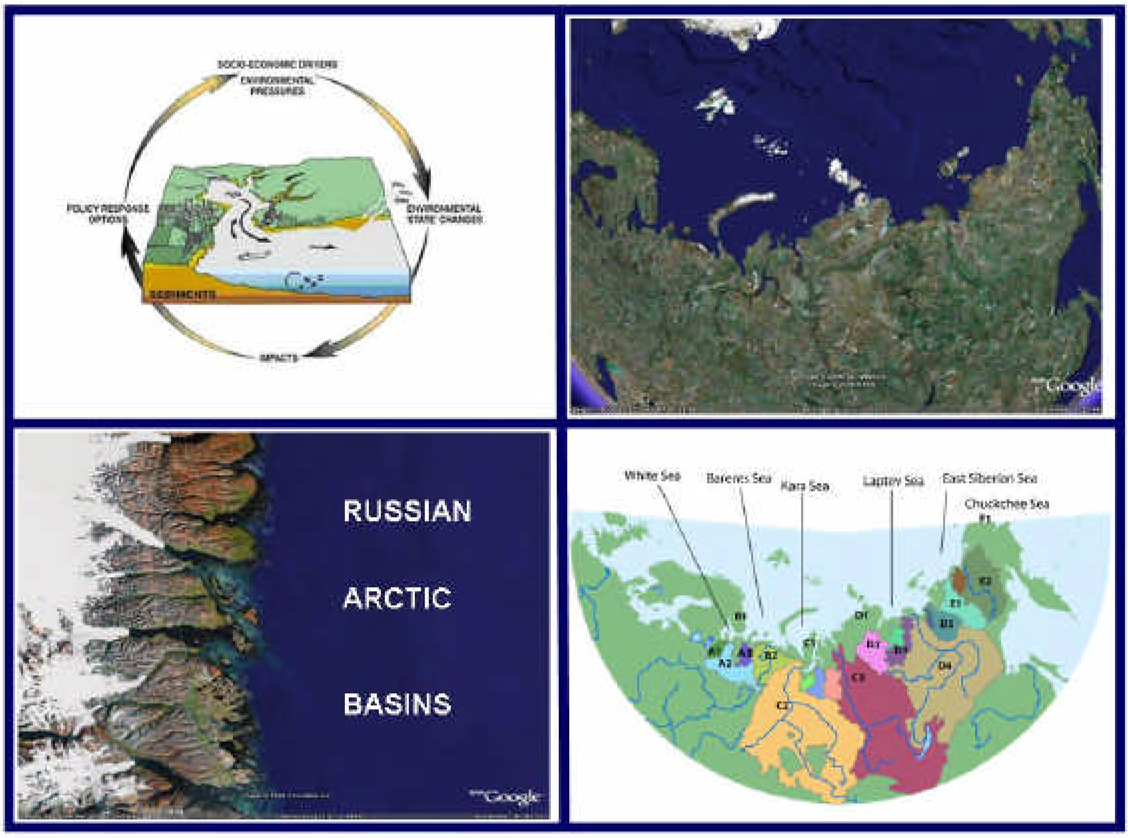
LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE (LOICZ)

Core Project of the

International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)

and the

International Human Dimensions Programme on Global Environmental Change (IHDP)



Russian Arctic Basins

LOICZ Global Change Assessment and Synthesis of River Catchment – Coastal Sea Interaction and Human Dimensions

Compiled and edited by: V.V. Gordeev, E.N. Andreeva, A.P. Lisitzin, H.H. Kremer, W. Salomons, J.I. Marshall Crossland

LOICZ

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by

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Cover: The cover shows three images of the Russian coast (from Google Earth and Crossland *et al.*, 2005) and the DPSIR framework cycle as shown in LOICZ R&S No. 11 (from Turner *et al.*, 1998)

