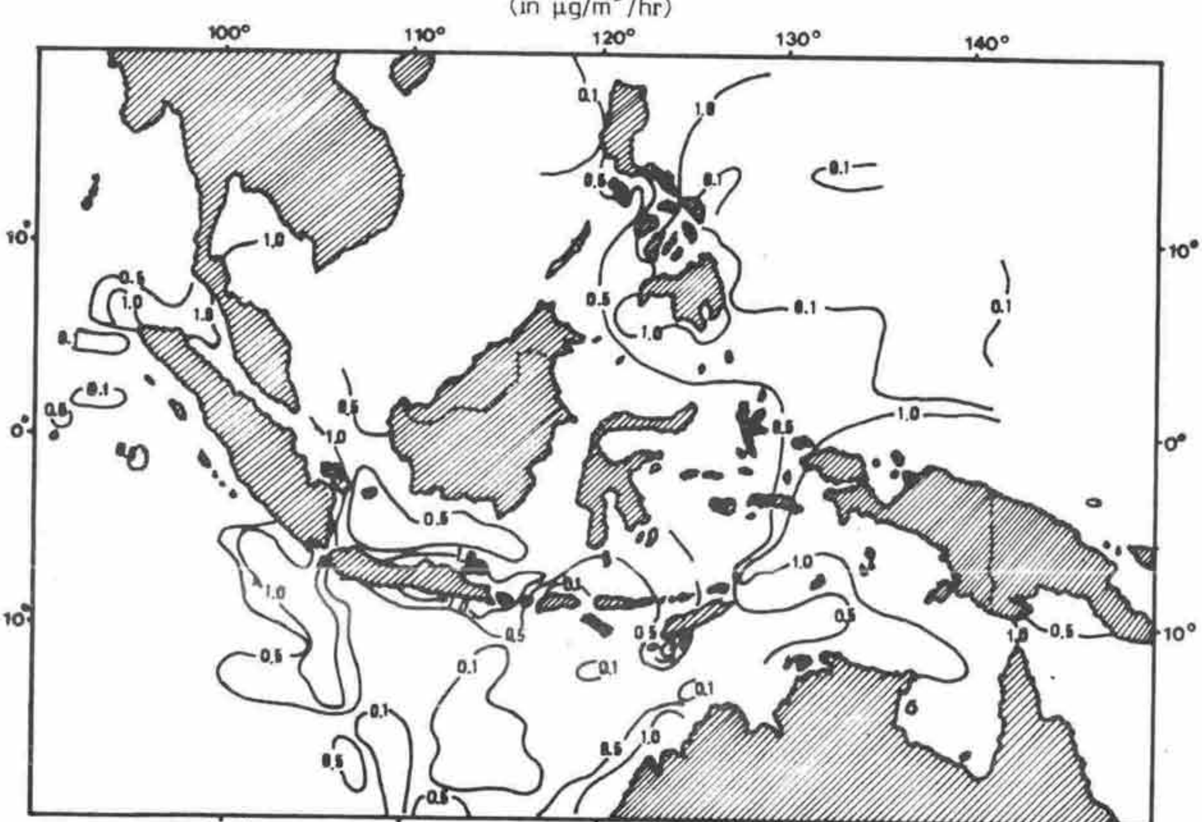


Figure 10 : Average surface primary productivity of South-East Asian waters during June to September

(in $\mu g/m^3/hr$)



CORAL REEF DEGRADATION AND POLLUTION IN THE EAST ASIAN SEAS REGION

H. T. Yap and **E. D. Gomez**
Marine Sciences Center, University of the Philippines
Diliman, Quezon City, Philippines

ABSTRACT

This paper updates knowledge on the status of coral reef resources and the causes of reef damage in South-East Asian waters. It summarizes recent data on the condition of coral reefs in each ASEAN country. Natural causes of reef degradation include water movement, geological dynamics, and biological interactions such as recently reported destruction by Acanthaster and Drupella. Among human activities causing destruction, siltation and damaging fishing techniques are still the most important, although extraction of building materials, tourism, collecting of reef invertebrates, and pollution are becoming increasingly significant. The establishment of marine reserves is one concrete response to these threats.

INTRODUCTION

The present paper constitutes an update of information presented in a previous one (Gomez, 1980) on the state of research on and degradation of coral reefs in the East Asian Seas. The status of reef resources in each of the countries comprising the ASEAN group (Indonesia, Malaysia, the Philippines, Singapore and Thailand) is first reviewed. While knowledge on this aspect is still largely inadequate, surveys have been initiated in most countries. The Philippines is most advanced in this regard where a comprehensive picture of reef conditions on a nationwide scale has emerged.

Important reef degradation problems in the East Asian Seas region were identified in the previous paper. Additional documentation on each problem in the different countries is presented here, in the hope that future directions for monitoring, management, and conservation may be indicated.

Aspects of the marine environment, coral distribution and diversity, as well as current research efforts, have likewise already been dealt with (Gomez, 1980), and will not be repeated here. A new dimension is added, however, in the discussion of measures for the conservation of critical coral reef areas by the establishment of marine parks and reserves. Among other things, current efforts in the different countries are described, as well as the latest counts on existing and proposed conservation areas.

STATUS

The distribution of coral reefs in the five ASEAN countries is detailed in Gomez (1980). Although all reef types are present, extensive fringing reefs are limited to the eastern Indonesian archipelago and the Philippines (Valencia, 1981b).

Indonesia

There exist at present no comprehensive reports on coral reef conditions in Indonesian waters. Programmes to evaluate the status of Indonesian reefs have been initiated only within the last five years (Wijsman-Best et al., 1981). Literature reviewed by Soegiarto and Polunin (1981) includes broad and detailed descriptions, mainly qualitative, of a number of localities, with the bulk of information concentrated on the Seribu Islands near Jakarta. Reef growth is known to be sparse on the east coast of Sumatra, most of the coastline of Kalimantan, and southern Irian Jaya because of intense land drainage and its concomitant stress factors (Soegiarto and Polunin, 1981).

Additional papers that have come to light contain mostly qualitative or semi-quantitative assessments of Indonesian reefs. Work on the coral reefs of the Spermonde Archipelago in South Sulawesi by Wijsman-Best et al. (1981), for example, revolves around speculations on origin, descriptions of geomorphology, and some subjective notes on reef conditions. The authors observe that it is difficult to distinguish between natural and anthropogenic causes of destruction.

McManus and Wenno (1981), working in outer Ambon Bay, provide descriptions of coral communities with an approximate scheme for ranking them according to degree of development and possible perturbation. Many of these showed signs of disruption related to human activities. After a survey in the Pulau Pari group of islands situated 35 km northwest of Jakarta, Gooding (1969) reported the best reef development as occurring in the lagoons of Goba Soa Besar and Goba Buntu, but again with no supporting quantitative data. Apparently, the islands as a whole exhibited good reef conditions as may be gleaned from the rich flora and fauna. Polunin et al. (1983) provide information on the proposed Bali Barat reserve in the form of descriptions of physical reef structure, common reef fish species, and depth ranges of the abundant hard corals. Decreases in the last parameter were found to relate to water clarity. Species richness and productivity appeared to be highest in the reefs around Pulau Menjangan.

Malaysia

In spite of a coastline greater than 1000 km, reefs in Peninsular Malaysia are concentrated in a few areas, such as around the offshore island groups in the northern and southern parts of both east and west coasts (De Silva, 1979). At present these are susceptible to exploitation through both recreational and commercial activities. Lulofs (1977) reports a marked increase in the latter since 1970, causing deterioration in the environmental condition of most reefs as well as localized depletions of certain species. It is believed that the south coast of Redang (Pulau Redang Archipelago on the southeastern coast of Peninsular Malaysia) is characterized by the most extensive and viable reefs still existing in Malaysian waters (Lulofs, 1979).

Observations by De Silva et al. (1980) have yielded a more or less comprehensive picture of reef conditions on the east coast of Peninsular Malaysia. These are reproduced in Figures 1-4, and include extent, distribution and percentage live and deal coral cover. Coral reefs encountered during the authors' survey were mostly of the fringing type, possessing an over-all similarity in terms of coral community structure and composition. Most rich shallow reefs were found in relatively sheltered conditions such as bays. Discrepancies in species diversity appeared to be associated with degree of destruction rather than locality. Reefs near uninhabited areas generally exhibited more damage.

A later survey by De Silva and Rahman (1982) covers the Pulau Paya/Segantang group of islands off the west coast of Peninsular Malaysia. Reef conditions are represented in a scheme similar to the above, and are shown in Figures 5-7.

Mention may also be made here of the quantitative assessment by Goh and Sasekumar (1981) of a fringing reef at Cape Rachado in the Malacca Straits. Live coral cover was found to be relatively low, with an average of 32.9%, along a belt transect used to sample the reef. This was attributed to sediment load.

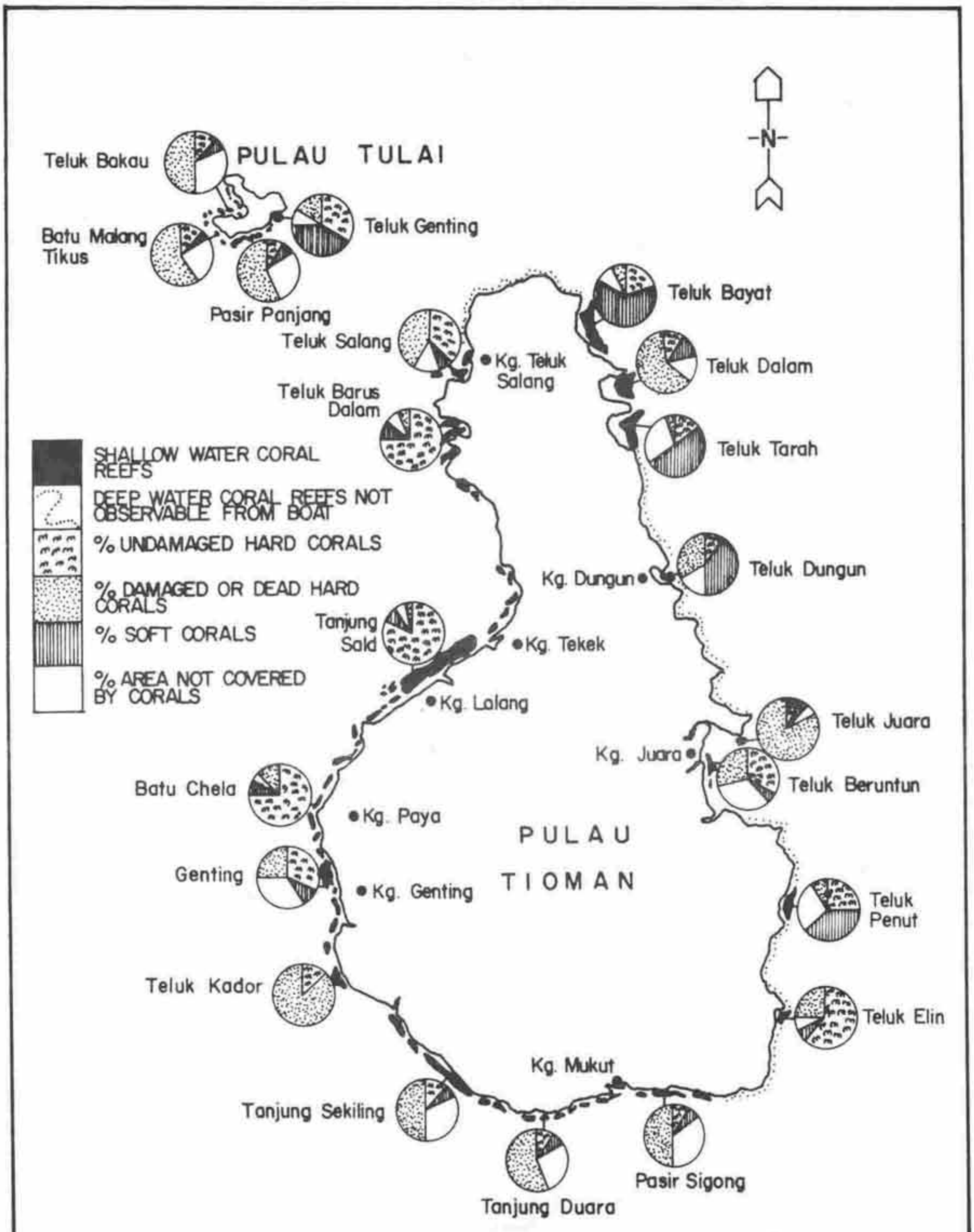


Figure 1 : The extent, distribution and quality of the coral reefs in terms of percentage cover by living hard corals, dead hard corals and soft corals around Pulau Tioman and Pulau Tulai off the East Coast of Peninsular Malaysia (after De Silva et al., 1980)

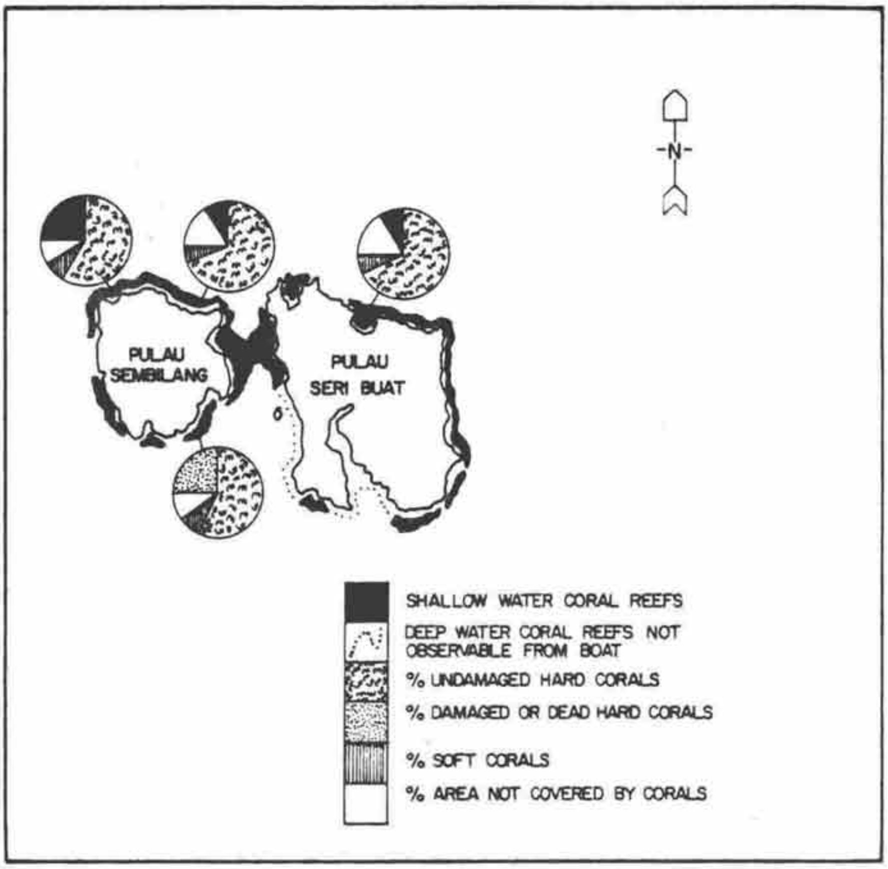


Figure 2 : The extent, distribution and quality of the coral reefs in terms of percentage cover by living hard corals, dead hard corals and soft corals around Pulau Sembilang and Pulau Seri Buat off the East Coast of Peninsular Malaysia (after De Silva et al., 1980)

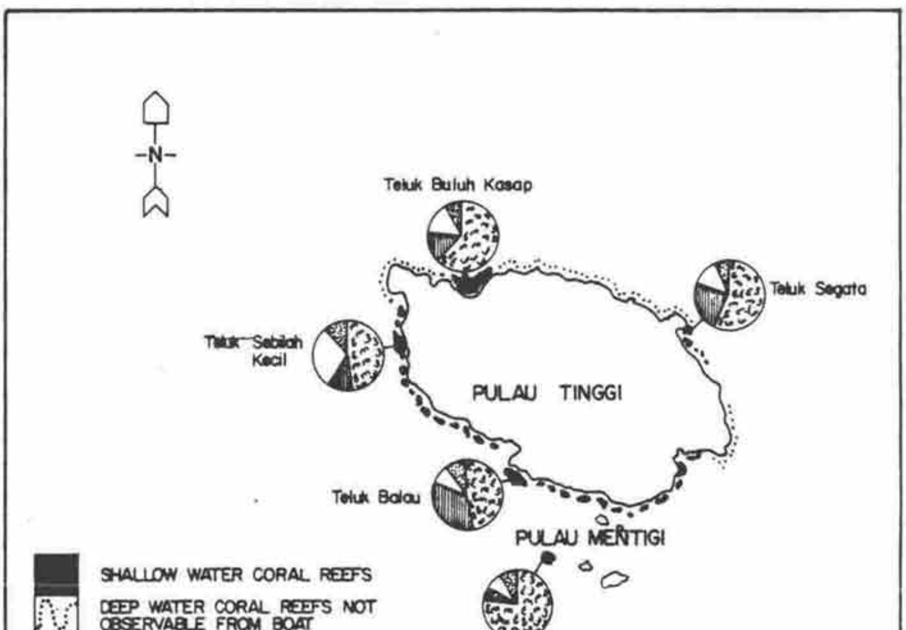


Figure 3 : The extent, distribution and quality of the coral reefs in terms of percentage cover by living hard corals, dead hard corals and soft corals around Pulau Tinggi off the East Coast of Peninsular Malaysia (after De Silva et al., 1980)

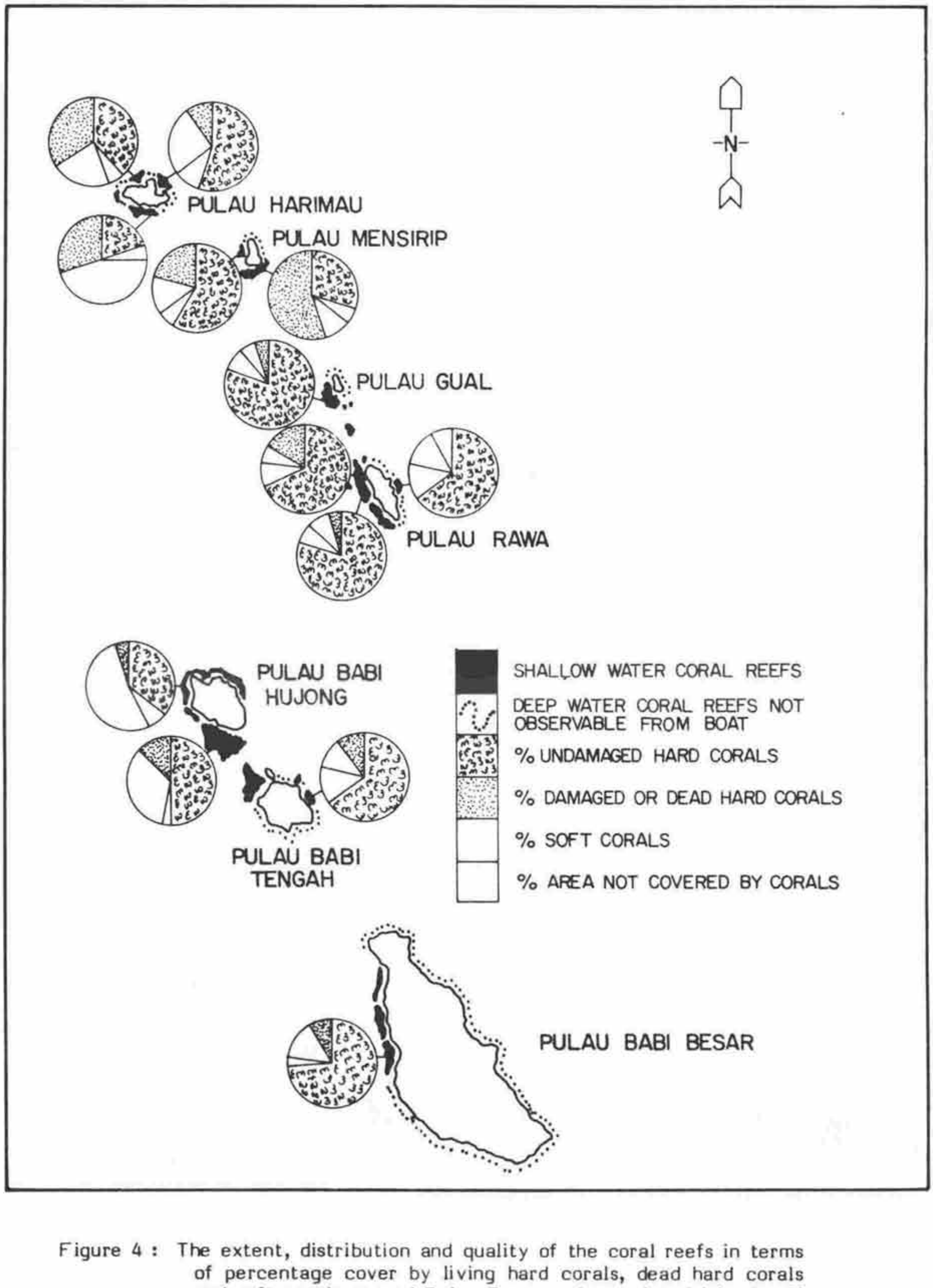


Figure 4 : The extent, distribution and quality of the coral reefs in terms of percentage cover by living hard corals, dead hard corals and soft corals around Pulau Rawa and associated islands off the East Coast of Peninsular Malaysia
(after De Silva et al., 1980)

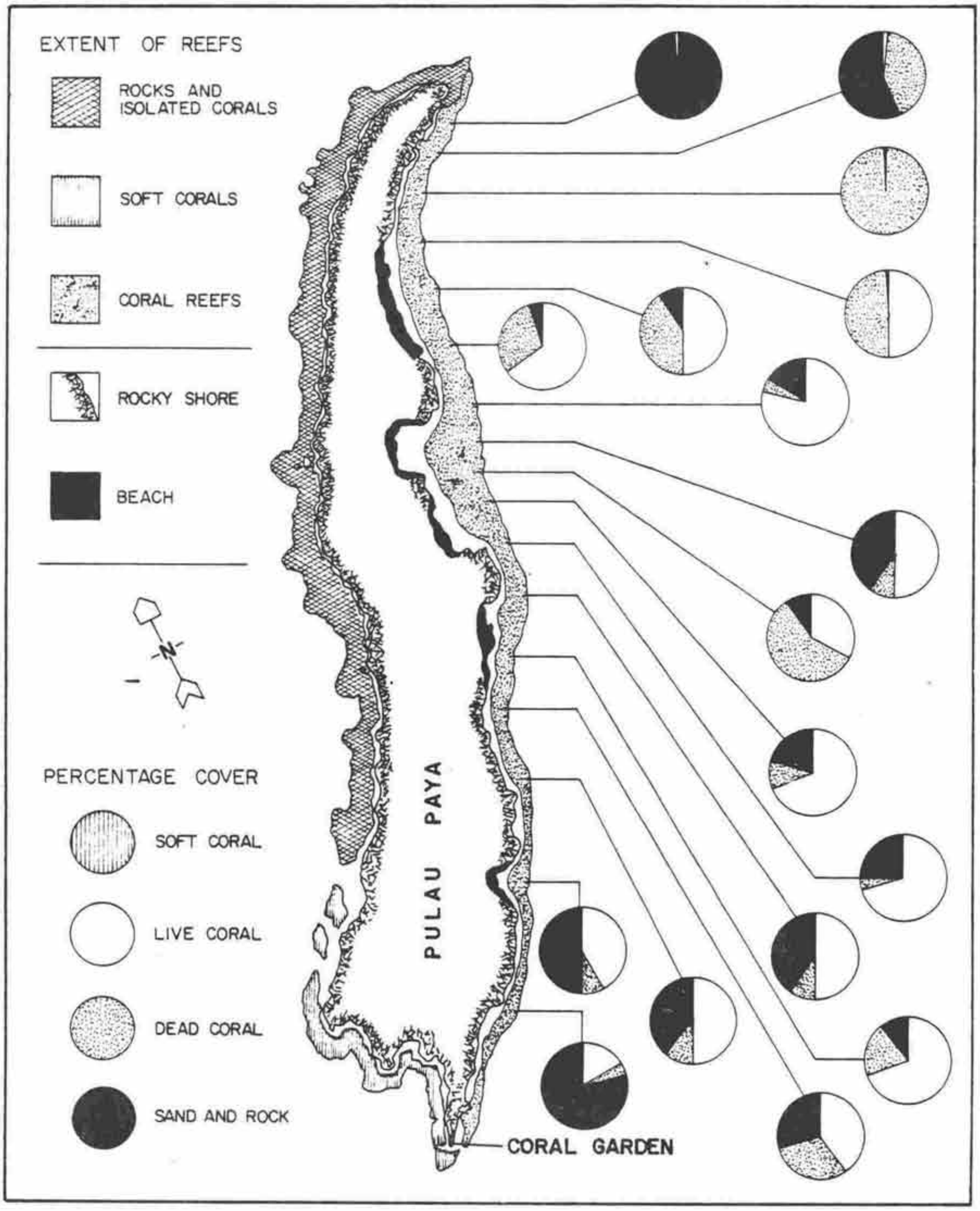


Figure 5 : The extent of the reefs at Pulau Paya and the quality of the reefs in terms of percentage cover by live and dead hard corals, soft corals, sand and rock
(after De Silva and Rahman, 1982)

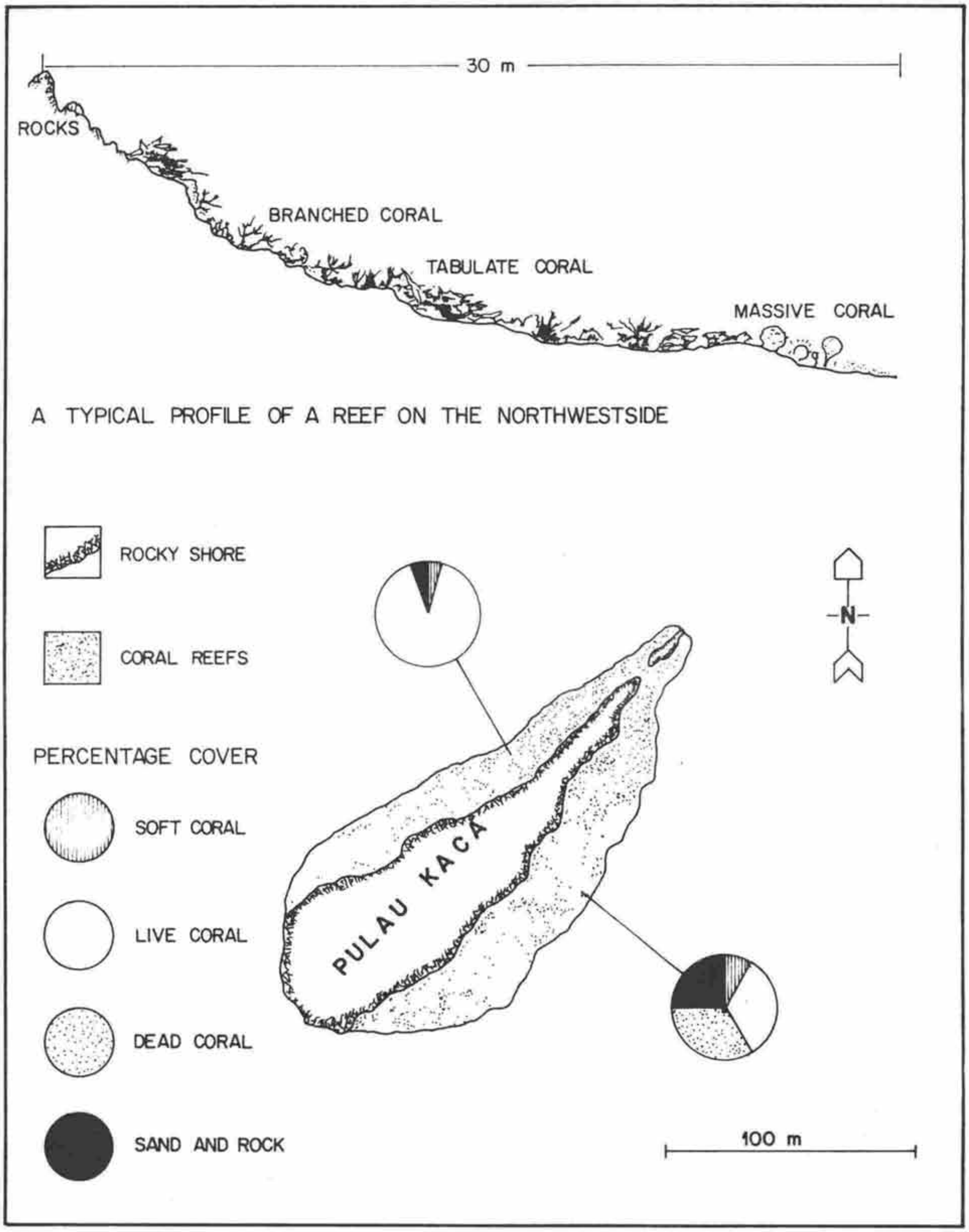


Figure 6 : A typical profile of a reef on the northwest side of Pulau Kaca (above). The extent of coral reefs at Pulau Kaca and their quality in terms of percentage cover by live and dead hard corals, soft corals, sand and rock (below).
(after De Silva and Rahman, 1982)

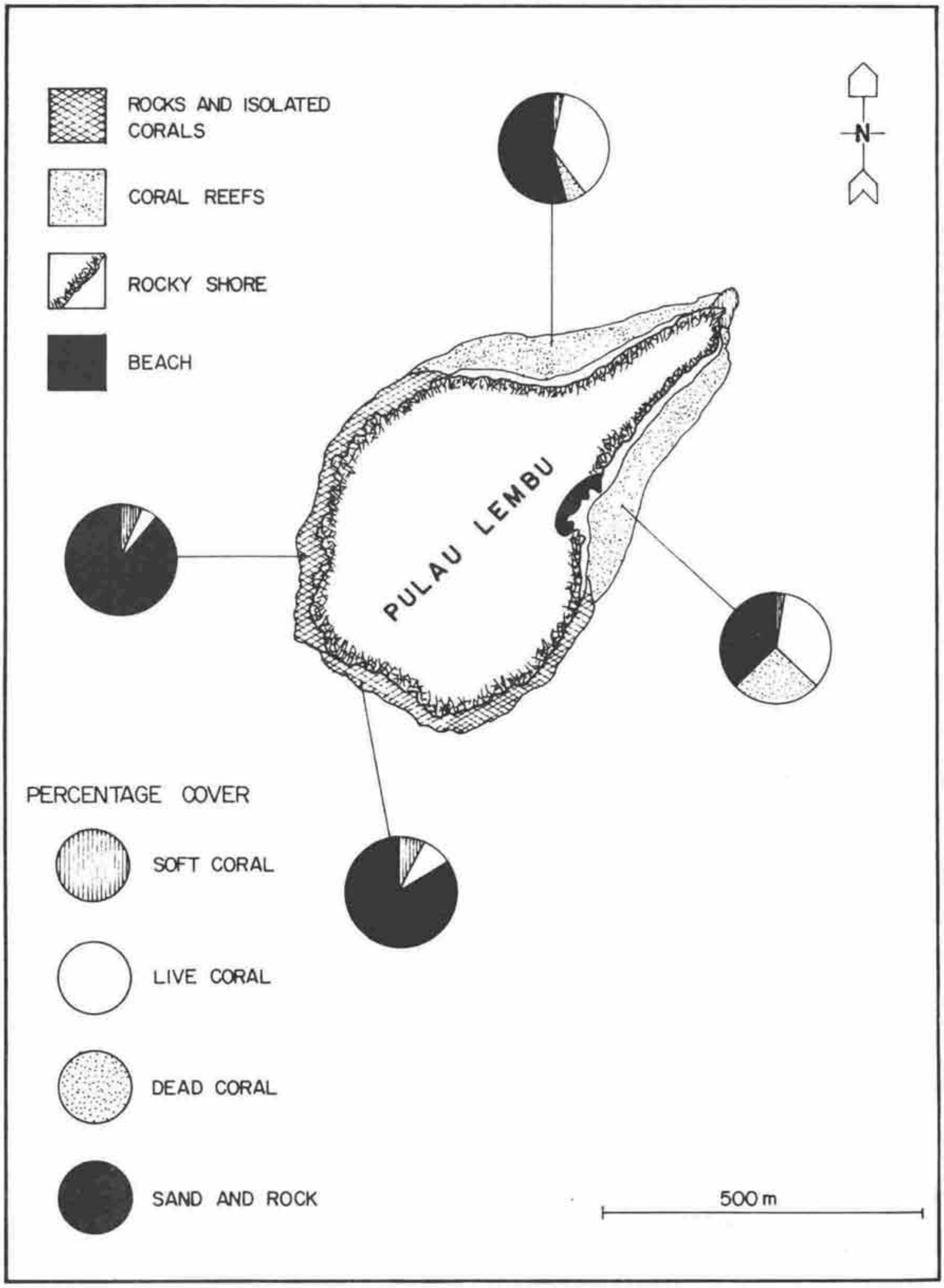


Figure 7: The extent of the coral reefs at Pulau Lembu and their quality in terms of percentage cover by live and dead hard corals, soft corals, sand and rock
(after De Silva and Rahman, 1982)

Coral reefs along the coast of Sabah are relatively undisturbed as compared to other parts of the country, though records exist of large-scale mining in the 1950's (Chua and Pathansali, 1977). After detailed work in this area, E. Wood (1979) reports a range of reef conditions for the different islands. These are presented in Table 1. C. Wood (1979) found greater numbers and a larger variety of coral-feeding chaetodontids on the east coast of Sabah, as opposed to the west coast. Chaetodontids are believed to be useful as indicators of the relative health of reefs. The greatest numbers and diversity were found at the offshore sites, such as Pulau Mengalum and Pulau Sipadan, off the west and southeastern coasts, respectively.

Qualitative descriptions are available for the Semporna islands, situated east of the Semporna peninsula, at the Borneo end of the Sulu Archipelago (E. Wood, 1981). These constitute a currently proposed marine park area. Reef development here is believed to be more extensive than in other areas around Sabah, with diversity and coral cover registering relatively high values. Some damage, however, was found to occur in the shallower areas.

Philippines

Data on the status of Philippines reefs as of 1982 are presented in Table 2. Out of a total of 632 stations surveyed to date, only 5.5% were found to be in excellent condition. Good reefs constituted a larger fraction of 24%, but the majority still fell under the fair and poor brackets, comprising 38.3% and 32.1% respectively. Thus it may be seen that reef resources for the country as a whole do not at all present a bright picture, and may be considered as relatively stressed or disturbed.

Singapore

No other publications are known of, aside from those compiled by Gomez (1980), that specifically deal on the assessment of reefs around Singapore, on either a quantitative or qualitative basis. Coral reef areas in Singapore are relatively few, and are mostly located around certain offshore islands (De Silva, 1981). A descriptive account of a fringing reef at Tanjong Teritip on the southwest coast is provided by Lee (1966). This reef is located in a relatively sheltered portion of the coast, and at the time of writing was found to be extensive and fairly undisturbed. This reef has apparently been adversely affected by development since that account.

Thailand

Studies on the conditions of reefs in Thailand are limited (Sudara, 1981). Estimates of the extent of reefs in certain localities in the Pattaya zone are provided by Ludwig (1976), and are here presented as follows:

Island	Extent of Coral (m^2)
Ko Lan	260,000
Ko Krok	13,000
Ko Sak	71,000

In addition, the following islands on the southwest coast in the Andaman Sea have been identified as having significant reef development (Ludwig, 1976): in Ranong Province - Ko Sin Hai, Ko Lam, Ko Pha Yam, Mu Ko Kam Noi and Mu Ko Kam Yai; in Phuket and Phangnga Bay - Rawai Beach, Ko Bon, Ko Hi, Ko Lon, Ko Phi Phi, Ko Mai Phai, Ko Khai, Ko Ba Da, Ko Ya Wa and Ko Kao Bulo; in Krabi province - Ko Hai and Ko Po; in Trang - Ko Muk, Ko Kradan and Ko Libong; and in Satun - Ko Tarutao.

Sudara (1981), working on the east coast of the Gulf of Thailand, provides general qualitative assessments of coral communities he encountered while doing a survey from north to south. Coral growth in different places was described as ranging from "not very healthy" to very good depending on degree of exposure, as well as influence from natural and human causes of destruction. Islands in the Andaman Sea off the coast of the Burma border were found to harbour reefs in very good condition (Sudara, 1981). Likewise, many offshore islands south of Phuket appeared to be characterized by very good reefs.

