Pollution in International Waters and its Effects on Biodiversity in Lake Tanganyika - contribution to the Inception Report for the Lake Tanganyika Biodiversity Protection project

Introduction

The aspect of the Lake Tanganyika biodiversity project that will attend to pollution and certain aspects of its effects on biodiversity, is crucial to the success of the programme (and attainment of the goal of protecting biodiversity in this lake) in the following respects:

- in establishing whether pollution is a threat to biodiversity; in this connection the work may need to (i) rank the 'value' of an organism on criteria such as its significance as a food source for another species, or its commercial value, and (ii) decide whether organisms that will almost definitely appear/burgeon (as a result of pollution by extending the existing spectra of physical and/or chemical conditions in the lake), are enhancing or threatening biodiversity

- in contributing to the process of selecting sites for reserve status

- in developing through training and education a programme of pollution and associated biodiversity monitoring that can (i) be sustained by the region and (ii) influence policies on pollution control, fisheries management and conservation

- by enhancing knowledge world-wide on the relationships between lacustrine pollution and biodiversity

This component of the Inception Report firstly provides background information using material from the Project Document relating to pollution. This indicates the general tenor of the work proposed at the outset. Secondly, it outlines the findings - especially gaps in knowledge - about pollution and its effects on biodiversity identified by the Baseline Review; albeit a mere summary of the review, this is important since relatively few delegates at the Inception Workshop had seen the full version. Thirdly, the section deals with what has been done since the production of the Baseline Review i.e. achieved during the Inception Workshop. The next part deals primarily with future steps envisaged at this stage. Following a Work Plan, some comments are made on what country actions are required. Finally, some links between the different Special Studies that are vital to the success of the whole programme are outlined.

Background

The work proposed from the outset in the section of the Project Document concerned with pollution-biodiversity issues reflects the the interests and expertise of the UK_s Freshwater Biological Association (FBA founded in 1929 and featuring prominently in the field of African limnology over many decades) and Institute of Freshwater Ecology (IFE - a component of the UK's Natural Environment Research Council, founded in 1964). The main elements envisaged were as follows:

- a proper description and explanation (with special reference to pollution in this case) of the observed distribution of the freshwater biota over various spatial and temporal scales

- a multi-disciplinary approach with research and extensive training in physical, chemical and biological aspects.

- a constant focus on the application of the ‘research_ to the better management of the lake, and the prediction of the effects of future changes in e.g. climate and land use.

- skilled handling and interpreting of data.

- appreciation of the especially strong interdependance of organisms and the physical and chemical features of their environment in aquatic ecosystems i.e. through processes driven from the ‘bottom-up_ (by photic, kinetic and chemical energy), and from ‘top-down (by predator-prey and other biotic interactions); this being the case, initial surveys of physical and chemical conditions and the nature of the biota, could be based on either physical factors such as water depth and substrate, or known distributions of major fish species.

- that, in some areas at least, the study should attempt to assess spatial and temporal variation in total species diversity i.e. of planktonic and substrate/attached assemblages of micro-algae, macrophytic vegetation, invertebrates and vertebrate species (including birds and mammals); trophic interactions should also be assessed by means of gut analyses in order to identify what may prove to be key food

species and feeding habitats - and ones which might be under pressure and thus of priority conservation interest/value.

- following on from the above, that data on physical features (e.g. water depth, movement and clarity) and chemical factors (e.g. nutrient and major ion status as well as pollutants) need to be included - not just because of the prevailing view that sedimentation and pollutants constitute a threat to biodiversity, but because the very nature/structure of biotic assemblages is determined by the basic physics and chemistry of the system; in assessing the sources and biological impacts of pollutants and excess sediment loads, the project will also be able to draw on the Institutes' unparalleled experience and knowledge on the relative importance to benthic biodiversity, for example, of physical factors such as substrate availability on the one hand, and pollution per se on the other.

- that sampling procedures are varied according to such features as the distribution in time and space, and the size and dynamics of the biota and biotic assemblages concerned; nevertheless, lakewide or whole-shoreline synopses and monitoring programmes will be generally tackled using stratified random and regular (grid) sampling strategies; zones known or suspected to be 'special' in terms of e.g. biodiversity, fragility, pollution status, in the harbouring rare or otherwise important species, will receive appropriately specific attention.