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1 Preface

The coastal and shelf zones of the Russian Arctic Seas are among the greatest in the World. The length of the coast in the Russian Arctic exceeds 40,000 km, some 27,000 km of which belong to the continental shoreline. Already from this point of view, the Russian Arctic coastal zone is a very important region featuring profound land–ocean interactions.
The coastal environment of the Russian Arctic is naturally characterized by severe cold climate conditions, widespread permafrost, huge fresh water runoff, river and sea ice, rich mineral resources plus oil and gas reserves, precious metals and others. On average it has a low population density, mainly indigenous people, and there is a variety of sensitive issues in terms of economic development of the region. On the other hand, even recently, the Arctic has still been considered as almost pristine because of its remoteness and low population (less than 4 Mio people). Nevertheless, at present the Arctic is exposed to contamination pressures originating from local sources as well as from distant regions of the world.

This desk study is a first attempt to apply the DPSIR (Driver-Pressure-State-Impact-Response) framework, originally promoted by OECD in 1993 and further developed within the LOICZ core project to the Russian Arctic river basins-coast systems. The data sources accessed include, first of all, the materials collected by the Russian water quality monitoring system which has been collecting relevant information most extensively in the World during the Soviet era. The recently published Year Books "Quality of surface waters in Russian Federation" (Anon. 2000, Anon. 2005), "Review of environmental pollution in the Russian Federation in 2000" (2001) and "Review of environmental pollution in 2003" (2005), and also the annual "State Report on the environmental conditions and use of water resources in the Russian Federation in 2000-2004" (Anon. 2001-2005) have been based on this work. Where possible, other available data including original data and published results of the authors have been analyzed and included in this synthesis.

The most widely used critical threshold information in Russia is the so-called "maximum allowed concentration" (MAC). It can be considered as a "single substance critical load" and observed environmental substance concentrations are measured and evaluated against this MAC. However, a more acceptable environmental quality criterion is the critical load (CL) that is defined as the flux of one or few pollutants entering an ecosystem without causing negative changes in its most sensitive parts. This critical threshold is much more difficult to obtain and currently there are only two cases in the Russian Arctic coastal zone where this criterion has been applied to assess the ecosystem conditions (the Kola Peninsula and the Norilsk region, looking at sulfur fluxes in both cases; see Table 2.4). In a few cases we also applied the so-called index of toxicity and the index of ecological risk (see section 2.3.2). The qualitative ranking of the impact (impact category) is given as an expert assessment based on a synthesis of all these available materials. This inherently means that these assessments while based on primary information still have certain subjectivity which asks for caution when using them from international comparison.

The review and synthesis of the results show that in general while being considered to be at least partly still almost pristine the Russian Arctic has several "hot spots" where the critical loads and additional environmental quality criteria indicate significant pollution exceeding critical levels during the last few decades. The most important "hot spots" are the Northern Dvina River and Arkhangelsk sub-region in the White Sea basin, the Kola Peninsula and the Pechora River in the Barents Sea sub-region, the Yamal Peninsula and the Ob and Yenisey River basins discharging into the Kara Sea. With a lesser degree of impact the Khatanga, Olenek and Lena Rivers in the Laptev Sea basin and the Indigirka and Kolyma Rivers in the East-Siberian Sea basin need to be mentioned. In the Western Russian Arctic industrialization, navigation and nuclear-power engineering, nuclear industry and Navy are among the main drivers reflecting societal demand for resources, energy, space, transportation and defense infrastructure. In further easterly direction among the anthropogenic drivers/pressures such as dumping, navigation and industrialization are facing a coast which is also subject to increasingly intensive natural change and impact, i.e. thermoabrasion, erosion (here: natural and partly anthropogenic origin) and sedimentation. However, the most immediate coastal impact/issues derive from pollution by heavy metals and hydrocarbons, acidification and radionuclide contamination. Impact categories that were scored highest (up to a maximum of 9-10) were detected in the White and Barents Sea basins (Arkhangelsk sub-region and the Kola Peninsula) and in the Kara Sea basin (Norilsk and other regions). Increasing trends of these impacts are expected in the Northern Dvina mouth - Archangelsk sub-region, the Kola Peninsula and the Pechora River basin and in the Lena and Indigirka-Kolyma River basins driven by progressing industrial development, navigation and more intensive mineral resources extraction and mining in the near future. At the same time, the nuclear pollution shows an evident decreasing trend due to the stop of nuclear weapon testing in the region.