Table 1 : Overall features of certain reefs in Sabah (E. Wood, 1979)

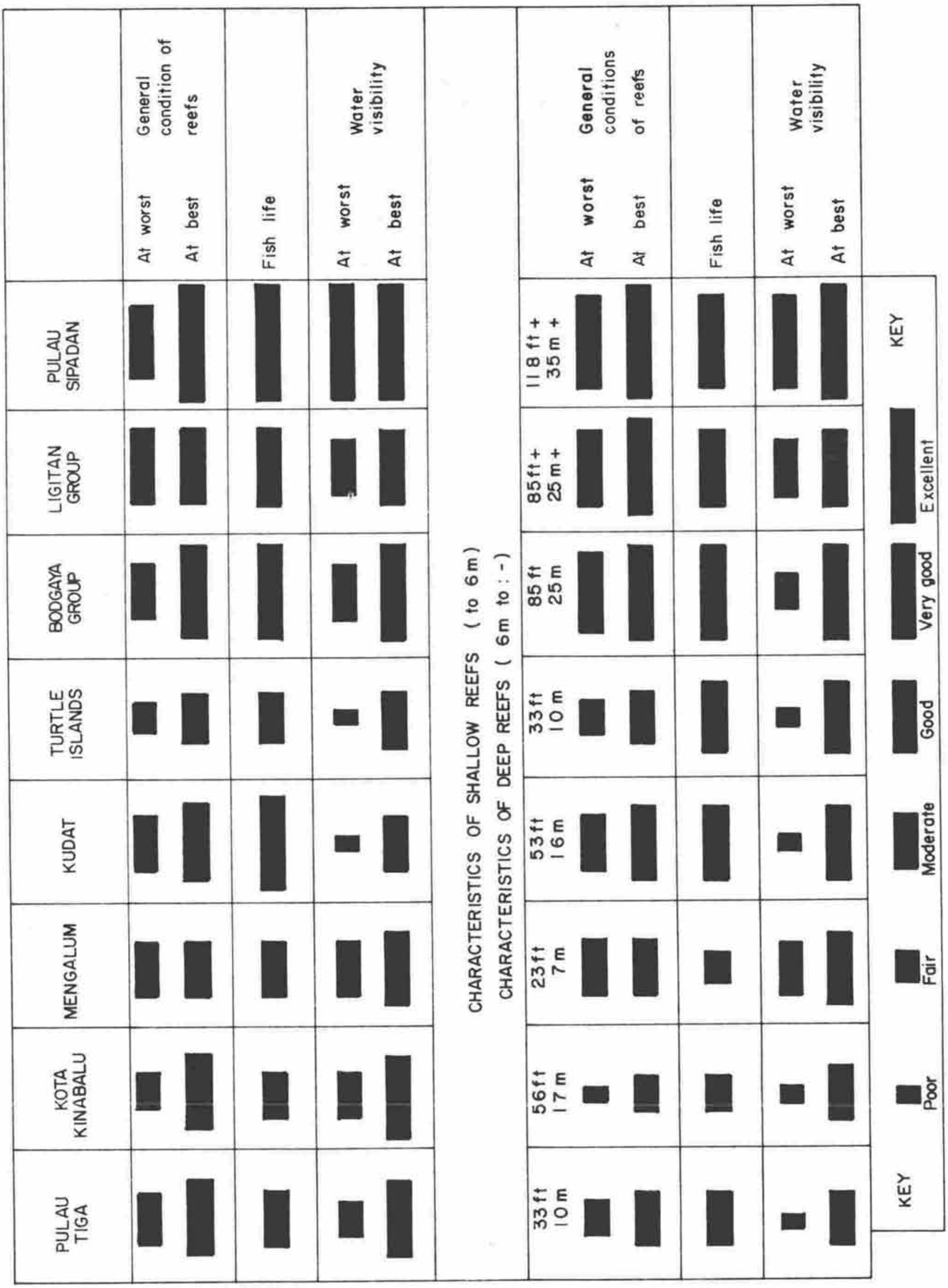


Table 2 : Status of Philippine coral reefs - 1982

Location	No. of Stations	Living Coral Cover							
		Excellent (75-100%)		Good (50-74.9%)		Fair (25-49.9%)		Poor (0-24.9%)	
		No.	%	No.	%	No.	%	No.	%
LUZON									
1. Albay	9	0	0	1	11 .1	5	55.6	3	33.3
2. Bataan	10	0	0	0	0	0	0	10	100.0
3. Batangas	25	0	0	6	24.0	11	44.0	8	32.0
4. Cagayan	4	0	0	2	50.0	2	50.0	0	0
5. Camarines Norte	13	0	0	1	7.7	7	53.8	5	38.5
6. Camarines Sur	2	0	0	0	0	2	100.0	0	0
7. Cavite	9	0	0	0	0	6	66.7	3	33.3
8. Isabela	3	0	0	2	66.7	1	33.3	0	0
9. La Union	5	0	0	1	20.0	2	40.0	2	40.0
10. Marinduque	5	0	0	0	0	4	80.0	1	20.0
11. Mindoro Occidental	31	1	3.2	8	25.8	15	48.4	7	22.6
12. Mindoro Oriental	11	1	9.1	2	18.2	4	36.4	4	36.4
13. Palawan	49	6	12.2	17	34.7	20	40.8	6	12.2
14. Pangasinan	37	0	0	8	21.6	14	37.8	15	40.5
15. Quezon	4	0	0	2	50.0	2	50.0	0	0
16. Zambales	12	0	0	2	16.7	3	25.0	7	58.3
Subtotal	**229**	**8**	**3.5**	**52**	**22.7**	**98**	**42.8**	**71**	**31.0**
VISAYAS									
1. Antique	12	2	16.7	10	83.3	0	0	0	0
2. Bohol	22	0	0	8	36.4	8	36.4	6	27.2
3. Cebu	64	6	9.4	14	21.9	27	42.2	17	26.6
Hilutangan Island	4	0	0	1	25.0	0	0	3	75.0
Mactan Island	15	1	6.7	3	20.0	3	20.0	8	53.3
Olango Island	7	0	0	1	14.3	4	57.1	2	28.6
Sumilon Island	4	0	0	3	75.0	0	0	1	25.0
4. Iloilo	64	9	14.1	18	28.1	27	42.2	10	15.6
5. Leyte	12	0	0	0	0	6	50.0	6	50.0
6. Negros Occidental	18	1	5.6	2	11.1	5	27.8	10	55.6
Refugio Island	4	0	0	1	25.0	1	25.0	2	50.0
7. Negros Oriental	98	5	5.1	20	20.4	41	41.8	32	32.6
Apo Island	5	0	0	5	100.0	0	0	0	0
8. Siquijor	31	0	0	9	29.0	9	29.0	13	41.9
Subtotal	**360**	**24**	**6.6**	**95**	**27.1**	**131**	**35.4**	**110**	**30.8**
MINDANAO									
1. Misamis Occidental	9	0	0	0	0	4	44.4	5	55.6
2. Misamis Oriental	1	0	0	0	0	0	0	1	100.0
3. Zamboanga del Norte	18	1	5.6	3	16.7	6	33.3	8	44.4
Aliquay Island	8	2	25.0	3	37.5	2	25.0	1	12.5
Selinog Island	7	0	0	0	0	1	14.3	6	85.7
Subtotal	**43**	**3**	**7.0**	**6**	**14.0**	**13**	**30.2**	**21**	**48.8**
TOTAL	**632**	**35**	**5.5**	**153**	**24.0**	**242**	**38.3**	**202**	**32.1**

Coral reefs along the northwestern coast of Phuket Island were surveyed by Chansang et al. (1981). These were generally situated in areas sheltered from direct wave action. Coral cover in the different reef areas ranged from 3% to 86%, depending on zonation and effect of prevailing environmental regimes. In general, percentage cover of the substratum was less than that of the other categories in all reefs except at Surin Beach which was relatively more exposed. The best developed reef was found at Patong Bay.

DEGRADATION

The following discussion represents additional documentation of problems already identified and described by Gomez (1980). Following his treatment, natural and human causes of reef degradation are described separately. As has been emphasized, effects of each individual factor are difficult to identify except in isolated cases, and frequently overlap.

Natural causes of destruction

Reefs growing naturally are not spared various types of perturbation. However, gradual evolution and adaptation through geologic time have allowed a dynamic balance to develop between reef growth and maintenance and the multitude of destructive processes. Occurrences of the latter in the East Asian Seas region are discussed under three major headings.

Water movement

In this category fall the mechanical forces generated by waves, currents and tides. In addition, tidal range is known to be a limiting factor to reef growth. Anomalously low tides, bringing about exposure of corals to the destructive effects of insolation or freshwater run-off, have been documented in the east coast of Peninsular Malaysia (De Silva et al., 1980), and the Laem Pan Qah Peninsula in Phuket, Thailand (Brown and Holley, 1981).

Damage to corals by the reduced salinity and sediment load associated with freshwater run-off has been reported for the east coast of the inner Gulf of Thailand (Sudara, 1981), and the Laem Pan Qah Peninsula (Brown and Holley, 1981).

Geological dynamics

This type of disturbance involves mainly tectonic movements, volcanic activity, landslides and coastal sedimentation patterns. An example of the latter is the growth of the Tjisadane river delta in Jakarta Bay which threatens to bury nearby reefs (Verstappen, 1953). The Pakis reef near Tdj. Bungin is also threatened with burial by sediments.

Biological interactions

Threats to the survival and maintenance of coral reefs are also posed by their biological components. Examples are competition of coral among themselves and with other reef inhabitants, boring of coral colonies by various organisms, disease and parasitism, and toxicity generated by certain algae. A factor which can achieve tremendous importance is predation, such as by the voracious coral-eating starfish Acanthaster planci. Destruction by this organism is considered a minor to major problem in Malaysia (De Silva, 1981). As of 1979, it was known to cause heavy damage in the northern part of the east coast of Peninsular Malaysia, in Pulau Parak off the northern part of the west coast of Peninsular Malaysia, and in reefs around several islands in Pulau Redang Archipelago, in the northern part of the East Coast (De Silva, 1979). In the Philippines, predation by Acanthaster has been reported to cause damage in the reef of Alcoy, Cebu (Alino et al., 1981), and in reefs in the vicinity of Bantayan Island, Cebu (Marine Sciences Center, 1982).

Significant destruction of specific corals in localized areas by another known coral predator has been observed in Mactan Island, Cebu (Moyer et al., 1982). This is the muricid gastropod Drupella rugosa. From the start of observation in April 1980, this organism has occurred in relatively high densities on numerous occasions, including swarms of up to 1500 individuals per 0.5 m^2.

Human activities causing reef destruction

Human activities contributing to reef degradation may be grouped into three broad categories: those bringing about the influx of significant amounts of toxic or otherwise harmful substances, those causing substantial physical alteration of the habitat, and those resulting in changes in the community structure of reef inhabitants. A particular activity may induce any or all of the above effects. Frequently, these effects are interrelated, such as in the variations in fish abundance and diversity correlated with alterations in substrate structure as determined by Carpenter et al. (1981) for certain Philippine reefs.

The relationship of increased reef degradation to rising human population levels has been noted (Gomez, 1980; McManus and Wenno, 1981; Wijsman-Best et al., 1981). Destruction of coral reefs is most evident near populated and industrial areas. Because of precisely these trends associated with modernization and population growth, many problems that do not as yet exist in severe proportions are anticipated in the near future, such as the various forms of pollution.

Siltation

Siltation constitutes one of the most important problems in the East Asian Seas region. As indicated in Gomez (1980), major causes of siltation are large-scale deforestation, bad agricultural practices, and mangrove denudation. Additional causes which may attain significant proportions in localized areas are terrestrial mining, dredging, offshore mining, oil drilling, road construction, land clearance for domestic or industrial purposes, construction of coastal structures, and harbour dredging.

In Indonesia, particularly heavy destruction by siltation is known to occur in the northern coast of Java due in part to intensive agriculture, and off Padang in western Sumatra, and Padangbai in eastern Bali from the construction of piers (Soegiarto and Polunin, 1981). Damage from siltation in Kalimantan and Sumatra is believed to be a relatively recent phenomenon (Soegiarto, 1975). Examples of resulting destructive effects are shoreline changes, modifications or burial of reefs, and alterations in patterns of sediment deposition, erosion and distribution (Soegiarto and Polunin, 1981).

Erosion caused by the dredging of reef corals is documented for Sanur and Kuta, and Balikpapan (Tsuchiya et al., 1976 and Samuel, 1979, in Ongkosongo, 1981). Sedimentation in Southwest Sulawesi is believed to have been aggravated by mangrove denudation, and appears to limit coral growth (Wijsman-Best et al., 1981). In Ambon, deforestation may be associated with high rates of siltation (McManus and Wenno, 1981).

At present, active offshore mining for tin, titanium and sand occurs in Indonesia (Cruickshank, 1981). Offshore tin mining has been a major industry in Indonesia and Thailand for many years, with as many as sixteen major dredges operating in the coastal islands. Depths worked are generally less than 15 m, with total digging depths of less than 30 m.

Recent siltation problems in Malaysia are attributed to dredging of channels for navigation near harbours and ports, and sand mining associated with the dredging operations (Chua and Pathansali, 1977). Also noted is indiscriminate deforestation (Rashid, 1980). Dredging associated with offshore mining is active in the case of iron and bauxite (Cruickshank, 1981). Offshore tin is a resource to be exploited.

Siltation from various causes is associated with the complete loss of several reefs in the Straits of Malacca, especially around Pulau Pangkor and Pulau Sembilan (Lulofs, 1977 in De Silva, 1979). Other damaged areas include reefs of some offshore islands of the east coast of Peninsular Malaysia, especially around bays near sites of agricultural development (De Silva, 1978 in De Silva, 1979). Destruction from similar causes has also occurred in Teluk Juara on the east coast of Pulau Tioman, and in the southern coast of Pulau Mensirip, both on the east coast of Peninsular Malaysia (De Silva et al., 1980).

Coral reefs in the Straits of Malacca are generally poorly developed because of high turbidity and sedimentation due to increasing land clearance (Liew and Hoare, 1979). Reef development is apparently also confined to relatively shallow depths because of reduced light intensity and smothering by sediment. In a fringing reef at Cape Rachado, significantly lower values of living coverage and diversity were attributed to sedimentation effects (Goh and Sasekumar, 1981).

In the Philippines, siltation from the different causes enumerated above is a widespread and chronic problem (Gomez et al., 1981). In addition to being a problem by itself, preliminary observations indicate that its presence in relatively large amounts may constitute an added burden to corals already stressed for another factor such as temperature (Yap and Gomez, 1981). This fact may cause the organism to exceed its threshold limits for survival.

Additional documentation of siltation effects in the Philippines exists for North Bais Bay and Pagatban River Estuary in Negros Oriental (Alcala, 1977). The poor to fair condition of the reefs, as compared to the relatively undisturbed reef at Sumilon Island, correlated with the amount of sediment as indicated by Secchi Disc readings. Damage attributable to siltation is also recorded for a reef in Albay (in the vicinity of a river mouth discharging effluents from geothermal activities), for reefs in the vicinity of Padre Burgos, Quezon, and for areas around Bantayan Island, Cebu (Marine Sciences Center, 1982). Dredging associated with offshore mining does not exist at present, but remains a potential problem in view of offshore reserves to be tapped such as gold, iron, chromite, silica sand, precious coral and coral sand (Cruickshank, 1981).

Siltation in Singapore is considered a problem, together with various construction activities along the coast (De Silva, 1981). Land reclamation is a priority in this small nation, with the result that some fringing reefs have been lost. Offshore mining does not exist as yet, but is a potential activity with respect to sand (Cruickshank, 1981).

One of the more important causes of siltation in Thailand is onshore and offshore dredging for tin, although potential offshore dredging may be in the offing for rock salt, coal, fluorite, and limestone for cement (Cruickshank, 1981). Small dredges operated in Thai waters by tin poachers number as many as 3000 at a time. Damage from siltation caused by tin dredging has been documented for the northwestern coast of Phuket by Chansang et al. (1981). Tin mines on land have been operating for about 70 years. These dump their tailings directly into the sea, or into canals leading into the sea. Tin dredging in the bay has been in progress for about six years. Three dredges operating for four months each year bring up to 200,000 yd^3 of material per month. Among other things, this has been observed to bring about a low transparency and discoloration of the water. Heavy damage has already occurred in Bang Tao Bay. In this bay, sedimentation has been so heavy in the northern portion that it built up a sand bar now connecting the island of Kala to Phuket (Sudara, 1977). Other areas that are hard hit are Ko Lon, Ko Hi and Ko Bon (Ludwig, 1976).

Brown and Holley (1981), working in the reef flats of the Laem Pan Qah peninsula in Phuket, detected considerably elevated levels of heavy metals in various invertebrate species from the reef below the tin smelter. Dead coral cover, however, was not significantly different from that of a reef situated several kilometres away.

Sudara (1981) observed reef damage from siltation in several localities along the east coast of the Gulf of Thailand.

Fisheries-related destruction

Destructive fishing is believed to be responsible for major reef degradation on a local scale in many areas (Gomez, 1980). Foremost among its agents is the use of explosives such as carbide bombs and dynamite. The wastefulness of such a practice is well known. Additional destructive fishing methods are the muro-ami and kayakas fishing techniques. Other harmful practices associated with fishing are enumerated in Gomez (1980). Additional discussions of the relevant ones in each country are presented here.

In Indonesia, the use of explosives in fishing is known to be a problem in the Seribu Islands, around Komodo in Nusa Tenggara, near Ambon (Soegiarto and Polunin, 1981), in the proposed Bali Barat reserve (Polunin et al., 1983), and in the Spermonde Archipelago (Wijsman-Best et al., 1981). In eastern Indonesia, blast fishing is believed to have caused the destruction of 30% and 80% of the islands of Pombo and Papagaran, respectively (Kvalvagnaes and Halim, 1979a and b, in Ongkosongo, 1981). Concern for the effects of the use of explosives has existed in the country since the 1920's (Soegiarto and Polunin, 1981).

The use of cyanide, another harmful fishing practice, occurs at least in eastern Java, and off Ujung Pandang (Soegiarto and Polunin, 1981). Indonesian reefs, in general, also suffer from the traditional heavy exploitation of food fishes. In Ambon, fishermen inflict damage on corals when they break these to shake out small fish, use them to disguise fish traps, drag the traps or weighted nets across the reef surface, and use hook-like anchors which break corals (McManus and Wenno, 1981). The famous reefs in the Islands of Banda have been partly damaged by fishermen dragging their fish traps over the coral heads (Soegiarto, 1975).

A growing cause for concern is the aquarium fish trade (Robinson et al., 1981). Although this fishery is still relatively small as compared to the total take of food fishes in Indonesia, conflicts arise when it comes to the maintenance of natural populations, such as in reserve areas. In addition, high mortality, and thus wastage, is known to occur during capture and transfer to middle-men. Of particular concern is the use of non-specific toxic chemicals which also cause the unnecessary local mortality of surrounding reef organisms. Sometimes, even the living coral substrate is destroyed in the search for specimens. In the proposed Bali reserve, species apparently depleted due to aquarium fish collecting are the anemone fish, the butterfly fish, and the angel fish (Polunin et al., 1983). Depletion of certain species has also occurred in the Seribu Islands and around eastern Java (Soegiarto and Polunin, 1981).

The main problem plaguing Malaysian reefs where fishing practices are concerned is the use of explosives. Although illegal, this is still practised widely (Langham and Mathias, 1977). In some areas, the practice is usually attributed to foreign fishermen, although some locals may be involved (De Silva, 1979). Heavy damage inflicted on reefs by blast fishing is reported to occur in many reef areas in Peninsular Malaysia, on the east coast and on the northern part of the west coast (De Silva, 1979). Investigations on the east coast of Peninsular Malaysia revealed the recent widespread use of explosives, particularly in the uninhabited localities of Pulau Tioman and Pulau Tulai (De Silva et al., 1980). In northwest Sabah, areas known to be stressed are those around Kota Kinabalu, Kudat and Labuan (Langham and Mathias, 1977).

In the Philippines, the use of explosives in fishing is likewise widespread, though illegal (Gomez et al., 1981). This practice was a major factor accounting for the condition of dead reefs observed in Bataan (Gomez, 1977). Effects of dynamite were also noted in the reef around Mactan Island, Cebu, in addition to damage by muro-ami and kayakas fishing, and anchoring by fishing boats (Sy et al., 1981). Additional evidence of blast fishing has been observed in Joroan, Albay, and in the vicinity of Bantayan Island, Cebu (Marine Sciences Center, 1982).

In a contribution to the general effort to curtail this harmful practice, Ronquillo (1950, 1961) presents descriptions of the anatomy of fish affected by dynamite to facilitate ready identification and, hopefully, apprehension of possible culprits. A study by Porter et al. (1977) in the outer barrier reef at Bohol, Philippines, suggests that dynamite fishing not only destroys resident reef fish populations and the reef surface, but also reduces demersal plankton production. The food supply available for the regeneration of reef benthos and fishes is thus also diminished. Alcala and Gomez (1979), investigating reef recovery after blast fishing in the central Visayas, postulated a recovery time to 50% areal cover (here considered to be indicative of good reef conditions) of approximately 38 years.

Finally, the aquarium fish industry, known to cause considerable damage to reef populations if mismanaged, is assuming larger proportions in the Philippines. It is currently a multi-million peso industry, with over 200 species of reef fish exported to other countries (Albaladejo and Corpuz, 1981).

Problems in Thailand involve the use of dynamite, electric shocks, and poisons to catch fish (Monkolprasit, 1981). The use of dynamite has caused extensive damage at Ko Lan Island in the Pattaya region - approximately 20% of the 260,000 m^2 of reef area (Ludwig, 1976). Some damage in Patong Bay on the western side of Phuket is probably due to blasting (Sudara, 1977). Sudara (1981) found evidences of illegal dynamite fishing along the east and west coasts of the Gulf of Thailand, and on the coast of the Andaman Sea. Destruction from bottom trawling was also observed in these localities. As far as exploitation of aquarium fishes is concerned, about 45 species are known to be exported from the country (Lubbock and Polunin, 1975).

Building materials

Throughout the ASEAN nations, corals are being harvested for a variety of construction purposes, for the production of lime and, more recently, the making of decorative tiles (Gomez, 1980). Additional accounts are presented here of the problem as it occurs in Indonesia and Malaysia.

In Indonesia, the extraction of coral and sand for the construction of roads, buildings, jetties and fishing weirs has caused heavy reef destruction, in spite of attempts to ban it in certain areas (Soegiarto, 1975; Soegiarto and Polunin, 1981). Estimates are available of as much as 12-25,000 m^3 having been taken annually (Hardenberg, 1939 in Soegiarto and Polunin, 1981). Problems of reef perturbation from coral mining activities are known for Jakarta Bay, southern Bali in the Sula islands, eastern Java, around Ujung Pandang in south Sulawesi (Soegiarto and Polunin, 1981), Ambon (McManus and Wenno, 1981), the Spermonde Archipelago (Wijsman-Best et al., 1981), the Seribu coral island area, the Komodo Islands, and the proposed nature reserves at Pombo and Papagaran Islands in eastern Indonesia (Ongkosongo, 1981). Coral mining is believed to have caused a decrease of the coral islands Ubi Besar and Nirwana to about one-half their original size (Ongkosongo, 1981).

The mining of reefs for limestone is probably the single most important form of human interference in the proposed Bali Barat reserve (Polunin et al., 1983). One of the more badly-hit areas in Bali is Sanur Beach, which is now reputed to be dirty and eroded (Anon., 1980). Large-scale coral extraction is also believed to be significantly lowering mean reef height, resulting in changes in wave energetics and beach form, and a decreased amount of sediment available for beach formation (Robinson et al., 1981). At Nusa Dua and Jembrana, both tourist areas, there are 139 limestone kilns (Anon., 1980). It is estimated that the 7.5 kilometres of coast loses 4000 m^3 of coral reef every month to this activity. Although mining for limestone is supposedly banned, enforcement is lax because ordinances have been delegated to the provincial government for their action; local authorities for the most part are unenthusiastic about eliminating a labour-intensive industry because of possible social and economic repercussions (Robinson et al., 1981).

Coral collection for construction purposes in Malaysia takes place near most coastal towns (Chua and Pathansali, 1981). Harvesting is carried out either by fishermen at low tide, or by large, crane-rigged barges. The operation frequently involves huge heads being dragged across the reef, inflicting considerable damage. In such an activity, the economic loss has been estimated to exceed all other benefits. Mining of sand is undertaken for reclamation and building purposes.

In Sabah, the construction of a port at Tawau involved the extraction of coral blocks from reefs off Pulau Bum Bum (E. Wood, 1981). Elsewhere, coral mining is carried out for road building and land reclamation, especially in the Labuan and Kota Kinabalu areas (Langham and Mathias, 1977). It is estimated that in recent times, about 20,000 yd^3 of coral have been removed per year. On an area basis, 100 coral heads mined per day is the equivalent of 43.7 ha of reef destroyed per year, or approximately 6.8 km of reef front per year, given an average width of 200 ft for the reef slope.

Tourism

The development of tourism has definitely resulted in reef perturbation in a number of localities. For example, siltation and pollution can and have resulted from the construction and maintenance of tourism facilities. Tourist activities which directly result in damage to the reef include spearfishing, diving, collection of the reef biota, and anchoring of boats on corals. A general review of the effects of tourism on the coastal environment is given by Gomez (1983a).

Tourism is reported as a threat to coral reefs in the Spermonde Archipelago in Indonesia (Wijsman-Best et al., 1981). In Malaysia, plans to develop tourism are at present heavily concentrated on the east coast, with the Malaysia Tourist Development Corp. intending to develop offshore islands as well (Anon., 1979). Careful, long-term management is certainly called for if reefs in the area are to be preserved. In a number of popular areas throughout the country, spearfishing by sportdivers is believed to be responsible for the decimation of certain species (Rashid, 1980).

Heavy tourism pressure currently threatens reefs at Larn Island in the Gulf of Thailand (Srithunya et al., 1981). At Patong in the northwestern coast of Phuket, extensive dead coral cover in Acropora-dominated areas is presumed to be caused by boat anchoring (Chansang et al., 1981). Collection of reef organisms by tourists likewise poses a threat (Ludwig, 1976).

Collecting of reef invertebrates

The illegal export trade in decorative corals continues to be a major problem in the Philippines, generating concern among various sectors. There is no reason to assume that this problem would not be felt by the other ASEAN nations, particularly those harbouring extensive coral reefs, in view of the growing worldwide demand for this commodity. Aspects of the coral trade in the broader Pacific region, as well as management possibilities, are discussed in another paper (Gomez, 1983b).

Aside from the collection of the corals themselves, additional problems involve other reef invertebrates which are sometimes harvested to the point of depletion. Such is the case for shells, echinoderms, crustaceans and other groups in reefs of the Spermonde Archipelago (Wijsman-Best et al., 1981). The collection of shells and corals for commercial purposes constitutes a major problem in East Malaysia (De Silva, 1981). Reefs at Larn Island in the Gulf of Thailand are disturbed partly by the collection of the reef biota for souvenir purposes (Srithunya et al., 1981).

Other Pollutants

The different forms of pollution are associated mainly with the drive of all countries in the East Asian Seas region for economic development and modernization, and associated activities such as the quest for oil. Examples will be presented for each country.

In Indonesia, pollution is likely to be significant in relatively sheltered areas where chronic conditions can develop, such as the Bay of Jakarta and the Bay of Ambon (Soegiarto and Polunin, 1981). Such pollution may stem from various causes. In localities where urbanization is taking place, nearby reefs may be subjected to the influx of industrial effluents. The intensification of agricultural programmes has resulted in an increase in the amount of pesticides since 1968 (Soegiarto, 1975). A fraction of this has certainly leaked out into the coastal environment where traditional artisanal fisheries contribute 98% of marine fisheries production.

Oil poses a major potential threat to Indonesian reefs. At present there are reports of oil and gas in commercial quantities in reefs throughout the country, so that a distinct possibility exists of drilling on living reefs on a large scale (Soegiarto and Polunin, 1981). Current problem areas are areas off the northwestern coast of Java, off the coast of Kalimantan, north of Balikpapan, and many coral islands of Seribu (Ongkosongo, 1981; Soegiarto, 1975). Concurrent with the increase in oil production is the mushrooming of petrochemical industries. A main problem associated with these is that of disposal of waste materials, so that containers frequently pile up along the coastline (Soegiarto, 1975).

Other pollutants consist of domestic refuse. Ambon Bay, for example, is littered with organic wastes, plastic containers, rags, cans, bottles and soap (McManus and Wenno, 1981). The proposed Bali Barat reserve is marred by domestic and industrial rubbish, particularly plastic bags (Polunin et al., 1983).

Like Indonesia, some reefs in Malaysia are threatened with oil pollution. Petroleum exploration is at present concentrated off the east coast of Peninsular Malaysia, precisely where some of the best reefs are found (Rashid, 1980). In the Semporna islands, tar balls were spotted in several beaches, a presumed source being the soft tar used to coat oyster rafts in a nearby pearl farm (E. Wood, 1981). Finally, industrial effluents are a growing problem throughout the country (Rashid, 1980).

In a study believed to be the first of its kind, Hudson et al. (1982) determined the effects of commercial drilling in an on-site investigation of a reef situated off northwest Palawan, Philippines. Drilling mud was not related to any suppression of massive coral growth, although this may have been due to its effective dispersal by the strong currents characterizing the area. The cuttings, however, were presumed to have caused a 70-90% reduction in the amount of foliose, branching and plate-like corals, probably by direct smothering.

In Singapore, much of the inshore coral at Labrador beach is believed to have been killed off by increased discharges of oil (Sharma, 1961).

Evidences of domestic effluent were observed by Sudara (1981) near the tip of Sataheep, in the east coast of the Gulf of Thailand. At Larn Island, various pollutants are a cause of growing concern (Srithunya et al., 1981).

An activity assuming significant dimensions in the South-East Asian region as a whole is shipping (Valencia, 1981a). Although its impacts are not as yet felt on a large scale, they will certainly pose a very real problem in the future, and as such deserve careful attention and planning. To be looked-out for, for instance, are possible spills of the more critical cargoes such as oil, liquefied natural gas (LNG), uranium ore, nuclear spent fuel and, eventually, hydrogen.

ESTABLISHMENT OF MARINE RESERVES

The increasing extent and severity of reef degradation throughout the world has stimulated some concern for their management and preservation. One of the more important concrete steps taken is the move to establish marine reserves in critical reef areas. Such a move has gained a foothold in the East Asian Seas region, although more vigorous and concerted effort is undoubtedly called for. Some of the steps taken toward this end in each country are described in this paper. A review of the major concepts, recent trends, and important issues pertaining to the marine reserve movement on the world scene, with particular focus on the Philippines, may be found in Gomez and Yap (1982).

In Indonesia, nature conservation began to receive higher priorities in central government planning in the 1970s, a manifestation of which was the growing commitment to the establishment of marine parks and reserves (Robinson et al., 1981). Other encouraging signs were the 1977 accession to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the creation of the Ministry of Development Supervision and Environment. Recent years have also seen the formation of the National Commission on Marine Parks System (Soegiarto, 1981), with the responsibility to develop a master plan for marine parks as an integral part of the country's Nature Conservation Programme. More than 40 potential sites are under study. Assistance is provided by outside sources such as the World Wildlife Fund (WWF), the Food and Agricultural Organization of the United Nations (FAO), Unesco, and UNDP. Government plans include increasing the area coverage of nature reserves from 8 to 10 million hectares within the next decade or so. There are reported at present five existing coral reef reserves in Indonesia, and two projects (Salvat, 1982). Proposed areas for declaration as marine reserves include reefs in the Bay of Jakarta (Unar, 1979), the Spermonde Archipelago (Wijsman-Best et al., 1981), and the marine area around Bali Barat (Polunin et al., 1983).

In Malaysia, there are at present at least three existing coral reef reserves, and two projects (Salvat, 1982). Proposed coral reef reserve areas include Pulau Redang Archipelago on the east coast, and Pulau Redak and the 4-island group off Kuala Kedah on the west coast (Lulofs, 1977, 1979; De Silva and Rahman, 1982); and the Pulau Tega group and Pulau Balumbangan in Sabah (Langham and Mathias, 1977). Extensive baseline surveys also in Sabah waters have been conducted by E. Wood (1979, 1981), as a prelude to the possible establishment of additional marine reserves. These include areas off the northeast coast of Sabah and around Kudat, and, more recently, islands off the Semporna peninsula and the oceanic island of Pulau Sipadan.

Trends in the Philippines are detailed in Gomez and Yap (1982), and are briefly summarized here. Moves towards the protection and conservation of the marine ecosystem may be considered to have started in 1932, with the establishment of the National Park System by virtue of Act No.3915 (Palaganas and Bina, 1981). To date there are some sixteen designated marine conservation areas (White, 1981). The only active marine reserve at present, however, is the one at Sumilon Island in the central Visayas administered by Silliman University. Proposed reserve areas include reefs at Sombrero Island, and Apo off the coast of Mindoro Occidental. A particularly innovative strategy is the involvement of local communities in conservation through the establishment of what are termed "municipal coral reef parks" (Castaneda and Miclat, 1981). Pilot sites exist at Guindulman, Bohol, and Sagay, Negros Occidental. Experience has shown that the implementation of reef conservation programmes is more effective where local communities are made to understand their significance (White, 1981), thus emphasizing the need for continuing education programmes (Cabanban and White, 1981). In the area of legislation, the reef conservation effort may be helped by the recent drafting of an Executive Order establishing a Marine Parks Management System, with emphasis on endangered marine species and their respective habitats.

There appear to be at present neither existing nor proposed coral reef reserves in Singapore (Salvat, 1982).

In Thailand, there is one reported existing coral reef reserve (Salvat, 1982). Efforts exist to conserve certain areas in the Gulf of Thailand, among them reefs around the islands off Pataya and Rayong, and the Ang Tong group of islands (Sudara, 1981). In addition, recommendations have been made for the classification of areas for preservation, tourism, and fisheries development, as well as the launching of informal education campaigns.

SUMMARY

Efforts to quantitatively assess the conditions of coral reefs on a relatively large scale date back only to the last decade or so in most of the ASEAN countries. These efforts, however, have picked up considerably in recent years, especially with the active incorporation by national governments of resource conservation and management goals in official policies. A comprehensive picture of the status of South-East Asian reefs should be emerging within the foreseeable future with the inception of the coral project of the East Asian Seas Regional Programme of UNEP.

Natural causes of reef destruction continue to figure significantly in the region. These include water movement, geological dynamics and biological interactions. Recent documentation exists of damage to corals caused by predation by the starfish *Acanthaster planci* and the gastropod *Drupella rugosa*. Other reports of destruction involve exposure during low tides, freshwater run-off and burial by river-borne sediments.

As gleaned from the literature, siltation and destructive fishing still constitute the most important man-caused factors of reef degradation in the East Asian Seas. The more significant activities bringing about siltation are widespread deforestation, bad agricultural practices and mangrove denudation. Dredging along the coast for various purposes including offshore mining is, however, also assuming greater importance.

Destructive fishing remains associated primarily with the use of various types of explosives, in spite of their ban in most places. The aquarium fish industry, for the most part overlooked, is a growing cause for concern, especially when mismanaged.

The mining of coral reefs for building materials has resulted in severe damage in a number of localities. Of a lesser magnitude but nevertheless deserving of attention is reef perturbation brought about by tourism and collection of the biota.

Various forms of pollution are associated with a growing human population and accelerated industrialization. Although their effects are concentrated at present in a few areas, these are bound to spread in the near future. Of particular relevance in the region is the problem of oil pollution, with many living reefs being tapped for oil exploration . Still other problems are associated with the inevitable growth of shipping activities.

As a manifestation of the growing concern over the increasing extent and severity of man-caused reef destruction, moves have been made in recent times to establish marine reserves in Indonesia, Malaysia, the Philippines and Thailand. Though small in number at present, these reserves will hopefully be incorporated into a larger network within a realistic scheme ensuring the viability of not only the reefs but the marine ecosystem as a whole. Concerned individuals in each country are currently working toward this end.

REFERENCES

Albaladejo, V.D. and V.T. Corpuz. 1981. A market study of the aquarium fish industry of the Philippines: an assessment of the growth and the mechanics of the trade. Proc. 4th Int. Coral Reef Symp. 1: 75-81.

Alcala, A.C. 1977. Effects of siltation on coral reefs of Negros Island, Philippines. Paper presented at the Asian Water Pollution Conference, Silliman University, Dumaguete City, Philippines, 11-15 April 1977.

Alcala, A.C. and E.D. Gomez. 1979. Recolonization and growth of hermatypic corals in dynamite-blasted coral reefs in the central Visayas, Philippines. Proc. Int. Symp. Mar. Biogeogr. Evol. S. Hem. 2: 645-661.

Alino, P.M., M. Ross, V. Rosaroso, and C. Orosco. 1981. A report on the subtidal marine environment around the Philippine Mining Services Corporation pier at Alcoy, Cebu. Philipp. Scient. 18: 129-138.

Anonymous. 1979. Malaysia adding 1000 east coast hotel rooms. Pac. Trav. News 23: 52.

Anonymous. 1980. The coast of Bali in danger. Conserv. Indon. 4(5): 8.

Brown, B.E. and M.C. Holley. 1981. The influence of tin smelting and tin dredging on the intertidal reef flats of Phuket, Thailand. Proc. 4th Int. Coral Reef Symp. 1: 214 [Abstract].

Cabanban, A.S. and A.T. White. 1981. Marine conservation program using non-formal education at Apo Island, Negros Oriental, Philippines. Proc. 4th Int. Coral Reef Symp. 1: 317-321.

Carpenter, K.E., R.I. Miclat, V.D. Albaladejo and .V.T. Corpuz. 1981. The influence of substrate structure on the local abundance and diversity of Philippine reef fishes. Proc. 4th Int. Coral Reef Symp. 2: 497-502.

Castaneda, P.G. and R.I. Miclat. 1981. The municipal coral reef park in the Philippines. Proc. 4th Int. Coral Reef Symp. 1: 283-285.

Chansang, H., P. Boonyanate, and M. Charuchinda. 1981. Effect of sedimentation from coastal mining on coral reefs on the northwestern coast of Phuket Island, Thailand. Proc. 4th Int. Coral Reef Symp. 1: 129-136.

Chua, T.E. and D. Pathansali. 1977. Marine science development in Malaysia. In Proc. 1st Ann. Sem. Role of Mar. Sciences in Nat. Dev., Mal. Sci. Soc., p. 18-34.

Cruickshank, M.J. 1981. Offshore and onshore mining overview, p. 27-31. In Proc. Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979. East-West Center, Honolulu.

De Silva, M.W.R.N. 1979. The threatened coral reefs of Peninsular Malaysia, p. 222-229. Proc. 2nd Symp. on Our Environment, Institute of Natural Sciences, College of Graduate Studies, Nanyang University, Singapore.

De Silva, M.W.R.N. 1981. Status of coral reefs of Sri Lanka, Singapore and Malaysia. Coral Reef Newsletter (IUCN) No. 3: 34-37.

De Silva, M.W.R.N., C. Betterton, and R.A. Smith. 1980. Coral reef resources of the east coast of Peninsular Malaysia, p. 95-158. In Chua Thia Eng and J.K. Charles (eds.). Coastal resources of east coast Peninsular Malaysia. Universiti Sains Malaysia, Penang.

De Silva, M.W.R.N. and R.A. Rahman. 1982. Coral reef survey of Pulau Paya/Segantang group of islands, Kedah, Malaysia. WWF Project No. MAL 41. World Wildlife Fund Malaysia, Kuala Lumpur, 84 p. [Unpublished].

Goh, A.H. and A. Sasekumar. 1981. The community structure of the fringing coral reef, Cape Rachado, Malaya. Atoll Res. Bull. 244: 1-11, 8 Figs.

Gomez, E.D. 1977. Species diversity of the epibenthos of a highly disturbed coral reef in the Philippines. Mar. Res. Indonesia 20: 1-17.

Gomez, E.D. 1980. Status report on research and degradation problems of the coral reefs of the East Asian Seas. Paper presented at the Meeting of Experts to Review the Draft Action Plan for the East Asian Seas, Baguio, Philippines, 17-21 June 1980. UNEP/WG. 41/INF. 15. South China Sea Fisheries Development and Coordinating Programme, Manila. 68 p.

Gomez, E.D. 1983a. Direct and indirect impacts of tourism on the coastal environment, p. 209-219. In Marine and Coastal Processes in the Pacific: Ecological Aspects of Coastal Zone Management. Unesco/ROSTSEA, Jakarta.

Gomez, E.D. 1983b. Perspectives on coral reef research and management in the Pacific. Ocean Management 8:281-295.

Gomez, E.D., A.C. Alcala and A.C. San Diego. 1981. Status of Philippine coral reefs - 1981. Proc. 4th Int. Coral Reef. Symp. 1: 275-282.

Gomez, E.D. and H.T. Yap. 1982. Recent trends and future directions of marine park/reserve development in the Philippines. Paper presented at the First National Conference on Marine Parks, Batulao Resort, Nasugbu, Batangas, Philippines, 4-6 October 1982, 28 p.

Gooding, R.U. 1969. Report on a preliminary survey of the Pulau Pari group of islands, Java Sea. SEAMEC Biotrop Coral Reef Project, 17 p.

Hudson, J.H., E.A. Shinn, and D.M. Robbin. 1982. Effects of offshore oil drilling on Philippine reef corals. Bull. Mar. Sci. 32(4):890-908.

Langham, N.P.E. and J.A. Mathias. 1977. The problems of conservation of coral reefs in Northwest Sabah. Mar. Res. Indonesia 17: 53-58.

Lee Siew Kein. 1966. The natural history of the shore flora and fauna off Tanjong Teritip, Singapore. Malay Nat. J. 19: 259-274.

Liew, H.C. and R. Hoare. 1979. The effects of sediment accumulation and water turbidity upon the distribution of scleractinian corals at Cape Rachado, Malacca Straits. Paper presented at "Conference on Trends in Applied Biology in South-East Asia", Universiti Sains Malaysia, Penang, Malaysia,11-14 October 1979, 14 p.

Lubbock, H.R. and N.V.C. Polunin. 1975. Conservation and the tropical marine aquarium trade. Environ. Cons. 2: 229-232.

Ludwig, H.F. 1976. Background information relating to environmental guidelines for zones in Gulf of Thailand. Report prepared for the Environmental Impact Evaluation Division, National Environment Board, Bangkok, 66 p., 11 Figs., 5 Tables.

Lulofs, R.B. 1977. Marine national parks. Malay. Natur. 3(4): 4-12.

Lulofs, R.B. 1979. Coral reefs, marine parks and reserves. Paper presented at the National Seminar on the Protection of the Marine Environment and Related Ecosystems, Kuala Lumpur, 21-23 June 1979, 13 p.

Marine Sciences Center. 1982. Investigation of the coral resources of the Philippines. Phase III (Terminal Phase) Final Report with Project Publications. Report submitted to the Ministry of Natural Resources. University of the Philippines, Quezon City [Unpublished].

McManus, J.W. and J.J. Wenno. 1981. Coral communities of outer Ambon Bay: a general assessment survey. Bull. Mar. Sci. 31(3): 574-580.

Monkolprasit, S. 1981. Investigation of coral reef fishes in Thai waters. Proc. 4th Int. Coral Reef Symp. 2: 491-496.

Moyer, J.T., W.K. Emerson, and M. Ross. 1982. Massive destruction of scleractinian corals by the muricid gastropod, Drupella, in Japan and the Philippines. The Nautilus 96(2): 69-82.