- that, in contrast to the original project design which suggested that the pollution Special Study should not begin until the results of the sediment plume work are known, all of the main 'lakewide' programmes start as soon as possible and be executed together; at the very least, this would simplify some aspects of data interpretation, and make best use of particularly the large vessels.

- that the catchment-lake studies are organised on the basis of the following simple relationship:

pressures + sensitivity = responses

where: the pressures are determined by catchment characteristics (land use, topography, climate) giving rise to eutrophication and 'classic' pollution; the factors determining the sensitivity of the systems to the pressures include a wide variety of physical and chemical features as well as the nature of the 'resident' biota; and the responses are the physical, chemical and (especially) biotic features of the lake; in this way an attempt can be made to assess the fluxes of eutrophicating elements and traditional pollutants from the land to the water, between the water and the sediments, and between water, sediments and biota.

- that species identification and the quantitative assessment of biodiversity present exciting challenges

- that there is a the real possibility of making available the following instrumentation to the project for short- to medium-term investigations at least, was highlighted: probes and deployable buoys for depth profiling and the instantaneous recording of temperature, light intensity and spectral characteristics, turbidity, conductivity, dissolved oxygen content, pH; and the continuous recording of weather and limnological parameters facilitating the real-time description of changes in water column stability; and pumped-intake systems for collecting plankton samples integrated over measured sectors of the lake.

- that the 'state-of-the-art' gear outlined above will be invaluable especially in the early stages of the work, when there will be a major need for extensive and rapid surveys; however, wherever possible and appropriate, however, the accent in the long-term will be on simpler techniques: thus, in the field, Secchi discs rather than photometers, and plastic tubes rather than closing water bottles for example, and in the laboratory, microbial abundance estimation using conventional rather than inverted microscopes.

- that a GIS-configured database of the major classes of land use and topographical features of the catchment, and information on the numbers, distribution and dispersion patterns of people, would facilitate estimates of inputs of certain nutrients and e.g. silt to the lake from the surrounding land; in parallel, analysis of water and sediment samples collected primarily from the mouths of the major feeder rivers throughout the year, would provide actual measurements of the loadings; supplementary samples would also be taken from known outfalls/emissions of nutrients and conventional pollutants associated with factories, villages and townships.

- that particulate and dissolved fractions of the following in the lake water, sediment and biota will be measured: major ions, nutrients, suspended solids, pesticide residues, acid-extractable metals, boat and ship fuels; the dispersion of sampling sites will take account of the FAO FINNIDA_s findings on lake

circulation; in this connection the advantages and disadvantages of hiring rather than purchasing expensive chemical analytical instrumentation e.g. AAS, GC, ICPMS, will need to be decided.

- that in addition to multivariate analysis of chemical and biological data, distribution/contour maps of the nature and concentrations of pollutants including nutrients, will be superimposed on corresponding charts of the biota, in order to establish the links between biodiversity and pollution.

The major findings and recommendations of the Baseline Review on pollution and its effects on Lake Tanganyka biodiversity

The following is the summary of the Baseline Review.

1. This study aims to:

- identify the main sources of pollution to Lake Tanganyika and, where possible, quantify the pollutant inputs
- obtain a lakewide assessment of pollution and its effects on lower organism biodiversity
- evolve systematic programmes of pollution and biodiversity description and monitoring that are repeatable - such that change (or lack of change) can be determined with confidence
- develop (in each of the riparian countries) teams capable of maintaining the investigations from planning and executing field and laboratory programmes, to analysing data, and reporting on the findings in the most appropriate ways to fellow scientists, lake managers and policy-makers
- develop pollution control strategies as necessary.

2. 'Pollution' in this study is taken as the anthropogenically accelerated inputs of nutrients (eutrophication), organic (oxygen-demanding) components of sewage and e.g. sugar cane factory wastes, heavy metals, pesticides and compounds likely to stem from oil exploration and shipping. As far as possible, 'biodiversity' will be taken as the total range of organisms present/detected - that is, excluding fish which are more appropriately handled by the sister studies on biodiversity per se.