The findings that revealed from this first RusABasins assessment, and the "hot spots" identified are derived through application of the standardized DPSIR assessment approach. Therefore they complement to and link to the wider global context of the series of comparable assessments undertaken within the same framework in Latin America, Asia, Africa and Europe (see www.loicz.org, and Salomons *et al.*, 2005). The synthesis presented follows the same analytical format as has been used for the coastal zone of other regions of the world. However, one needs to be aware that the situation of driver/pressure links and impacts, the interplay of climatic and anthropogenic global change reflecting in the Russian Arctic is very specific allowing rather limited potential for comparison with other regions.

The information compiled is aimed to be particularly important for a better understanding of the circumpolar processes, regional pressures and impacts and to identify key questions that call for international scientific cooperation in the Arctic for the common goal of sustainable development. Secondly it may serve as an initial framework of analysis for coastal zone managers which as such may benefit from experiences deriving from other regional studies in the global LOICZ network. In this context it may assist the regional planning in taking into account the quite specific states and processes in the sensitive coastal zone and the scale on which impact on biological productivity of arctic ecosystems is relevant. This includes to enable insight into the institutional dimensions of anthropogenic versus environmental global change processes in the Arctic, and to evaluate and recognize the role of coastal communities and ecosystems, and their vulnerability under the anticipated scenarios of global change and anthropogenic activity. Obviously there is a strong rational for follow up projects which could ideally follow at least loosely the other Basins derived international river catchment – coast interaction studies i.e. EuroCat (http://www.cs.iia.cnr.it/ EUROCAT/project.htm), AfriCat (http://www.start.org/Networks/ Africa_network_ AfriBasins.html), and daNUbs (http://danubs.tuwien.ac.at/). This approach may prove useful when studying the main "hot spots" in the Russian Arctic, trends and vectors of changes. The objective is to predict and mitigate the impacts on local, regional and global level and to maintain the natural and human values for future generations.

In this context it is worthy to note that in 2005 the Ministry of economical development and trade of the Russian Federation in cooperation with the United Nation Environment Program (UNEP) and Global Environmental Facility (GEF) has elaborated a large scale project on the protection of the marine environment from land-based sources of pollution. The main objectives of the project are:

- adoption and realization of the Strategic Action Program on the removal of damage and threats on the arctic environment from land-based activities in the Russian Federation;
- direct or indirect improvement of the environmental protection system (legislative and normative base, institutional and technical possibilities);

- activation of measures directed to ecological stabilization in the Arctic, liquidation and neutralization of the most dangerous “hot spots”;
- realization of actions against new ecological risks.

It is planned to focus on pre-investitional investigations of identified priority hot spots with known significant transboundary consequences.
Moreover, it is suggested to realize three demonstration projects with the aim 1) to clean the marine environment from oil pollution with the help of brown seaweeds, 2) rehabilitation of the territories of two former military bases with the subsequent transfer into civil use, and 3) participation of indigenous people in the management of environment and resources use. The duration of the Program is till 2010.

2 Regional assessment and synthesis: Northern Russia

2.1 Introduction

As many places of the world, Russian coastal areas have a great potential for economic and social development. Due to decades of "cold war" a substantial part of coastal areas was considered as a borderline and had not been used leaving rather favorable natural and economical conditions. One other possible reason is that in contrast to the overall global tendency of growing concentration of population in the coastal zone, Russia does not feature such a typical settlement pattern. Nevertheless, this is different in the southern coastal areas due to their rich recreational resources, along with port facilities, and agricultural lands all of which attracted considerable growth in population. Wide rural and urban settlements developed rather quickly. In turn northern, western and eastern parts of the Russian coastal zone are connected more with industrial development (mining, refining, shipbuilding, construction including defense industry) and commercial fisheries. All types of settlements, from well-developed urban areas along the Baltic Sea coast to small rural settlements along the northern coasts, are present.