Ongkosongo, O.S.R. 1981. Human activities and their environmental impacts on the coasts of Indonesia, p. 67-74. In Proc. Workshop on Coastal Area Development and Management in Asia and the Pacific. Manila, Philippines, 3-12 December 1979. East-West Center, Honolulu.

Palaganas, V.P. and R.T. Bina. 1981. Marine park/reserve development program in the Philippines. Paper presented at the National Conference on the Conservation of Natural Resources, Manila, Philippines, 9-12 December 1981, 13 p.

Polunin, N.V.C., M.K. Halim and K. Kvalvagnaes. 1983. Bali Barat: an Indonesian marine protected area and its resources. Biol. Conserv. [In press]

Porter, J.W., K.G. Porter and Z.B. Catalan. 1977. Quantitative sampling of Indo-Pacific demersal reef plankton. Proc. 3rd Int. Coral Reef Symp. 1: 105-112.

Rashid, R. 1980. Coral reefs - the case for conservation. SEKITAR 2(213): 40-46.

Robinson, A., N. Polunin, K. Kvalvagnaes and M. Halim. 1981. Progress in creating a marine reserve system in Indonesia. Bull. Mar. Sci. 31(3): 774-785.

Ronquillo, I.A. 1950. Anatomical evidence in cases of fish killed by explosives. Bull. Fish. Soc. Philipp. 1: 52-56.

Ronquillo, I.A. 1961. Effects of explosives on fish and how to detect them. Souvenir Handbook (14th Anniversary) of the Philippine Bureau of Fisheries, p. 37-39.

Salvat, B. (ed.). 1982. Census of existing coral reef parks and reserves. Coral Reef Newsletter (IUCN) No. 4: 13-37.

Sharma, R.E. 1961. Malayan coral reefs. Malay. Nat. J. (Special Issue): 224-229.

Soegiarto, A. 1975. The impact of human activities upon the coastal environment in Indonesia, p. 111-113. In Special Symposium on Marine Sciences, Pacific Science Assoc., Hongkong.

Soegiarto, A. 1981. The development of a marine park system in Indonesia. Proc. 4th Int. Coral Reef Symp. 1: 287-291.

Soegiarto, A. and N. Polunin. 1981. The marine environment of Indonesia. Report prepared for the government of the Republic of Indonesia under the sponsorship of the International Union for Conservation of Nature (IUCN) and the World Wildlife Fund (WWF). Department of Zoology, University of Cambridge for IUCN and WWF, 257 p.

Srithunya, S., S. Muchacheep, S. Srirattanachai, and V. Harden. 1981. Pattern of distribution and correlated parameters of corals in coral reefs at Koa Larn, Chonburi, Thailand (a preliminary report). Proc. 4th Int. Coral Reef Symp. 2: 309-313.

Sudara, S. 1977. Preliminary survey on the possible effect of pollution from offshore mining on coral reef at Phuket, p. 299-305. In Annual Symposium on Mining, Bangkok, 1977.

Sudara, S. 1981. Conditions of the coral reef in Thailand and the potential usage in the future. Proc. 4th Int. Coral Reef Symp. 1: 209-211.

Sy, J.C., F.S. Herrera and J.W. McManus. 1981. Coral community structure of a fringing reef at Mactan Island, Cebu, Philippines. Proc. 4th Int. Coral Reef Symp. 2: 263-269.

Unar, M. 1979. Coral reefs as marine parks and the consideration for their fishery resources. Bio Indonesia No. 6: 53-61.

Valencia, M.J. 1981a. Shipping, energy, and environment: South-East Asian perspectives for the 1980s. Workshop report based on papers presented and discussions at a Workshop at the East-West Center, Honolulu, Hawaii, 10-12 December 1980. East-West Center, Honolulu, 25 p.

Valencia, M. J. 1981b. South-East Asia: an overview, p. 13-21. In Proc. Workshop on Coastal Area Development and Management in Asia and the Pacific, Manila, Philippines, 3-12 December 1979. East-West Center, Honolulu.

Verstappen, H.T. 1953. Djakarta Bay: a geomorphological study on shoreline development. Drukkerij Trio, 's-Gravenhage, 101 p.

White, A. 1981. Management of Philippine marine parks. ICLARM Newsl. 4(3): 17-18.

Wijsman-Best, M., H. Moll, and L.G. de Klerk. 1981. Present status of the coral reefs in the Spermonde Archipelago (South Sulawesi, Indonesia). Proc. 4th Int. Coral Reef Symp. 1: 263-267.

Wood, C.R. 1979. The occurrences and distribution of butterflyfishes (Pisces: Chaetodontidae) in Sabah. Malay. Nat. J. 33(2): 87-103.

Wood, E.M. 1979. Ecological study of coral reefs in Sabah. World Wildlife Fund, Project Malaysia: 15, 163 p. [Unpublished].

Wood, E.M., (ed.). 1981. Semporna Marine Park survey: expedition report and recommendations. WWF Project No. MAL/34. World Wildlife Fund Malaysia, Kuala Lumpur, 90 p. [Unpublished].

Yap, H.T. and E.D. Gomez. 1981. Growth of Acropora pulchra (Brook) in Bolinao, Pangasinan, Philippines. Proc. 4th Int. Coral Reef Symp. 2: 207-213.

INTEGRATED COASTAL DEVELOPMENT IN MALAYSIA AND POSSIBLE REGIONAL IMPLICATIONS

A. Maheswaran
Division of Environment, Ministry of Science, Technology and Environment
Kuala Lumpur, Malaysia

ABSTRACT

Development in Malaysia depends in large part on the exploitation of its rich resources including marine resources. An increasing awareness of the limits to these resources has led to a strategy for environmental management implemented at different levels of government through the Environment Division of the Ministry of Science, Technology and Environment. The strategy includes the reduction of existing pollution through statutory and non-statutory controls, and environmental planning to avoid emerging problems through guidelines and zoning. An environmental impact assessment proceedure is in preparation. Implementation requires realistic approaches backed by sustained enforcement. Regional co-operation is important to control marine pollution, and is being developed through the ASEAN Sub-regional Environment Programme. Education is also necessary to ensure the integration of environmental dimensions with development.

Introduction

The present prosperity and relatively high living standard of Malaysians draw heavily on Malaysia's rich renewable and non-renewable resources ranging from forestry, land, fossil fuels and minerals to the most basic resources of all such as water.

Among these resources, Malaysia has a relatively long coastline of about 4,800 km endowed with valuable marine resources and ecosystem. There are extensive beaches which serve as national amenities, not to mention tourist attractions, and mangrove swamps amounting to 147,180 hectares in Peninsular Malaysia, 175,890 hectares in Sarawak and 370,148 hectares in Sabah. In addition, the Strait of Malacca is the most important fishing ground in Peninsular Malaysia, accounting for approximately 400,000 metric tons or 70 percent of the total fish landings, whilst the South China Sea waters bordering the east coast produced approximately 150,000 tonnes of fish in 1978. This provides employment for over 50,000 fishermen working aboard licensed boats.

For many years the major environmental problems in Malaysia stemmed predominantly from the lack of development and inadequate infrastructure, in short the pollution of poverty. To break free from this the country for a decade and more after Independence adopted plans for accelerated development programmes including mining, forestry, estate development, agriculture, land settlement and industrial development. The high rate of sustained economic development has made substantial inroads into the reserves of minerals, soils, forests and water to the extent that some resources may be exhausted by the end of the present century.

The Malaysian experience shows how crucial it is for small developing countries to protect the source of their wealth, both currently available and that of the future. Since most basic resources are finite, these countries must be constantly vigilant to ensure farsighted and enlightened resource husbandry at all times. In particular renewable resources require a healthy environment. Thus the right balance between development and the environment has to be struck.

In recent years, there has been some serious re-thinking among both developed and developing countries on the directions and pace of future development efforts. In many ways, this has been prompted by new perceptions of the need to harmonize economic development goals and policies with those of environmental protection and improvement to ensure a better quality of life for the people. The prospect of near depletion of resources has accelerated this process.

It has now become clear that the problems of environmental protection are inseparable from the problems of economic development. They are in fact two sides of the same coin, two aspects of the same goal, one reinforcing and underpinning the other. It is then just a matter of prudent management to approach environmental protection as a dimension of economic development. We desire neither an immaculate and pristine environment for its own sake, nor all-out economic development at the other extreme which extracts a heavy price in terms of a degraded environment.

In the past, there has been a tendency to equate development with the more narrowly conceived objective of economic growth as measured by the rise in gross national product or by physical indicators alone. It is usually recognized today that high rates of economic growth, necessary and desirable as they are, do not by themselves guarantee the easing of urgent social and human problems. Indeed in many countries high growth rates are accompanied by increasing unemployment, rising disparities in incomes between groups and between regions, and the deterioration of social and cultural quality of life. A new emphasis is thus coming to be placed on the attainment of social and cultural goals as part of the development process. The recognition of environmental issues in developing countries is an aspect of this widening of the development concept. It is part of a more integrated or unified approach to development objectives. This is timely in the Malaysian context as we are now on the threshold of the Fourth Malaysia Plan, and as we depend particularly on natural resources for the generation of economic activities.

The economic growth, progress and well-being of a nation depend largely on adequate resource availability as well as the systematic development and use of these resources, both renewable and non renewable. However, even renewable resources are limited to the capacity of the whole ecological system. Thus there are, in a sense, limits to growth.

Much will depend on the prudent management of these resources and the extent to which extraction and distribution impacts on the environment, which in turn affects productivity. The capacity of the environment to generate essential renewable resources must be maintained, restored or improved. Otherwise, negative side-effects on the environment will reduce the pay-off from the hoped-for development to significantly less than the optimum.

While Malaysia, compared to most developing countries, has seemingly abundant resources, these have experienced rapid growth in the rates of exploitation, producing various environmental problems.

Strategy for environmental management

In view of the interaction that exists between resource development and environmental quality, environmental management is understood to mean prudent or optimal use, maintenance and enhancement of both the quality of our natural resources.

Since the prospects for an abundant supply of natural resources are weak in the long run, and technological innovations are inadequate, discrete and unpredictable, the developing countries have to take a serious look at their resource limitations, especially renewable resources, and tailor their development efforts accordingly. This does not imply sacrificing development itself. What it does imply, though, is that the patterns of resource development and resource use have to be restructured through resource management policies which are integrated, innovative and imaginative, and focus on employment and efficiently organized productive activities while treating environment as an important parameter. Essentially resource management should aim at:

(i) Minimizing wastes in the process of resource development, and utilization of wastes that are produced.

(ii) Developing appropriate technology for the management and control of wastes.

(iii) Limiting the environmental problems.

Since the development of natural resources is a continuous process which involves intentional changes to the environment, it must be accompanied by conscious effort to guide these environmental changes towards sustainable economic growth to provide an increasingly better standard of living not only in the material sense but also in the value of life itself. This requires the proper long-term management of the resources, maintaining an equilibrium between the resources and rising needs while staying within environmental limits. It simply means a farsighted view of our resources so that we can continue to use then or even improve their yield for a long time to come.

Malaysia has a three-tier system of Government - Federal, State and the local Authorities - with each level having legislative and administrative competence in specific fields, and with potential for affecting the environment through their actions. Resource management is currently being carried out in Malaysia both at Federal and State level by the various departments responsible for the development of the respective resources. Therefore the task of environmental management has to be shared. State Governments and Local Authorities, in view of their legislative and administrative competence in specific fields, have a considerable role to play in solving environmental problems. Through effective co-ordination and willing co-operation they could contribute considerably towards effective environmental protection and management through making good use of available resources of manpower and funds and avoiding duplication. In this context, the Government has pledged to undertake the leadership role in the overall management of man's relationship with environment. It passed the Environmental Quality Act, 1974, and established the Environment Division under the Ministry of Science, Technology and Environment.

The policy of the Government in administering the Act rests on two facts. First, Malaysia is a developing country and essentially must pursue a policy of economic growth. Second, Malaysia's economy today and for a long time to come depends on the renewable resource sectors and these, for a small country like ours, are limited, fragile, and in urgent need of comprehensive protection and sustained production. Malaysia's overall environmental policy therefore takes account of the following factors (Government of Malaysia, 1976):

(i) The impact that population growth and man's activities in resource development and industrialization have on the environment;

(ii) The critical importance of maintaining the quality of the environment relative to the needs of the population, particularly in regard to the productive capacity of the country's land resources in agriculture, forestry, fisheries and water;

(iii) The need to maintain a healthy environment for human habitation;

(iv) The need to preserve the country's unique and diverse natural heritage, all of which contribute to the quality of life; and

(v) The interdependence of social, cultural, economic, biological and physical factors in determining the ecology of man.

In the light of these factors, the responsibilities for environmental management fall under four basic tasks :

(i) environmental assessment which includes monitoring, research and review;

(ii) planning;

(iii) controlling; and

(iv) decision-making in such areas as resource allocation, land use, economic and industrial development and planning.

The above elements underpin and reinforce each other in the strategy of the Government in terms of the overall structure, content and thrust of the environment programme. The first and essential task is environmental assessment which seeks to examine, assess and evaluate the environmental conditions prevailing in various localities through the air and water quality monitoring programme, baseline studies and source emission inventory surveys which are being currently undertaken by the Environment Division of the Ministry of Science, Technology and Environment. These activities are geared to provide not only the fundamental inputs for development planning, but also are expected to be useful in themselves for the formulation of the pollution control programme. The data on standards of environmental quality which are being generated by these activities will provide feedback information in environmental management to help influence the future course of development.

Existing environmental control

Environmental problems are not solved by remedial measures alone but also by a combination of proper environmental planning and pollution control, integrating both preventive and restorative measures.

Logically it would be sensible to work out a proper environmental plan to be carried out within the general 'planning' framework before any pollution control work is carried out. However, in the Malaysian context, due to the necessary gestation period required to evolve a sound plan (data collection, resources, trained manpower, etc.) and the urgency of anti-pollution measures a simultaneous approach is not only desirable but also inescapable.

Therefore, pollution control has been the central activity in the Environment Division's programme for environmental conservation and enhancement of environmental quality. Important as these measures are for controlling existing and future environmental problems, they must be planned and designed within the framework of the growth targets of the development plan, and take due account of administrative procedures at both the Federal and State levels.

In the final analysis, these control measures must be consistent and workable within the framework of the Federal Constitution, insofar as it concerns the relationship between the Federal Government and the States. With this constitutional framework, the Environment Division is adopting a two-pronged approach involving both statutory control and non-statutory control.

The choice of these control measures and their application depends significantly on the areas to be controlled. Statutory control is adopted in areas which are expressly within the ambit of the Environmental Quality Act, 1974 or more precisely in those matters which are specified in the Federal or Concurrent Lists. Non-statutory control, on the other hand, is applied in areas where the existing responsibilities are shared by various government agencies and in those areas which are within the competence of the State Governments. Matters such as land, agriculture, forestry, mining, soil erosion, drainage and irrigation which are fundamentally important in environmental management are explicitly under the State and Concurrent Lists, and it is in these areas that non-statutory control must be directed with great care to avoid undue administrative conflicts.

The legal controls are being applied through various Regulations which have been drawn up on the advice of the Environmental Quality Council in accordance with the Environmental Quality Act, 1974. They are, among others:

(i) Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977;

(ii) Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations, 1978;

(iii) Sewage and Industrial Effluents Regulations, 1979;

(iv) The Clean Air Regulations, 1978.

These Regulations are directed principally against industrial pollution in the form of discharges and emissions which damage our common property resources, namely land, air and water. However, they are by no means the complete answer in themselves. For example they will not be able to deal with those problems arising from the development of land and natural resources which are as serious as pollution from industrial sources. Nevertheless, these Regulations constitute positive steps towards the control of pollution from point sources.

Under these Regulations, control is affected through the establishment of criteria or standards for the reduction of pollutants, enforced by both legal and administrative methods including 'resource charges'. With the enforcement of these regulations, it is estimated that a total of 820 licensed premises (sources) and more than 7000 non-licensed premises are subject to these regulatory measures. The fundamental reason for this approach is to induce a polluter to install anti-pollution devices and absorb the social costs for the use of resources. The imposition of 'resource charges' in particular provides scope for each polluter to choose the mix of approaches which will keep the cost of pollution control as low as possible.

It is evident from the above that although action could be initiated by the Environment Division, it is unrealistic to expect it to be involved with the detailed procedures and control mechanisms for coping with environment-related matters (e.g. use of pesticides, mining discharges). Further, it is only logical for the implementing agencies to take heed of environmental safeguards in the course of the implementation of their various projects.

Environmental planning

The environmental problems arising from the development of Malaysia's land and natural resources are complex and can only be overcome through an integrated approach entailing advance or forward planning for the long term conservation of environmental assets. Thus whilst preparing as best we can to cope with those situations which it is too late to avoid, we should focus on emerging problems, striving to head them off by timely action before they assume serious or crisis proportions. For this purpose, it is important to ensure that an environmental consciousness pervades the decision-makers and planners in both the public and private sectors so that the imperatives of environmental protection are built into development projects and the need for costly and time-consuming remedial measures are obviated.

The machinery and the commitment to planning already exist. What is needed is the development of an enlarged planning methodology so that environmental dimension can be incorporated in a systematic way into development planning right from the start. The integration of the environmental dimension in resource management requires a broader elaboration of development goals encompassing qualitative aspects in addition to the mere increase in gross national product. Generally speaking the optimal development process should be one which sets, as one of its main objectives, the satisfaction by present and future generations of their basic requirements without transgressing the outer limits of the biosphere's tolerance of man's activities. There is a delicate balance here and it demands very careful consideration. For such rational management to be achieved, methods must be developed to deal more adequately with the full social and environmental - and not just economic - costs and benefits of development-related activities. It is necessary to find techniques for quantifying the impacts, both favourable and unfavourable, of development projects on environment, so that the society can choose projects with a fuller knowledge of their social costs and benefits in the light of a number of options generated. All too often the social costs of various projects are ignored or receive short shrift in the initial appraisal especially in the context of a laissez-faire economy. Society's recognition of many of the environmental disruptions resulting from these projects then comes at too late a stage to permit effective and timely remedial action. It is important that the social costs should be ascertained to the maximum extent possible before undertaking development projects, so that society can carefully assess whether they are still worthwhile, whether some of the costs could not be minimized through careful design of the project, and whether some of the costs could not be avoided or at least deferred through adoption of alternatives.

In this context, the Environment Division under the Ministry of Science, Technology and Environment has undertaken the leadership role in providing the necessary instruments of control. It has prepared several guidelines to help State Governments and other Agencies to incorporate environmental considerations into their development plans. The most important guidelines are:

(a) guidelines for zoning and siting of industries;

(b) guidelines for environmental impact assessment;

(c) guidelines for selection of sites for solid waste disposal and management of site; and

(d) guidelines for prevention of erosion and siltation.

The usefulness of zoning is self-evident. Without it environmental problems can grow to unmanageable proportions. The main advantages can be summarized as follows:

(i) **Isolation of residual pollutants and their impact**
The Malaysian approach to regulatory control of pollution is largely based on the best practicable means (B.P.M.) concept with provisions for gradual integration with air quality management concepts. The best practicable means are defined by technical feasibility and economic viability. Therefore, the installation of in-plant control equipment and the adoption of control measures would limit the discharge of pollutants to a certain level but not necessarily totally eliminate it, and as much as 5% to 10% of the "residual pollutants" may still be discharged into the environment from each polluting source. The provision of buffer zones would isolate the people from the impact areas.

(ii) **Reduced cost of control measures**
As the degree of control becomes more stringent, the cost increases exponentially. If the polluting source could be located well away from populated areas, control measures need not be as stringent as would otherwise be necessary. In the ultimate analysis pollution control cost are borne by the consumers, hence the reduction of control costs would reduce the burden on the people and the country as a whole.

(iii) **More efficient and effective infrastructure planning**
The provision of various zones for housing, buffers, and compatible industries would help to lower the cost of infrastructure such as commuting routes, sanitary services, centralized treatment systems for industries, water and electricity supplies, water recycling plants, etc.

Under the proposed Environmental Impact Assessment Procedure, which is currently being refined by the Division of Environment for submission to the Cabinet Committee on Investment, projects with high potential impact will require an assessment to be submitted to the Ministry for review. Initiators of the project will be required to describe the various environmental and pollution impacts which can be foreseen and quantified so that steps may be taken in advance to plan to control or mitigate their environmental consequences.

The advantages of the Environmental Impact Assessment are self-evident. While the primary goal of the environmental impact assessment is to determine the impact of a project on the surrounding environment, it also serves the following purposes:

(i) The findings of an impact assessment may be utilized in selecting the site for a project where the resulting adverse environmental impact and the associated cost of implementing control measures to reduce the impact will be minimized, and the hoped-for benefits maximized.

(ii) With regard to existing facilities, the assessment will help to determine the actual need for and extent of control required.

(iii) The environmental consequences of an activity will be disclosed to government agencies, and to the public if and when necessary.

The Guidelines for selection of sites for solid waste disposal and management of site are intended to help the various Local Authorities to avoid haphazard selection and management of waste disposal sites disregarding environmental factors.

The problems of soil erosion and siltation can only be overcome by employing suitable controls and preventive measures, especially at the planning stage of a project, whether for agriculture, mining, housing, road construction or logging. The guidelines for prevention of erosion and siltation contain well-defined and precise specifications for preventive measures to control siltation, such as silt traps and other appropriate control structures.

Implementation of strategy

In putting the strategy to work, the need for a pragmatic, systematic, graduated and co-ordinated approach not just at the level of the environment protection agency but of all environmentally-related agencies including research institutions and universities, cannot be over-emphasized.

In the context of developing countries particularly, environmental control regulations, however skilfully formulated and drafted in themselves, constitute no magic cure for the environmental ills of society. An immense amount of hard work is necessary to ensure that the standards set are realistic in terms of protecting the environment, that the technology for treatment is either available or can be developed readily, and that the treatment involved is cost-effective in the sense of being within the means of the industry concerned. This has to be backed up by systematic and sustained enforcement to get across the message that the authorities mean business.

The success to date in Malaysia in reducing environmental pollution to manageable proportions is in the main due to the pragmatic, systematic and business-like approach consistently adopted by the Environment Division, backed up by an uncompromising, firm yet fair approach to enforcing the regulations in the public interest.

The good working relationships built up over an extended period of time with the research institutions in Malaysia, all five universities, and a whole spectrum of public sector agencies at both the Federal and State levels, have stood us in good stead.

Regional co-operation

Marine pollution control is a very complex problem. It requires control not only of activities on the sea itself but also of activities on land. Further the oceans of the world flow together. In this sense, they are an ecological whole and it is right to think of marine pollution as a single problem. But when thinking in terms of solution, it is more helpful to think in terms of different levels of problems - global problems, regional problems and national problems.

The need for co-operation in the ASEAN (Association of South-East Asian Nations) region is considerable since the member states share not only many common problems, but also similar characteristics of the coastal and marine environment. Further, the economies of the member states in ASEAN depend on the seas through fishing, off-shore petroleum production, mining and shipping.

Co-operation among ASEAN member states can and should take place in the following areas:

(a) monitoring the quality of the marine environment;

(b) establishing close rapport among ASEAN countries on maritime activities which have a direct impact on the marine environment;

(c) developing effluent standards for discharge of polluting effluents directly or indirectly into the marine environment;

(d) conducting research pertaining to marine pollution and its effects on the living aquatic resources;

(e) conducting inter-calibration exercises involving the determination, in water and in biological tissues, of heavy metals through atomic absorption spectrophotometry, organochlorine pesticide and PCB's through gas chromatography, and dissolved and dispersed petroleum hydrocarbons through spectrofluorometry;

(f) holding workshop/seminars of scientists involved in research in the marine environment to promote the dissemination and exchange of information and experience;

(g) organizing training programmes for technical staff engaged in marine pollution investigations;

(h) formulating laws and regulations related to the enhancement of marine environment;

(i) developing low cost technology for waste treatment suitable to local situations.

Substantial progress has been achieved in regional co-operation through the ASEAN Experts Group on the Environment. An outcome of such co-operation is the formulation of the ASEAN Sub-Regional Environment Programme (ASEP) with the marine environment as one of the priority areas. It is a joint collaborative programme among the five members of ASEAN and has been in operation since 1978.

An Action Plan for the protection of the marine environment and coastal areas of the East Asian Region was drafted with support and assistance from the United Nations Environment Programme (UNEP). It has been adopted by the ASEAN Member States and is in the process of being implemented.

Conclusion

Assaults on the environment are many and varied, arising from the wide range of activities in a rapidly developing economy. While the cost of measures to improve and protect the environment are fairly apparent to people at large and to the affected groups in particular, their benefits, which often spread beyond the initial sector of environmental control, are not so clearly seen or appreciated. The result is that benefits from environmental measures are understated.

The developing countries find it difficult in practice to make inroads into the traditional methodology and approach of project evaluation adopted by development planners and decision-makers. The lack of systematic studies demonstrating clearly in a comprehensive and quantitative manner the benefits accruing from environmental measures, and the constraints imposed by competing policy priorities and alternative claims on resources, have too often led to the expediency of ignoring environmental dimensions in resource management. These countries need some assurance or even conclusive proof that environmental management, far from being a handicap, can actually contribute to the success of resource development programmes. It should in fact become evident that the environmental protection approach is a resource management concept while economic development is generally pursued as a resource use concept and that the whole objective of integrating environmental planning with development is to absorb the resource management ideas into the process of planning for resource use.

In Malaysia the Environment Division is making a great effort to get this message across through the promotion of environmental education. The quarterly magazine 'Sekitar' published by the the Environment Division is yet another step in our strategy to promote environmental education to key target groups.

REFERENCE

Government of Malaysia. 1976. Third Malaysia Plan Document 1976-1980, Chapter 11, p. 214, paragraph 664.

THE STATE OF HYDROCARBON POLLUTION IN THE EAST ASIAN SEAS BASED ON STUDIES IN THE SOUTH-EAST ASIAN SEAS REGION

Jaspar Bilal
Oil and Gas Technology Development Center "LEMIGAS"
Jakarta, Indonesia

ABSTRACT

The description of the production and transport patterns for oil in South-East Asian waters gives an indication of the actual and possible inputs of oil contamination in the marine environment. The distribution of dispersed oil and tarballs depends on the geographic and hydrographic features of the region. While oil pollution is widely recognized as a regional problem, its impact is difficult to assess because available data are scarce and hard to compare.

Introduction

It is universally accepted that petroleum is derived from organic material. It resulted from the combined action of pressure, temperature and physical/chemical processes on organic material such as plants and animals deposited in the last 600 million years in layers of sedimentary rocks.

Offshore hydrocarbon reservoirs are found along the continental margins, particularly on the continental shelf and the upper part of the continental slope. The existence of commercially exploitable accumulations beyond the continental rise is considered unlikely in the foreseeable future.

In the Asia-Pacific region, oil and gas deposits are most promising in sedimentary basins, many of which lie in ocean basins limited by volcanic island chains.

It is now recognized that some of these basins may be located under the sea, and that their nature cannot be predicted from land data. Recent findings from oil and gas exploration in the offshore areas of South-East Asia confirm this.

The description of production and transport patterns for oil gives an indication of actual and possible inputs of oil contamination in the marine environment. Oil contamination and accumulation in the form of dispersed oil in water, and floating and stranded tarballs are global phenomena which depend on the geographic and hydrographic features of the region.

Oil pollution of the marine and coastal environment is widely recognized as a problem as noted at various regional meetings over the last few years. However, oil pollution and its impact on the environment, particularly in South-East Asian countries, are difficult to assess because the needed research and survey data are so scarce and fragmentary.

Hydrocarbon producing basins

The actual and potential hydrocarbon producing basins in the South-East Asian Region are found in variable geological settings.

In **Indonesia,** the known basins extend from Sumatra, including the northern offshore extension into the Straits of Malacca, through Java to Kalimantan, as well as the basins in and offshore West Irian.

In **Malaysia** and **Brunei**, the Northwest Borneo basin and its offshore extension are of recent interest as are the Saigon-Brunei basin in the southern part of the South China Sea and the Gulf of Thailand basin.

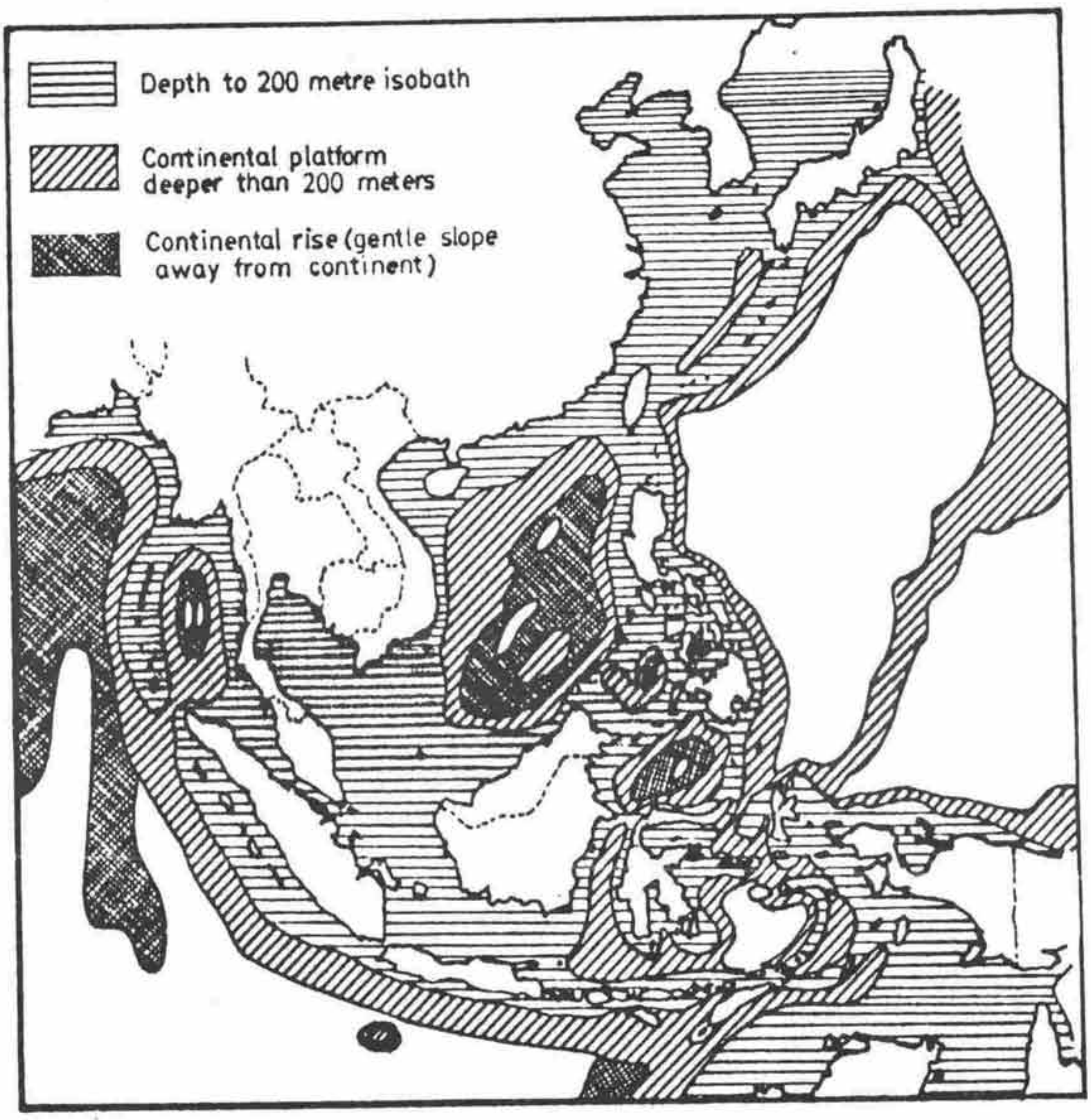
The Gulf of **Thailand** basin extends to the North into the land area of Bangkok. Of special interest also is the sedimentary area in the Andaman Sea between the Andaman and Nicobar Islands extending down to the Malacca Straits.

In the **Philippines** producing fields have been found in the offshore area of Palawan Island in the South China Sea (Siddayao, 1980).

Some recent discoveries in South-East Asia, particularly in the offshore areas, have greatly changed earlier concepts of estimating hydrocarbon potential based on the projection of land geology.

Figure 1 shows the seabed areas in South-East Asia with their topographic gradients and Figure 2 shows the prospective hydrocarbon basins and oil and gas producing areas in South-East Asia. Table 1 provides data on hydrocarbon resources in the submarine areas of the South-East Asian region.

Figure 1 : Seabed areas in South-East Asia showing topographic gradients (from Siddayao, 1978)



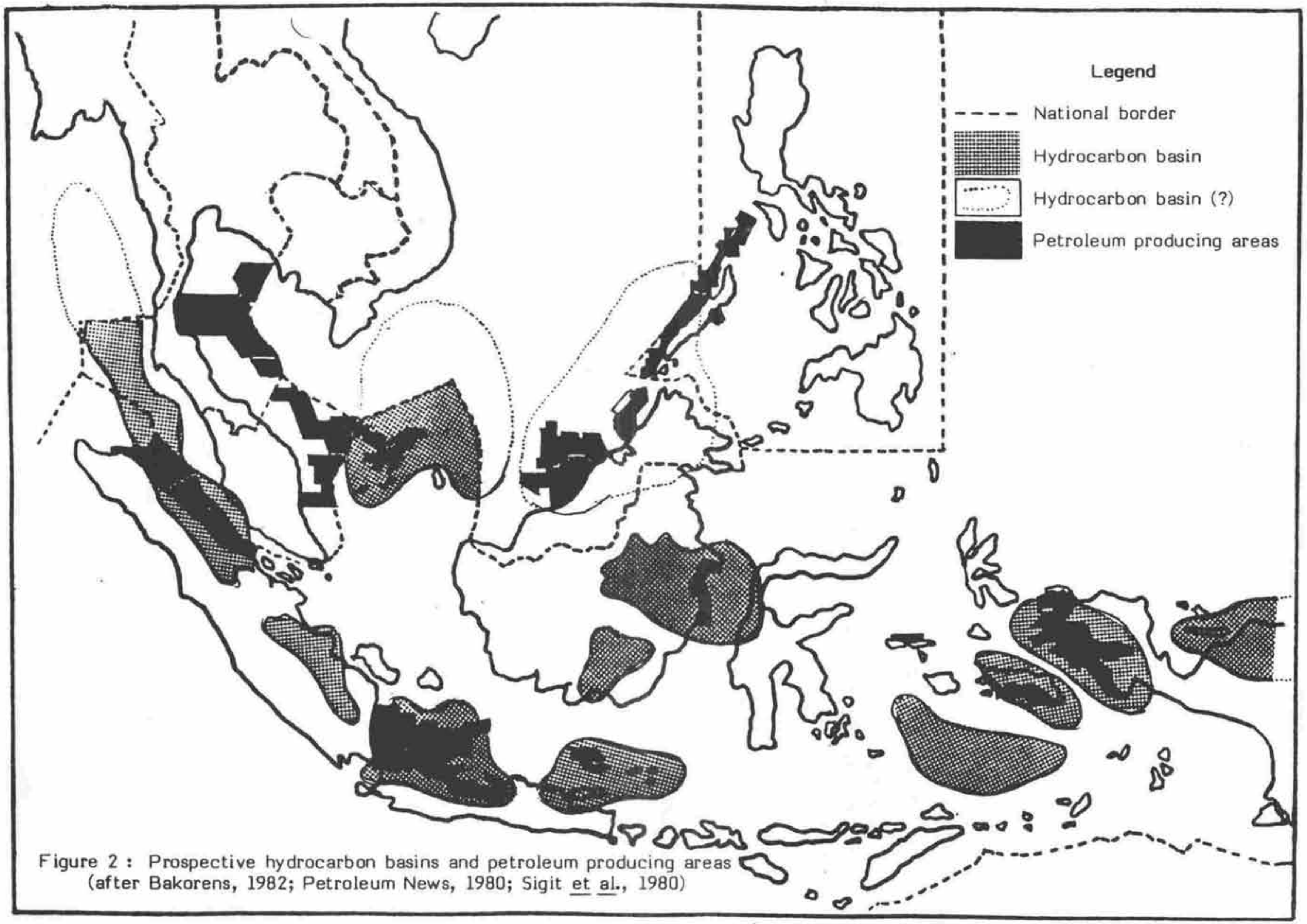


Figure 2 : Prospective hydrocarbon basins and petroleum producing areas (after Bakorens, 1982; Petroleum News, 1980; Sigit et al., 1980)

Table 1 : Hydrocarbon resources in the ocean waters of South-East Asia (in barrels per day)
(after Siddayao, 1980; Sigit et al., 1980; Bilal and Kuehnhold, 1980)

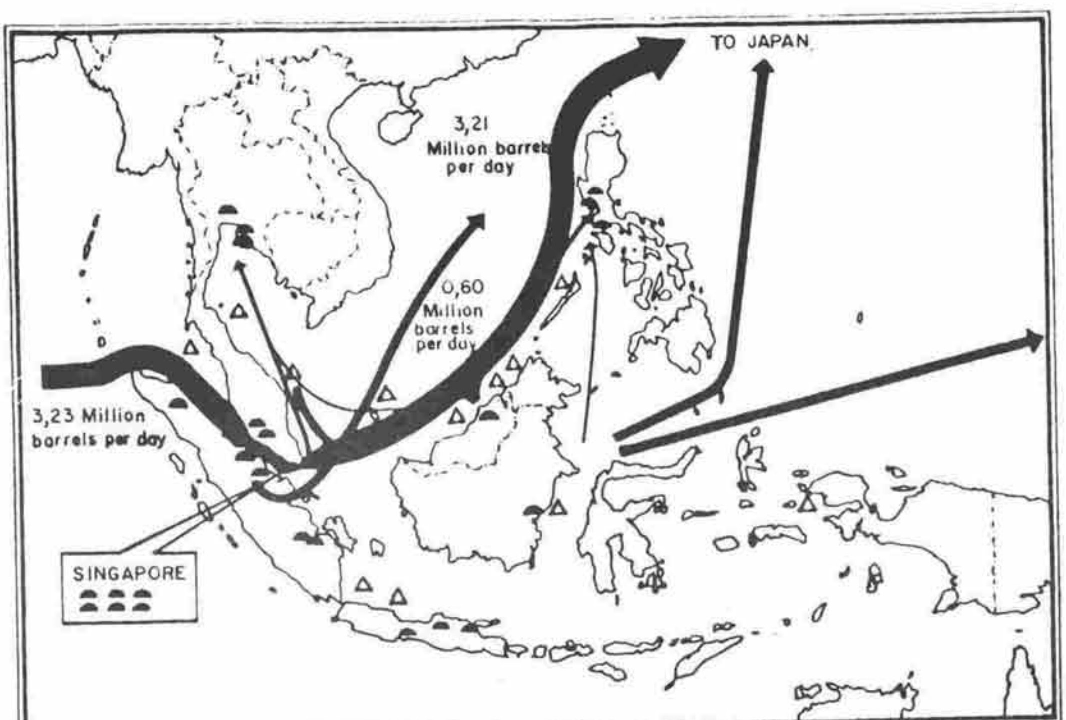
Country	Production 1978 Total	Production 1978 Offshore	Production 1980 Total	Production 1980 Offshore
Brunei	209,400	179,100		
Indonesia	1,634,790	545,240	1,576,546	536,876
Malaysia	196,500	196,500		300,000
Philippines	40,000	40,000	40,000	40,000
Singapore	0	0	0	0
Thailand	200	0	200	0

Oil activities

Transportation, shipping casualties and operations

Figure 3 shows that most of the oil shipped through and in South-East Asian waters is in transit to Japan while the rest goes to the USA and to other East Asian countries, together accounting for more than 90% of the oil supplied.