3. The extraordinary number of species in the lake is attributed very much to the large size of the lake, to its great age and 1.8M-y isolation, and to the ecological diversity. In addition, however, a number of physical features such as large size and depth, also render the lake susceptible to pollution as they result in it retaining very high percentages of the water- and wind-borne pollutants entering it. As in many lacustrine systems, there is always the possibility too, of the 'cascade' effect of pollution on one species affecting species at other trophic levels relatively quickly.

4. From databases comprising more than 3,000 titles relating to Lake Tanganyika, approximately 200 are cited. Very few of these refer to either 'pollution' or 'biodiversity, and documentation on the effects of the one on the other is scant indeed. Moreover, with very few exceptions, papers on 'species diversity' are of somewhat limited value. First, they are restricted to relatively few phylogenetic groups and second, they usually amount to little more than lists with no indication of the 'effort' invested in generating the species data; the new project aims to address these shortcomings by (i) attempting - at some sampling sites at least - to describe species diversity in toto i.e. from the sub-micron picoplankton to lower organisms and rooted plants decimetres and metres in greatest dimension, and (ii) providing information on sample size, such that future workers can generate comparable datasets.

5. Many of the references cited are of inestimable value however, in providing information that aids decision-making on the arrays of measurands, the numbers and locations of sampling sites, the sampling schedules, and the human and equipment resources needed to carry out the work. As a basis for discussion, the following areas are considered in need of priority attention:

-eutrophication in the Kigoma (Tanzania) and Bujumbura (Burundi) areas
- atmospheric pollution lakewide
- pesticide inputs from cotton plantations in the Rusizi catchment (Burundi)
- heavy metals from diamond mining in the Malagarasi catchment (Tanzania)
- waste from sugar cane processing in Uvira area (Zaire)
- oil pollution lakewide.

6a. Open and in-shore waters will be investigated, and samples of water and biota representative of the water column from the surface to the sediment, the sediment itself surface will be collected and analysed for pollution and biodiversity status. In order to establish the effects of pollution on biodiversity, the

species composition/richness/diversity at approximately 10 polluted sites (visited on average 8 times per year) will be compared with that found at 10 unpolluted sites similarly sampled, and corresponding as far as possible in features such as aspect, exposure, water depth, bottom substrate, and proximity to shore or inflow.

6b. The range of physico-chemical determinands presently envisaged is as follows:

- light, temperature, transparency, total suspended particulates
- conductivity/salinity, dissolved oxygen, pH, alkalinity
- calcium, sulphate, fluoride, silica (reactive and total)
- ammonia, nitrate, nitrite, organic nitrogen
- phosphorus (P), including the soluble (dissolved) reactive and unreactive phosphate fractions, and the total P present
- organic matter (dissolved and total)
- chlorophyll a
- oils (fuel, bilge etc.) in water, sediments, and the tissues of selected molluscs, crustaceans and fish
- pesticides and PCBs in fish tissues and molluscs (possibly also PAHs)
- trace elements, Cu, Zn, Mn, Fe, Pb, Cd, Hg (in molluscan, crustacean and fish tissues)

[Note added following the Inception Workshop: the parameters/determinands of major interest were agreed, although again, modifications will be made as time progresses. In this connection, it is very likely that the GEF project will carry out a programme of activities that is considerably more comprehensive than the 'post-GEF' schedule; indeed, the development of the programme can be viewed as a sorting and prioritisation of the options.]

7. The estimated costs of equipment considered necessary for successful completion of the Pollution-Biodiversity work are far from finalised, but they amount to approximately £800,000 (1.2M US$). This is excluding costs of the use of the large vessels. However, it embraces a considerable resource by way of office, field and laboratory gear that can be shared by the other projects. Also, approximately 50% of the sum is earmarked for (good) microscopes. This reflects the considerable importance attached to the very careful and meticulous approaches that will be necessary in order to properly address biodiversity assessment and species identification. It is possible, however, that some microscopes can be 'lent' from UK, and/or in part, be purchased from the training/education budgets.

8. The number of local staff required for the work is presently estimated at approximately 35 per country - including drivers, field operatives, technicians, scientists, and administrative and office support staff. These have not been costed - although it will be a simple matter to do so once the latest rates of pay are available. We propose to place one or two British graduates in Africa for the duration of the project; this contribution is in addition to, not a substitute for the existing British consultant input.

9. Equipment and other resource requirements, and a draft costed work schedule are appended.

Inception Workshop results and priorities

The coordinators of the Pollution Special Study approached the Workshop with the following major views in mind:

- that we do not know as yet to what extent pollution is affecting biodiversity in Lake Tanganyika.