However, despite of this generally still limited use of the coastal zone as compared to other marine countries, the environmental state of certain parts of the coastal zones and in particular their future development is a major concern. It seems that an urgent shift in management policy is required towards sustainable development of coastal natural resources and more reasonable use of coastal space. This refers to many areas of the western part of the coastal zones (washed by the Baltic Sea), the southern part (by the Black, Azov, and Caspian Seas) as well as to the Barents, Kara and Laptev Sea.

Geopolitical changes happened in the beginning of the 1990ies, since the Soviet Union's demise, and transformed wide parts of Russia into a typical northern country. Now the northern regions occupy more than 64 % of the whole territory of the Russian Federation. Therefore in terms of resources, ecosystem goods and services, environmental and social and economic state these regions are of crucial and growing significance for the current and future development of the whole country. The rest of the country, occupying the more southern latitudes is already of extremely high importance although offering provision of services on a rather limited geographical space, although under usually more favorable climatic and living conditions for most parts of the population.

The combined length of the Russian coastline exceeds 60,000 km accommodating a population of around $17x10^6$ people. More than 40,000 km are Arctic coast, some 27,000 km of which belong to the continental shoreline (Mikhaylichenko, 1998). The Russian Arctic has a long history of resource use and development, but most of the activities concentrate in the more recent period as referred to from the beginning of the 1930ies to our days. Due to the severe climatic conditions and great expenditures needed to explore and develop Arctic areas, river and marine transport lines were and are the most important part of the Arctic infrastructure. The great rivers – the Northern (Severnaya) Dvina river, the Pechora river, the Ob river and its tributaries, the Yenisey river, the Lena river, the Khatanga river, the Jana river, the Indigirka river, the Kolyma river are flowing to the Arctic ocean gathering their waters from huge catchment basins (Figure 2.1). These basins are under considerable pressure from populated and industrially developed areas, particularly to the west of the Yenisei River. Teleconnected effects originate from airborne and waterborne pollutants finding their way to the Arctic via long-range transport pathways (Figure 2.2). Main characteristics of the Russian Arctic Rivers and their delta areas are given in Table 2.1.