Figure 3 : Transport of crude oil in South-East Asia (1975)
(after FAO, 1976 and Finn et al., 1979)



< 0.1 million barrels per day (7 barrels = 1 metric ton)
0.1-0.2 million barrels per day
0.2-1.0 million barrels per day
> 3 million barrels per day
Δ Offshore production site
Refinery

According to Finn et al., (1979), 3.23 million barrels (mainly crude) enter this region daily through the Straits of Malacca, and 3.81 million barrels per day (crude and refined products) leave it en route through the South China Sea. Another 0.6 to 1.2 million barrels leave the Macassar Straits for Japan and the Pacific (Bilal and Kuehnhold, 1980). The Port of Singapore, situated at key intersection of major sea routes, ranks as the world's third busiest port. Its strategic location has also contributed to Singapore's emergence as a center for ship repairs and service for oil tankers. Table 2 shows frequencies of tanker movement in South-East Asia and Table 3 shows the origin, size and numbers of tankers that transit through the Straits of Malacca. However there are many factors that affect or that may affect the pattern of oil shipment in South-East Asia. For example, unpredictable new resource discoveries within the region, e.g. offshore Vietnam and China, may change patterns of supply.

Table 2 : Frequencies of tanker movements in South-East Asia (Valencia, 1981)

Destination (Route)	Hypothetical Vessel Size	Frequency
South Korea and Japan	200,000 DWT	984/yr (1/0.4 days)
Japan (Lombok-Makassar-Sulawesi Sea-east or west of the Philippines)	VLCCs	140/yr (1/2.6 days)
Sulawesi Sea	VLCCs + Tankers	25-30/yr (1/13.5 days)
Port Dickson, Malysia	90.000 DWT	40/yr (1/9 days)
Singapore	VLCCs	91/yr (1/4 days)
(Singapore-Straits)	Various	15,356/yr (1/.024 days or 1/34 min.)

Table 3 : Origin, size spectrum and number of tankers in transit through Straits of Malacca. Numbers in parentheses show percentage of total Japanese oil imports and percentage of number of tankers importing oil to Japan (Finn et al., 1979)

Origin	Tanker size (thousand dwt)					Amount of oil (thousand tons)	No. of tankers
	<100	100-150	150-200	200-250	250-300		
Persian Gulf	284	261	106	321	86	192,830 (73%)	1,058 (58%)
Indonesia	198	30	2	-	-	17,419 (6%)	230 (13%)
Africa	40	13	6	5	-	8,117 (3%)	64 (4%)
Total	522	304	114	326	86	218,355	1,352 (74%)

In the **Straits of Malacca**, the transit of international tankers results in very dense traffic, and casualties can always happen causing oil spills. In 1975, 5,500 tons spilled in the Straits of Malacca from the tanker "Diego Silang". There were two major oil spills in the South China Sea from collisions: that of a supply ship with the storage barge "ESSO Mercia" which spilled 500 tons of bunker C oil, and the other between M.V. Fortuna and USS "Ranger" which spilled 10,000 tons of crude oil. Table 4 shows ship casualties in Malaysian waters (Bilal and Kuehnhold, 1980).

Table 4 : Ship casualties in Malaysian waters from 1975 to early 1980
(from Bilal and Kuhnhold, 1980)

Name of vessel or incident	Cause	Location	Date	Amount and Type of oil
Tolo Sea	Grounding due to fire	Penang Harbour	20.05.1975	60 tons bunker fuel oil
Oil Slick	Unknown	South Channel Penang	03.05.1979	Estimated 10-15 tons bunker fuel oil
Diego Silang	Collision with Russian Ship Vystok	Malacca Straits	24.07.1976	5,500 tons Kuwait crude
M.V. Asian Guardian	Rupture of discharge pipe to power station	Malacca Straits	16.05.1977	60 tons light fuel oil
M.V. Montessa	Accidental discharge due to mechanical failure	Malacca Straits	30.06.1979	Arabian light crude (amount unknown)
Shell Refinery	Accidental discharge due to pipe rupture	Malacca Straits (Port Dickson)	30.11.1979	Arabian light crude (50 tons)
Tesahino Maru	Leakage of delivery pipeline	Malacca Straits (Port Klang)	20.01.1980	Bunker fuel oil (amount unknown)
Toan Chuen Chun	Accidental discharge due to mechanical failure	Johore Straits	10.05.1979	Bunker fuel oil (amount unknown)
Esso Mercia	Collision with supply ship Florence Tide	South China Sea	30.10.1978	505 tons bunker fuel oil
M.V. Fortuna	Collision with USS Ranger	South China Sea	5.04.1979	10,000 tons Kuwait light crude

In the southern part of **Singapore,** oil contamination comes mainly from ships that use the busy sea-lane of the Straits of Singapore and from those that anchor at the various designated anchorage areas which occupy practically the whole of the southern territorial waters of Singapore. Because of the heavy traffic, a number of oil spills have occurred through the collision or grounding of tankers. Table 5 gives a list of casualties and oil spills for the period 1975 and 1976.

Menasveta (1980) reported that there is a problem of oil contamination due to oil activities in **Thai** waters but it is still relatively small. An accidental oil spill occurred in April 1974 when the 5000 ton coastal vessel "Visahakit" collided with another ship about 8 km from the mouth of the Chao Phraya river. The spill was estimated at 9000 barrels of oil.

The biggest oil spill in **Indonesian** waters was in the Straits of Singapore, where a super tanker of 273,698 dwt, "Showa Maru", grounded on treacherous shoals near the Buffalo Rock Beacon. It spilled approximately 54,000 barrels of Middle East crude (Kantaatmadja, 1981).

Oil spills due to shipping accidents in the waters of the **Philippines** have been listed by the National Operation Center for Oil Pollution. The record for 1978 is given in Table 6.

Aside from oil spills through casualties, discharges of oil occur also from operational shipping activities. These discharges consist of activities such as deballasting, tank cleaning, dry docking, bunkering, cargo loading and unloading. The incidence of operational or deliberate oily waste discharges in the area of the East Asian Seas has been studied by Kurashina (1975) and Nasu et al., (1975). The result is as follows:

	Annual number of dirty ballast and tank cleaning	Amount discharged in 1000 tons/year.
SE Japan area	74	578
Taiwan area	87	616
South China Sea	392	4705

Table 5 : Shipping casualties in the Straits of Singapore (after Finn et al., 1979; Kantaatmadja, 1981)

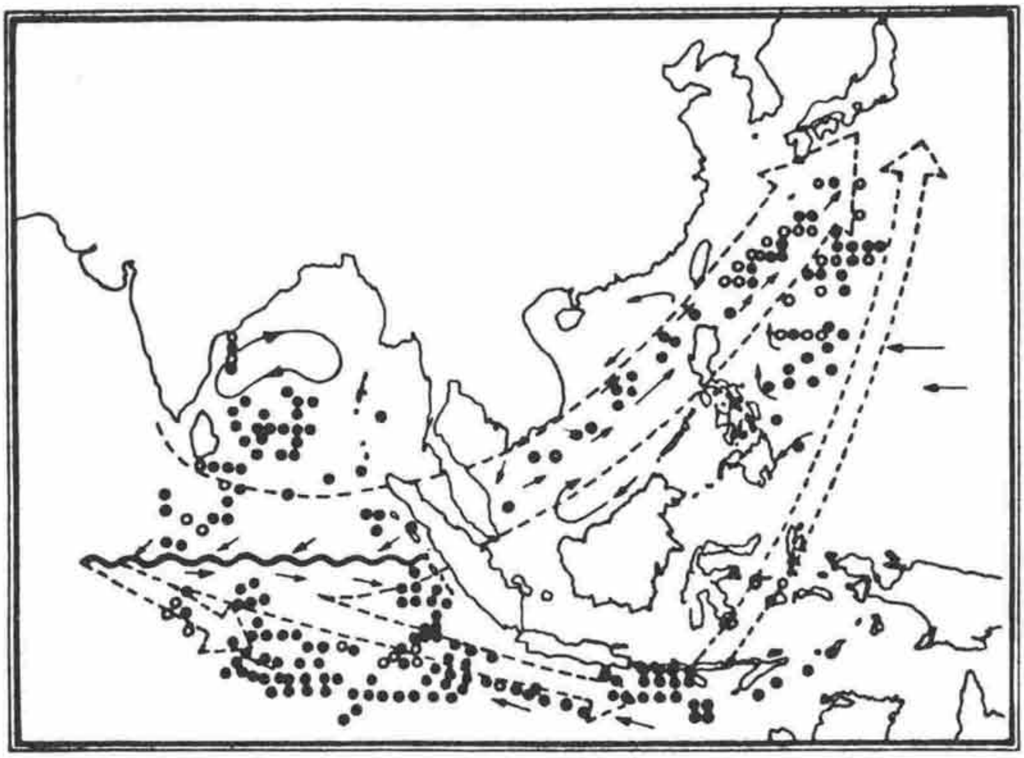
Date	Name of ship	Type (Tonnage)	Cause	Location	Comments
06.01.75	Showa Maru	Tanker (273,698)	Grounding	Buffalo Rock, off Singapore	**7,700 tons oil spilled**
16.01.75	Isuzugawa Maru Silver Palace	Tanker (122,233) Tanker (21,226)	Collision	Outside of Singapore Port limits	Isuzugawa Maru had cargo of crude oil; no spillage
05.04.75	Mysella	Tanker (212,759)	Grounding	1°12'04"N 103°50'54"E	**2,000 tons oil spilled**
18.04.75	Tosa Maru Cactus Queen	Tanker (42,790) Tanker (152,035)	Collision	1 mile south of St.John's Island	Tosa Maru broke in two and sank
14.06.75	Kowei Baru Monte Cristo	Freighter Freighter	Collision	Eastern Roads, Singapore	
30.06.75	Liengku	Freighter	Collision	Malacca Straits	Ship sank
17.07.75	Neissei Maru Ravi	Tanker (231,986) Freighter	Collision	1°15'03"N 104°09'03"E	Neissei Maru had cargo of crude oil
24.10.75	Seatiger	Tanker (123,693)	Collision, grounding	4.8 km south of St. John's Island	
29.10.75	Kriti Sun	Tanker (123,484)	Struck by lightning	Singapore Port	
11.12.75	Sachem Gen. Madalineki	Tanker (29,908) Bulk Carrier(23,298)	Collision	Eastern anchorage, Singapore	
17.05.76	Margo Georg Hanake	Freighter Freighter	Collision	Eastern anchorage, Singapore	
26.07.76	Forresbank Mareva A.S.	Freighter Freighter	Collision	Eastern anchorage, Singapore	
06.09.76	Soyakaze Marrita E.	Freighter Freighter	Collision	Off St. John's Island	
26.10.76	Citta di Savona Philippine Star Esso Spain	Tanker (64,805) Tanker Tanker (81,827)	Collision	Eastern anchorage, Singapore	**Savona and Star had cargos of crude oil; 1,000 tons oil spilled**

Table 6 : Oil spills by shipping accidents in Philippine waters in 1978 (after Gomez, 1978)

Name of Vessel/Company	Cause	Date	Location
AGEP Wood Preserving Div.	Discharge to Pasig River 3-4 drums bunker oil	12.04.78	Pasig River
William Lines motor vessel	Waste oil spillage	19.05.78	Iloilo River
Compania Maritima vessel	Waste oil spill 20 gallons	20.05.78	North Harbor, Manila
Motorized banca (Samasco)	Waste oil spill 20-30 gallons	22.05.78	Bauan, Batangas
Motorized tank (Las Vivas)	Discharge of waste oil	06.08.78	Shell-Batangas Bay
Barge (Luzon Stevedoring)	Spillage of 4,000 barrels of auto turbo fuel	27.09.78	Bataan Refining Co. Lamao, Bataan
Motorized tank (Las Vivas)	Oil spill due to grounding	27.09.78	Bataan Refining Co.
Barge (Luzon Stevedoring)	Spill of 7,000 barrels of premium gasoline by sinking	27.09.78	Bataan Refining Co. Lamao, Bataan
Barge (Luzon Stevedoring)	Spill of bunker oil (and 20,000 bags fertilizer) due to grounding	09.10.78	Manila Bay
Barge (Luzon Stevedoring)	Bunker oil spill by grounding	09.10.78	Manila Bay
Motorized tank (C. Robles)	Oil spill due to sinking	10.10.78	Bataan Refining Co.
Barge (Sealink Inc.)	Spill of 1,300 barrels lubo oil due to sinking	14.11.78	Pasig River

Oil released during deballasting operations is in the form of tar lumps and weathering produces tarry residues and tarballs. Figure 4 shows the distribution of oil lumps in relation to eastbound tanker traffic and surface currents.

Figure 4 : Oil lumps, transport of oil, and surface currents in South and East Asia (after Nasu et al., 1975)



- Few oil lumps
- Many oil lumps
- Transport of oil (width indicates amount)
- Average surface currents
- Border between currents

The Straits of Lombok, the Straits of Macassar and the Celebes Sea are an alternative route for Ultra Large Crude Carriers (ULCC, over 300,000 dwt) sailing to Japan and the West coast of America, both because of the physical environment in the Straits of Malacca and because of the characteristics of vessels involved in the oil trade between the Western Pacific and the Middle East.

In 1975, three ULCCs, the "Globtik London" (483,960 dwt), the "Globtik Tokyo" (483,684 dwt) and the "Nisseki Maru" (372,698 dwt) sailed through these waters in addition to the 25 to 30 Very Large Crude Carriers (VLCC, 200,000-300,000 dwt) and 100 to 150 tankers that transit these waters each month (Hayes, 1979).

Refineries and production fields

There are numerous loading ports, production fields and refineries located along the coast of the Straits of Malacca and adjacent to the Straits of Singapore. Twelve coastal refineries with a total output of over 1,400,000 barrels per stream day are located on the coast of **Straits of Malacca and Singapore.** Port Dumai in east Sumatra is one of the world's biggest crude oil exporting terminals. In 1973 it exported 2.5 million tons of crude oil (Finn et al. 1979).

Along the coast of the southern part of the **South China Sea** there are 8 refineries having a total capacity of 445,000 barrels per stream day.

One refinery is located on the east coast of Kalimantan (**Straits of Macassar**) with a capacity of 75,000 barrels per stream day.

Furthermore a new refinery center is located on the southern coast of the island of Java; it has a capacity of 100,000 barrels per stream day, which is being extended to 300.000 barrels per stream day. The oil terminals, production fields and refineries continuously release oily effluent into the adjacent waters. Sometimes accidental spills have resulted from technical failures and human errors like leaks, overfilling and mismanagement. Table 7 shows a list of refineries with their capacities and Figure 2 indicates the locations of producing and prospective oil fields in South-East Asia.

Table 7 : Coastal refineries and capacities
(from Petroleum News South East Asia, 1980)

Country	Capacity (bl/day)	Location
BURMA		
Petrochemical Industries Corp., Chauk	6,300	
Petrochemical Industries Corp., Syriam	22,000	Andaman Sea
New Refinery, Maluk, 2,000 bl/day (1980)		
New Refinery, Mann, 25,000 bl/day (1982)		
INDONESIA (all owned by state enterprise Pertamina)		
Cilacap, South Java (200,000 bl/day extension by 1984)	100,000	Indian Ocean
Balikpapan, Kalimantan	75,000	Straits of Macassar
Dumai, Sumatra	100,000	Straits of Malacca
Sungai Gerong, Sumatra	79,000	"
Plaju, Sumatra	111,000	"
Pangkalan Brandan, Sumatra	4,000	"
Sungai Pakning, Sumatra	50,000	"
New Refinery, Batam, 200,000 bl/day (planned)		Straits of Singapore
MALAYSIA		
Esso, Port Dickson	36,000	Straits of Malacca
Shell, Port Dickson	90,000	"
Shell, Lutong, Sarawak	14,000	South China Sea
Petronas, New Refinery, Westcoast, 150,000 bl/day		Straits of Malacca
Petronas, New Refinery, Paka, Trengganu (20,000-30,000 b/d on stream by 1984)		South China Sea
PHILIPPINES		
Bataan Refining, Limay	104,000	South China Sea
Caltex, South Luzon	74,000	"
Philipinas Shell, Batangas	68,000	"
SINGAPORE		
British Petroleum, Pasir Panjang	28,000	Straits of Singapore
Esso, Pulau Ayer Chawan	213,000	"
Mobil, Jurong	180,000	"
Shell, Pulau Bukom	500,000	"
Singapore Refining Co., Pulau Merlimbau (100,000 bl/day by late 1980)	70,000	"
THAILAND		
Esso, Sri Racha	35,000	Gulf of Thailand
Summit, Bangchok	80,000	"
Summit, Fang	1,000	"
Thailand Oil Refining, Chonburi (65,000 bl/day expansion approved)	65,000	"

In the **South China Sea** active offshore exploration and exploitation are taking place in the Gulf of Thailand where gas and gas condensate have been found. Eastward in Indonesian Waters, the area around Pulau Natuna (Natuna Island) produces 30,721 barrels per day (bl/day). Further to the East, fields off of the island of Palawan produce 40,000 bl/day. To the South the Malaysian Sabah and Sarawak waters yield a total production of 180,000 bl/day while the offshore production of the East Coast of Peninsular Malaysia is 120,000 bl/day. The waters of Brunei produce 179,100 bl/day (1978 figures). Off the north coast of Java, an offshore oil field has a production of 234,013 bl/day. Another offshore field within Indonesian waters in the Straits of Macassar produces 292,956 bl/day (Sigit et al 1980).

Oil contamination in marine waters

The data from the Marine Pollution (Petroleum) Monitoring Pilot Project (MAPMOPP) of the Integrated Global Ocean Survey System (IGOSS) on hydrocarbons and floating tarballs (oil lumps) (see Figure 5 and Figure 6) provide the only overview of the state of oil contamination in the East Asian Seas. The hydrocarbon concentration ranges from 0.01 - 4 ppb with both extremes occurring in the southern part of South China Sea. The Malacca Straits, eastern South China Sea, Celebes Sea, and northern Philippine Sea have values of 0.06 and 0.07 ppb. Higher values of 0.2 to 0.7 ppb are found in waters around Japan.

Some countries in South-East Asia make surveys and occasional observations of hydrocarbons in coastal waters, but the results and data are scattered, so it is impossible to integrate this information with the MAPMOPP/IGOSS data. Even for an assessment within the region, interpretation is difficult because of the various methods of sampling and analysis used.

The hydrocarbon contamination data given below by country represent an effort to compare the available information regardless of the purposes for which they were produced. Accumulations of oil pollution are strongly dependant on the hydrographic and geographic features of the region.

Figure 5 : Regional distribution of tarball concentration and number of samples by 5° squares

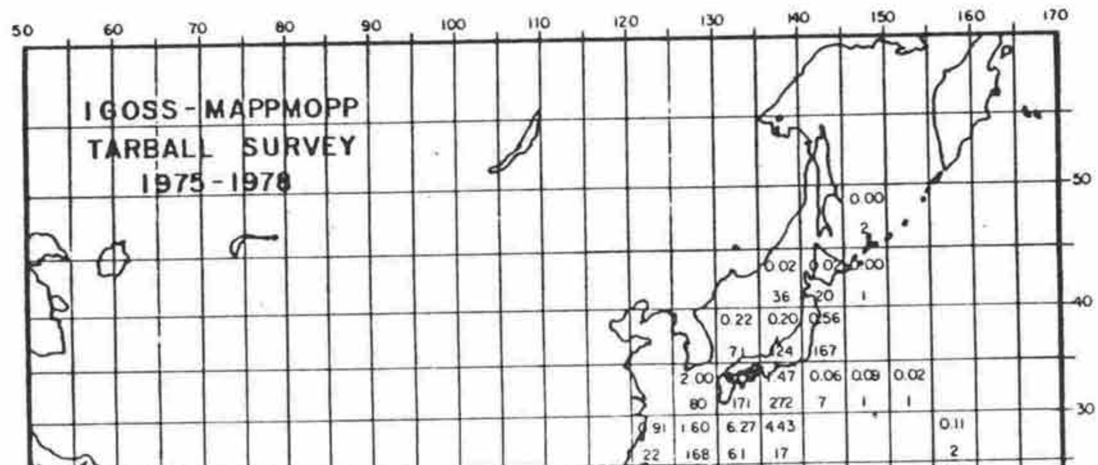
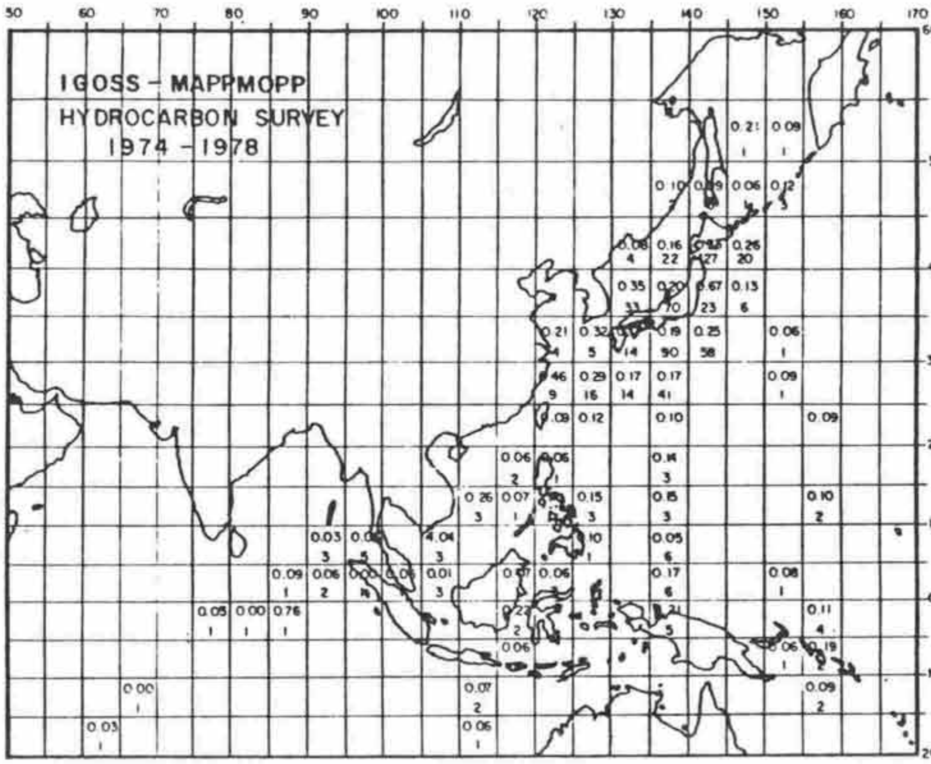


Figure 6 : Regional distribution of the concentration of hydrocarbons in water (ppb) and number of samples by 5° squares



Current system

Generally the ocean currents in this region are influenced by the monsoon. The monsoon changes the current circulation patterns twice a year; currents are practically reversed over large areas at the time of the strongest monsoon influence.

Figures 7 and 8 show the circulation patterns during the northeast monsoon and the southwest monsoon. The southwest monsoon current is dominant in the middle part of the South China Sea and the Java Sea where the westward flow into the Java Sea comes from the Banda Sea and the Celebes Sea through the Straits of Macassar, and goes out of the Java Sea predominantly through the Straits of Karimata and partly through the Straits of Malacca. The main currents reverse direction during the northeast monsoon, with the currents from the South China Sea setting through the Karimata Straits eastward into the Java Sea and Banda Sea to the Pacific.

Dispersed/dissolved hydrocarbons in water

Measurements in various **Indonesian** waters showed concentrations of below 1 ppm adjacent to the oil production field north of the Bay of Jakarta (Muchtisar et al., 1977; Bilal et al., 1979). The range of concentrations between Port Dumai and Pangkalan Brandan (Malacca Straits) is reported as 0.1 to 7.2 ppm (Wasilun, 1978) and in Riau Archipelago, Philipp Channel, is reported as 0.7 to 3.2 ppm (Lemigas Lab. Report, 1977).

The concentration in **Malaysian** waters, adjacent to Pulau Penang (Glugor, Teluk Kumbar and Teluk Bahang) was found to range from 0.01 to 0.12 ppm (Phang et al., 1980).

A survey along the east coast of the **Gulf of Thailand** between Samut Songkhram and Chonburi, reported the highest concentration of "oil and grease" as 38 ppm (Vashrangsi, 1978).

In Batangas Bay, **Philippines** (South China Sea) where two refineries are located, hydrocarbons range from 0.8 to 5.5 ppm (Bilal and Kuehnhold, 1980).

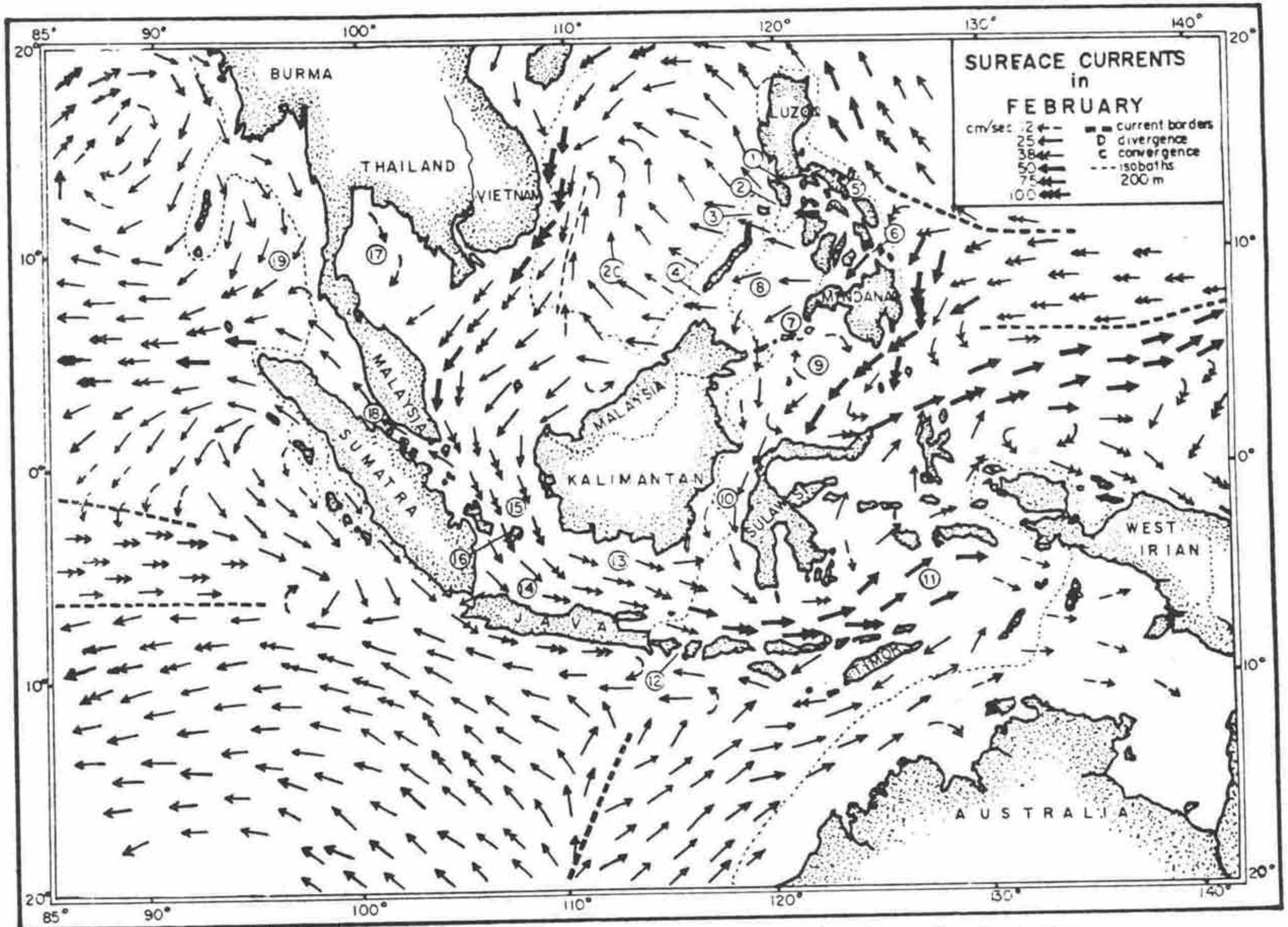


Figure 7 : Surface current patterns in South-East Asia during the northeast monsoon, February (Soegiarto and Birowo, 1975)

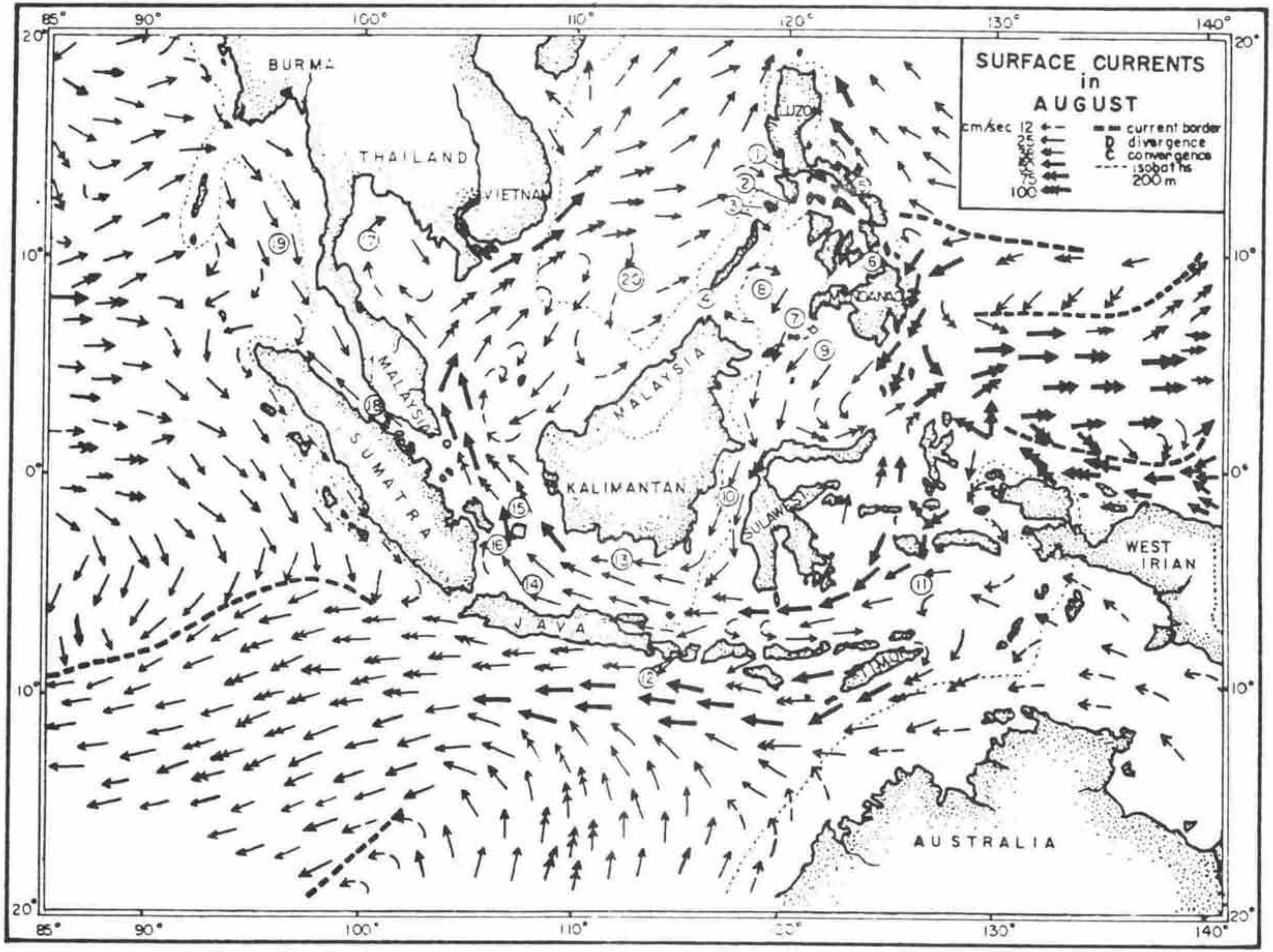


Figure 8 : Surface current patterns in South-East Asia during the southwest monsoon, August (Soegiarto and Birowo, 1975)

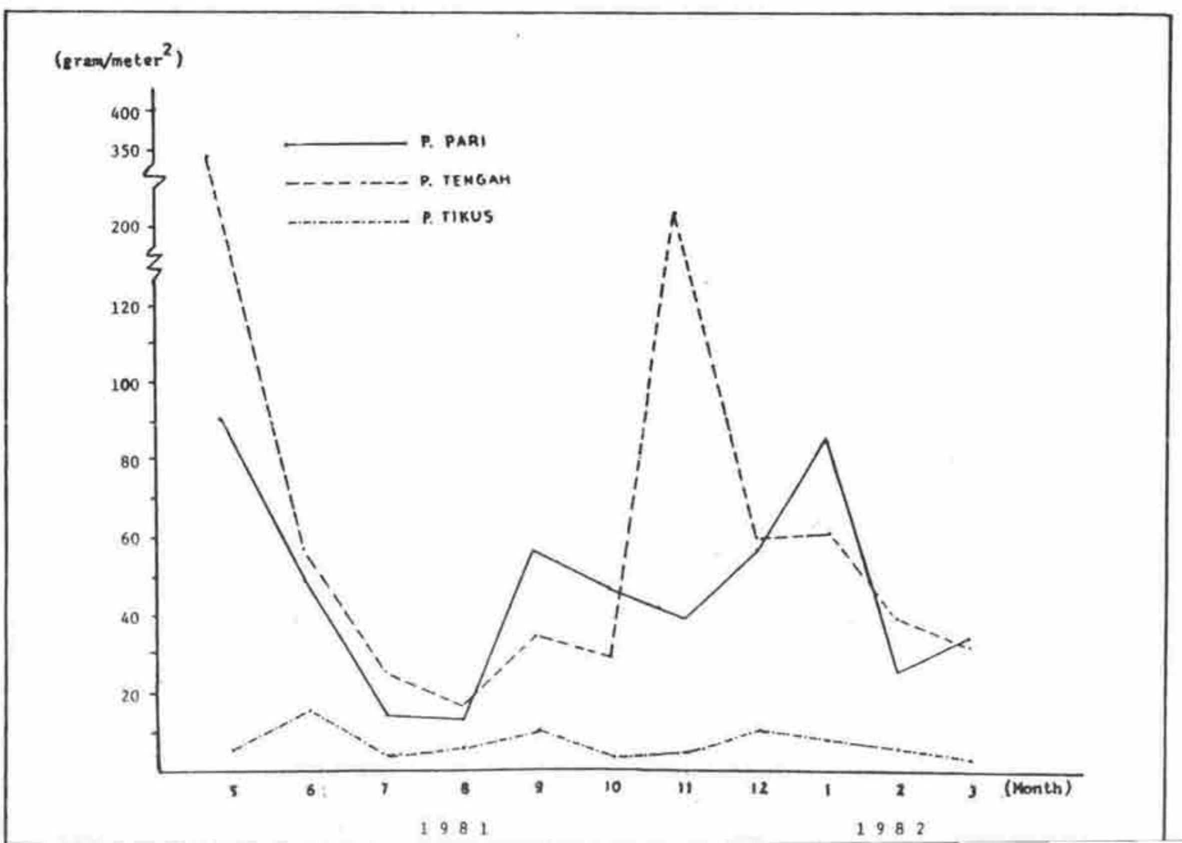
The following methods were used for hydrocarbon analyses. MAPMOPP/IGOSS presumably used 5 litres of sample extracted by n-hexane and analysed by fluorescence spectrometry (IOC/WMO, 1976). Phang et al. (Malaysia) used 2.5 litres of water sample extracted in CCl_4 and analysed with an infra-red spectrophotometer (Atwood et al., 1972). Oil and Gas Technology Development Center "Lemigas" (Indonesia) used 5 litres of water sample, extracted in CCl_4, shaken with Florisil to remove polar hydrocarbons and finally analysed by infra-red spectrophotometry (CONCAWE, 1972). The National Pollution Control Commission of the Philippines analysed the water sample by extraction with a solvent and weighing gravimetrically without any separation of the polar and non-polar hydrocarbons. These differences of method make comparisons difficult.

Tarball occurrence

Referring to Figure 5 from MAPMOPP/IGOSS, "Regional distribution of tarball concentration 1974 - 1978" and Figure 4 from Nasu's study on "Petroleum pollution in the high seas" gives the following summary of the tarball status in the East Asian Seas. To the north of Luzon (Philippines), there are 0.63 kg/km^2 (=0.63 mg/m^2) and northeast of this area tarball values reach 1.6 kg/km^2 (=1.6 mg/m^2). In the direction of Japan the contamination reaches higher values. As stated above, the discharge of tanker's dirty ballast is much more frequent in the South China Sea than in Taiwanese and Japanese waters; thus the question of tarball contamination in the South China Sea is quite interesting. In the Philippine Sea the plots indicate "only" 0.06 mg/m^2.

Stranded tarballs have been observed by some countries in South-East Asia. In Pulau Pari, where the Indonesian Institute of Oceanology is located, tarballs have been observed regularly for the last four years. Pulau Pari itself is a pseudo-atoll consisting of five small islands, and on three of these, stranded tarballs have been observed. The result of a 1981/1982 survey is given in Figure 9. It shows that the fluctuation of the quantity depends on the monsoon. The lowest quantity is in August (12.3 gr/m^2) and the highest (81 gr/m^2) is in November (Toro and Djamali, 1982). In August 1982, Lemigas and the French Centre National pour l'Exploitation des Oceans (CNEXO) made a reconnaissance survey in the Riau Archipelago (Straits of Singapore) and the southern part of the West Celebes coast (Straits of Macassar) among other areas. Although this was the month with the lowest concentrations, tarballs were still found in Pulau Pari, Riau Archipelago and the west coast of Celebes.

Figure 9 : Mean quantity of stranded tarballs per month (g/m^2) on Pulau Pari, Pulau Tengah and Pulau Tikus (Toro and Djamali, 1982)



On the coast around the Gulf of Thailand, tarballs were found during March and April. At Songkhla beach, the highest accumulation was 0.2 to 715 gr/m^2. Also on the beaches of Phuket Island, facing the Indian Ocean and Andaman Sea, such as the beaches of Karon, Patbong, Naiyang and Laem Phanwa, the accumulation ranged from 0.1 to 180 gr/m^2. The accumulation increased from August onward (Pyakarnchana et al., 1978).

On the eastern coast of Peninsular Malaysia from Kota Baharu to Mersing, including the offshore island of Pulau Tioman, contamination by oil residues and tarballs has also been found (Maheswaran, 1978).

Discussion and conclusion

The South-East Asian waters including the South China Sea are at present densely occupied by oil activities such as oil exploration, production, refining and transportation. As a consequence of low level discharge by refining and production processes, spills by shipping casualties, as well as spills due to technical failure or human error in handling of oil, the waters in this region are continuously contaminated by oil. The accumulations of dispersed/dissolved oil in water, floating oil lumps and stranded tarballs are very dependent on such physical factors as the winds, ocean currents and tidal movement. However, local currents and seabed topography in the Malacca Straits, the Gulf of Thailand and the Java Sea may influence predicted sites of accumulation.

At present the Straits of Malacca and the South China Sea waters are the most vulnerable areas for oil pollution because of the increasing size and frequency of tankers traversing the area, as well as oil activities and hydrographic and geographic patterns. Before tankers enter the shallow strait they have to reduce their draft by discharging ballast water. Whether the deballasting operation occurs in the western or eastern entrance of the strait is a significant question, because these operations lead to oil slicks and tarball formation. Deballasting in the South China Sea is more probable and frequent, although this depends on the transportation schedule and destination of cargo. Tankers from the Middle East to Japan not only load and unload at the beginning and end of their voyage, but also unload and take on cargo at intermediate ports such as Singapore or Port Dickson.

The Gulf of Thailand receives water from the current circulation in the South China Sea during the yearly monsoon (Wirtky, 1961). This might possibly explain the tarball deposition along the coast of the Gulf and the eastern coast of Peninsular Malaysia. It is interesting to note that the accumulations and their locations vary seasonally, in close relation to the current circulation and tanker routes as suggested by the studies of Kurashina (1975) and Nasu et al. (1976).