- that sampling and data recording activities within each of the Special Studies (and those of pollution, sedimentation and biodiversity in particular) need to be a very strongly linked and harmonised.

- that methods relating to all stages and activities of the pollution-biodiversity programme must be standardised for all 4 countries

- above all, each team, regardless of its major pre-occupation (e.g. in sediment pollution or biodiversity) must be able to collect samples (water, sediment, biota) for the other groups, since there will be no margin for sites to be visited by more than one team on any one occasion - particularly where remote open water sites are concerned

Four aims characterised the discussions held over the 5 days. They are as follows:

- to establish a common consensus as to what constitute the main issues at this stage of the project
- to prioritise the pollution issues to be investigated
- to progress with the selection of sampling sites
- to identify the organisations/institutions that will carry out the work.

Establishing a common consensus as to what constitute the main issues

The first concern was to explore with all 4 riparian countries whether there were any aspects/statements in the Baseline Review which were unclear, or with which the regional personnel disagreed. There was a need too, to establish whether the topics selected by the authors of the Pollution Baseline Review were also considered of priority importance by the country personnel - and therefore of major significance in the workshop. In the event, the country presentations identified few gaps in the Baseline Review on pollution and its effects on biodiversity; indeed, the overall response was very encouraging and indeed, complimentary. However, regional personnel did raise a number of pollution issues that they considered worthy of greater attention than the Review suggests; all of these items are itemised later - since, even though some of them are actually mentioned in the Review, the document was not seen by some of the delegates. They also expressed some doubts regarding the large number of staff estimated for the pollution and pollution-related biodiversity work; however, the Baseline Review had emphasised that - in common with its high estimates of the costs of equipment required - these resources would in large part also cover the requirements of a number of the activities under the Sediment Pollution and Biodiversity programmes. Curiously, the discussions did not comment further on the 'science-to-policy' strategy on which the authors of the Baseline Review attached considerable importance.

Prioritisation of the pollution issues to be investigated

The workshop was pre-eminent in assembling the regional expertise. This provided the opportunity for improving on many aspects of the programme design - and especially the prioritisation of pollution and pollution-related biodiversity issues. The following issues (that is, those mainly in addition to the ones already featured in the Review) were thus itemised:

- *Eichhornia* as a potential threat to the well-being of Lake Tanganyika (although the Review did draw attention to the burgeoning of this plant in Lake Victoria, and the presence, and thus potential problems of another floating macrophyte - *Pistia*- in Lake Tanganyika)
- afforestation of deforested areas - cobalt and nickel
- *Pistia* and other floating plants (as potential indicators and filtrators of pollutants e.g. copper)
- cattle 'ranching_ and trampling effects on river margins
- *Salvinia* infestations (Zambia)
- poisons used in some fishing practices
- fertiliser and pesticide runoff - Rukwa area
- de-forestation - Mpulungu area

It was also suggested that where possible, attention be paid to assessing the combined effects of pollution (on biodiversity) of effleunts, discharges and inflows containing a multiplicity of pollutants.

From the total array of pollution issues, the following 7 were selected for priority attention:

- domestic waste water
- industrial waste water
- hydrocarbons, fertilisers and pesticides
- heavy metals
- contaminants associated with water- (river-)borne sediment
- non-human organic waste e.g. from sugar refining operations
- atmospheric polluton - wet and dry deposition
- pollutants from shipping operations

Selection of sampling sites

Even at the earliest stages of exploration, sampling sites will provide material on which to test methods of sampling and sample analysis. As importantly, the very processes of sampling and analysis will form the basis of training in all aspects of the work envisaged i.e. planning of field surveys; reaching the

sampling sites; collecting water, sediment and biota; the immediate treatment of samples and their transport back to the laboratory; the main analyses of the materials and samples; the logging and analysis of the data; and the interpretation and presentation of the results, as appropriate to policy-makers, fellow scientists, lake managers and conservationists.