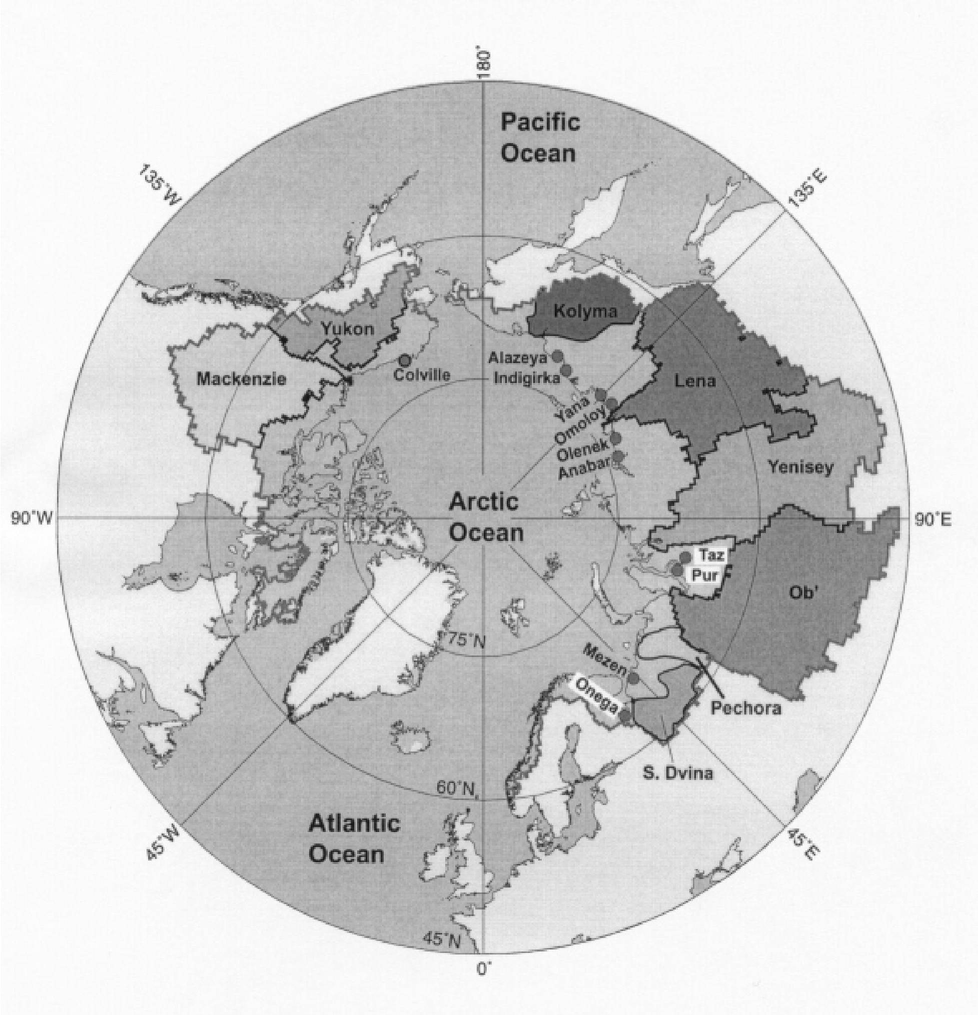

Figure 2.1: Circumpolar map of catchment river basins

Because of prevailing sea currents, the Arctic Ocean acts as a sink for a wide range of pollutants including, among others, heavy metals, toxic substances, hydrocarbons, PCBs, and nuclear wastes (Griffiths and Young 1990). In recent years various economic endeavours have been launched to extract vast quantities of natural resources, which caused a change of geopolitical interrelations in the area and made this region an arena of international cooperation.

The notion of environmental safety is particularly relevant to the Arctic for several reasons. Among them, priority concerns the fragility of northern ecosystems and their extreme vulnerability to human disturbance. Second, the area has profound influence on global (or at least hemispheric) environmental processes such as atmospheric and oceanic circulation, global warming, and ozone layer depletion (e.g., Broadus and Vartanov 1994).

The processes in the Arctic coastal seas are strongly controlled by regionally specific phenomena, such as the sea-ice cover and transition between onshore and offshore permafrost. During the long winter season a thick and extensive sea-ice cover protects the coastline from hydrodynamic forcing. During the open water season, mainly after break-up in spring, the sea-ice is an important transport agent for coastal sediments. Global and regional climate changes will significantly affect physical processes, biodiversity and socio-economic development in the Arctic coastal areas. In reverse, Arctic coastal systems, via material flux generated by eroding coasts and the greenhouse gases emission from degrading coastal permafrost, likely feedback into the global systems (Rachold *et al*. 2003a; Figure 2.2).

Traditional economy of the indigenous people connected with use of renewable natural resources such as reindeer pastures, hunting areas and fishery in fresh and marine waters, still remains a noticeable feature of arctic regions. However, the main pillar of the economic development can be found in diversified industrial use of non-renewable resources such as oil and natural gas, coal, minerals, raw materials, rare and precious metals. Therefore the Arctic coastal environment is under growing pressure from both local industrial centers and traditional economies, changing the horizontal and atmospheric flows of pollutants, water and sediments in the large contributing river basins. All northern rivers on their way to the Arctic deltas are passing several climatic zones where human activities feature considerable differences. Consequently, environmental and resource management regulations for coastal zone activities are unlikely to be effective if they do not consider detrimental impacts and systemic change along the entire water continuum of the catchment-to-coast basin.