In the region of Pulau Pari, currents conform with the general pattern of the Java Sea. Measurements were made during October and November 1970 at Kepulauan Seribu (Seribu Archipelago) north of Pulau Pari. During the transitional period between monsoons, the maximum velocity of the general current was only 0.08 m/sec at low tide. At high tide, rates tend to increase to 1.0 m/sec. This current system, particularly the relative stagnancy of the waters, may explain the deposition of tarballs at the islands.

Surveys and monitoring of oil contamination in the South-East Asian countries are being conducted to assess the extent of oil pollution, but it is difficult to define the status of pollution in the region because of no clear definition of the oil analysed.

To clarify the status of hydrocarbon contamination in this region, more systematic action should be organized within the countries. There is also a need for standardization of methods to ensure comparable data for regional interpretation.

REFERENCES

Anonymous. 1980. South-East Asia Petroleum News map, Singapore.

Atwood, H. R., R. W. Hannah and M. V. Zeller. 1972. Determination of oil in water by infra-red spectroscopy. Perkin-Elmer INFRA-RED Bulletin No. 11.

BAKOREN, National Energy Co-ordination Body. 1982. General policies on energy. Dept. of Mines and Energy, Jakarta, Indonesia [in Indonesian].

Bilal, J. and W.W. Kuehnhold. 1980. Marine oil pollution in South-East Asia. FAO/South China Sea Fisheries Development and Coordinating Programme, Manila, Philippines.

Bilal, J., B. Prasetyo, I. A. Bachtiar and R. Sani. 1979. Activities report on environmental study in the 2nd Five Year Plan 1974-1979. Department of Mines and Energy/Lemigas, Jakarta, Indonesia [in Indonesian].

CONCAWE. 1972. Methods for the analysis of oil in water and soil, I/72. CONCAWE, Stichting, The Hague.

Finn, Daniel P., Yuzuru Harayama, M.J. Meimandi-Nejab, Twesukdi Piyakarnchana and James N. Reeves. 1979. Oil pollution from tankers in the Straits of Malacca: a policy and legal analysis. East-West Center, Honolulu, Hawaii, USA. Open Grants Papers No. 6.

Gomez, E.D. 1978. Status report on research and monitoring of the impact of pollution on the mangrove ecosystem and its productivity in the Philippines. Marine Science Center, University of the Philippines.

Hayes, T. M. 1979. Mission reports, Lombok/Makassar Strait/Celebes Sea shipping route - Subregional arrangements for combating marine oil pollution. IMCO Report No. A6/A-UNDP/Int/Mar/Poll.

IOC/WMO. 1976. Guide to operational proceedures for the IGOSS pilot project on marine pollution (petroleum) monitoring. Manual and Guide No. 7, UNESCO, Paris.

Kantaatmadja, K. 1981. Marine oil pollution international claim. Alumni, Bandung, Indonesia [in Indonesian].

Kurashina. 1975. The present situation of tarballs. Hydrographic Research Bulletin No. 93, Japan.

Lemigas. 1977. Laboratory Report no. 588-592/TR/RPK/77, Lemigas, Oil and Gas Technology Development Centre, Jakarta, Indonesia, (unpublished).

Maheswaran, A. 1978. Marine pollution and its control. Paper presented at First Marine Science Conference, Kuala Lumpur, Malaysia.

Menasveta, D. 1980. Paper presented in FAO/UNEP/UNESCO/IUCN Expert Consultation Meeting on Assessment of Oil Pollution and its Impact on Living Aquatic Resources in South-East Asia, Manila, Philippines, (unpublished).

Muchtisar, D. P. and C. Muluk. 1977. Oil industry effluent: a case study on the aspects of technology and environment. Lemigas, Jakarta, Indonesia [in Indonesian].

Nasu, Kamiyanagi and Kitani. 1975. Petroleum pollution in the high seas. Oceanographic Survey Notes No. 2, Japan.

Phang, S., T. K. Hwang and T. T. Ang. 1980. A study of the hydrocarbon content in the coastal water along the east coast of Peninsular Malaysia. In Coastal Resources of East Coast Peninsular Malaysia, Universiti Sains Malaysia, Penang, Malaysia.

Pyakarnchana, T., J. Temiyavanich, T. Sakarin, Sukmimit and P. Wootistiraphinyoe. 1977. Survey of tarballs on the beaches in Thailand 1977-1978. In Proc. of the Symp. on Marine Pollution Research in Thai Waters, National Research Council, Bangkok, Thailand.

Siddayao, Corazon Morales. 1978. The offshore petroleum resources of South East Asia. Oxford University Press, Kuala Lumpur, Malaysia.

Siddayao, Corazon Morales, 1980. Submarine hydrocarbons in South-East Asia: Resources, environment and policy. GeoJournal 4,5: 393-406. August 1980.

Sigit, S., Reksosoemitro, S. Sediono and B. Soegito. 1980. Indonesian mining yearbook 1980. Department of Mines and Energy, Jakarta, Indonesia.

Soegiarto, Aprilani, and A.T. Birowo. 1975. Oceanologic atlas of the Indonesian and adjacent waters, Volume 1. National Institute of Oceanology, Jakarta, Indonesia [in Indonesian].

Toro, V. and T. Djamali. 1982. Fluctuation of tarball in Pulau Pari Kepulauan Seribu. National Institute of Oceanology, Jakarta, Indonesia [in Indonesian].

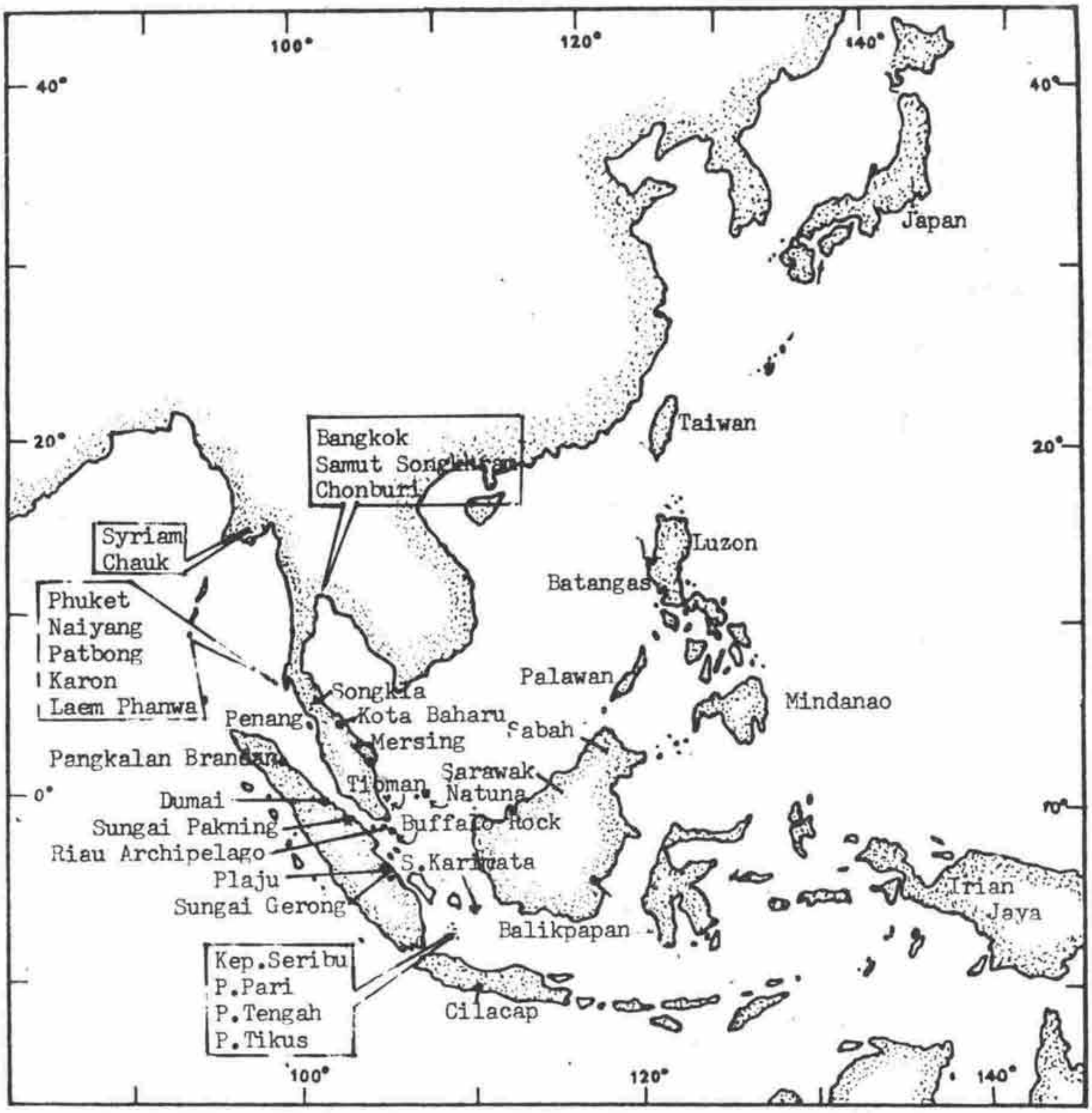
Valencia, Mark J. 1981. Shipping, energy and environment: South-East Asian perspective for the 1980's. Workshop Report, East-West Environment and Policy Institute, East West Center, Honolulu, Hawaii, USA.

Vashrangsi, C. Proc. of the Symposium on Marine Pollution Research in Thai Waters 1977-1978, National Research Council, Bangkok, Thailand.

Wasilun, K. 1978. Monitoring of pollution along the eastern coast of Sumatra in November 1976 and July-August 1978. In Marine Fisheries Report No. 1/1978, Marine Fisheries Research Institute, Jakarta, Indonesia [in Indonesian].

Wirtky, K. 1961. Physical oceanography of the South-East Asian waters. Naga Report, Vol. 2, Scientific Result of Marine Investigation in the South China Sea and the Gulf of Thailand, 1959-1961. University of California, La Jolla, Cal. USA.

Annex 1 : Map of places mentioned in the paper



PLANNED REGIONAL CO-OPERATION IN EAST ASIAN SEAS FOR NON-OIL POLLUTION RESEARCH - PROBLEMS AND POSSIBLE SOLUTIONS

Amando F. Kapauan
Department of Chemistry, Ateneo de Manila University
Loyola Heights, Quezon City, Philippines

ABSTRACT

The monitoring of pollutants other than oil in the marine environment as part of a Regional Seas programme requires a scientific infrastructure that does not yet exist in the developing countries of South-East Asia. Creating this infrastructure requires solutions to institutional problems, spatial and temporal requirements and constraints, and the difficulties of assembling national research infrastructures. The quality of technical personnel must be improved through appropriate selection and training. Such training could also help to solve difficulties with equipment maintenance and calibration.

Introduction

Regional co-operation in the seas common to the East Asian countries of Malaysia, Singapore, Thailand, Philippines and Indonesia has begun with support from the United Nations Environment Programme. Numerous papers, pertinent to the East Asian region and to the various other Regional Seas programmes, have been written about such co-operative research projects. This short paper attempts to focus on some important problems associated with non-oil pollution research in the East Asian seas. The Philippines is emphasized as being 'typical' of the developing countries involved with respect to various capabilities required for participation in such a regional co-operation project. This analysis will focus on the problems associated with monitoring pollutants other than oil, which is a core component of the Regional Seas programmes.

Institutional problems

Unlike many developed countries with well established research traditions in both the basic and applied fields, many of the developing countries in the region have few well developed research institutions. Those they have are usually very specialized, having been established to support economically important activities in these countries (e.g. rubber in Malaysia, coconut in the Philippines). Thus in an area such as non-oil pollution research in the marine environment, institutions are either non-existent or not as fully developed as would be required for a regional monitoring programme.

However, a careful look at the total capabilities within any given country shows that the ingredients that should go into such a Regional Seas programme already exist in fully developed form, or nearly so, in bits and pieces among several other institutions. In the Philippines, for example, facilities of the Philippine Coast Guard, The Bureau of Coast and Geodetic Survey, the National Pollution Control Commission, the Philippines Atomic Energy Commission, the Food and Nutrition Research Center, the University of the Philippines and one or two other universities, taken together, yield a fairly complete system for such an undertaking. Similar statements could be made for Malaysia, Thailand, and Indonesia.

The biggest problem associated with such a 'multilithic', as opposed to a monolithic, system is, of course, that of co-ordinating the various components. Each individual institution has its own concerns, with which involvement with a Regional Seas monitoring and research programme might conceivably interfere. Moreover the phenomenon of bureaucratic territoriality makes co-ordination very difficult among several different institutions.

There are however, in each country, examples in which multi-institutional projects have been undertaken and made to work. Citing again the Philippines, a nationwide project to survey the degree of mercury pollution was undertaken during the 1970's which involved one private university, the Food and Nutrition Research Institute, the laboratories of the Ministry of Science, the National Pollution Control Commission, the Ministry of Natural Resources, and the Philippine Atomic Energy Commission. The system worked beautifully under the direction of a committee which called itself the Mercury Study Group.

Two of the most important ingredients for such successful co-operation within a country are: (1) proper choice of the people to co-ordinate work within their own institutions, and (2) funding for the extra people and work needed to join the co-operative project. The first of these is obvious. Without dedicated and concerned people, no co-operative projects are possible. The second is more practical. Institutional budgets usually cannot accommodate activities other than those that are the major concerns of the institution, and for them to engage in other activities, funds for these activities must be made available. In the case of the Philippines' Mercury Study Group, funds were made available through a grant from the Ministry of Science.

Spatial and temporal requirements and constraints

A Regional Seas monitoring programme, unlike that for open oceans, is by necessity a complicated one in terms of spatial and temporal needs and constraints. This is particularly true of the East Asian Seas, which include such regional bodies of water as the Gulf of Thailand, the Java, Banda, Flores, Celebes, Sulu and South China Seas - to name only those of concern to the ASEAN countries. It would be more correct to think of the regional programme , not as a programme for the region, but rather as a system of interacting national programmes which must somehow be co-ordinated to yield meaningful data for the region.

Each participating country in the programme must of necessity concern itself mostly with those aspects which have their greatest impacts within the country and only secondarily with the region. Moreover, most of such concerns will be within each country's territorial limits (including the 200 mile economic limit which many countries accept). The spatial and temporal aspects of the Regional Seas programme must therefore be very carefully worked out so that each participating country can gain the maximum benefit from it while at the same time realizing the objectives of the regional programme. Particular attention must be paid to those regions in which each subdivision of the seas system interacts with another subdivision. Thus Malaysia, Indonesia and Singapore would be particularly interested in the Andaman Sea and the Gulf of Thailand, the Java Sea, and the southern end of the South China Sea through the Straits of Malacca; similarly interactions between the South China Sea, Sulu Sea and Celebes Sea would interest the Philippines, Malaysia, and Indonesia.

Unlike the open oceans where time scales can be quite extended, the fluxes in the East Asian regional seas could change much more quickly so that great care should be taken in the design of the temporal aspects of the co-operative programme. There is evidence from reports of the Japan Meteorological Agency that concentrations of mercury and cadmium, for example, can change by up to a factor of 10 between winter and summer and a factor of about 3 within a three month period.

In view of the above, a planning committee which must take into consideration both national and regional concerns must be constituted as the group that will decide on the spatial and temporal aspects of the co-operative projects. The committee members must be familiar with their own national concerns and also have a broad perspective on the various Regional Seas programme activities.

National research infrastructure

One problem area within the region needs careful examination because the solution could in some cases involve considerable investment by the national governments. This is the creation of a research infrastructure which fulfills the demands of a good Regional Seas programme. This infrastructure includes the vessels, equipment and laboratories that will enable each participating country to obtain the necessary samples at the various places and times required by the programme, transporting them to the laboratories and analysing the various components to give valid results. This is an entirely different problem from the institutional problems mentioned earlier.

In most cases, the problem of research infrastructure could be met through co-ordination within the country. However, not all of these problems can be so resolved. For example, although the need for vessels to get samples could be met by taking care of by taking advantage of the various governmental and non-governmental sailings within a given sea, the acquisition and use of specialized equipment could not. No amount of "co-operation" between various institutions can create a specialized piece of equipment that is not already there. The countries in the East Asian region vary greatly in their ability to set up the proper research infrastructure. For example, the Malaysian Government seems to be quite generous in its support for the acquisition of research materials and equipment, while in contrast, the Philippine Government has a de facto ban on the importation of research equipment which makes their acquisition quite difficult.

Therefore, the country representatives on a regional co-ordinating committee or council must move their respective governments and institutions to make available the necessary facilities and equipment required for the Regional Seas co-operative projects.

Personnel and training

In general, there is need to improve the quality of personnel in the various institutions in the region who will do the day to day work on the co-operative project. Although a significant amount of environmental work is already being done in many places, the intensity and depth of the undertakings fall short of the rigorous requirements of a Regional Seas programme.

Within each country, institutions competent in training for such work already exist. The problem lies in co-ordinating these for the purposes of the programme so that the quality of training would be of a uniformly high level. The alternative would be to bring together the personnel involved at one facility especially active in the field and give them a rigorous training in the various techniques required. A several month training programme, perhaps in Australia, has been suggested by some, although for psychological reasons (among others), training in one of the developing countries, supported as necessary to upgrade facilities to a sufficiently high level, would be an alternative that should be explored.

A problem that could well arise in this area of personnel and training is the proper choice of the people to be sent for training. In many countries in the region, bureaucratic "favourites" tend to be chosen again and again, often to the detriment of the aims of training programmes if these favourites happen not to be the people who will do the work.

Equipment maintenance and calibration

Equipment and proceedures should be such that data obtained from the various parts of the region are directly comparable within the region and with data obtained from the various other Regional Seas programmes. This requires training programmes on the proper maintenance and calibration of equipment for personnel involved in the co-operative project.

A recent workshop on instrument maintenance and calibration in the region sponsored by the Federation of Asian Chemical Societies showed that the bulk of maintenance and calibration of analytical instrumentation is carried out, not by the analysts who should be responsible for the quality of their analytical data, but by technicians from the instrument suppliers. In some cases this does not pose a real problem, especially if the dealers' service headquarters happens to be nearby, but in many cases it contributes to unacceptably long down-times for certain instruments.

Since the analysts performing the instrumentation procedures are often not trained to maintain and calibrate their instruments and have to rely on service technicians for this, analytical throughput can be severely impaired. This is understandable if instrument troubles were generally of such magnitude as to require the service of such technicians (as for example when a single element of a multi-element chip fails), but very often the problem is as simple as a blown fuse.

The Regional Seas programme needs therefore to initiate a rational programme of instrumentation maintenance, calibration, and, if necessary, repair to ensure the continuing flow of data. Such capabilities have already been perceived as necessary in many countries in the region. Perhaps this could be put into effect immediately by training the analysts to do routine maintenance and calibration on their own instruments together with their training in instrumental methods mentioned in the previous section.

Conclusion

This short paper has examined some of the problems and their possible solutions which face a Regional Seas programme for East Asia given the capabilities and limitations of the institutions in the region. The Philippines have been taken as a reference point, but the same general problems apply to most of the other countries of the region. Hopefully these points will be considered in the design and implementation of the East Asian Seas regional programme of co-operation.

MARINE POLLUTION BY HEAVY METALS IN THE EAST ASIAN SEAS REGION

Manuwadi Hungspreugs
Department of Marine Science, Chulalongkorn University
Phya Thai Road, Bangkok 5, Thailand

ABSTRACT

With increasing pollution in the coastal waters of South-East Asia, greater attention is being directed to the concentrations of heavy metals in the marine environment. The levels of potentially toxic metals have been analysed in seawater, sediments and marine organisms, but studies are also needed of river and atmospheric inputs and of the historical record of deposits in coastal sediments. A brief review of available information on heavy metal pollution is given for each ASEAN country.

Increasing industrialization and urbanization in South-East Asian countries result in mobilization and discharge into the marine environment of large quantities of actually harmful or potentially harmful materials, both organic and inorganic. However, East Asian countries rely heavily on marine fisheries as principal source of low cost protein. To maintain this resource in a healthy and productive state is vital.

HEAVY METALS IN THE MARINE ENVIRONMENT

Many toxic or potentially toxic metals are released into the oceans, especially into the coastal zones. Several metals such as iron, copper, cobalt, chromium, manganese, molybdenum, nickel, vanadium and zinc are known to be essential to living organisms, but if present in excessive amounts, they are toxic.

The oceans receive heavy metals through the atmosphere, land run-off and rivers. Anthropogenic metals enter the natural biogeochemical cycles at rates that depend on their physico-chemical forms which are often different from naturally-occurring metals.

Heavy metals in seawater

Owing to the difficulties in determining trace metals in seawater (very low concentrations of these heavy metals; high concentrations of major ions; contamination of the sample during sampling, storage, and chemical manipulations; ease of interference by major ions present; etc.) relatively few measurements are reliable. The comparison between values given by different authors is complicated by the use of different methods which often measure different physico-chemical forms and fractions of the total amount present. On the other hand the distinction between these different forms is very important because they act differently in biogeochemical cycles and have different effects on marine organisms. Most heavy metals are more toxic in ionic than in complexed forms. Only since the mid-1970's has chemical speciation in seawater received much attention.

Influences from land obviously affect the concentration of heavy metals in near-shore regions, so a distinction must be made between the expected level of metals in these regions and in the "open sea" or "oceanic" seawater. The concentrations in coastal seawater are markedly affected by local influences such as anthropogenic sources, river inputs and land run-off. Analyses of oceanic seawater will indicate the general level of heavy metal concentrations in the open sea, almost always at a much lower level.

Often, a direct comparison is made between the level of metals in coastal waters and the average world ocean values, and if the former level is considerably higher, then it is judged to be "very polluted". In fact, as any marine scientist knows, the natural background levels of the two systems are vastly different, and estuarine areas must be compared to similar coastal environments.

Heavy metals in sediments

The study of sediments is of great importance in measuring the distribution of heavy metals, since for the majority of the elements and substances, sediments are the ultimate "sink" or "deposit". Natural sediments are mixtures of sands, clays and organic substances. The relative abundance of these components varies considerably with different types of sediment. The interaction of heavy metals with the sediments depends on their composition. Higher concentrations of metals are usually found in mud and silt, rather than in sand, so the grain-size characteristics of the sediment samples must be assessed in interpreting the metal values observed.

Heavy metals in marine organisms

The concern about heavy metals in food has stimulated the analysis of toxic metals in fishery products: edible crustaceans, molluscs, and fish. Different species collected at the same site show great differences in their metal concentrations. Consequently body contents can only be compared between specimens of the same species, preferably of the same age or size. Details on the use of aquatic organisms as biological indicators are given by Phillips in his book "Quantitative Aquatic Biological Indicators" (1980a). His proposal for monitoring studies on the contamination of the East Asian Seas by trace metals and organochlorines (Phillips, 1980b) is a very useful guide.

The ability of bivalves to concentrate substances far above their levels in the environment makes them useful as sentinel organisms for indicating level of pollutants in coastal marine waters. This is the basis for the Mussel Watch Programme (Goldberg et al., 1978), now in operation in the U.S. and some European countries for some years. Some countries in the East Asian region have also joined the programme.

Heavy metals in rivers

Yeats et al. (1978) have demonstrated that river monitoring gives a faster and more reliable warning of changes due to anthropogenic activity than monitoring of coastal waters. Thus major rivers should also be monitored for any possible change in pollutant levels.

Heavy metals in the atmosphere

Garrels and Mackenzie (1971) estimated that rivers account for 90% of the total seaward transport of dissolved and suspended solids. However Windom (1981) reported that in some cases, the atmospheric flux to the continental shelf environment is similar to, or greater than the riverine flux, as in the latter only the soluble fractions reach the continental shelf, while most of the suspended sediments are trapped in the estuary. Thus he suggests that atmospheric flux cannot always be ignored.

Heavy metal record in coastal sediments

The sediment accumulation rates for cores from delta stations can be determined by geochronological methods with suitable isotopes like Pb-210. It is then possible to assign ages to the vertical sediment strata. Evaluation of the vertical distribution of heavy metals in these cores gives a historical record of the input of elements to that area.

If a deposit shows increased concentrations of a suspected pollutant, such as a metal, in its uppermost levels relative to the deeper sediment, the differences in concentration are ascribed to anthropogenic sources. However, special precautions must be taken before final conclusions are drawn (Bertine, 1978).

BRIEF REVIEW OF HEAVY METAL POLLUTION IN ASEAN COUNTRIES.

Although studies of trace metal pollution have increased in the East Asian Seas region recently, most reports are made for local use only, and little information is more widely available.

Ferguson Wood and Johannes (1975) mention in their book "Tropical Marine Pollution" that "libraries in the coastal tropics are often poorly equipped. In addition, the literature on tropical marine pollution is widely scattered and often hard to obtain. Research on and evaluation of tropical marine pollution has therefore often been based on information obtained from a smattering of inappropriate but relatively accessible information on temperate marine pollution." This book cites the few studies on heavy metals in the tropics, including those of levels in the sediment and marine biota of Pearl Harbour, Hawaii, tests of copper toxicity in South Florida marine organisms, and copper and nickel from desalination plant corrosion.

The following brief review of the heavy metal pollution status in each ASEAN country is based on the very few papers available to the author.

Indonesia

Indonesia is a vast country consisting of more than 13,000 islands, of which the most populated is Java. Soegiarto (1975) reported that the major sources of pollution are sedimentation, accelerated erosion due to inappropriate land management, dredging, and mining. Water quality problems arise from soil erosion in the headwaters of rivers, sediment deposition in the coastal plains which aggravate drainage problems, and pollution caused by the density of human settlement and industry in the plains. Several reservoirs are filling up with sediments at an alarming rate (UNESCO/UNEP, 1980).

The results of pollution monitoring over the last few years indicate an increase in heavy metal concentrations in various waters such as Jakarta Bay and the Bangka Straits. Therefore, the government has established a Task Force for a Heavy Metal Monitoring Programme with instructions:

- to monitor other bodies of water, in particular around big cities and industrial centres;

- to measure heavy metal concentrations at various toxic levels in phytoplankton, zooplankton, fish, benthic and sessile fauna, including commercially exploited or cultured shellfish;

- to study the impact of heavy metal pollution on the health of fishermen and their families through interviews and analysis of samples of hair and urine; and

- to find out the possible and potential sources of heavy metal pollution in coastal waters.

Malaysia

The Division of Environment, Ministry of Science, Technology and Environment has established key stations for water quality monitoring throughout Peninsular Malaysia. Analyses are performed by the Department of Chemistry and include most of the toxic substances (UNESCO/UNEP, 1980).

Silvalingam (1980a) found fairly low levels of total mercury in tropical algae at Penang, from below detectable level to 0.35 μg/g dry weight except for Padina sp. at 1.02 μg/g, although a study on the Juru River on the mainland opposite Penang indicated high levels of mercury. Sivalingam and Sani (1980) found no correlation between biodeposited mercury in hair from fishing communities of Penang, and mercury concentration in local fish. The level of mercury in fish muscle ranges from 0.237 to 3.265 ppm, in liver 1.48 to 7.500 ppm and in heart 0.945 to 16.345 ppm dry weight. The highest mercury in hair was found in the human age group over 40.

Sivalingam et al. (1981) studied the trace metals in sea water, sediments and molluscs around Penang, and found the following:

For seawater (ppm)

Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
0-0.05	0-0.18	to 0.35	0.00	0-0.01	0.06-0.43	0-2.07	0.07-0.26	0-0.04

For sediments (ppm dry wt.)

Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
0-1.25	4-36	2-28.5	1-26.5	1,500-18,750	12-189	1.8-29.25	6.5-35.25	8-76

One study on bioaccumulation mechanisms (Sivalingam, 1981) was made on the Malaysian oyster, Saccostrea cucullata, under very high concentration stresses of from 5 to 200 ppm cadmium, cobalt, chromium, copper, iron, mercury, manganese, nickel, lead and zinc. These concentration levels are so high as to exceed the solubilities in seawater of many metals, e.g. lead; thus a great proportion of the metal is in suspension, not in solution. The salts used were cadmium, chloride, cobalt chloride, copper chloride, ferric chloride, mercuric chloride, manganese chloride, nickel chloride, potassium dichromate and lead nitrate.

The Philippines

In the Philippines there are many government agencies directly linked with monitoring of marine pollution and pollution in general.

Most pollution studies were made in the Manila Bay area, a highly populated urban area of 4.5 million people and only 12-15% sewered in 1978 (Gomez, 1981). Coliform bacterial contamination of the Bay may average as high as 1000/100ml with a range of 200 to 2,000,000 per 100ml along some shores; the National Pollution Control Council standard for bathing beaches is 1000 colonies/100 ml. The Pasig River draining into the Bay had a mercury content of 0.1 to 85.3 ppb (Kapauan 1973) while the Honda Bay area in Palawan, into which 2 rivers wash over cinnabar, contained 0.003 to 0.419 ng/g mercury in seawater and 0.004->2 µg/g in sediment around the jetty (Kapauan et al., 1979). The 1978 figure for mercury in Manila Bay averaged 10 ppb. The levels of other metals in the water were reported to be cadmium 0-0.09, copper 0-0.19, iron 0.68-1.34, manganese 0.08-0.18, lead 0.06-0.29 and zinc 0.06-0.30 mg/litre. The sources of heavy metal pollution are the industrial effluents from metal-plating and battery factories, and mine-tailing effluents. There are many mines in the Philippines. However, the mercury, cadmium and lead contents of the fish, oysters and mussels from Manila Bay are still under the WHO permissible limit of 0.5 ppm.

Other areas of the country are still pollution-free and beaches are beautiful and clean (Gomez, 1981).

Kapauan et al. (1979) made an extensive report on the contents of cadmium, copper, lead and zinc in a variety of fish, mussels and oysters from samples collected from different regions in the Philippines from 1975-1977. A nation-wide survey of mercury and other heavy metal pollution in Philippine waters, aquatic life and sediments was made by the Food and Nutrition Research Institute and the Philippines Atomic Energy Commission (1973-1978). Lead and cadmium were determined by differential pulse anodic stripping voltammetry and copper and zinc by atomic absorption spectrophotometry. The results of these studies are summarized below in µg/g wet weight.

	Cd		Cu		Pb		Zn	
	range	average	range	average	range	average	range	average
fish	0-0.129	0.009	0.205-9.93	0.97	0-0.448	0.035	2.59-42.3	8.37
mussel	0-0.271	0.054	1.86-5.0	2.95	0.024-0.244	0.098	10.4-53.9	16.7
oyster	0.054-0.45	0.183	10.6-54.0	31.3	0-0.190	0.084	25.6-27.9	13.2

The ratio of these heavy metals in oyster/mussel/fish was:

Cd	20/	6/	1
Cu	32/	3/	1
Pb	2.4/	2.8/	1
Zn	16/	2/	1

Fourteen species of shellfish were studied but here only the results of Anadara granosa, Crassostrea cucullata and Mytilus viridis are summarized, with the range for all stations in µg/g dry weight:

	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Anadara granosa	1-5	5.5-9	16-18	8-13	560-1020	11-19	16-24	7-18	72-104
Crassostrea cucullata	5-8	4-15	16-18	89-528	300-1070	9-22	22-31	4-18	650-1400
Mytilus viridis	0-3	3-18	to-16	to-18	220-860	6-26	22-50	4-7	48-102

Singapore

The land area of Singapore is small and none of its rivers are large. In addition several rivers have water supply reservoirs or have been diverted. Water storage areas have been established in several estuaries and so considerable effort is expended to maintain a high water quality for storm run-off. The quantity of pollutants discharged to the sea by rivers is now small. Sewage is treated to a high standard and agricultural waste is small. (UNESCO/UNEP 1980).

The only study available to the author on heavy metals in the Singapore environment was by Rahman, Sien and Ping (1981) who worked on cobalt, nickel, lead and mercury in seawater and sediments around Singapore.

The values found in seawater were (µg/l):

Co	0-0.15
Ni	0.55-1.0
Pb	0-40
Hg	0 (detection limit 0.1 µg/l)

In sediment the following levels of heavy metals were measured (mg/g dry weight):

Co	12-21
Ni	0-9.8
Pb	20-28
Hg	14.0-16.0

Thailand

Thailand is bordered on the south by two seas: the Gulf of Thailand to the east is part of South China Sea (the Pacific Ocean), and the Andaman Sea to the west is part of the Indian Ocean. The problem area is the Upper Gulf of Thailand which receives water from 4 major rivers draining past populated cities and carrying with them waste water, mostly raw without any form of treatment. These wastes are largely domestic wastes from urban areas. Moreover, along the coast there are additional waste inputs from human settlements, tapioca flour factories, etc. Since the Upper Gulf has a limited water exchange with the Lower Gulf, this creates great stress on the Upper Gulf which is an important nursery ground for marine animals, including cockle farms, oyster farms, and mussel farms as well as some shrimp farms.

Systematic pollution monitoring of the Gulf of Thailand was started in 1973 by a working group of scientists from several government agencies, with the Department of Fisheries of the Ministry of Agriculture and Co-operatives and the Department of Marine Science of Chulalongkorn University taking the lead, under the co-ordination and sponsorship of the National Research Council. Later on the Andaman Sea coast was included in the programme. The Office of the National Environment Board has played an increasingly greater role since its recent establishment.

The monitoring and research programme on metal pollution in marine waters can be broadly divided into four sectors: seawater, sediments, marine animals, and river water input.

Sea water

The sea water in the Upper Gulf of Thailand has been receiving a lot of stresses from multi-purpose uses. The four major rivers, especially the Chao Phrya River running through the Bangkok urban area, carry a high content of municipal wastes, largely untreated, as well as accumulated industrial wastes from small uncontrollable industries. The oxygen level of the Chao Phrya River in the Bangkok area becomes low in the dry season. However, as far as the heavy metals are concerned, the levels are still normal.

There is some controversy as to the real baseline levels of trace elements in seawater, as is partly shown in Table 1 below. However, allowing for the methods used to obtain each set of figures, the discrepancies can be explained and the real value should be nearer to the first column; as methods are refined further, the difference could become even less.

Table 1 : Comparison of the trace metals in seawater obtained by various workers (in µg/l)

Element	Hungspreugs[1](1981) Total	Hungspreugs[1](1981) Dissolved	Idthikasem[2](1981)	Polprasert[3](1979)
Cd average	0.11	0.05	-	77.3
range	0.03- 0.26	0.01- 0.16	0.1- 3.4	47.6- 87.3
Cr average	-	0.24	-	252.8
range	-	0.20- 0.29	-	112.0-365.4
Cu average	2.0	0.90	-	59.5
range	1.2- 4.4	0.50- 2.00	1.0-20.0	37.8- 70.0
Pb average	3.0	0.55	-	463.8
range	1.9- 4.4	0.06- 1.16	2.0-38.0	334.5-560.2
Zn average	18.4	12.9	-	74.9
range	14.2- 39.9	10.8 -21.0	1.6-49.0	37.4-124.2

Summary of methods used:

1. Hungspreugs (1981)

Co-precipitation of metal-APDC chelate from acidified seawater with cobalt-APDC, centrifuge at 8000 rpm, stir and wash the precipitate with quartz double-distilled water, centrifuge again. Dissolve the precipitate in redistilled nitric acid. Measurements are made in an atomic absorption spectrophotometer (AAS) with graphite furnace equipped with deuterium background correction. Standard addition method is used. Clean-room technique is practised.

2. Idthikasem et al. (1981)

Solvent extraction of metal-APDC complex in sample into MIBK, then subjected to air-acetylene flame atomic absorption spectrophotometer.

3. Polprasert et al. (1979)

After acidification of 500-1000 ml of seawater with nitric acid, evaporate in a glass beaker until 10 ml. remain, then injected directly into the atomic absorption flame.

Sediments

It is difficult to compare the values of heavy metals in sediments made by different workers using different methods of digestion. Moreover differences in grain size of sediments also influence their heavy metal content; small, silt-sized muds always contain a higher metal load than larger sandy sediments. A general survey of the heavy metals in sediments in the Gulf of Thailand is shown below. These were digested in hot concentrated nitric acid.

Upper Gulf of Thailand, mainly fine mud, in ppm dry weight (Idthikasem, 1981):

Cd	0.05 - 0.21
Co	4.0 - 18
Cu	3.8 - 23
Hg	0.1 - 0.13
Pb	17 - 35
Zn	5.8 - 115

Middle and Lower Gulf of Thailand (Hungspreugs, 1983)

Cd	0.13 - 0.61
Cr	24.8 - 48.0
Cu	9.0 - 14.0
Pb	10.5 - 21.0
Zn	22.9 - 42.0

The Andaman Sea (Hungspreugs and Yuangthong, 1982)

Cd	0.10 - 0.37
Cu	3.41 - 8.99
Pb	0.71 - 19.25
Zn	12.62 - 77.50

In the study of sediments for pollution, it is not enough to analyse only the surface sediment. The history of sedimentation must also be studied to detect any increase over the natural level caused by anthropogenic sources. This is done by analysing the metal contents of various strata in the sediment core, coupled with radioactive geochronology of the core. Examples of such studies done elsewhere are Goldberg et al. (1979), Bertine (1978), etc. Windom et al. (1982) made one such study in the Upper Gulf of Thailand and found the sedimentation rate to be between 3.3 and 8.9 mm/year with the highest rate at the mouth o the Chao Phrya River.

Marine organisms

A few authors have reported on the heavy metal contamination of marine organisms i Thai waters, namely Huschenbeth and Harms (1975), Wattayakorn et al. (1979) an Hungspreugs and Siriruttanachai (1981). Menasveta and Cheevaparanapiwat (1981) an Siwaraksa et al. (1981) worked on mercury in marine animals. Both groups found mercur content in fish to be mostly below 0.1 ppm in agreement with the results of Huschenbeth an Harms (1975). However, the local workers' values for cadmium and lead must be regarded a rather high, due to the inferior instrument in use up to 1980. In the case of lead in th oyster Crassotrea commercialis, Hungspreugs (1981), using an AAS with flameless graphit furnace and deuterium background correction, found a much lower value of around 0.35 pp dry weight for lead and 0.26 ppm for cadmium instead of the former high values of 15.0 an 8.9 ppm respectively. The most recent values for cadmium and lead in economically importar bivalves are (in µg/g dry weight):

	Cd µg/g	Pb µg/g
Perna viridis	0.49	0.48
Paphia undulata	0.42	0.26
Anadara granosa	0.77	0.47
Crassostrea commercialis	0.26	0.36
Amusium pleuronectes	0.48	0.41

which are all within the limits set by the Australian National Health and Medical Researc Council in 1979 (1.0 for Cd and 2.5 for Pb).

For fish, Huschenbeth and Harms (1975) found a range of 0.003 to 0.25 ppm f cadmium, 0.20 to 1.25 ppm for copper, 0.01-0.22 ppm for lead and 2.9 to 19.9 ppm for zinc marine fish from all major areas.

Brown and Holley (1983) made a study of the effect of tin dredging and smelting on t marine animals nearby and found no increase in metal levels in those animals. The dissolv metal content of the water did not change significantly. They explained that perhaps the organisms reject the metal particulates, so the increase in particulates had no effect on them. Hoff, Thompson and Wong (1982) reported a temporary increase in metal levels after mixing mine tailings with seawater in a laboratory experiment.

River water study

Up to now, the marine pollution study group has worked mainly in the sea, but recently, it has become clear that the characteristics of individual river basins, such as their climate, vegetation, geomorphology and the mineralogical composition of their soils and rocks, constitute the background conditions that determine the chemical composition and quantities of materials carried by the rivers to the sea. The human factors superimposed on the natural pristine condition largely arise from technology, the culture of the inhabitants, and the population density. All these have a direct influence on the coastal seas. To trace the problems of the estuarine areas, one must go up the river to find the possible causes. It is thus necessary to study the river system.

Conclusions and recommendations

The last few years have seen great progress in the ASEAN countries in the field of marine pollution and in marine science in general. However, this review has been limited by the lack of available published information. Much recent work is not yet widely available and even more is in progress.

After evaluating past studies on heavy metal pollution and considering the rapid increase in recent work, a few points need to be emphasized. Some of these are taken from the Report of ASEAN/UNEP Study Tour and Technical Workshop on Water Quality Monitoring and Management, Singapore (1981) on laboratory staff training.