Table I lists the sites selected so far. An attempt was made to identify for each polluted site, a site that is essentially ‘pristine_, although this exercise is not yet completed. The Baseline Review enlarges on this approach, but the main thinking behind it is that attention by the project to un-polluted areas is as important as that given to polluted zones. The idea of paired sites is attractive, in that it provides an opportunity to investigate pollution and biodiversity in areas

Preliminary selection of sites to be sampled for the assessment of Pollution in International Waters, and its effects on biodiversity in Lake Tanganyika - as a result of discussions in Dar es Salaam, 27 March 1996.

which will be, ideally, the same in terms of e.g. aspect, substrate and water depth, but contrasted with respect to ‘pollution_; this is significant in the context of international cooperation in that in some cases the polluted site and the unpolluted equivalent are in different countries. Such an approach also avoids potential problems such as those perceived along the Burundi shoreline where relatively few 'pristine' areas are apparent. Of course, the same dataset generated from this array of sites can also be analysed to assess biodiversity variation over the whole pollution spectrum, or over sites characterised by one particular pollutant, type of pollution, or combination of pollutants. The delimitation of a sampling ‘site_ can only be determined from field surveys and sampling trials, but in a number of cases, where a pollutant issues by way of a pipe or feeder water from the catchment, sampling along variously angled transects passing along the shore, and from the shore to open water are envisaged. In this way, variation in the association between biodiversity and pollution over a number ‘within-site_ spatial scales can be investigated, and the results can be compared with any variation in pollution-biodiversity associations found between sites and over the lake as a whole.

It was recommended that the pollution programme measure pollutant levels at their sources, and not just where they enter the lake (unless the source enters the lake directly).

It was also stressed that while pollution issues of major concern to the riparian countries were prioritised, all plans are accepted as provisional. This makes sense considering that the approaches will certainly be modified in any event, but especially after the first year or so which is to be considered as providing the basis for training rather than the generation of information/data in the more or less routine manner envisaged for the 'final' version of the monitoring scheme. Thus, a series of 'pilot', synoptic' and 'scoping' exercises would be mounted as soon as equipment and staff are in place; then the process of finalising sampling schedules can be initiated; a figure of approximately 12 localities (not necessarily comprising a single type of habitat) was considered to be a useful starting point; in any event, 'opportunist' and sampling focussed on places that are already considered to be important, would be attempted in addition to the planned network of areas selected on a stratified random basis; difficulties over the selection of sites due to wind- and current-related dispersal of pollutants were recognised.

Identifying the country organisations that wish to be involved in the work

The national delegates proposed the following organisations for involvement in the work:

In Burundi:
The University of Burundi - Chemistry Department
The University of Burundi - Biology Department
FAO FINNIDA LTR station, Bujumbura (plus links with Uvira)
INECN, Bujumbura

In Tanzania:
Ministry of Water, Environment and Minerals, Tanzania
TAFIRI
NEMC

In Zaire:
National Council of Scientific Resaerch, Lusaka (especially for Analytical Quality Control)
The University of Kinshasa: Institut Superiere Pedagogie, Bukavu.
Centre Recherche d_Hydrobiologique, Uvira

In Zambia:
UNZA
Centre de Recherche en Science Naturelle, LWIRO
CCRHA facilities Bujumbura
ECZ
Food and Drug Laboratory
Department of Water Affairs

A number of curriculum vitae of persons wishing to be involved at especially, the field and laboratory levels, have been received. This is especially encouraging bearing in mind that while fish and fisheries aspects are well-resourced in East Africa, capacity building in the areas of pollution and biodiversity are still rudimentary in comparison.

pollutant	study site	'pristine' site
Domestic waste water	B: Bujumbura, Rumonge T: Kigoma Zb: Mpulungu Zr: Uvira, Kalemie	B: Kigwena T: Zb: Nsumbu Za: Penba
Industrial waste-water	B: Bujumbura T: Kigoma Zb: Zr: Uvira, Kalemie	 Penba
HC's, fertilisers; pesticides in runoff	B: Bujumbura, Rusizi mouth T: Malagarasi Zb: Mpulungu, Lufubu Zr: Uvira, Kalemie	Kigwena Yungu
Heavy metals	B: Bujumbura T: Malagarasi Zb: Zr: Uvira, Kalemie	Kigwena
Contaminants associated with river borne sediment	B: Rusizi + smaller rivers to be added later T: Malagarasi Zb: Lufubu Zr: Moba	Kigwena Mvua
Non-human organic waste e.g. sugar cane	B: T: Zb: Zr: Uvira	
Shipping operations	lake-wide but esp. major ports	