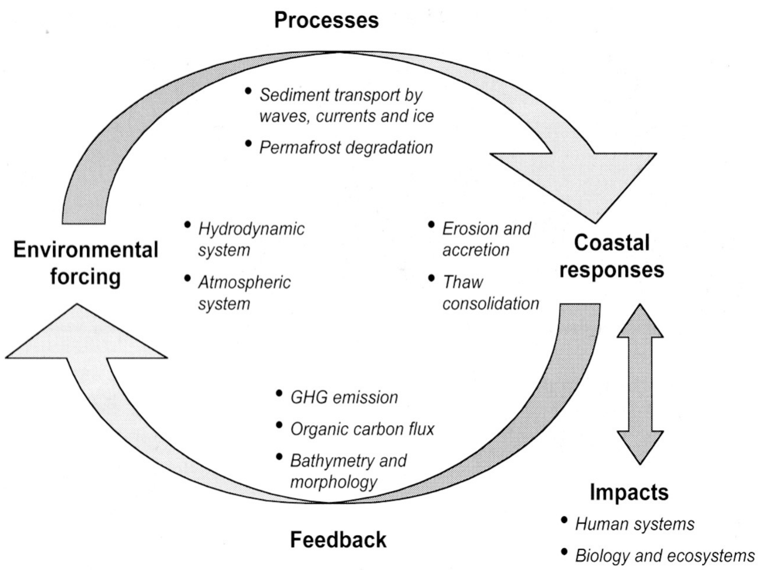

Figure 2.2: Environmental forcing, coastal processes and responses, impacts and feedbacks (Rachold *et al* 2003b).

Brief introduction into the LOICZ Basins approach

The LOICZ Basins approach for studies of river catchment-based coastal changes (see Annex for detailed methodology) gives a comprehensive assessment of key natural processes and coastal states which are under impact of both, natural and anthropogenic driving forces. Rivers and their lower reaches have great significance in coastal development, exchange of energy, sediments, water runoff, and impact on biodiversity, attractiveness of shores for human habitation, recreation and economic activity. For natural and social scientists, the LOICZ Basins studies expand their understanding of the causes of coastal environmental changes and transformations, and give a new vision of links between the elements of coastal ecosystems. The coastal zone may be considered as the interface area between continents and oceans but everything that happens in the coastal zone is affected considerably by spatial processes originating far beyond its borders.

Table 2.1 Characteristics of main rivers in the Russian Arctic and their delta areas (Mikhailov 1997; Gordeev *et al.* 1996; Holmes *et al.* 2002)

River catchment (index as given in Figure 2.3)	River length	Catchment area	Delta area,	Delta length,	Water runoff,	Sediment load,	Salt load,	Length of penetration, km		
	km	10^3 km^2	km^2	km	km^3 y^{-1}	10^6 t y^{-1}	10^6t y^{-1}	Tides	Storm surges	Seawater
North Dvina (A2)	744	357	900	45	110	4.1	22.0	135	135	45
Kola River (B1.1)	83	3.85	0	0	1.46	1.9	-	-	-	-
Tuloma (B1.2)	64	21.5	0	0	7.63	-	-	-	-	-
Pechora (B2)	1810	322	3200	120	130	8.5	-	190	160	10
Ob (C2)	3650	2990	3200	144	402	13.0	54.0	50	350	0
Yenisey (C3)	3490	2580	4500	196	597	13.0/ 4.9*	70.0	445	870	-
Khatanga (D2)	1636	364	0	0	105	5.2	6.3	227	-	-
Lena (D4)	4400	2448	32000	175	523	20.7	55.0	-	-	-
Yana (D5)	872	238	6600	140	33.1	4.2	1.5	30	70	60
Indigirka (E1)	1726	360	5000	130	53.9	11.9	11.0	24	200	-
Kolyma (E2)	2130	647	3200	120	119	12.1	-	185	185	-

Catchment classes < 10 x 10^3 km^2 – small; 10 – 200 x 10^3 km^2 – medium; > 200 x 10^3 km^2 – large (see also Lacerda *et al*. 2002)
*** values before and after regulation**