1. A training programme is needed to enable (new) staff to acquire the skills necessary for analytical procedures.

2. Staff need to understand the meaning of the results obtained and their relationship with other parameters. Thus there is a need to include a short course on concepts related to the laboratory tests performed, in addition to training in laboratory skills.

3. Staff need to be interested in and capable of equipment maintenance.

4. The competency of the staff must be regularly checked to minimize discrepancies in results.

5. Advanced laboratory equipment should not be purchased merely for its sophistication, but also for practicality and usefulness, and the ability of the supplier to provide prompt and satisfactory maintenance service.

REFERENCES

Bertine, K. 1978. Means of determining natural versus anthropogenic fluxes to estuarine sediments, p. 246-250. In Biogeochemistry of Estuarine Sediments, Proceedings of a UNESCO/SCOR Workshop, 1976.

Brown, B.E., and M.C. Holley. 1983. Metal levels associated with tin dredging and smelting and their effect upon intertidal reef flats at Ko Phuket, Thailand. Journal of Coral Reef Research [In press].

ESCAP. 1980. Review of activities and consideration of issues in the field of the Environment. Report of the Regional Meeting on the Protection of the Marine Environment and related Ecosystems in Asia and the Pacific, Fourth Session, September 1980, Bangkok. E/ESCAP/IHT 4/21.

Ferguson Wood, E.J. and R.E. Johannes [ed.]. 1975. Tropical Marine Pollution. Elsevier, Amsterdam. 192p.

Garrels, R.M. and F.T. Mackenzie. 1971. Evolution of Sedimentary rocks. W.W. Norton, New York, N.Y. 397 p.

Goldberg, E.D., V.T. Bowen, T.W. Farrington, G. Harvey, J.H. Martin, P.L. Parker, R.W. Riseborough, W. Robertson, E. Schneider, and E. Gamble. 1978. The Mussel Watch. Environmental Conservation 5(2): Summer 1978.

Goldberg, E.D., J.J. Griffin, V. Hodge, and M. Koide. 1979. Pollution history of the Savannah River Estuary. Environ. Sci. and Tech. 13: 588-594.

Gomez, E.D. 1979. The Philippines marine environment 1978. Marine pollution and degradation of ecosystems, p. 506-531. In Proceedings of the Fourth Symposium on the Co-operative Study of the Kuroshio and the Adjacent Region, 14-17 February 1979, Tokyo.

Hoff, J.T., J.A.J. Thompson, and C.S. Wong. 1982. Heavy metal release from mine tailings into seawater - a laboratory study. Mar. Pollut. Bull. 13(8): 283-286.

Hungspreugs, M. 1981a. A likely baseline level of cadmium, copper, lead and zinc in seawater from the Upper Gulf of Thailand. J. of Scientific Research, Faculty of Science (ISSN 0625-6335) 6: 35-47.

Hungspreugs, M. 1981b. The natural levels of cadmium and lead in the economically important molluscs of Thailand. J. of Scientific Research, Faculty of Science 6: 203-209.

Hungspreugs, M. and S. Siriruttanachai. 1981. Accumulation of cadmium, copper, lead and zinc in the oysters in the Gulf of Thailand, p, 188-195. In Proceedings of the Second Seminar on the Water Quality and the Quality of Living Resources in Thai Waters, 26-28 May 1981. National Research Council.

Hungspreugs, M. and C. Yuangthong. 1982. Cadmium, copper, lead, zinc and oxidizable organic matter in the sediment strata from the Andaman Sea. In Proceedings of the Second Seminar on Marine Science, Bang Saen, 8-10 September 1982 [In press].

Idthikasem, A., R. Bamrungrajhiran, W. Kaewpakdee, and K. Chingchit. 1981. Analyses of some trace metals in sea water and marine sediments, p. 165-179. In Proceedings of the Second Seminar on the Water Quality and the Quality of Living Resources in Thai Waters, 26-28 May 1981. National Research Council.

Jothy, A.A. 1976. Report on marine pollution problems in Malaysia. International Workshop on Marine Pollution in East Asian Waters, Penang, April 1976. IOC/IWMPEAW/11.

Kapauan, A.F., P.A. Kapauan, E.O. Tan, and F.P. Verceluz. 1979. Total mercury in water and sediments from the Honda Bay Area in Palawan. Final Report submitted to NSDB and PAEC, Technical Report No. PAEC (C) IE 8005 (NSDB).

Kapauan, P.A. and I.A. Ronquillo. 1981. Marine pollution research and monitoring in the Philippines. UNESCO/IOC/TTMPRM/CP/8. Manila.

Kapauan, P.A., L.A. Salamat, F.P. Verceluz, and P.G. Beltran. 1979. Cadmium, lead, copper and zinc in Philippines aquatic life. Fisheries Research Journal of the Philippines 4 (1), vol 2, p.1

Menasveta, P. and V. Cheevaparanapivat. 1981. Total and organic mercury in marine fish of the Upper Gulf of Thailand. In Proceedings of the Fourth Symposium on the Co-operative Study of the Kuroshio and the Adjacent Region, Tokyo, 14-17 February, 1979. p. 449-459.

Phillips, D.J.H. 1980a. Quantitative aquatic biological indicators. Applied Science Publishers. 488 pp.

Phillips, D.J.H. 1980b. Proposal for monitoring studies on the contamination of the East Asian Seas by trace metals and organochlorines. UNEP/WG 41/INF 13.

Polprasert, C., S. Vongvisessomjai, B.N. Lohani, S. Muttamara, A. Arbhabhirama, S. Traichaiyaporn, P.A. Khan, and S. Wangsuphachart. 1979. Heavy Metals, DDT and PCB in the Upper Gulf of Thailand. Research Report No. 105, Division of Environmental Engineering, Asian Institute of Technology, Bangkok. 316 p.

Rahaman, A., C.L. Sien, and D.C.S. Ping. 1981. Pollution of water by hydrocarbons and heavy metals around Singapore. Proceedings of the Second Symposium on Our Environment, Singapore, November 14-16, 1979. p. 274-293.

Report of ASEAN/UNEP Study Tour and Technical Workshop on Water Quality Monitoring and Management, Singapore, 14-19 December 1981.

Sivalingam, P.M. 1980a. Bioaccumulation mechanisms of trace metals by the Malaysian rock oyster, Saccostrea cucullata, under high concentration stresses, p. 343-355. In Proceedings of the Second Symposium on Our Environment, Singapore, November 14-16, 1979.

Sivalingam, P.M. 1980b. Mercury contamination in tropical algal species of the Island of Penang, Malaysia. Mar. Pollut. Bull. 11: 106-107.

Sivalingam, P.M., and A.B. Sani. 1980. Mercury content in hair from fishing communities of the State of Penang Malaysia. Mar. Pollut. Bull. 11: 188-191.

Sivalingam, P.M., T. Yoshida, H. Kojima, and I. Allapitchay. 1981. Trace metals biodeposition and its extent of pollution in coastal molluscs, sediments and sea water samples from the Island of Penang, Malaysia, p. 532-544. In Proceedings of the Fourth Symposium on the Co-operative Study of the Kuroshio and the Adjacent Region, Tokyo, 14-17 February, 1979.

Sivaraksa, S., P. Oriboon, L. Viriyasiripaisarn, T. Klintrimas, and T. Boonyashotmonakul. 1981. Mercury content in marine faunas, p. 238-242. In Proceedings of the Second Seminar on the Water Quality and the Quality of Living Resources in Thai Waters, 26-28 May, 1981. National Research Council.

Soegiarto, A. 1975. The impact of human activities upon the coastal environment in Indonesia, p. 111-113. In Pacific Science Association Special Symposium on Marine Sciences, Hong Kong, 7-16 December 1973.

UNESCO/UNEP. 1980. River Input to South-East Asian Seas. Project No. FP/0503-79-08 (2099) Final Report, Paris, November 1980.

Waldichuk, M. 1980. Lead in the marine environment (Editorial). Mar. Pollut. Bull. 11: 241-242.

Wattayakorn, G., M. Hungspreugs, and O. Chanpongsang. 1979. Accumulation of certain heavy metals in marine animals from the Upper Gulf of Thailand. Chulalongkorn University Research Journal 6: 37-49.

Windom, H.L. 1981. Comparison of atmospheric and riverine transport of trace elements to the continental shelf environment, p. 360-370. In River Inputs to Ocean Systems. Proceedings of a SCOR/UNESCO/IOC/UNEP Review Workshop, Rome, March 1979.

Windom, H.L., M. Paulsen, and M. Hungspreugs. 1982. Rates of sedimentation in the upper Gulf of Thailand using the lead-210 method. In Proceedings of the Second Seminar on Marine Science, Rang Saen, 8-10 September, 1982. [In press]

Yeats, P.A., J.M. Bewers, and A. Walton. 1978. Sensitivity of coastal waters to anthropogenic trace metal emissions. Mar. Pollut. Bull. 9: 264-268.

TIN MINING AND SEDIMENTATION EFFECTS ON SHALLOW WATER BENTHIC COMMUNITIES

Hansa Chansang
Phuket Marine Biological Center
P.O.Box 60, Phuket, Thailand

ABSTRACT

Tin mining is a major economic activity in parts of South-East Asia. Bucket or suction dredges are increasingly being used to mine tin deposits in shallow coastal areas. Dredging depreciates coastline aesthetic values and thus hurts tourism. It also destroys important shallow water benthic communities such as coral reefs, sea grass beds and mangroves, both by physical disturbance and particularly by siltation. Information on the extent of damage to these resources is still limited. Studies of coastal resources in southern Thailand are being used to plan measures to reduce the environmental effects of mining activity, particularly as they affect tourism and fisheries.

In South-East Asia, tin is one of the major mineral resources that are important to the national economy. Exploration for tin ore has been conducted extensively in Indonesia, Malaysia and Thailand. In 1980, Thailand produced 45,986 metric tons of tin, worth US$ 577 million, making it the second major tin producing country of the world (Suwansing, 1982). Most of the tin ore is from the three southern provinces of Ranong, Phang-nga and Phuket along the Andaman coast.

Tin ore is mined as cassiterite (SnO_2) which is often associated with granite and pegmatites, generally in alluvial deposits on land and in coastal waters. Ore deposits on land are mainly mined hydraulically by what is locally known as the gravel pumping method. Dredging is used to recover mineral deposits from shallow waters and swampy areas.

Tin mining on land

Gravel pumping mining involves liquefying unconsolidated deposits in an open pit with a high pressure water jet, after removing the top soil. The mixture is pumped to a slightly sloping sluice box. Tin ore and other heavy materials settle on the bottom of the sluice box and are prevented from flowing down by rows of baffles, while lighter materials are washed away as mine tailings. Tailings are fed into bunded areas and old mine pits where solids settle out and water is recycled or discharged into natural water-ways. This method of mining creates several environmental problems both during operation and after the mines are abandoned.

One of the most obvious problems is surface water pollution, although regulations exist regarding the discharge of water into natural water-ways. The limit on the amount of suspended solids in discharged water is high (6 g/l), and often the regulations are not enforced. During the rainy season, runoff from tailings areas and sometimes the failure of the embankments of retention ponds result in liquid waste streams rich in suspended materials. This leads to highly turbid waters and sediment deposition in the water-ways and coastal waters, particularly in protected bays in areas of intensive mining.

In addition, mining degrades the value of the land for agriculture or reforestation. Most mining areas were originally agricultural land or natural forests. Top soils are removed during the mining process. Once the operation ceases, a large pit perhaps 15 m deep is usually left, with big piles of stones and gravel scattered around on an uneven surface covered with fine and coarse sand. Very few plants can grow and the area is subject to severe erosion during the rainy season.

Kitching (1982) estimated the area covered by tailings and the annual addition to these areas in Malaysia, Indonesia and Thailand as follows:

	Tailings area (ha)	Annual increment (ha)
Malaysia	208,000	2,000
Indonesia	82,000	400
Thailand	61,000	300

Coastal dredging

In Thailand and Indonesia, offshore and coastal mining has increased in recent years. In 1980 over 50% of tin production in Thailand came from coastal waters. Production from coastal waters is increasing as onshore deposits become depleted.

Coastal mining causes two major types of environmental damage. It results in the depreciation of coastline aesthetic values through turbid water, mud deposition on the bottom, and changing the morphology of the shoreline if dredging is done close to shore. It also destroys important shallow water benthic habitats such as coral reefs, sea grass beds, mangrove swamps and other benthic communities by direct destruction or by disturbance from sedimentation. These coastal habitats are known to be highly productive and are important breeding and nursery grounds for commercially valuable marine organisms.

Most mining effects are from physical disturbance, mainly from siltation and direct destruction. There are no reports of chemical hazards from tin mining, as potentially toxic heavy metals are seldom found. Although lead and arsenic are associated with cassiterite in some localities, they generally occur in small amounts in insoluble forms.

Dredging is the method used to remove ore deposits from swamp areas and shallow waters down to about 30 metres. The methods were adapted from canal or harbour dredging and were first applied to tin mining in Phuket Bay, Thailand in 1907. The sediment is brought up either by bucket ladder or suction. Tin ore is separated by gravity as in land based mines. Tailings are discharged directly from the rear of the dredge. The heavy fractions immediately sink to the bottom while fine particles form a turbid plume and are distributed in the vicinity of the dredge depending upon the current regime before settling out.

The types of dredge widely accepted as efficient in retrieving tin ore are the ladder type chain bucket dredge and the suction dredge. The former was the first kind of dredge used in shoreline and offshore mining. This type of bucket dredge generates sediment plumes from all parts of its operation: dredging sediment from the bottom, transporting it up the ladder and discharging tailings. Such a dredge can generate quite substantial amounts of suspended sediment. It can remove up to 1,140 m^3/hr of sediment and operate 24 hours a day. In protected areas, it can operate up to 300 days a year. The suction type dredges are of smaller size and involve less capital investment. The suspended sediment plume is generally created by releasing the mine tailings back into the surface waters. A third type of dredge commonly found in Thailand is the diver guided suction dredge. These were modified from fishing boats when near-shore dredging began 10 years ago. These small dredges are concentrated in shallow water up to 18 metres deep along the coast of Phang-nga province in the concession area of the provincial government. The method employed uses the same principle as the larger suction dredge. With a diver guiding the suction head, they can selectively collect the rich deposits. However, the small size of their sluice box makes them inefficient in separating ore from tailings. In 1981 there were some 6,000 boats in operation. This large number of boats can cause rather serious destruction and sedimentation in the area. However, no information is available on the extent of environmental damage created by these small boats.

Most of the coastal mining in Thailand is along the west coast of Phang-nga Province facing the Andaman Sea. Weather conditions limit mining in these areas to the calm seas of the northeast monsoon (November-April) each year. When in operation, the sediment plume from an aggregation ot small boats or from large dredges can easily be detected by satellite.

Effects of mining

Within the last few years, the effects of mining in coastal waters have created public concern in Thailand with respect to both the aesthetic value and the productivity of coastal ecosystems. Public reaction also depends upon the location of the dredging. Most concern arises from conflicts of interest in the utilization of coastal resources by various sectors. For this reason, some information is available regarding potential environmental damage to resources from mining off the west coast of Phuket Island, although mining on the west coast is recent in comparison to the 75 years of mining on the east coast and in Phang-nga Bay. The main issue concerns the mining of rich deposits along the west coast which have become popular resorts because of their beautiful sandy beaches and clear waters. Income from tourism has become more important locally and nationally at about the same time as tin deposits on land have become depleted after more than 100 years of mining on Phuket Island. Recently, the National Environmental Board of Thailand has completed a 3 year study of the physical environment and living resources of the coastal waters. The study will be used for future planning of resource utilization to minimize such conflicts of interest and to prepare measures to decrease environmental damage from mining operations.

In brief, these studies found turbulent water movement up to 40 metres depth along the shore (Charoenlaph, 1982). Therefore any suspended solids brought up dredging would spread along the coast, only settling out at a speed determined by the current velocity. Unless measures can be taken to limit plume distribution effectively, the water quality of several beach resorts will be affected. Mining close to shore could also cause beach instability.

Coral reefs

With regard to effects on benthic communities along the west coast, coral reefs are identified as one of the major resources affected by mining activities. An inventory of reef resources (Chansang et al., 1982) showed that fringing reefs are found along the west coast within bays and along protected shorelines. Since reefs are highly valued both their unique attractiveness and their importance as highly productive resources, the destruction of coral reefs has been one of the major issues, together with turbidity, in the public debate about mining. The same report showed that in Bang Tao Bay on the west coast with ongoing dredging activity, the reef areas covered by dead coral are 67.7% on the northern side and 62.3% on the southern side. All dead corals are covered by sediment. At the northern reef, sediment may also have come from the land in the past, as there is substantial land accretion at the mouth of a canal draining into the bay at the northern end.

In general, the effects of sedimentation upon coral reefs are quite well known (Johannes, 1975; Bak, 1978). Drawing on the results of various investigators, Loya (1976) summarized the detrimental effects of sedimentation on corals as follows: a) causing the death of corals when they are heavily coated or buried by sediments, b) reducing coral growth potential directly by abrasion and smothering and indirectly by blocking light, c) inhibiting coral planulae settlement and development and d) modifying the growth of corals sometimes toward the evolution of forms more resistant to sedimentation.

The damaged reefs at Bang Tao Bay are clear evidence of the effect of uncontrolled mining operations. In trying to accommodate dredging activity while maintaining water quality and preserving the environment in some localities, as the National Environmental Board intends, one of the main challenges will be to establish water quality standards in dredging areas on a sound scientific basis to ensure that both immediate and long term effects of increasing turbidity will not occur. It is quite likely that the mining industry would object to any high water quality standard since the technology for limiting plume distribution has not yet been tried in tin dredging and since capital investment would be higher. However, a compromise in the water quality standard would mean increased long term turbidity which would be likely to affect both coral reefs and tourism. Coral reefs along the west coast of Phuket are already in more turbid waters than other known reefs which attract tourism; increasing turbidity would reduce their value even further. Changes in their community structure are also possible.

Marine fauna and flora

Besides the direct effect on corals, which are the building blocks of reefs, the effects of turbidity on the associated fauna and flora have not been studied. Poopetch et al. (1982) reported on a preliminary investigation of the effect of sediment on larvae of the spiny lobster Panulirus versicolor. The median lethal concentration was about 138 ppm of suspended solids over 96 hours. In general, the reproductive phases and early stages of aquatic animals are particularly vulnerable to disturbance by suspended solids and sediments (Muncy et al., 1979).

The effect of mining on macroinvertebrate communities of the sandy bottom along the west coast of Phuket has been studied by Nateewathana et al. (1982). In the vicinity of a dredging site, benthic macrofauna decreases in density, biomass and species composition. The effect is localized, and recolonization occurs after a certain period of time. The dredging effect is superimposed on natural fluctuations due to sea states associated with the monsoon seasons. At present, it is not possible to predict the full recovery of benthic macrofaunal populations affected by mining. However, the data show that this would require more than a year. With respect to the effect of dredging on benthic macrofauna which are food for demersal fishes, the present mining activity in Bang Tao Bay would have a minimal effect on the demersal fishery of the west coast. However, most of the west coast areas have potential value for tin dredging. Therefore, the significance of the effect of dredging on the demersal fishery of the west coast will depend upon the extent of mining activity.

The studies sponsored by National Environmental Board do not provide information on the importance of these areas as breeding and nursery grounds. Trawling has shown that the gravid females of certain commercially important prawns, Penaeus monodon, P. sulcatus and P. merguensis, are found off the west coast of Phuket. Other circumstantial evidence also indicates that these areas may be breeding grounds for squid. Squid are commonly netted in coastal waters from November to February. At the same time, squid eggs are often brought up by bottom trawls. Hence the possible effect of dredging activity upon populations of these commercially important species is unknown.

Mangroves

Apart from information available from the west coast study, not much is known regarding the effects of tin dredging or tailings run off on other shallow water benthic communities. In protected bays in the tropics, shorelines are usually fringed with mangrove vegetation and shallow bottoms are covered by sea grasses and macroalgae. These mangrove fringe estuaries are known to be highly productive and also to serve as nursery grounds for marine organisms living offshore. In some of the mangrove bays along the Andaman coast, dredging or sediment accumulation from tailings have been going on for a long time. No information is available regarding the extent of environmental change or the effect of mining activity on productivity in the bays. Within these 3 provinces, the whole area of 39,000 ha of mangrove forests contains tin ore. The Royal Forestry Department has a large scale project for replanting mangrove trees in abandoned mining areas. The regeneration of seedlings after dredging is quite successful compared to planting areas damaged by other mining methods. Although mangrove trees are known to thrive in turbid water with high sedimentation, the trees can be killed by suffocation of aerial roots if the sedimentation rate is higher than under natural conditions (Odum and Johannes, 1975). In some areas of Phuket, large stands of mangrove trees were killed by siltation from land based mines nearby. The accretion of sediment from mining may also change the composition of the soil, making natural regeneration of mangrove seedlings more difficult or altering the forest community.

Not much is known about the effects of sedimentation on food webs in estuarine ecosystems and on impairment of the area as a nursery ground. This can only be inferred from the general effects of turbidity and sedimentation on the estuarine ecosystem elsewhere.

Sea grasses

Among the various tropical shallow water benthic communities, sea grass communities are probably the least studied, although it is generally accepted that they are among the highest in productivity. Their importance as nursery areas and as a source of food supply to coastal ecosystems via the detritus food web is generally recognized. The distribution and productivity of the sea grass beds in the Andaman Sea are not yet known. They are generally found near reef areas and as patches in estuaries from low tide level down to a depth of about 8 metres. Besides their importance as a shallow water habitat for marine organisms and as primary producers, turtles and dugongs feed directly on sea grasses. Dugongs reared in captivity at the Phuket Marine Biological Center were fed Halophila ovalis, a common sea grass species in the area.

Reviewing the effect of pollution on tropical sea grass ecosystem, Zieman (1975) stated: "of all forms of man-made or induced disturbances of the estuarine and near-shore environments, dredging and filling presents the greatest potential for damage to the sea grass beds and has undoubtedly caused the destruction of more desirable grass bed habitat than any other form of pollution."

Besides direct physical destruction, the secondary effects can be far more serious depending upon the intensity of dredging. Turbidity reduces light availability to sea grasses in nearby areas. Fauna associated with grass beds or on the bottom could be smothered by excess sedimentation, or suffocated by low oxygen levels due to the high oxygen demand of the organic matter dredged up from anoxic layers.

Changing sediment composition would change both the flora and fauna of bottom communities, not only of grass beds. These organisms are either food for commercially important species or young stages of such species. Therefore mining effects on the production of bottom communities need to be estimated.

Conclusion

In conclusion, the effects of tin mining on shallow water benthic communities are both direct and indirect. The direct effect is the physical destruction at the mining site by dredging. The secondary effect is the disturbance of surrounding areas by suspended sediment. There is no evidence for other effects from mining besides disturbance by sedimentation. Sediment from mining has caused the death of corals in the vicinity and decreased the population of other benthic macroinvertebrates. Recovery of benthic macrofaunal populations after mining is possible. At present no information is available on the extent of damage from mining to other benthic communities such as sea grasses or the detrital base food web of mangrove fringe estuarine ecosystems.

REFERENCES

Bak, R.P. 1978. Lethal and sublethal effects of dredging on reef corals. Marine Pollution Bulletin 9(1):14-16.

Chansang, H., P. Boonyanate and M. Charuchinda. 1982. Status of coral reefs along the south and west coasts of Phuket Island, Thailand [in Thai]. Technical report submitted to the National Environmental Board, Bangkok, Thailand.

Charoenlaph, J. 1982. Preliminary report of a study of current patterns along the west coast of Phuket Island, Thailand. Report presented at Joint Thai-Japanese Symposium on Mangroves and Marine Science, 3-5 September 1982. Phuket, Thailand.

Johannes, R.E. 1975. Pollution and degradation of coral reef communities, p. 13-51. In E.J. Ferguson Wood and R.E. Johannes [ed.], Tropical marine pollution. Elsevier, Amsterdam.

Kitching, H.W. 1982. Environmental management in mineral resources development, p. 19-48. In Proceedings of the working group meeting on environmental management in mineral resource development. Mineral Resources Development Series No. 49. United Nations, New York.

Loya, Y. 1976. Effect of water turbidity and sedimentation on the community structure of Puerto Rican corals. Bull. Mar. Sci. 26(4):450-466.

Muncy, R.J., C.J. Atchison, R.V. Bulkley, B.W. Menzal, L.C. Perry, and R.C. Summerfelt. 1979. Effects of suspended solids and sediment on reproduction and early-life of warm water fishes: a review. U.S. Environmental Protection Agency, EPA 600/3-79-042. 101 p.

Nateewathana, A.J. Hylleberg and B. Chatrananthavej. 1982. Effect of sedimentation from offshore mining on benthos of west coast of Phuket Island [in Thai]. Technical report submitted to the National Environmental Board, Bangkok, Thailand.

Odum, W.E. and R.E. Johannes. 1975. The response of mangroves to man-induced environmental stress, p. 53-62. In E.J. Ferguson Wood and R.E. Johannes [ed.]. Tropical marine pollution. Elsevier, Amsterdam.

Poopetch, T., et al. 1982. Potential effects of offshore tin mining on marine ecology, p. 70-74. In Proceedings of the working group meeting on environmental management in mineral resource development. Mineral Resources Development Series No. 49. United Nations, New York.

Suwansing, P. 1982. The environmental management of mineral resource development in Thailand, p. 113-118. In Proceedings of the working group meeting on environmental management in mineral resource development. Mineral Resources Development Series No. 49. United Nations, New York.

Zieman, J.C. 1975. Tropical sea grass ecosystems and pollution, p. 63-74. In E.J. Ferguson Wood and R.E. Johannes [ed.]. Tropical Marine Pollution. Elsevier, Amsterdam.

SOUTH-EAST PACIFIC REGION

ACTION PLAN FOR THE PROTECTION OF THE MARINE ENVIRONMENT AND COASTAL AREAS OF THE SOUTH-EAST PACIFIC

Luis Arriaga M.
Comision Permanente del Pacifico Sur
Paez 370 y Robles 6ºP, Quito, Ecuador.

ABSTRACT

The five countries bordering the Pacific coast of South America (Colombia, Chile, Ecuador, Peru and Panama) met in a conference of Plenipotentiaries in November 1981 to sign the "Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific", which includes five components: Environmental Assessment; Environmental Management; a Legal Component; Institutional and Financial Arrangements; and Supporting Measures. The conference also approved a "Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific" and an "Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons and other Harmful Substances in Cases of Emergency". This paper describes the activities in progress to implement the Action Plan.

Background

The member states of the Permanent Commission of the South Pacific (CPPS, originally Chile, Ecuador and Peru, with Colombia joining in 1979), adopted as an activity of common interest the study of the problems of marine pollution in the South-East Pacific, with the goal of developing regional co-operation for the protection of the marine environment.

The first regional activity was a survey on pollution in the South-East Pacific (Chile, Ecuador and Peru) in 1975 with the support of FAO. As a result, a CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific took place in Santiago de Chile (November, 1978), with the participation of the five states of the region: Colombia, Chile, Ecuador, Panama and Peru. This meeting laid the basis for the Regional Action Plan which is being executed at the present time.

In 1979, the Governing Council of the United Nations Environment Programme (UNEP) approved the inclusion of the South-East Pacific as one of the areas in the UNEP Regional Seas Programme. This has encouraged the application of the Regional Seas approach: to establish the causes and consequences of environmental degradation, and to combat environmental problems through an integrated regional approach to the management of the coastal and marine areas.

Preparatory phase of the Action Plan (July 1980 - December 1981)

A UNEP-funded project permitted the analysis of the pollution problems, the existing capacity for research and management, and the legal framework for environmental protection, as related to the marine environment and coastal areas of the South-East Pacific. Based on this information, the Action Plan and its programmes were elaborated. The main results of this phase were as follows:

1. Surveys of sources, levels and effects of marine pollution in Colombia, Chile, Ecuador, Panama and Peru during 1980 (CPPS, 1981), including:

   - Pollution by domestic wastes;
   - Pollution by industrial wastes;
   - Pollution by pesticides and herbicides;
   - Pollution by oil;
   - Legislation related to the protection of the marine environment and the administrative structure for environmental management; and,
   - Bibliography on marine pollution in the South-East Pacific.

2. Publication of the "UNEP-CPPS Directory of South-East Pacific Marine Science Research Centres, 1981" which includes information on specialists, technical facilities and programmes.

3. Oil Spill Control Training Course (CPPS/UNEP/IMCO/Government of Chile, Vina del Mar, Chile, 6 to 15 April, 1981).

4. Workshop: The Legal Practice for the Protection of the Marine Environment against Pollution (Bogota, Colombia, 4-8 May, 1981).

5. Meeting of Experts to Review the Draft Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific (Lima, Peru, 21-25 September, 1981).

6. Conference of Plenipotentiaries of Colombia, Chile, Ecuador, Panama and Peru (Lima, Peru, 9-12 November, 1981), which approved: the Action Plan for the South-East Pacific; an "Agreement for the Protection of the Marine Environment and Coastal Area of the South-East Pacific", an "Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons and other Harmful Substances in Cases of Emergency"; and, the "Institutional and Financial Arrangements for the Implementation of the Action Plan in the South-East Pacific Region" (UNEP-CPPS, 1982).

Characteristics of the Action Plan

"The geographical area for the application of the Action Plan includes the marine environment and the coastal areas of the following states: Colombia, Chile, Ecuador, Panama and Peru".

The **goals** of the Action Plan are as follows:

- - "The evaluation of the present conditions of the marine environment and coastal areas...", with the aims of giving advice to the Governments for the protection of such areas and of establishing regional co-operation in this field;

- - "The adequate management of the activities that can affect the quality of the marine environment and coastal areas and the development of measures to obtain the criteria to determine the economic impact of ecological damage";

- - "The formulation of legal instruments, national and regional, for the protection of the marine environment and coastal areas", advice to the Governments on the application of International Agreements such as the International Maritime Organization (IMO) conventions, and the "implementation of legal measures to obtain compensation due to ecological damage" as a result of oil spills, etc.; and

- - "The establishment of institutional, financial and supporting means" for the execution of the Action Plan, "including the structure and mechanisms of national and regional co-ordination".

The **components** of the Action Plan, in accordance with the above-mentioned goals are the following:

The **Environmental Assessment** component aims to provide a scientific basis for the implementation of the other components of the Plan. This includes activities to determine the quality of the marine environment and coastal areas through the study of the predominant pollutants in the region in all their aspects (sources, concentration, dispersion, persistence, effects, transformations).

The first step in this component is to standardize methodologies in the region and to promote efficiency in the research institutions, in particular by incorporating activities for training personnel in every programme.

This component also calls for ecological studies in areas of special interest (mangrove swamps, coastal lagoons, estuaries, areas for species reproduction, etc.), as a basis for evaluating the effects of pollutants.

The **Environmental Management** component focuses on the formulation and application of programmes to prevent, monitor, reduce and control the pollution of the marine environment and coastal areas, whatever the pollutants.

This component includes the preparation of standards for the discharge of domestic, mining, industrial and agricultural wastes as well as of criteria on water quality for different uses.

It likewise includes assistance to the governments to establish or strengthen their institutional capabilities and the co-ordination mechanisms for adequate environmental management, including personnel training for such activities.

The **Legal Component** seeks to establish the legal framework for the protection of the marine environment and coastal areas, as well as to ensure the necessary implementation.

Several activities in this legal component are foreseen: analysis of the legal institutions provided for in the United Nations Convention on the Law of the Sea that are concerned with the protection and preservation of the marine environment, and their regional application; promulgation or modification of national legislation for the application of the regional agreements adopted in Lima in 1981, together with the Action Plan and others that may be adopted in the future; maintenance of an updated register of national legislation related to the subjects of the Action Plan; advice to the governments on the application of other international agreements for the protection of the marine environment to which they are party (e.g., IMO Conventions); adoption of complementary protocols such as on pollution of the marine environment from land sources; pollution as result of the exploration and exploitation of the Continental Shelf; responsibility and compensation for damages due to the pollution of the marine environment; scientific and technical co-operation; and special protected areas.

The **Institutional and Financial Arrangements** component defines the institutional structure and the mechanisms for co-ordination of the Action Plan, as well as the means for its financing. The institutional structure includes:

- The **General Authority** (Autoridad General, AG) of the Action Plan, with representatives of the governments (intergovernmental meetings), responsible for the evaluation of the progress of the Action Plan, the approval of the programmes and their financing;

- The **Consultative Group** (Grupo Consultivo, GC), constituted by experts nominated by the governments to analyse and to give advice on the scientific and technical aspects of the Plan;

- The **Regional Co-ordination Unit** (Unidad Coordinadora Regional, UCR), which is the General Secretariat of the Permanent Commission of the South Pacific, and which handles relations with national focal points and international organizations;

- The **National Focal Points** (Punto Focal Nacional, PFN), one in each country, responsible for the co-ordination of the programmes within the country and for liaison with the UCR; and

- The **National Institutions** (Instituciones Nacionales, IN), which are appointed by the governments to execute specific technical work under the Action Plan.

Supporting measures for the other components provide for the following: the facilities that the institutions must furnish to execute specific projects; the organization of workshops or other special meetings related to the Action Plan; the granting of fellowships to train personnel within or outside the region; the execution of systematic publicity campaigns; and the inclusion of environmental protection concepts in educational programmes.

Execution of the Action Plan

With the support of UNEP, the following activities are being executed under the Action Plan in 1982-1983:

Preparation of specific programmes (by consultants)

- Preparation of an updated review on marine pollution from land based sources in the South-East Pacific region (November 1982 - February 1983).
- Preparation of a draft programme to monitor and control marine pollution by oil, as well as by domestic, industrial and agricultural sources (November 1982 - February 1983).
- Preparation of a draft contingency plan to combat oil pollution in case of emergency (November 1982 - February 1983).
- Preparation of a draft protocol to control marine pollution from land based sources (June 1982, already accomplished).
- Preparation of a draft complementary protocol concerning co-operation in combating pollution by oil in cases of emergency (December 1982).
- Preparation of a draft programme to carry out baseline ecological studies for the assessment of heavy metals, some organic materials, and the effect of pollution on selected marine ecological communities (November 1982 - February 1983).

Workshops, Meetings, etc.

- Workshop of legal and technical experts to review and revise the draft protocol on marine pollution from land based sources in the South-East Pacific region (Quito, Ecuador, 27-30 Sept., 1982, already accomplished).
- Workshop of the Consultative Group of legal and technical experts to review and revise draft programmes and protocols (prepared by consultants) for the South-East Pacific (Quito, Ecuador, 11-15 April, 1983).
- Workshop on intercalibration methods for monitoring marine pollution in the South-East Pacific (Lima, Peru, 9 - 14 May 1983).
- Meeting of the General Authority of the South-East Pacific Action Plan (Quito, Ecuador, June 1983).

Although the Action Plan for the South-East Pacific is only in the early phases of implementation, it demonstrates the usefulness of an integrated regional approach to the management of coastal and marine areas.

REFERENCES

CPPS. 1981. Series Seminars and Studies, 2:1-388.

UNEP-CPPS. 1982. Conference of Plenipotentiaries on the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific, Final Act, Lima, Peru, 9-12 November 1981. UNEP-CPPS/IG.32/4.

MARINE POLLUTION IN THE SOUTH-EAST PACIFIC

Luis Arriaga M.
Comision Permanente del Pacifico Sur
Paez 370 y Robles, 6ºPiso, Quito, Ecuador

ABSTRACT

From studies done as part of the Action Plan for the South-East Pacific (UNEP-CPPS), the following cases of marine pollution stand out: (a) the Gulf of Panama, which receives domestic effluents with an organic load estimated at 12,100 tons BOD/year (10,900 from the city of Panama) and wastes from 674 industries (88.6% from the city of Panama); (b) Buenaventura Bay (Colombia), which receives some 4,000 tons BOD/year in domestic sewage, plus discharges from 57 industries and oil and lubricants dumped in the port; (c) Estuary of the Gulf of Guayaquil (Ecuador), whose domestic effluents contain an organic load estimated at 19,900 tons BOD/year and wastes from 856 registered industries as well as dumped fuel and lubricants; (d) the Lima-Callao area (Peru), with domestic effluents containing 87,500 tons BOD/year, wastes from 622 industries and dumped fuel and lubricants; and (e) Bay of Concepcion-San Vicente Bay (Chile), which receives domestic sewage with 6,500 tons BOD/year, and wastes from 44 important industries creating pollution problems from active chlorine and mercury and other heavy metals. The activities to take place in the present phase of the Action Plan are summarized.

Introduction

The surveys done as part of the activities of the "Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific" have permitted an evaluation of the sources, levels and effects of marine pollution in the region, of the institutional structure for research and environmental management, and of the existing legal framework for pollution prevention and control.

The Action Plan, which is supported by UNEP's Regional Seas Programme, covers the waters of the Eastern Pacific along the coasts of Panama, Colombia, Ecuador, Peru and Chile. The Permanent Commission of the South Pacific (CPPS) is responsible for regional co-ordination.

This paper presents a summary review of marine pollution problems in the South-East Pacific region, emphasizing the most relevant facts.

MARINE POLLUTION IN THE SOUTH-EAST PACIFIC

The main pollution problems in the South-East Pacific region result from: discharges from the major cities of the region of domestic and industrial effluents, mainly without treatment; industrial effluents, especially from mining and fishing industries located in areas outside of the main cities; and the dumping or spilling of oil. There is very limited information about pollution by pesticides and other substances.

In selecting areas with major pollution problems (Figures 1 and 2), the criteria were: the simultaneous occurrence of domestic and industrial effluents; areas subject to a great volume of waste or tailings from mining industries; and the risk of oil pollution from major oil pipeline terminals, refineries, etc.