Of course, the Institute of Freshwater Ecology is to be involved, and not least by way of training as well as some aspects of the coordination of the work in collaboration with the National and Regional Coordinators. In addition, it is hoped that a number of short-term student placements mainly (though by no means solely) from Africa to UK/Europe, can be accommodated and arranged as soon as possible - in order to enhance expertise and experience in the planning and execution of field and laboratory activities and establish baseline data on the pollution and biodiversity status of the lake.
In relation to training, many of the country delegates, highlighted the need for resourcing by way of literature. In this connection the FBA has produced manuals for the determination of adult and larval stages of approximately 30 major freshwater invertebrate groups; while these focus on UK species, the criteria on which the organisms are classified are likely to be applicable to the African situation. Under the Curatorship of Dr J W G Lund FRS, the Windermere Laboratory also houses the Fritsch Collection of (currently) more than 500,000 illustrations of algae and some Protozoa originating from approximately 20,000 of the publications held in its library. Micro-fiche versions of the Collection can be made available to the project.

Action and times (work plan)

The following schedule of activities is the version presented in the Baseline Review, modified in the light of discussions at the Inception Workshop mainly by bringing the date for the completion of the Special Studies back to end 3/99 as opposed to the end of 10/99. This is not without its consequences however. This is particularly so, bearing in mind that the Baseline Review on pollutuion and pollution-related biodiversity investigations recommended that visits around the region to assess existing human and equipment resources (needed for the first synopses to provide training material etc.), should start in 4/96.

The likely schedule (with the Baseline Review and the present Inception Report having been submitted to NRI on 23/1/96 and 3/5/96 respectively), would now appear to be as follows, the :

- main 'exploratory, thrust for the ollution-biodiversity work is 5/96 to 3/99 inclusive, by about which time (?) the FLTSP has to be completed; the following targets are set within this period:

5/96 or 6/96 to 5/97 or 6/97 inc. - 'settling in' and establishment of laboratory bases; procurement of equipment; furnishing of laboratories; appointment of local personnel; African-UK collaboration and training in field, laboratory and office methods practices, using material collected from the lake and catchment waters; preliminary selection and establishment of sampling sites; first installations of recording equipment e.g. staff gauges.

6/97 to 9/97 inc. - 'trial' analyses, reporting and presentation of data generated from 'practice' samples; revision (where appropriate) of sample sites, and first decisions regarding the schedules/frequencies of sampling.

9/97 to 12/98 approx. - routine sampling schedules - with options for adjustment/modification as appropriate; on-going sample analysis, data logging and analysis and writing-up.
12/98 approx. to 3/99 inc. - production of final report.

3/99 on ? contribution to (i) the plans and recommendations on sustainability and future monitoring of pollution etc., (ii) the selection and management of 'reserves', (iii) establishment of a 'research-to-management-to-policy' - and coordination of activities at the regional level.

Linkages amongst Special Studies

Some of these issues have been covered. However, the need for standardisation and harmonisation of methods of chemical and biological analyses and techniques used in the field and in the laboratory cannot be over-emphasised. In this connection, reasons have also been given for ensuring that field teams are capable of recording observations, and collecting data and samples relating to each of the main Studies regardless of whether the personnel are primarily concerned with e.g. pollution or biodiversity. The Study coordinators also need to collaborate closely over the logging and analysis of data; a good example relates to the accumulation, storage and presentation of information most appropriately combined in a GIS.

These comments imply that every means should be explored to improve on (admittedly difficult) situations regarding phone, fax and electronic mail facilities.

The Baseline Review has placed considerable emphasis on training - and the preference for handling trainees in small, rather than large groups. This does not rule out the involvement of personnel from each of the main Studies at such sessions, however; indeed, we should facilitate as much inter-collaboration as possible at field and laboratory levels.

Future steps

Put into practice as soon as possible, the activities recommended above. In particular, the National and Regional coordinators must arrange very quickly, clearance and permission for the UK consultants to visit all countires, and place graduates alongside national counterparts e.g. on short-term placements. Without this, we will not be able to take the early steps crucial to assessing existing resources, and improving on these at least to the point of facilitating synoptic sampling and analytical tests, and the training programmes based on these.+