The DPSIR framework terminology

This desk study (LOICZ Russian Arctic Basins - RusABas) is a first attempt to apply the D-P-S-I-R (Driver-Pressure-State-Impact-Response) framework to Russian river basins. This multidisciplinary approach originally promoted by OECD in 1993 and further developed within the LOICZ project (Turner *et al.*1998, Ledoux *et al.* 2005, Crossland *et al.* 2005) allows to combine the knowledge and experience of natural and social scientists. Data and information are reviewed in such a way as to produce a complex picture of interactions of economic sectoral activities that affect coastal zone ecosystems and social processes, and to reveal further indicator functions and impacts on natural and social values of coastal zone. The analysis should assess the response of society on environmental and anthropogenic changes in the coastal zone.

Drivers: the catchment-based sectoral economic activities for the Arctic coastal zone

- mining and refining industry
- demand for energy that results in oil and gas development
- timber woodworking and pulp and paper industry
- port facilities and urbanization
- shipping operations
- agriculture
- fisheries
- aquaculture
- land-use change (e.g. demand for space and water)

Pressures: processes affecting key ecosystem and social system functioning

- damming and other water-course construction
- river diversion and water abstraction
- discharge of industrial effluents (industrialization), agricultural and domestic wastes
- navigation and dredging
- extraction of river-bottom sediments (building materials, gold mining)
- sea level rise induced by land-based activities affecting the coastal zone.

State and state change: the indicator functions and how they are affected

- water, nutrient and sediment transport (including contaminants where appropriate) observed in the coastal zone as key indicators for trans-boundary pressures within the water pathway;
- geomorphological settings, erosion (thermoabrasion), sequestration of sediments, siltation and sedimentation;
- economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity including the valuation of natural resources, goods and services.

Impacts on system characteristics and provision of goods and services

- habitat alteration
- changes in biodiversity
- social and economic functions
- resources and services availability, use and sustainability
- depreciation of natural capital.

Response: action taken

- scientific response: research efforts, monitoring programs

- policy and/or management response to either protect against changes such as increased nutrient or contaminant input, secondary sea-level rise; or to ameliorate and/or rehabilitate effects following adverse development and land-use change and to ensure or re-establish the chance for sustainable use of the system resources.

2.2 Indicators of coastal change

LOICZ Russian Arctic Basins (RusABas) aims to use existing quantitative environmental indicators, accepted in hydrochemical analysis to evaluate and confirm/update the qualitative expert assessment of environmental state (biochemical and biological) in the coastal zone. Both types of indicators may be interchangeable, so that if quantitative measurements are not available for a site, qualitative indicators may help understanding and assessing possible environmental change in coastal zone processes. A set of environmental indicators of pressures and state change applied to the Russian Arctic context is presented in Table 2.2.