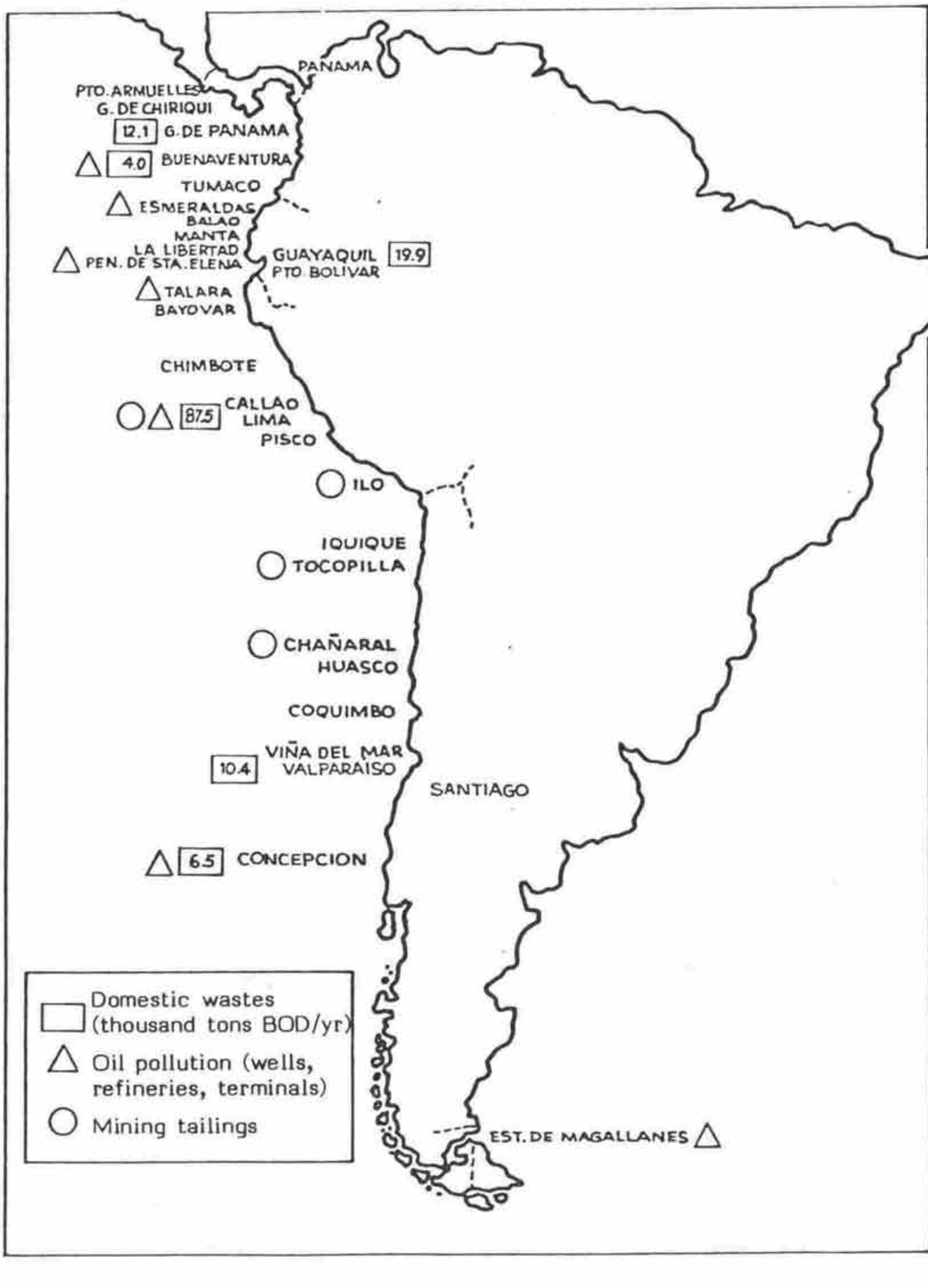


Figure 1 : Areas of the South-East Pacific with major pollution problems

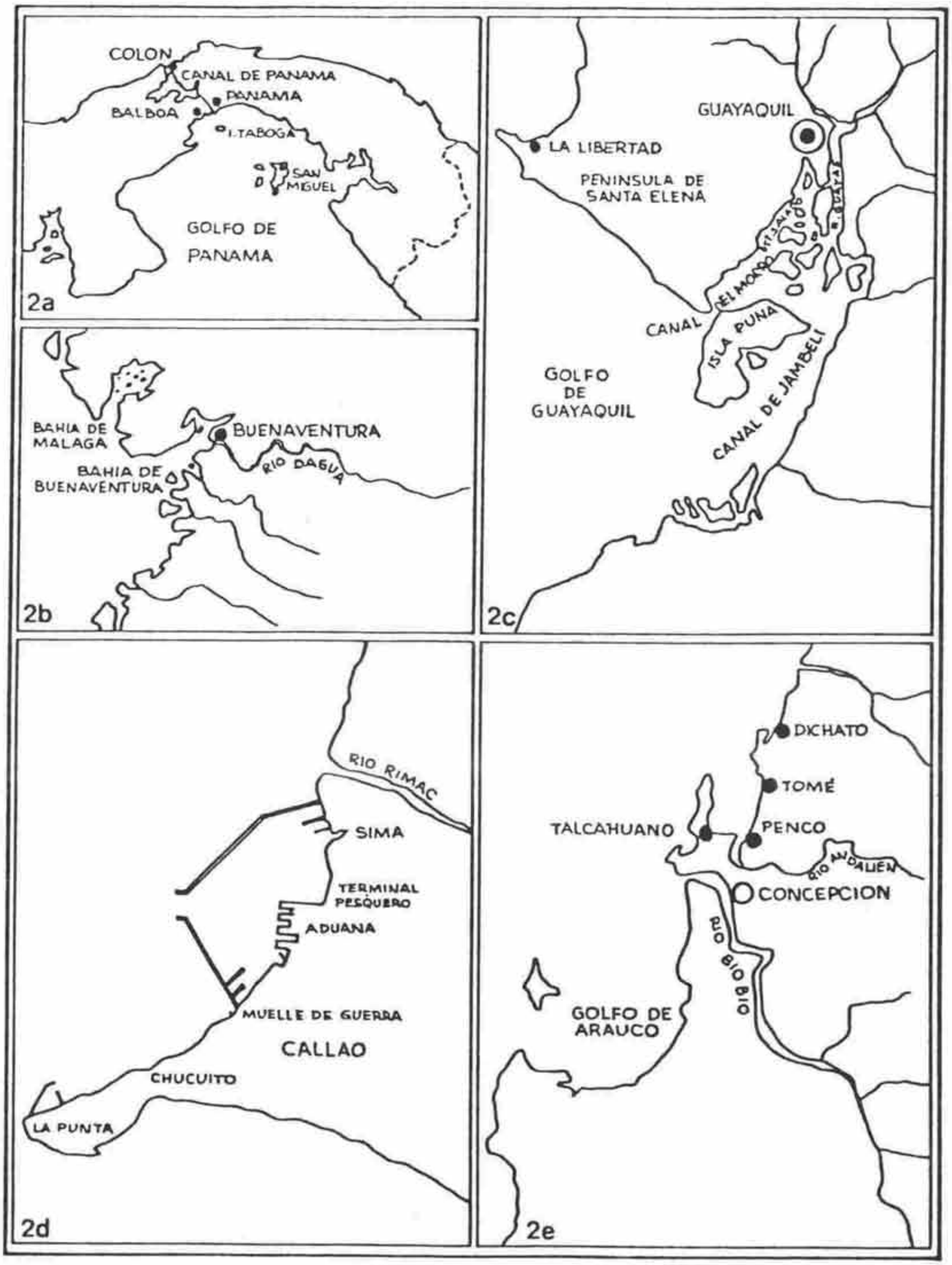


Figure 2 : Areas of major contamination in the South-East Pacific
2a. Gulf of Panama — 2c. Gulf of Guayaquil
2b. Buenaventura Bay — 2d. Lima-Callao
2e. Bay of Concepcion-San Vicente Bay

Theoretical values for the organic load were used as an indicator of pollution by domestic wastes. This organic load, expressed as Biochemical Oxygen Demand (BOD), was estimated for the population with sewerage services using the following factors: 25 kg/person/year (non-treated wastes) and 20 kg/person/year (treated wastes). Direct measures of BOD are practically non-existant in the region.

The following areas include the most relevant cases of pollution in the South-East Pacific.

Gulf of Panama

Concerning pollution by **domestic wastes,** Kwiecinsky (1981) determined that over 45 million tons of sewage are discharged by Panama into the Pacific Ocean, of which more than 90% does not receive treatment. The total organic load reaches about 12,500 tons BOD/year (Table 1). Of this amount, 12,100 tons BOD/year (96.8%) enters the Gulf of Panama (Figure 2a), almost entirely in the Bay of Panama: 10,900 tons BOD/year coming from the city of Panama (570,000 inhabitants in 1980); and 800 tons BOD/year from the Canal terminal in the Pacific Ocean (Balboa). The remaining 300 tons includes indirect discharges through six rivers (Zarati, Oria, La Villa, Santa Maria and Guarare) which flow in the Gulf of Panama.

Table 1 : Estimated organic load from domestic wastes in the South-East Pacific region (surveys from the South-East Pacific Action Plan)

	Organic load (thousand tons BOD/year)		
	Direct discharges	Indirect discharges	Total
PANAMA			
Pacific coast	11.9	0.6	12.5
Gulf of Panama	11.8	0.3	12.1
COLOMBIA			
Pacific coast	5.6	3.6	9.2
Buenaventura Bay	4.0	-	4.0
ECUADOR			
Total coast	7.1	41.7	48.8
Guayaquil Gulf (Rio Guayas basin)	?	19.9	19.9
PERU			
Total coast	97.9	3.3	101.2
Lima-Callao	87.5	?	87.5
CHILE			
Total coast	21.7	80.0	101.7
Maipo River basin	-	56.4	56.4
Concepcion Bay-San Vicente Bay	3.1	3.4	6.5

With reference to **industrial waste** pollution, most industries in the country are located in and around the city of Panama, but it is not possible to obtain reliable data about the volume and characteristics of the effluents. From the 761 industries mentioned in the survey done by Kwiecinsky (1981), 674 (88.6%) discharge into the Gulf of Panama, directly or through rivers, mostly in the Bay of Panama. Table 2 shows the kind and number of industries whose residues are discharged directly or indirectly into the Gulf of Panama.

The sources of **oil pollution** in the Bay of Panama include: (i) the supply operations and dumping in the port of Balboa; and (ii) dumping by the fishing fleet (300 ships) in Vacamonte port (Vergara and Pizarro, 1981). Data on oil spills in Panama Bay are shown in Table 3. These figures from Vergara and Pizarro (1981) are significantly lower than those given by Kwiecinsky (1981), who indicated dumping of fuels and lubricants in Vacamonte port averaging 2,000 barrels/year (318 m^3) and less than 100 barrels/year in Balboa, the Panama Canal terminal.

Table 2 : Industries discharging directly or indirectly into the Gulf of Panama (from Kwiecinsky, 1981)

Food Industries Kind	Number	Chemical and other industries Kind	Number
Fisheries	44	Fertilizers	1
Sugar	3	Pharmaceutical, chemical	57
Milk	12	Pesticides, herbicides	10
Cured meat, slaughterhouses	2	Metallurgy	72
Fruit, vegetables	2	Shipyards	3
Oils, fats	12	Textiles	143
Breweries, distilleries, etc.	18	Mining	6
Mills (coffee, rice)	51	Detergents	13
Others	43	Cement	2
		Paints, resins	14
Total	187	Plastics	38
		Batteries	7
		Wood	69
		Others	52
		Total	487

Table 3 : Hydrocarbon spills in Panama Bay (from Vergara and Pizarro, 1981)

	Balboa	Vacamonte
Frequency of spills	4.4/month	3.1/month
Average spill size	0.8 m^3	0.003 m^3
Causes:		
ships	70.8%	87.2%
land installations	16.7%	2.6%
others	12.5%	10.2%
Hydrocarbons:		
marine diesel	3.3%	-
light diesel	0.7%	39.4%
bunker C	28.5%	-
uncleaned ballast and others	67.5%	60.6%

The available information suggests that the pollution problem in the Gulf of Panama, centered in the Bay of Panama, is "serious" on the basis of the following facts (Kwiecinsky, 1981):

- biological pollution indicated by the presence near the shore of the bay of faecal coliforms reaching 160,000/100 ml as a result of untreated domestic discharges;

- eutrophication and the presence of hydrogen sulfide (up to 1.5 ppm) in the center of the Bay (between Paitilla and Casco), producing a "drastic decrease in the diversity of marine fauna" and disagreeable odors, mainly caused by wastes from fishing industries;

- negative effects in recreational areas (Amador Beach); and

- the presence of amounts of lubricants and fuels.

Buenaventura Bay(Colombia)

The organic load of **domestic wastes** directly or indirectly discharged along the Pacific coast of Colombia amounts to 9,200 tons BOD/year, according to data given by Rodriguez (1981) (Table 1). Of this, 4,000 tons BOD/year enters Buenaventura Bay (Figure 2b). The port of Buenaventura has 300,000 inhabitants and a sewerage system serving 60% of the population. The domestic wastes do not receive treatment.

Industrial activity in this area is very limited and there is little information about the drainage of **industrial wastes.** Rodriguez (1981), offers the following information about the number and kind of industries located in Buenaventura:

Fisheries	8
Detergents	1
Metalworking	3
Wood	37
Construction	4
Shipyards	4
TOTAL	57

The sources of **oil pollution** are the port activities and the oil pipeline of the Pacific (Cali-Buenaventura) which transports clean products and fuels (gasoline, diesel, kerosene, bunker 5 and 6). There are no measurements of the volume of spilled hydrocarbons or of the frequency of operational accidents. Buenaventura does not have means for oil spill control.

Vergara and Pizarro (1981) mention the case of a coastal vessel which transports fuels from Cartagena and Santa Marta (in the Caribbean) to Buenaventura. After unloading, it takes on ballast and steers to Tumaco (the terminal of the Trans-Andean oil pipeline which transports crude oil from Orito) to load crude oil. Because of the short distance between Buenaventura and Tumaco (240 km), the ship washes badly or does not wash its tanks, dumping dirty ballast in the harbour.

The only recorded case of an important accidental spill while transporting oil is the sinking of the tanker "Saint Peter" in 1976 off the border between Ecuador and Colombia with 33,000 tons of crude, affecting coastal areas.

The general characteristics of pollution in Buenaventura Bay are:

- Discharge of untreated domestic and industrial wastes;
- Biological pollution, shown by the presence of faecal coliforms and pathogenic micro-organisms;
- Presence of tannins and wastes from the wood industry; and
- Pollution by hydrocarbons from dumping in the port.

The Bay of Buenaventura is very narrow, with an average width of 2 km and a length of more than 8 km; its maximum depth of 10 m is maintained by frequent dredging.

Gulf of Guayaquil (Ecuador)

The estimate for the whole coast of Ecuador (10 coastal cities and 9 main river basins), indicates an organic load from **domestic wastes** of 48,800 tons BOD/year (Table 1), which corresponds to 20,000 tons BOD/year in the Gulf of Guayaquil (Figure 2c), mainly in the estuary of the Guayas River, which drains a basin of 35,245 km^2.

The major volume of domestic wastes comes from the city of Guayaquil (1,100,000 inhabitants), which drains its effluents into the Guayas river and into a bay named Estero Salado. Since 58.18% of the population of Guayaquil has sewerage service, the organic load of its domestic wastes would be equivalent to 16,000 tons BOD/year. Of this, about 10,000 tons drain into the Estero Salado, an area with major pollution problems. In addition, Solorzano (1981) states that eight cities (157,000 inhabitants) located along the tributaries of the Guayas river have sewerage service; therefore these cities add 3,900 tons BOD/year of organic load. Note that discharges of domestic wastes by several small coastal cities located by the Gulf have not been included.

Studies done between 1974 and 1978 in El Estero del Muerto (a branch of Estero Salado) showed bacteriological counts of 5,000 to 493,000 coliforms/100 ml, and low oxygen levels of about 0.6 ml/l (Valencia et al., 1979). According to Solorzano (1981), de Guzman found between 680 and 2,400 faecal coliforms MPN/100 ml in 1975.

In the survey by Solorzano (1981), data were obtained for 80 **industries** which discharge wastes into the Gulf of Guayaquil, 62 of them located in Guayaquil. Only 27 industries do some type of treatment (Table 4). This information is incomplete because the city Potable Water Department registered a total of 856 industries (1978) for Guayaquil and its surroundings. In general, they discharge their wastes into the two sewerage systems: one for rain water and other for sanitary wastes. The lack of information about the pollution problems caused by industrial wastes is even more noticeable than in the case of pollution by domestic wastes.

Table 4 : Industries discharging into the Gulf of Guayaquil (Solorzano, 1981)

Location	Industry	Number	Treatment	Effluent disposal
Guayaquil	Fisheries	25	?	Direct to river or sewer
	Fruits, vegetables	1	?	?
	Oils, fats	2	2 Skimmers	Storm drain
	Brewery		Oxidation pond	Individual collector
	Others (food)	5	1 Septic tank 2 Skimmers 1 Decantation	Storm drain
	Milk	3	3 Septic tanks	Sanitary sewer
	Metalworking	10	6 Septic tanks 1 Sedimentation 3 ?	7 Storm drain 3 ?
	Textiles	2	1 Neutralization and sedimentation 1 Stabilization pond	Storm drain
	Tannery	1	Stabilizer sediment.	Storm drain
	Cement	1	?	Storm drain
	Plastics	4	1 Septic tank 2 Deposit 1 None	Storm drain
	Batteries	3	2 Primary 1 ?	1 Sanitary sewer 2 ?
	Others	4	2 Septic tank	Storm drain
Pt. Bolivar Machala	Fisheries	4	?	?
Anconcito	Fisheries	2	?	?
Posorja	Fisheries	6	?	?
Chanduy	Fisheries	6	?	?

In reference to **oil pollution,** the main sources include the loading and unloading operations in the seaport (Estero Salado) in Guayaquil, as well as in Puerto Bolivar (El Oro province), Duran (Rio Guayas), el Salitral (Estero Salado), and places where the fishing fleet operates (Anconcito, Chanduy, Posorja). A probable source of oil pollution is the exploratory drilling on the Continental Shelf of the Gulf.

In summary, marine pollution in the Gulf of Guayaquil is concentrated in the estuary of the Guayas River, especially in the Estero Salado. This body of water has a very slow turnover that depends on tidal flushing; the retention time for pollutants has been estimated at 45 to 90 days. The most important problems are:

i) discharge of domestic and industrial wastes, practically without treatment;
ii) biological pollution, especially in the Estero Salado;
iii) dumping of oil, lubricants and fuels from the city of Guayaquil and its port; and
iv) a possible drainage of agro-chemical substances from farming and animal husbandry activities in the Guayas River basin.

Lima-Callao area (Peru)

From data given by Guillen (1981), the total **domestic discharges** into the littoral of Peru (2,864 km of coast) contain an organic load of more than 100,000 tons BOD/year from the main coastal cities and the indirect discharges of 16 river basins (Table 1). The major input is from Lima and Callao (together with 5,536,000 inhabitants in 1980) (Figure 2d), with domestic wastes containing an organic load of 87,500 tons BOD/year (volume of the effluents 1,038,800 m^3/day).

A sewerage system serves 63.2% of the population of Lima and Callao; it discharges directly to the sea through two drainage ditches without treatment of the domestic wastes. Guillen (1981) indicates one case of the presence of Vibrio parahaemoliticus bacteria on "Arena Amarilla" Beach in Callao, and negative effects of pollution by domestic wastes on the fishing resources (anchovy, pejerrey, lisa, etc.).

68% of the **industries** in Peru are located in the Lima-Callao area (Guillen, 1981). Table 5 gives information on 622 industries (with a minimum of 5 persons) considered in the survey. The Rimac River, which flows through the northern part of Callao, also receives the treated residues (16,020,843 m^3/year) of 6 mining industries.

Table 5 : Industries discharging in the Lima-Callao area
(from Guillen, 1981, Tables 6, 7, and 8)

Industry	Number	Pollutants and other data
Fisheries	17	Organic matter, fat, fish scraps (no treatment)
Sugar	2	Sugar residues, hypochlorite
Milk	15	Organic matter, Na, Ca, P, fats
Cured meat, slaughterhouse	7	Organic matter, alkaline residues, heat
Fruits, vegetables	5	Organic matter, peel and seed residues
Oils, fats	4	Oleaginous seed residues, oils, detergents
Breweries, distilleries	13	Musts, fermented barley residues, alcohols
Mills (sugar, coffee)	12	Skin residues, solids
Other food industries	28	Organic matter, pH
Paper, paper pulp	84	Fibres, suspended organic matter and solids, sulfate liquors, heat (1 industry discharges 37,000 m^3/year)
Fertilizers	8	Wastes, heat, pH, organic matter (1 industry discharges 1,809,000 m^3/year)
Pharmaceutical, chemicals	79	Organic & inorganic substances, heat (1 industry discharges 1,729,080 m^3/year)
Metallurgy	17	Acids, organic & inorganic residues, heat
Shipyards	11	Metallic residues, wood, resins, paints
Textiles	49	Acids, heat, dyes, pH, chemicals, detergents
Tanneries	26	Tannins, fibres, dyes, alkaline residues, chrome salts
Detergents	18	Organic matter, fats, detergents, pH, sulfates, sodas
Cement	2	Dissolved and suspended solids
Paints, varnishes	19	Pigments, chemicals, resins, heat (1 industry discharges 233,400 m^3/year)
Plastics, rubber	59	Chemicals, heat
Batteries	12	Acids, lead, ball tars
Woodworking	18	Wood residues
Petrochemistry	6	Oils, fats, hexavalent chrome, phenols, heat (1 industry discharges 233,400 m^3/year)
	9	Lime, dyes
Other chemical industries	102	Chemical residues, heat, pH

Guillen and Aquino (1978) and Guillen et al. (1978) identified anoxic waters in Callao Bay (samplings in May-June, 1977) right in front of the mouth of the Rimac River. They also found very low values for dissolved oxygen along the Bay (Muelle de Pescadores and Base Naval), due to high concentrations of organic matter, and a high concentration of hydrogen sulfide, up to 3.29 µg-at/l. In areas close to the SIMA shipyard they found high concentrations of copper (17.5 ppb) and iron, as a consequence of paints and residues coming from the shipyard.

In November 1978, low values for dissolved oxygen were again found at the sea surface (to 0.04 ml/l) and at the bottom (to 0.15 ml/l) in the same areas (Guillen et al., 1978). The highest values of hydrogen sulfide (1.26 µg-at/l) were found at the mouth of the Rimac River, associated with the lowest quantities of oxygen and a high concentration of nutrients.

Pollution by metals was quantified as follows:

	Sea water (surface)	Sediments (average)
Fe (total soluble)	7.7 - 27.0 ppb	1,573.4 ppm
Cu (total soluble)	2.3 - 27.0 ppb	93.8 ppm
Pb (total soluble)	0.0 - 68.0 ppb	75.5 ppm

The sources of **oil pollution** include loading and unloading in the port of Callao and the Refinery of La Lampilla (Callao).

Pollution in this area is considered to be "heavy", especially in Callao Bay, because of the following:

- Direct discharges to the sea of organic wastes from the fishing industry;
- Discharge of untreated industrial wastes, mainly from the SIMA shipyard;
- Discharge of the Rimac River, containing domestic and industrial wastes, mainly untreated;
- Observations of effects on organisms (fish kills);
- Damage to the recreational beaches;
- Occasional oil spills and discharges of wastes in port operations;
- Observations of anoxic areas or areas with very low levels of oxygen in Callao Bay, as a consequence of domestic and industrial discharges; and
- Metal pollution (Fe, Cu, Pb) in Callao Bay, especially at the mouth of the Rimac River.

Bay of Concepcion-San Vicente Bay area (Chile: Region VII).

This area (Figure 2e) is considered as one of the most affected in Chile, especially because of the combination of pollutants from domestic wastes and industries. The organic load of **domestic wastes,** discharged directly or indirectly, amounts to 6,500 tons BOD/year (Table 1), according to data given by Castilla (1981). He also states that only areas near the sources of effluents in the Bay of Concepcion are affected by biological pollutants, indicating counts of E. coli of 1,100/100 ml off the beaches of Lirquen, Penco and Tome.

With reference to pollution by **industrial residues,** Castilla (1981) gives information for 44 industries (Table 6), noting the elimination of a crab species (Hemigrapsus crenelatus) in the area and damage to the seaweed Gracilaria sp. In San Vicente Bay, Cabrera (1979) indicates mercury amounting to 1.2 kg/day in the discharges of industries located in the Estero Lenga, and concentrations of 50 to 2,000 ppm of active chlorine.

Referring to **pesticide pollution,** Castilla (1981) lists the following concentrations found by the Department of Oceanology of the University of Concepcion:

	Sea water (ppb)	Aulacomya ater (ppb)
i) Concepcion Bay		
DDT	0.5	14.3
DDE	0.15	5.1
ii) San Vicente Bay		
DDT	0.7	9.4
DDE	0.2	2.9

Table 6 : Pollution by industrial wastes in the VII Region of Chile (from Castilla, 1981)

Location (Discharge point)	Industry	Treatment	Discharge volume m^3/day	Pollutants and other data
Bahia-Concepcion (Tomé-Talcahuano)	19 Fisheries	None	1,500	Organic matter
	3 Shipyards	None		Various pollutants
Bahia-Concepcion (San Vicente)	1 Mining	Sedimentation neutralization	195,610	Iron residues, ammonia, oils, phenols
	2 Petrochemical	Neutralization & separation of solids	38,300	Acidity, possibly Hg
Chiguayante (Bio-Bio River)	1 Textile	None	700	Alkalinity, anilines, resins
San Pedro (Bio-Bio River)	3 Pulp and paper	Foam retainer sieves	171,371	Dissolved solids, fibres, organic matter, dyes, chlorolignins, sodium lignate
Tomé	3 Textile	None	4,000	Analines
Arauco	2 Fisheries	None	?	Organic matter
	1 Pulp and paper	None	90,000	Dissolved solids, fibres, organic matter
	2 Mining	None	?	(Infiltration ponds)
	2 Wood	?	?	(Direct emitter)
San Vicente Bay	1 Pharmac.chemical	Decant. neutraliz.	2,500	Sulfides, phenols, oils
	1 Metallurgy	?	?	?
	1 Cement	?	?	(Direct emitter)
	1 Plastics	?	?	(Direct emitter)
Bio-Bio River	1 Tannery	?	?	?

Possible sources of **oil pollution** are the refinery and the two oil terminals located in San Vicente.

The pollution problems in this area can be summarized as follows:

i) In San Vicente Bay and the Bio-Bio Estuary, there are "severe" pollution problems, mainly due to:

- toxicity from active chlorine and metallic mercury;
- pollution by heavy metals;
- pulp and paper mill wastes, an oil refinery and other industries;
- lack of treatment of industrial and domestic wastes;
- harmful effects observed on organisms (crab and seaweeds);
- coastal salt marshes (Estero Lenga) and migratory birds affected by levels of active chlorine, mercury and cadmium.

ii) In the Bay of Concepcion-Los Reyes Islands area, there are also "serious" pollution problems due to:

- eutrophication;
- coastal salt marshes polluted with residues of fishing industries;
- untreated domestic discharges (Andalien river), especially from Concepcion;
- presence of biological pollutants in restricted areas near the effluent discharges in the bay.

Other areas with important pollution problems

Additional areas of the region with important pollution problems or zones at risk such as oil pipelines, terminals and refineries are shown in Figure 1.

On the Pacific coast of Panama, **Armuelles Port** (Chiriqui Gulf) is a risk area. Here crude oil from Alaska is transferred to smaller tankers for transporting through the Panama Canal. About 15,000,000 barrels of oil pass through the Panama Canal per year (Kwiecinsky, 1981). Copper may eventually be mined in Cerro Colorado, Chiriqui province.

On the Pacific coast of Colombia, the port of **Tumaco** has hydrocarbon pollution resulting from the dumping of dirty ballast (Vergara and Pizarro, 1981) and a risk of pollution by crude oil from the Trans-Andean pipeline terminal (Orito-Tumaco).

On the coast of Ecuador, the following areas have risks of oil pollution or have pollution problems:

- **Estuary of the Esmeraldas River,** as a result of effluents from the oil refinery;
- **Balao Area** (Esmeraldas), pipeline terminal for crude oil coming from the Oriental Region;
- **La Libertad Port** and nearby areas on the Peninsula of Santa Elena, oil terminal, refinery and oil wells very close to the shore;
- **Manta Bay,** port for coastal vessels and much of the fishing fleet of Ecuador, dumping by fishing industries.

In Peru, the following areas with significant pollution problems must be considered (Guillen, 1981):

- **Talara Bay** and nearby areas, oil wells on the continental shelf and close to the shore, effluents from the oil refinery, terminal for loading and unloading both crude and refined products, dumping of ballast, natural oil seeps;
- **Bayovar Bay,** pipeline terminal for crude oil;
- **Chimbote Bay,** discharge of domestic and industrial wastes, especially by fishing industries; dumping of oil and by-products; pollution described as "grave"; reports of occasional signs of eutrophication;
- **Ports of Supe, Pisco** and **Ilo,** mainly due to direct discharges from the fishing industries;
- **Ite Bay,** tailings from the copper mines of Toquepala and Cuajone; pollution considered "serious"; reports of the absence of fish and other marine organisms and of damage to the beaches.

In Chile, Castilla (1981) mentions the following areas:

- **Iquique Bay,** domestic and fishing industry wastes;
- **Tocopilla-Caleta Minchilla,** copper concentrating plant with pollution by iron, copper, acids, and inert material and the absence of animal and plant life on parts of the coast where the untreated washings are discharged;
- **Chanaral,** concentrating plant for copper and molybdenite, tailings from El Salvador copper mines producing "severe" pollution and the disappearance of benthic organisms;
- **Huasco-Chapaco Bay,** iron pelletizing plant and deposits of clay materials;
- **Coquimbo Bay,** domestic wastes producing biological pollution affecting bivalve molluscs and beaches; copper concentrating plant; "grave" pollution;
- **Valparaiso-Vina del Mar,** port activity, industrial discharges, and an organic load of domestic wastes estimated at 10,400 tons BOD/year;
- **Con Con Estuary of the Aconcagua River,** oil refinery, discharges from the Aconcagua basin, reports of organic decomposition, toxicity and oxygen depletion;
- **Constitucion,** cellulose factory producing oxygen deficiency, toxicity, organic solids, fibres;
- **Estrecho de Magallanes,** high pollution at localized points, oil exploitation, route of supertankers;
- **Maipo River** (Metropolitan Region) with one tributary (Mapocho River) which crosses the city of Santiago; the estimated organic load from domestic wastes received by the Maipo river is 56,400 tons BOD/year.

It is clear from the above listing of significantly polluted areas in the South-East Pacific that much remains to be done in the framework of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific to prevent further degradation of the environment and to correct existing problems.

REFERENCES

Arriaga, L. 1976. Contaminaction en el Oceano Pacifico Suroriental (Ecuador-Peru-Chile). Rev. Com. Perm. Pacifico Sur 5:3-62.

Cabrera, N. 1979. Contaminacion marina en Chile. Rev. Com. Perm. Pacifico Sur 10:113-145.

Castilla, J.C. 1981. Fuentes, niveles y effectos de la contaminacion marina en Chile. CPPS, Serie Seminarios y Estudios 2:1-50.

Guillen, O. 1981. Fuentes, niveles y effectos de la contaminacion marina en el Peru. CPPS, Serie Seminarios y Estudios 2:51-116.

Guillen, O. and R. Aquino. 1978. Contaminacion en los Puertos de Callao y Chimbote y su efecto en la productividad. Inst. Mar Peru, Inf. No. 61.

Guillen, O., R. Aquino, B. Valdivia and R. Calienes. 1978. Contaminacion en el Puerto de Callao. Inst. Mar Peru, Inf. No. 62.

Kwiecinsky, Bogdan. 1981. Contaminacion marina del Pacifico de Panama. CPPS, Serie Seminarios y Estudios 2:117-171.

Rodriguez, Francisco. 1981. Contribucion al conocimiento de la contaminacion y su problematica en el Pacifico Colombiano. CPPS, Serie Seminarios y Estudios 2:243-287.

Solorzano, Lucia. 1981. Fuentes, niveles y efectos de la contaminacion marina en Ecuador. CPPS, Serie Seminarios y Estudios 2:173-241.

Valencia, M., et al. 1979. Contaminacion marina en Ecuador. Rev. Comision Permanente del Pacifico Sur 10:245-282.

Vergara, I. and F. Pizarro. 1981. Diagnostico sobre la contaminacion marina por hidrocarburos en el Pacifico Sudeste. CPPS, Serie Seminarios y Estudios 2:289-368.

OIL POLLUTION IN THE SOUTH-EAST PACIFIC: REGIONAL CO-OPERATION AND CONTINGENCY PLANS

Francisco Pizarro A.
Jefe Division Asuntos Internacionales (IMO), Armada de Chile
Errazuriz 537, Valparaiso, Chile

ABSTRACT

As in many other regions of the world, the South-East Pacific region has been affected by oil pollution due to marine transportation activities, offshore platforms, and tanker and other shipping accidents.

With the support of UNEP and the co-operation of the other specialized agencies of the UN system, the countries of the CPPS (Colombia, Ecuador, Peru and Chile) and Panama are implementing an Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific.

Special emphasis is being given to regional co-operation, considering the magnitude an oil spill could have in some extreme circumstances and the response capabilities of these countries to deal with a major spill.

A diplomatic Conference held in Lima, Peru in 1981 approved an Agreement on regional co-operation in case of serious spills of oil or other harmful substances, as well as a Protocol on operational matters.

Various meetings have been held with the active participation of representatives of all the countries involved. These meetings have covered legal (national and international) and technical aspects, including modern techniques and equipment for combating oil pollution at sea.

One of the most important topics included in the Plan is the formulation of National Contingency Plans, since prior planning and organization are essential to a rapid response.

Introduction

Marine pollution is unavoidable, it is part of the price mankind must pay for the development of an industrial society. Man must learn to live with this problem and try to manage it. He must also learn that marine pollution may affect everyone equally, that it has no frontiers, that it can extend to all regions of the world, and that it may affect both developed and developing countries. He has to learn that it is a global and interdisciplinary problem which involves ecological, technical, political and legal aspects. He has to learn that it is a problem concerning the whole world.

Among the many types of water pollution, oil and its products have been the most widespread contaminants in the sea; according to the most optimistic calculations made by the Intergovernmental Maritime Organization (IMO) in 1982, more than 3 million tons are discharged into the sea every year. Oil spills due to accidents are spectacular because of the localized damage they cause. However, the greatest quantity of oil discharged into the sea comes from routine ship operations such as indiscriminate discharges of oily ballast, contaminated water from tank washing and bilge water discharges, as well as the operation of off-shore terminals, off-shore drilling, refineries, etc.

There is a reasonable understanding of the effects that oil may have on ecology, tourism, fisheries, recreation, human health, coastal industries, scientific research, etc. These may include the elimination or changes in behaviour of marine species, particularly larvae and juvenile fish; the disturbance of food chains; sea bird mortality; beach pollution; a decrease in catch of or demand for sea products; the possibility of carcinogenic effects on human health; the impossibility of using polluted water for cooling, desalting or washing operations; restrictions on scientific research; etc., all of which finally have economic and social costs that affect everyone.

As in many other regions of the world, the South-East Pacific region has been affected by oil pollution due to marine transport activities, offshore platforms, and tanker and other shipping accidents. Although this pollution may not be extremely serious, it has an extraordinary importance because of the value of the resources threatened.

Oil pollution problems in the South-East Pacific

Off-shore oil activity

Along the South-East Pacific Coast, Chile and Peru are the only two countries with off-shore oil production. In Chile these off-shore oilfields are located in the Magellan Straits, and in Peru, in the northern part of the country. Off-shore production in Chile exceeded 2.5 million cubic metres in 1982.

There are also exploration and drilling activities in other zones within the region, such as those in the Gulf of Panama, southern Colombia, the Santa Elena Basin in Ecuador, the central-north basin in Peru, and off the Pacific west coast of Panama (Chiriqui). Furthermore Chile and Ecuador have activities related to off-shore gas production.

In general, except for one incident on a platform in the north of Peru in October 1982, no incidents of great proportions are known in off-shore production within the region, such as the one that affected the IXTOC I well in Mexico. The minor spillages that have occurred have been regarded as a routine part of normal exploration and production operations.

Oil refineries

At present, there are 9 coastal refineries in the region: 3 in Ecuador, 2 in Peru, and 4 in Chile. The total refining capacity exceeds 20 thousand cubic metres per day.

Many of these refineries are equipped with API separators for the treatment of oily water resulting from normal refining operations and, in general, the oil content of these effluents is within internationally accepted limits. Recently, the Refineria de Concon, Chile, has installed a novel recycling system for cooling the waters employed in the refining process, avoiding oil pollution as well as the thermal pollution of the Aconcagua River.

Loading and discharge terminals

Along the South-East Pacific Coast there are 17 terminals for the loading and discharge of crude oil. In addition, most commercial ports have terminals for the discharge of oil products involved in coastal trade.

Most of these ports have facilities for the reception of oily ballast (except in Colombia), although their capacity may be inadequate, since often weather conditions on the shipping routes require tankers to take on more ballast than the terminals are capable of receiving. Although measures are taken to drain only the water that has already separated, a certain degree of pollution is always caused.

Generally, oil pollution in terminals during the loading and discharge of crude oil is comparatively small; it is mainly due to human errors in connecting or disconnecting flexible hoses or in removing the pipelines when the discharge is completed. Almost all the terminals carry out regular preventive maintenance and periodic surveys, both on submarine pipelines and on mooring buoys, which are also subject to overhauls and changes of worn out parts or fittings. However, some spills have have occurred due to failures in submarine pipelines, such as the breakage of the submarine pipeline leading to the multibuoy terminal at Quintero, in February 1977, which caused a spill of more than 800 cubic metres.

Oil transport in the region

Almost 99% of the foreign trade in Latin America is carried out by sea, and this is particularly true in the South-East Pacific. On a world scale, oil transport represents 55% of the total seaborne trade. In Latin America, the proportion is 45%. Oil transport in the region depends on foreign trade and on the needs of domestic coastal trade.

The total regional trade can be estimated at slightly over 30 million cubic metres per year, with some countries such as Ecuador and Peru being exporters, and the others importers, such as Chile. Panama is a special case since an important part of the Alaskan production carried in VLCC's is discharged at Port Armuelles on the Pacific Coast. Until October 1982, this oil was carried in "Panamanian" type tankers through the Panama Canal, although now it is pumped through an oil pipeline to the Atlantic. If this volume of oil is added to the region's own volume, nearly 60 million cubic metres of oil is carried yearly in the region.

There is no doubt that this movement of oil in the region generates routine pollution from tankers because facilities for the reception of oily ballast, tank washings, sludge drainage, etc. are absent or are of insufficient capacity. For instance, the only tanker owned by Colombia carries crude oil from the Pacific Coast (Tumaco) to refineries in the Atlantic (Santa Marta), crossing the Panama Canal. After discharging its cargo, the ship goes to sea for tank washing and then returns to port to load products that are immediately carried to the Pacific (Buenaventura).

In addition, the total capacity of the region's tanker fleet is insufficient for the volume of oil transported. It thus becomes necessary to charter tankers that do not always meet the standards of the international provisions in force (COW, IG, SBT, CBT, etc.). Since such tankers are not allowed to trade with countries with very severe regulations (USA, Japan), they are operated in this region because they are cheaper, and because standards for the prevention of oil pollution are not fully implemented in the region and monitoring and control systems are not very effective and complete.

Marine incidents and casualties in the region

In general, the South-East Pacific has not been affected by major marine casualties except in Chile, where because of weather conditions and irregular geography a number of incidents have occurred causing major pollution. In the other countries, the only serious case registered is the "Saint Peter" which sank off the coast between Colombia and Ecuador, polluting the coast and a wide zone of mangrove swamps and causing prawn mortality that resulted in economic effects of nearly 8 million dollars.

Given the high volume of traffic in countries such as Panama, Ecuador and Peru, the region has been lucky not to have more incidents.

The case of Chile is different. In 1973 the Greek tanker "Napier" carrying some 30,000 tons of crude oil from Bolivia stranded off Guamblin Island in the southern part of the country. The effects of this oil pollution could never be quantified, since the ship was burned from the air.

In 1974, the VLCC "Metula" stranded in the Magellan Straits spilling some 52,500 tons of oil, which at that time was considered the second largest oil spill after the "Torrey Canyon". The "Metula" caused major pollution that still continues to affect the shores and inlets of the area.

Another serious case was the Chilean tanker "Cabo Tamar" that stranded in the Bay of San Vicente in 1978 and spilled about 12,000 tons, causing major pollution of the nearby beaches and bays. No great ecological damage was caused, however, because of the oil spill control and recovery carried out.

National contingency plans and organization

Contents of a contingency plan

A contingency plan defines in advance what measures are to be taken in the event of an oil spill, who is responsible for carrying them out, and what kinds of resources are available.

Among other things, a contingency plan should include:

1. A list of the persons and organizations that must be notified immediately in the event of an oil spill.

2. A list of duties, in order of priority, that must be performed whenever a spill occurs.

3. The designation of the responsible authority, with the chain of command and the assignment of qualified personnel to specific duties in response to an oil spill.

4. A communications link to ensure adequate co-ordination and an effective response.

5. Reference material, such as maps of sensitive areas and other technical data, that could be useful to people responsible for control measures.

6. Statistics identifying possible oil movements under different weather conditions.

7. An inventory of the type and location of the response equipment available.

Contingency plans in the region

Chile and Ecuador have the most comprehensive contingency plans, both at the national and local levels. Peru is quite advanced in the development of its national contingency plan. Colombia has a contingency plan at the level of the oil company ECOPETROL. Panama is also developing its national contingency plan, although it has well implemented local plans at Balboa, Colon and the Canal Zone.

Organization

The organization of the countries in the region to deal with oil spill emergencies differs from one country to another. While Chile with the financial support of UNDP and the assistance of IMO has established a well organized framework, the other countries have not yet reached so advanced a state of development. Panama has adequate equipment and trained personnel for oil spill control. Colombia has a minimum of equipment to deal with spills and few trained personnel. Ecuador has a certain amount of equipment in the maritime terminals and some experts that are developing training courses.

Peru is the country that needs a major effort to implement control measures since it lacks equipment and has very few trained personnel. However, with the co-operation of IMO, Peru is developing an ambitious improvement plan covering both maritime safety and pollution.

In Chile, the above-mentioned project has permitted the training of more than 200 people in: oil control techniques, the management of an emergency, operation of equipment, oil tanker salvage, contingency plans, and oil pollution control at off-shore platforms. The authority responsible for pollution control in the country has allowed personnel from the oil industries and shipping companies to participate in the training activities carried out. This has permitted the Empresa Nacional del Petroleo and the oil distribution companies to become involved in the problems of oil pollution, and they have just formed a kind of co-operative for the acquisition of equipment. In addition to the equipment the Authority has assigned to the control centers, Chile will soon have equipment amounting to US$ 1.5 million, as well as highly trained personnel. Furthermore, with the co-operation of the Universidad de Valparaiso, a laboratory was developed in Chile to carry out dispersant toxicity tests, a pre-condition to getting permission to use dispersants within the country.

Co-operation protocols in the event of emergencies

Action Plan for the South-East Pacific

With the support of the United Nations Environment Programme (UNEP) and the assistance of other agencies of the United Nations system such as FAO, IOC and IMO, the countries of the region have developed an Action Plan for the Protection of the Marine Environment and Coastal Areas in the South-East Pacific, to promote the health and preserve the welfare of present and future generations.

Agreement on regional co-operation

A Diplomatic Conference held at Lima, Peru in 1981, approved not only the Action Plan, but also an "Agreement on regional co-operation in combating pollution of the South-East Pacific by hydrocarbons and other harmful substances in cases of emergency", which was prepared with the co-operation of IMO.

The Agreement requires all parties to co-operate in taking the measures needed in the event of severe and imminent dangers to the marine environment, the coast, and related interests of one or more parties, because of the presence of great quantities of oil or other harmful substances that threaten to contaminate or are contaminating the South-East Pacific up to the 200 mile zones of maritime jurisdiction of the contracting parties, and in the high seas to the extent that the contaminants spilled present a pollution danger.

"Related interests" refers to resources and activities in coastal waters, ports and estuaries, including fisheries, historic or tourist amenities, nautical sports and recreation, the health of coastal populations, and the preservation of living resources.

This co-operation among the parties will include, in particular, the equipment, ships, aircraft, trained personnel and manual labour required for the operations in the event of an emergency.

In addition, the Agreement covers aspects of monitoring and control, the exchange of information at the level both of national authorities and of ship masters and aircraft pilots, and the co-ordination needed for the rapid and effective use of this information.

This type of collaboration among countries is the only way to deal successfully with these emergencies, which otherwise would be almost impossible to cope with separately, given that this would require an economic effort beyond the means of developing countries such as those in the region.

Complementary protocol

The above-mentioned Agreement on co-operation establishes a general framework for mutual assistance between the states of the region in special pollution circumstances. The emergency situations considered will require the rapid implementation of co-operative mechanisms according to the means available in the respective countries.

To speed the establishment of concrete mechanisms in the event of spills, and to determine the shares to be assumed by the countries of the region, a Complementary Protocol has been prepared under the Agreement. This Protocol, which was in the final draft stage in November, 1982, is intended to regulate in some detail the measures to be adopted by the countries so as to rationalize the employment of equipment and experts, and to keep enforcement from becoming an economic burden. It establishes the manner in which each country will ask for or provide assistance, either in equipment or experts; the estimated cost of the assistance; methods of payment; and arrangements allowing for the temporary entry of equipment and materials into the country requesting the assistance. It also includes a description of the National Contingency Plans referred to in the Agreement on Regional Co-operation, specifying some of the aspects that should be included such as the assignment of institutional and individual responsibilities for the management and performance of cleanup and control operations, the determination of sensitive areas, the provision of financial resources, etc.

Regional co-operation

The Action Plan for the South-East Pacific supported by UNEP as part of its Regional Seas Programme includes provision for seminars and training courses.

An "International Course on Oil Spill Control" was held at Vina del Mar in April 1981, with the attendance of representatives from all the countries of the region. The course included techniques for the control of spills and practice in the use of the equipment available in Chile for these purposes.

A "Seminar on Marine Pollution Legislation" in the different countries of the region was also held at Bogota, Colombia in May 1981.

In October 1982, a Seminar on "Salvage of Oil Tankers, National Contingency Plans, and Pollution from Off-shore Oil Platforms" was held at Vina del Mar, as part of the UNDP project in Chile, and representatives from all the countries of the region were invited to participate.

The Action Plan includes a number of other activities that will implement closer regional co-operation at every level, including scientific, technical and legal aspects.

Conclusions

Off-shore oil activity is becoming important in the region and will continue to grow in the near future. In addition there is growing activity in oil transport in the region.

The resources threatened by eventual oil spills are abundant and valuable, justifying protective measures. Even though the major oil spills to date have occurred in Chile, this does not exclude the rest of the countries from the possibility of suffering a serious incident, particularly given the great movement of oil in the region.

The countries have shown great interest in this problem at a regional level and within the Permanent Commission for the South Pacific, and with the support of UNEP and the technical assistance of IMO, FAO and IOC, they are developing a Regional Co-operation Action Plan. The many Conventions, Agreements and Protocols approved and in preparation demonstrate the resolve of governments to protect themselves from oil pollution, and will certainly lead to the future formulation of a Regional Contingency Plan.

OCEAN CIRCULATION IN THE EASTERN PACIFIC AND EL NINO

Pablo Lagos
Instituto Geofisico del Peru
Lima, Peru

ABSTRACT

Recent atmospheric and oceanographic studies show that sea surface temperature (SST) anomalies in the tropical Pacific plays an important role in the global atmospheric circulation and climate. The SST anomalies, in turn, are a consequence of anomalous fluctuations of surface winds that drive the circulation in the tropical Pacific. When the SST is anomalously large along the coast of Ecuador and Peru as far south as 12 degrees, the name "El Nino phenomenon" has been given. The causes of El Nino are not fully understood. However, the paper will describe the recent scientific ideas related to the warming of waters off western South America based on observations and numerical model results.

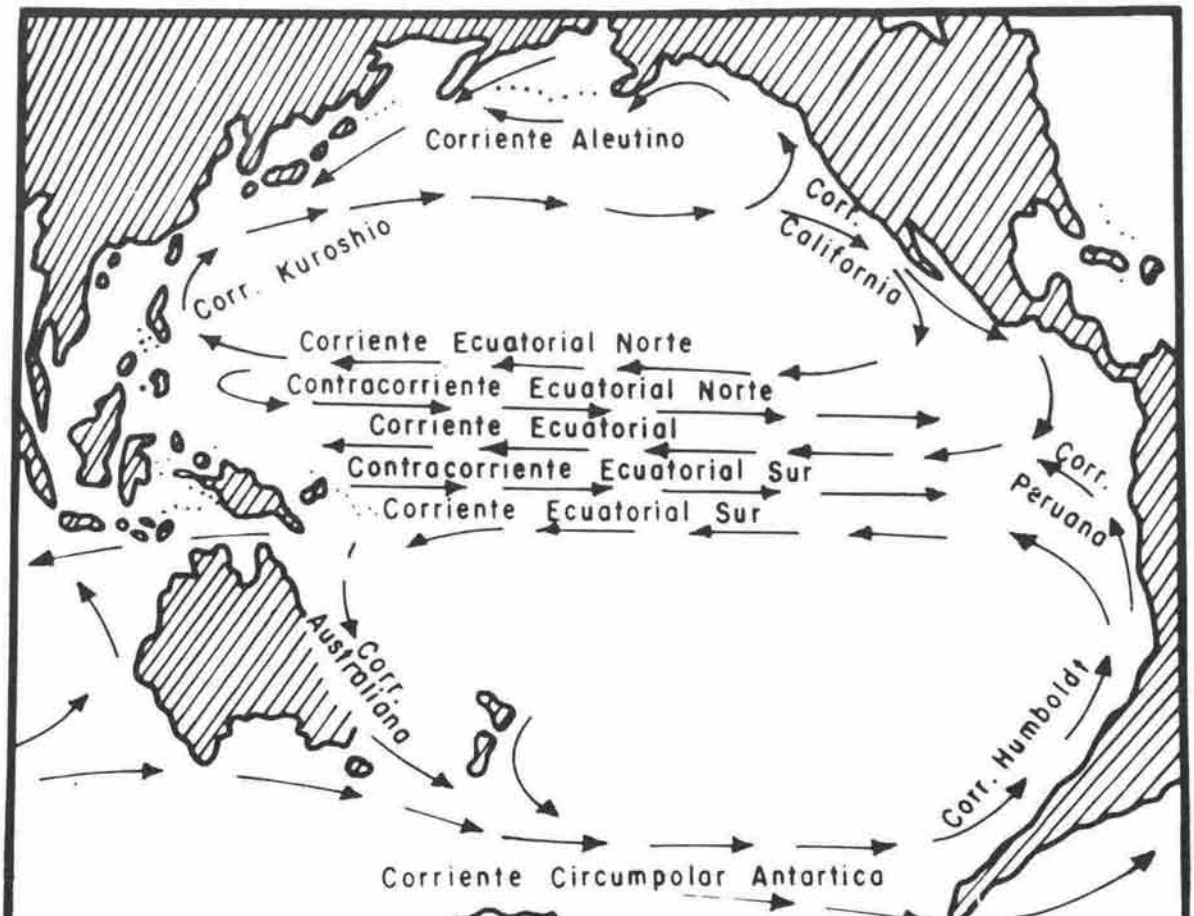
Normally the climate on the coast of Peru is cool and foggy, unlike the hot and humid climate of the east coast of South America at the same latitude. This is due to the presence of cold water derived partly from the Peru current, which flows from south to north parallel to the coast bringing water from the Antarctic, and partly from the upwelling of low-temperature subsurface water from a depth of 100 metres or more, resulting from the action of the winds along the coast. The biological effect of the upwelling is extremely important. The constant renewal of the nutrients enables the phytoplankton and zooplankton to develop as part of a food chain culminating in the anchovy. As a result, anchovy catches are abundant. In 1970, Peru supplied over one-fifth of the world's fish protein. During the summer months, the climate alters slightly as a result of the presence of warmer tropical water.

"El Nino" is an atmosphere-regulated oceanographic phenomenon which appears more or less periodically in the form of very warm water off the Peruvian coast and torrential rain in northern Peru, causing the deaths of millions of anchovies and guano-producing birds. The presence of warm water alters the climate along the coast of Peru and throughout the world. The clear skies typical of summer last an extra few months. In the United States and Europe, the winter is colder. In India, the monsoon is less pronounced. In the Pacific, rainfall increases and abnormal hurricanes develop. During the last 25 years, this phenomenon has occurred in 1957-58, 1965, 1972-73 and 1976, the last period but one having the greatest intensity.

Theories Regarding El Nino

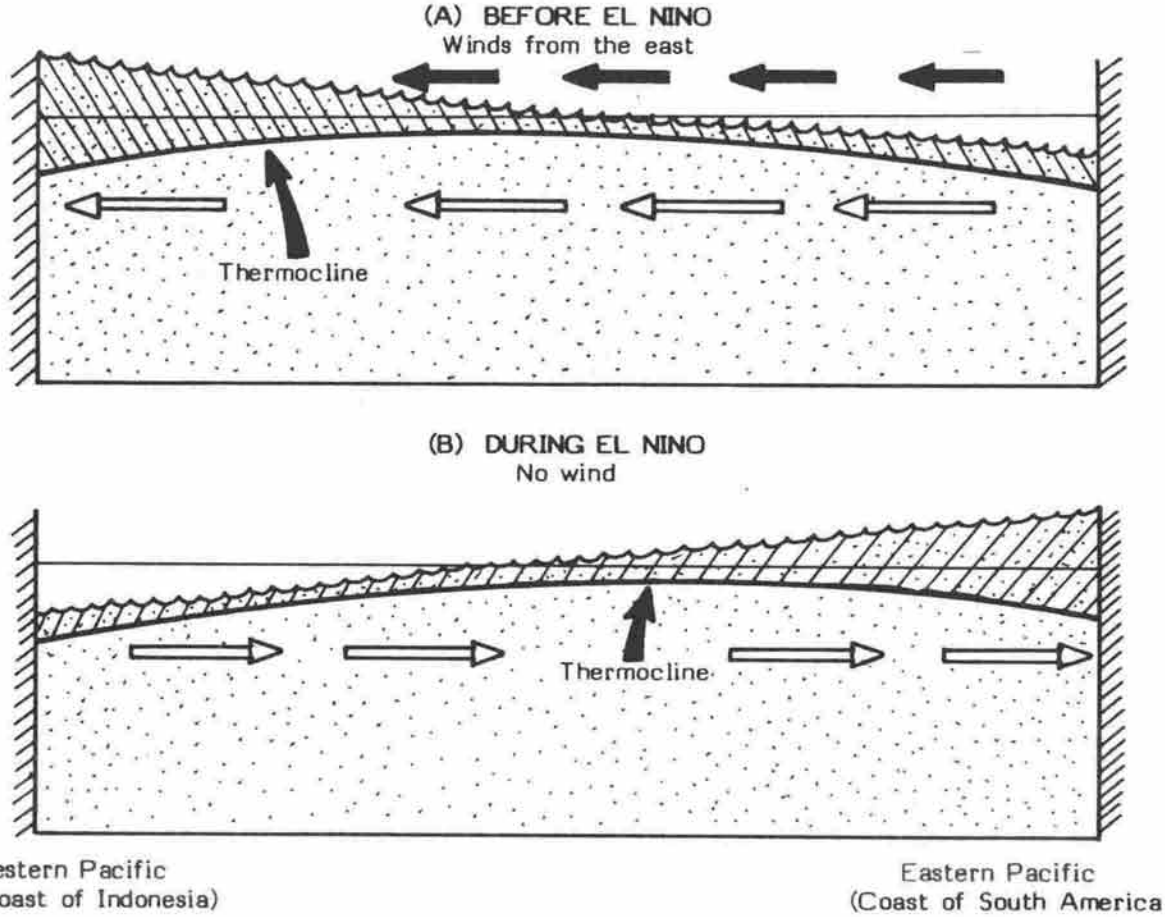
The causes of the El Nino phenomenon are still not entirely clear. The most recent theories link the presence of warm water off the coasts of Ecuador and Peru to atmospheric events thousands of kilometres to the west, in the tropical central Pacific. Dr. Klaus Wyrtki, oceanographer at the University of Hawaii, maintains that El Nino is the result of the action of easterly and south-easterly winds in the central equatorial region of the Pacific Ocean (Wyrtki, 1975; Wyrtki and Meyers, 1976). Wind fluctuations generate a disturbance in the ocean which spreads eastwards in the form of a wave. As the wave spreads, the thermocline sinks. The thermocline is the layer separating the warmer and less dense surface water from the colder and denser deep water. When the thermocline lies deep, the volume of warmer water increases. Dr. Wyrtki has documented his observations of the winds, sea level and thermocline depth throughout the tropical Pacific for the period 1960-1978. On the basis of these data he explains that El Nino originates during the transition from one system of atmospheric circulation to another. In the first circulation system, the easterly and south-easterly winds in the equatorial region of the Pacific becomes stronger, as does the South Equatorial Current which flows east-west to the south of the equator (Figure 1). The result of these conditions is an accumulation of warm water, the sinking of the thermocline and a rise in the level of the western Pacific, while the temperature of the eastern Pacific, particularly along the coast of Peru, remains low. This situation in the atmosphere and the ocean develops slowly and may last for several years (Figure 2 A). In the second circulation system, the easterly and south-easterly winds are light, the South Equatorial Current is slow, the thermocline in the eastern Pacific sinks and the sea temperature is high. This situation is typical of the El Nino periods (Figure 2 B).

Figure 1 : The ocean current system in the Pacific
(adapted from Rand McNally Atlas of the Oceans)



El Nino originates during a sharp change from the first circulation system to the second, i.e., when the easterly and south-easterly winds suddenly lighten or die after being abnormally strong. This abrupt change, which occurs mainly in the equatorial central Pacific, generates a disturbance in the ocean in the form of a wave, known as a Kelvin Equatorial Wave, which takes approximately three months to reach the east coast. When this wave reaches the South American coast, the thermocline is at a greater depth and warm water accumulates off the coast. The presence of this warm water (at least 2°C above normal) off the coast of Ecuador and Peru for more than four months is known as the El Nino phenomenon.

Figure 2 : Diagram of ocean circulation patterns in the tropical Pacific before and during El Nino, showing the variation in the thermocline



Prospects for the occurrence of El Nino in 1983

Let us assume that the occurrence of El Nino can now be forecast as an oceanographic phenomenon caused by winds. Strictly on the basis of Wyrtki's theory and of experience of the last four occurrences of El Nino, indications are that El Nino will not occur in 1983, and possibly not in 1984, since the necessary condition for the occurrence of a moderate or strong El Nino is the existence of a preparatory phase, without which it could not occur. This preparatory phase can be identified by the existence of independent parameters: unusually strong equatorial winds for at least 18 months, sinking of the thermocline and a rise in the sea level on the western Pacific coast, and low temperatures along the equator in the Pacific. When these four conditions are met, El Nino can be expected to appear during the southern hemisphere summer immediately following the winter in which the collapse of the equatorial wind system begins. These conditions have been observed in association with the last four occurrences of El Nino.

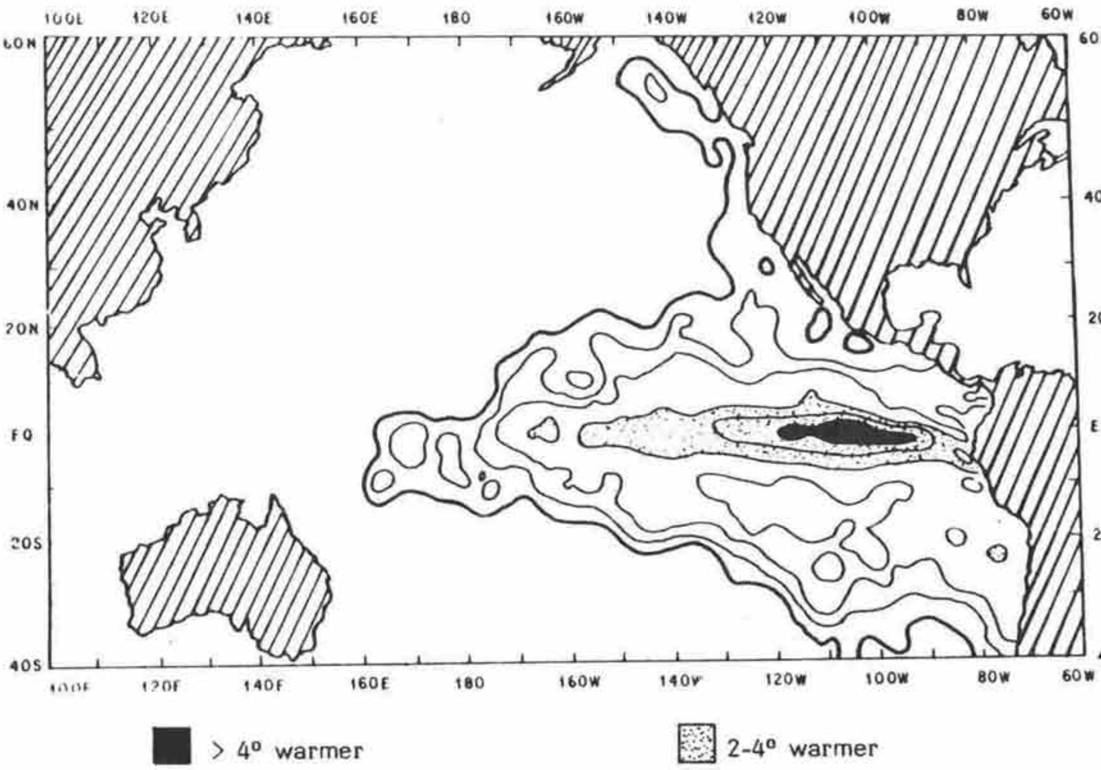
At present (late 1982), there are no indications of this preparatory phase. Cloud movements observed by weather satellites indicate that the equatorial winds were normal from the beginning of 1981 to June 1982. The level of the sea on the western coast of the Pacific was lower than usual. To date, there are no data on the thermocline in the western Pacific, but the sea surface temperature in the equatorial region of the Pacific was normal in 1981 and in the early months of 1982. It was not until May 1982 that the temperature began to rise slightly, while the temperature along the Peruvian coast was lower than usual during the first five months of the year. Since the preparatory phase has not materialized, the occurrence of El Nino in 1983 has been forecast as improbable. More recent information, however, indicates an abnormal rise in temperature in the equatorial region of the eastern Pacific.

Further Outlook

Can El Nino occur without a preparatory phase, i.e., an El Nino completely different from those which have occurred over the last 30 years? There is as yet no definitive answer. Recent observations in the equatorial Pacific, from August to November, 1982, suggest that El Nino may even now be occurring. The Climate Analysis Center of the National Oceanic and Atmospheric Administration in Washington, D.C. has just issued a special climate diagnosis (NOAA, 1982) in which reference is made to an abnormal rise in temperature in the equatorial region of the eastern Pacific (Figure 3). This document notes that during September and October of this year, global climatic variations were somewhat abnormal. East and south-east winds in the equatorial Central Pacific have not only diminished, but are blowing from west to east, i.e., they have changed direction by 180°, a phenomenon never before observed. The sea surface temperature in the equatorial eastern Pacific has already reached alarming levels over an area extending nearly to the coasts of Ecuador and northern Peru. In addition, two United States scientific vessels, Conrad and Researcher carried out observations in this area, Conrad in the equatorial central and eastern Pacific from west to east during September and October 1982 (Toole, in press), and Researcher in the eastern Pacific from north to south in November (Hayes, 1982). Both vessels met with abnormally warm water along their routes, and found the thermocline at previously unrecorded depths. These conditions are without question identical to those which occur during the periods in which El Nino occurs. In this circumstance, the answer to our question above would be in the affirmative, in which case it would be possible to forecast the non-occurrence of El Nino not one or two years in advance, but only three to four months in advance, as with forecasts of its occurrence. The behavior of the winds in the equatorial Pacific during the southern hemisphere winter should be monitored in order to predict the occurrence or otherwise of El Nino.

A definitive answer, however, will have to await the results submitted by two Peruvian scientific vessels, Humboldt and Unanue, currently off the southern and northern Peruvian coast respectively. The information provided by scientific and merchant vessels in the equatorial Pacific, fixed stations along the coasts of Ecuador and Peru, the fixed stations on the Pacific islands and instrument-carrying buoys in the equatorial region of the eastern Pacific will also be required.

Figure 3 : Anomalies in the surface temperature of the sea in October 1982 (courtesy of NOAA)

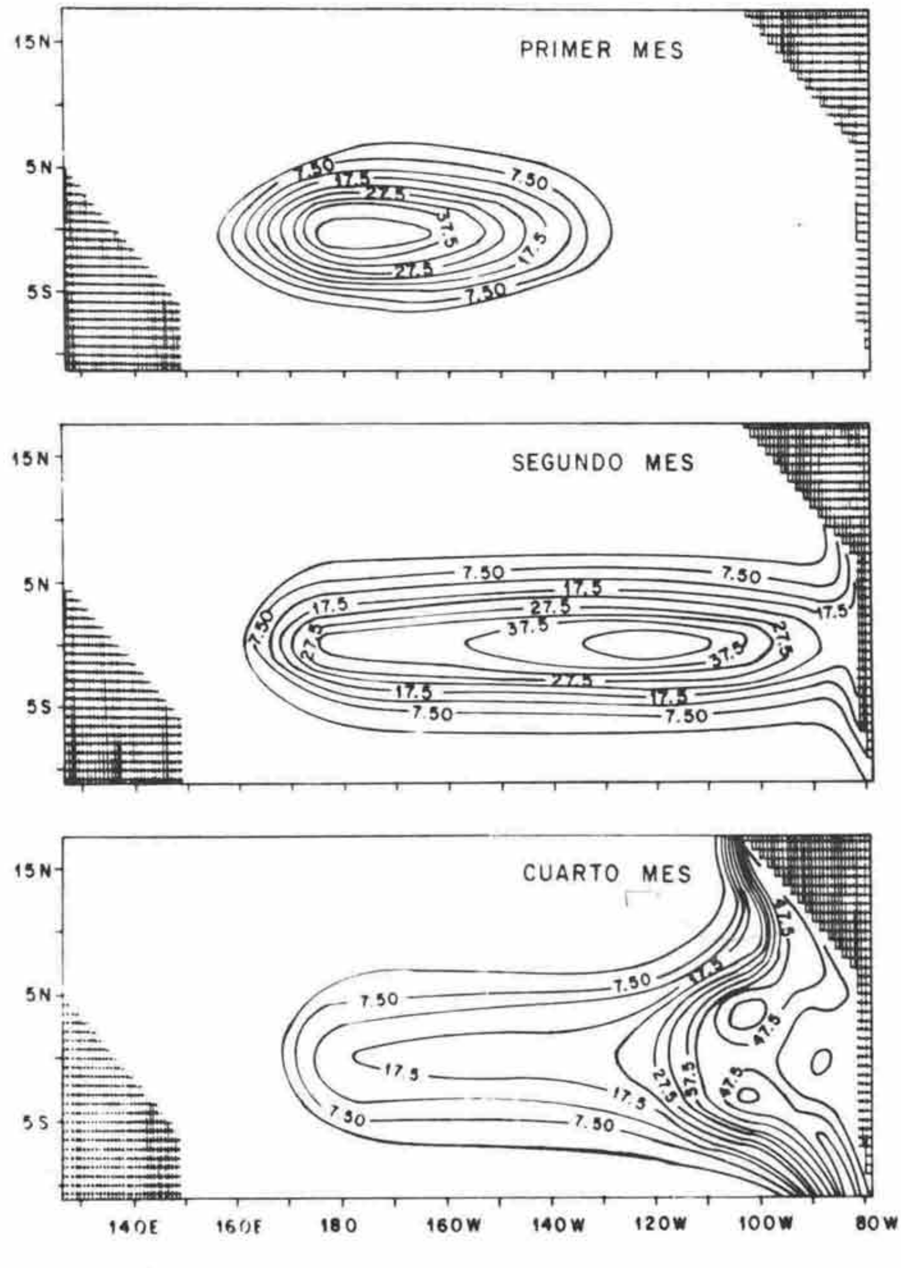


Observation of winds the key to forecasting El Nino

El Nino is the ocean's reaction to the decrease in the equatorial winds in the equatorial central Pacific. This has been observed in the past and is being observed at present. It has also been confirmed by mathematical models simulating the phenomenon. Basically, these models do no more than show whether, given the wind system in the tropical Pacific before and during the occurrence of El Nino, it is possible to reproduce the oceanic observations obtained during the occurrence of El Nino. Numerical simulation studies carries out recently (O'Brien et al., 1980) have shown that many of the oceanic characteristics observed during El Nino may be reproduced (Figure 4). This suggests that it is the winds which in fact provide the key to forecasting the occurrence or otherwise of El Nino. Consequently, it is important to concentrate all possible efforts on obtaining data concerning the winds without further delay. These data come from weather satellites, scientific and merchant vessels and fixed weather stations.

Figure 4 : Diagram of the disturbance of the thermocline
(based on results of numerical simulation by O'Brien et al., 1980)

Note the spread of the disturbance eastwards in the form of Kelvin's Wave and its reflection in the form of Rossby's Wave.



For the Future

Although the ocean's response to the decrease in the equatorial winds is well-known, the reasons for this change in wind patterns is unknown. This question will have to be answered if a forecast of El Nino is to be made several months in advance. This will require further observation of the ocean-atmosphere system and the mechanisms which govern it. Research programmes are now being set up at the national and international levels for this purpose. The results of this effort will provide us with a better understanding of the mechanism which causes the decrease in the equatorial winds.

ACKNOWLEDGEMENTS

I wish to thank Dr. Alberto Giesecke and Dr. Ronald Woodman, whose valuable comments have clarified the substance of this paper.

REFERENCES

Hayes, S.P. 1982. Cruise Report NOAA Ship Researcher (EP4-82-RS). 18 October-16 November 1982.

NOAA. 1982. A major warm episode in the eastern equatorial Pacific Ocean. Diagnostics Branch Climate Analysis Center, NMC, NWS, National Oceanographic and Atmospheric Administration, Washington, D. C. November 10, 1982.

O'Brien, J. J., A. Busalacchi and J. Kindle. 1980. Ocean models of El Nino, p. 159-212. In M. H. Glantz [ed.], Resource management and environmental uncertainty. Wiley, New York.

Toole, J. M. In press. Preliminary Observations of the Equatorial Pacific: Fall 1982. November 4, 1982. (submitted to Trop. Ocean-Atmos. Newsletter).

Wyrtki, K. 1975. El Nino - the dynamic of the equatorial Pacific Ocean to atmospheric forcing. J. Phys. Oceanogr. 5:572-584.

Wyrtki, K. and G. Meyers. 1976. The trade wind field over the Pacific Ocean. J. Appl. Meteor. 15:698-704.

INTER-REGIONAL CO-OPERATION

INTER-REGIONAL CO-OPERATION: SUMMARY OF DISCUSSIONS

Arthur Lyon Dahl, Rapporteur
B.P. 1146, Noumea, New Caledonia

ABSTRACT

As part of the UNEP-sponsored session on Regional Cooperation on the Protection of the Environment at the Pacific Science Congress, the participants in the different Regional Seas Programme action plans in the Pacific held a round table discussion on inter-regional co-operation. The discussion highlighted the need for inter-regional co-operation in monitoring and in managing common environments or ecosystems such as mangroves or coral reefs. There is a need for more communication between regions on common problems, techniques and results, and on legislation, as well as between specialists with common interests. The regional seas approach balances inter-regional standards and co-ordination with local solutions to local problems.

After viewing each action plan area separately in the previous sessions (see the sections above), it was natural to ask how the three separate programmes in one ocean should co-operate for their common benefit. A round table discussion was organized under the chairmanship of Dr. Stjepan Keckes, Director of the UNEP Regional Seas Programme Activity Centre, with Dr. Luis Arriaga M., co-ordinator of the South-East Pacific Action Plan, Dr. Kasem Snidvongs, co-ordinator of the East Asian Seas Action Plan, and Dr. Arthur Dahl and Dr. Jeremy Carew-Reid, respectively the former and newly-appointed co-ordinators of the South Pacific Regional Environment Programme. The following topics were raised in the discussion.

Monitoring

The United Nations Environment Programme (UNEP) has a mandate to monitor pollution at the global level (including the Pacific) through the Global Environmental Monitoring System (GEMS). This requires uniform methodologies and costly facilities such as the background reference station now being planned for the Pacific.

The South Pacific does not have major regional marine pollution problems, but it does have local problems needing monitoring. Ignorance of the problems will prove more expensive than monitoring; disease from polluted beaches hurts tourism, and export products must be monitored to verify that they do not have contamination above importing country requirements. Deciding what has to be monitored or researched is a regional decision, which may well be different from global priorities. There is already much material published by developed countries on the Pacific. The South Pacific Regional Environment Programme (SPREP), for instance, is compiling the information on radioactivity in a useful form.

The infrastructure for pollution monitoring and the interpretation of the results is very weak, especially in the South Pacific. In the Caribbean, UNEP had to create a regional monitoring centre on St. Lucia. The South-East Pacific has been able to build monitoring on their existing oceanographic and meteorological infrastructure. In the South Pacific, developing a monitoring capability for such a large area will take time and money. It may be necessary to look at possible intermediate steps and simpler techniques. A balance is required between immediate needs for monitoring, such as in areas of coastal pollution or where there are fears of pesticide contamination, and the need for education and public information so that the need for monitoring will be more clearly understood. The results of monitoring can

PUBLICATIONS IN THE UNEP REGIONAL SEAS REPORTS AND STUDIES SERIES

No. 1 UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. (1982)

No. 2 UNIDO/UNEP: Survey of marine pollutants from industrial sources in the West and Central African region. (1982)

No. 3 UNESCO/UNEP: River inputs to the West and Central African marine environment. (1982)

No. 4 IMCO/UNEP: The status of oil pollution and oil pollution control in the West and Central African region. (1982)

No. 5 IAEA/UNEP: Survey of tar, oil, chlorinated hydrocarbons and trace metal pollution in coastal waters of the Sultanate of Oman. (1982)

No. 6 UN/UNESCO/UNEP: Marine and coastal area development in the East African region. (1982)

No. 7 UNIDO/UNEP: Industrial sources of marine and coastal pollution in the East African region. (1982)

No. 8 FAO/UNEP: Marine pollution in the East African region. (1982)

No. 9 WHO/UNEP: Public health problems in the coastal zone of the East African region. (1982)

No. 10 IMO/UNEP: Oil pollution control in the East African region. (1982)

No. 11 IUCN/UNEP:Conservation of coastal and marine ecosystems and living resources of the East African region. (1982)

No. 12 UNEP: Environmental problems of the East African region. (1982)

No. 13 UNEP: Pollution and the marine environment in the Indian Ocean. (1982)

No. 14 UNEP/CEPAL: Development and environment in the Wider Caribbean region: A Synthesis. (1982)

No. 15 UNEP: Guidelines and principles for the preparation and implementation of comprehensive action plans for the protection and development of marine and coastal areas of regional seas. (1982)

No. 16 GESAMP: The health of the oceans. (1982)

No. 17 UNEP: Regional Seas Programme: Legislative authority. (1985)

No. 18 UNEP: Regional Seas Programme: Workplan. (1982)

No. 19 Rev. 2. UNEP: UNEP Oceans Programme: Compendium of projects. (1985)

No. 20 CPPS/UNEP: Action Plan for the protection of the marine environment and coastal areas of the South-East Pacific. (1983)

No. 21 CPPS/UNEP:Sources, levels and effects of marine pollution in the South-East Pacific. (1983) (In Spanish only)

No. 22 Rev. 2. UNEP: Regional Seas Programme in Latin America and Wider Caribbean. (1985)

No. 23 FAO/UNESCO/IOC/WHO/WMO/IAEA/UNEP: Co-ordinated Mediterranean Pollution Monitoring and Research Programme (MED POL) - Phase I: Programme Description. (1983)

No. 24 UNEP: Action Plan for the protection and development of the marine and coastal areas of the East Asian region. (1983)

No. 25 UNEP: Marine pollution. (1983)

No. 26 UNEP: Action Plan for the Caribbean environment programme. (1983)

No. 27 UNEP: Action Plan for the protection and development of the marine environment and coastal areas of the West and Central African region. (1983)

No. 28 UNEP: Long-term programme for pollution monitoring and research in the Mediterranean (MED POL) - Phase II. (1983)

No. 29 SPC/SPEC/ESCAP/UNEP: Action Plan for managing the natural resources and environment of the South Pacific region. (1983)

No. 30 UNDIESA/UNEP: Ocean energy potential of the West and Central African region. (1983)

No. 31 A. L. DAHL and I. L. BAUMGART: The state of the environment in the South Pacific. (1983)

No. 32 UNEP/ECE/UNIDO/FAO/UNESCO/WHO/IAEA: Pollutants from land-based sources in the Mediterranean. (1984)

No. 33 UNDIESA/UNEP: Onshore impact of offshore oil and natural gas development in the West and Central African region. (1984)

No. 34 UNEP: Action Plan for the protection of the Mediterranean. (1984)

No. 35 UNEP: Action Plan for the protection of the marine environment and the coastal areas of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. (1983)

No. 36 UNEP/ECLAC: The state of marine pollution in the Wider Caribbean region. (1984)

No. 37 UNDIESA/UNEP: Environmental management problems in resource utilization and survey of resources in the West and Central African region. (1984)

No. 38 FAO/UNEP: Legal aspects of protecting and managing the marine and coastal environment of the East African region. (1983)

No. 39 IUCN/UNEP: Marine and coastal conservation in the East African region. (1984)

No. 40 SPC/SPEC/ESCAP/UNEP: Radioactivity in the South Pacific. (1984)

No. 41 UNEP: Socio-economic activities that may have an impact on the marine and coastal environment of the East African region. (1984)

No. 42 GESAMP: Principles for developing coastal water quality criteria. (1984)

No. 43 CPPS/UNEP: Contingency plan to combat oil pollution in the South-East Pacific in cases of emergency. (1984)

No. 44 IMO/ROPME/UNEP: Combating oil pollution in the Kuwait Action Plan region. (1984)

No. 45 GESAMP: Thermal discharges in the marine environment. (1984)

No. 46 UNEP: The marine and coastal environment of the West and Central African region and its state of pollution. (1984)

No. 47 UNEP: Prospects for global ocean pollution monitoring. (1984)

No. 48 SPC/SPEC/ESCAP/UNEP: Hazardous waste storage and disposal in the South Pacific. (1984)

No. 48/ Appendices SPC/SPEC/ESCAP/UNEP: Hazardous waste storage and disposal in the South Pacific. (1984)

No. 49 FAO/UNEP: Legal aspects of protecting and managing the marine and coastal environment of the East African region: National Reports. (1984)

No. 50 IUCN/UNEP: Marine and coastal conservation in the East African region: National Reports. (1984)

No. 51 UNEP: Socio-economic activities that may have an impact on the marine and coastal environment of the East African region: National Reports. (1984)

No. 52 UNEP: Arab co-operation for the protection and development of the marine environment and coastal areas resources of the Mediterranean. (1984)

No. 53 UNEP: UNEP Regional Seas Programme: the Eastern African Experience. (1984)

No. 54 UNIDO/UNEP: Contingency planning for emergencies associated with industrial installations in the West and Central African region. (1985)

No. 55 FAO/UNEP: Marine mammals: global plan of action. (1985)

No. 55/ Annex FAO/IUCN/IWC/UNEP: Marine mammals: global plan of action. (1985)

No. 56 GESAMP: Cadmium, lead and tin in the marine environment. (1985)

No. 57 IMO/UNEP: Oil spills and shoreline clean-up on the coasts of the Eastern African region. (1985)

No. 58 UNEP: Co-operative programmes sponsored by UNEP for the protection of the marine and coastal environment in the wider Indian Ocean region. (1985)

No. 59 UNEP: Environmental problems of the marine and coastal area of India: National Report. (1985)

No. 60 IUCN/UNEP: Management and conservation of renewable marine resources in the Indian Ocean region: Overview. (1985)

No. 61 UNEP: Action Plan for the protection, management and development of the marine and coastal environment of the Eastern African region. (1985)

No. 62 IUCN/UNEP: Management and conservation of renewable marine resources in the South Asian Seas region. (1985)

No. 63 IUCN/UNEP: Management and conservation of renewable marine resources in the Kuwait Action Plan region. (1985)

No. 64 IUCN/UNEP: Management and conservation of renewable marine resources in the Red Sea and Gulf of Aden region. (1985)

No. 65 IUCN/UNEP: Management and conservation of renewable marine resources in the East Asian Seas region. (1985)

No. 66 IUCN/UNEP: Management and conservation of renewable marine resources in the Eastern African region. (1985)

No. 67 UN/UNEP: Coastal erosion in West and Central Africa. (1985)

No. 68 GESAMP: Atmospheric transport of contaminants into the Mediterranean region. (1985)

No. 69 UNEP: Environment and resources in the Pacific. (1985)

No. 70 UNESCO/ROPME/UPM/UNEP: Proceedings of the Symposium/Workshop on oceanographic modelling of the Kuwait Action Plan (KAP) region. (1985)

No. 71 IUCN/ROPME/UNEP: An ecological study of the rocky shores on the southern coast of Oman. (1985)

No. 72 IUCN/ROPME/UNEP: An ecological study of sites on the coast of Bahrain. (1985)

No. 73 SPC/SPEC/ESCAP/UNEP: Ecological interactions between tropical coastal ecosystems. (1985)

Issued and printed by:

Programme Activity Centre for Oceans and Coastal Areas
United Nations Environment Programme

Additional copies of this and other publications issued by
the Programme Activity Centre for Oceans and Coastal Areas
can be obtained from:

Programme Activity Centre for Oceans and Coastal Areas
United Nations Environment Programme
P.O. Box 30552
Nairobi
Kenya