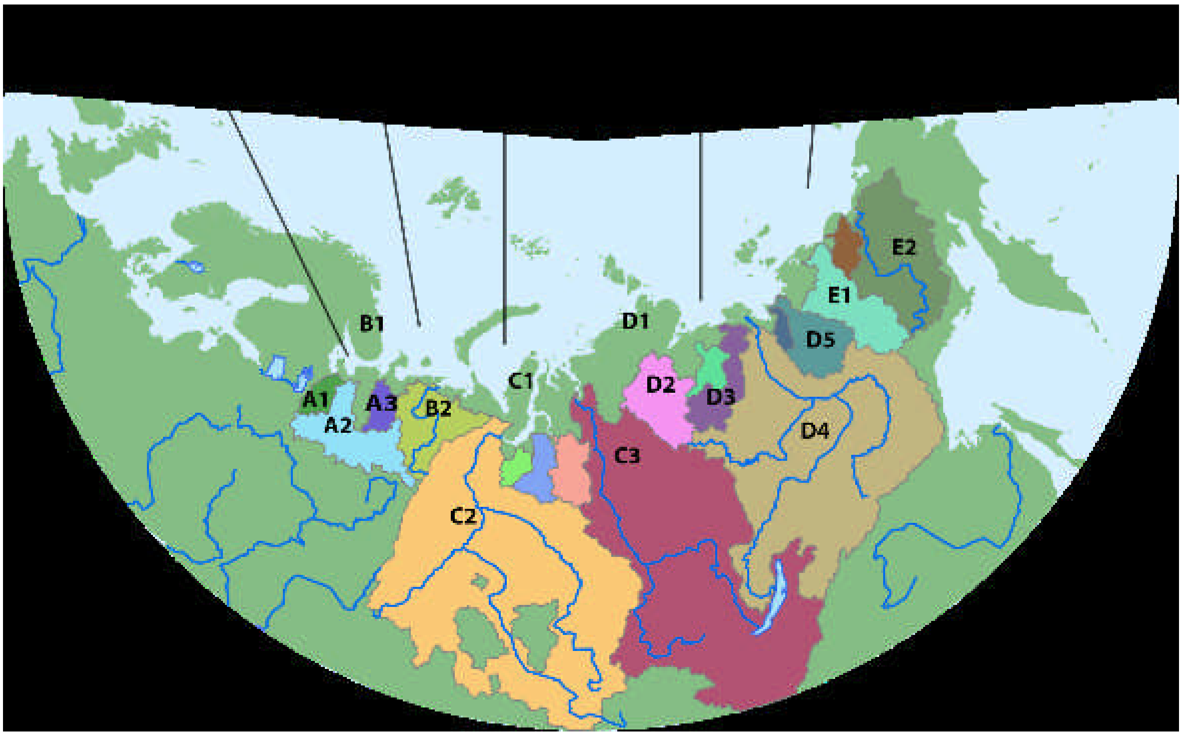

Figure 2.3: The larger Russian river basins discharging into the Arctic Ocean (from Crossland *et al.,* 2005)

Table 2.2. Summary of environmental indicators of pressures and state change applied to the Russian Arctic context

Drivers / Pressures pressure	Environmental conditions	Response	Indicators (examples)
Oil and gas production and processing	Concentrations of organic pollutants	Maximum allowed concentrations (MAC)	Frequency of occurrence and level of surpassing the MAC
Emission of heavy metals	Concentrations of heavy metals in water, sediments and biota	MAC	Frequency of occurrence and level of surpassing the MAC
Emission of sulfur	Concentrations of sulfates in rain water, masses of sulfur deposited, pH of waters	Critical loads (CL) of sulfur deposited on unit of area in unit of time	Percent exceeding CL
Radioactive pollution	Concentrations of radionuclides in water and sediments, soils, biota	MAC Magnitude of total radioactive dose in biological tissue	Frequency of occurrence of surpassing the MAC and critical radioactive dose
Emission of nutrients (C, N, P)	Concentrations of nutrients C, N, P in waters and sediments	MAC	Dissolved oxygen, primary production rates
Sedimentation	Total suspended solids concentrations (TSS); Sedimentation rates	MAC	Frequency of occurrence of surpassing MAC Historical variations of sedimentation rates
Erosion	Coastal erosion rates	Integrated coastal zone management	Loss of beaches Dune destruction rates
Fisheries losses	Fish stocks	Maximum catch, fisheries management legislation, total allowable catch (TAC) allocation	Change in fisheries stocks, catch diversity
Freshwater withdrawal	Ground water salinisation	MAC	Change in water regime in the coastal zone; Groundwater salinity variations along the gradients.

2.3 Coastal issues, drivers/pressures, state changes, critical loads and ranking

2.3.1 Regional drivers/pressures and hot spots

Catchment basin activity is irregular in the Russian Arctic (Figure 2.4). In the Western Arctic, the normal resource uses encompass sectors such as navigation, fisheries, timber industry and reindeer breeding; in parallel industrial production sectors are developed, such as metallurgic plants (Severonickel, Pechenganickel, Norilsk), incl. mining and concentrating and processing industry (Apatit, Pechora-coal) as well as high-capacity oil and gas related complexes. The data are summarized in Table 2.3, which also lists initial findings of the most important "hot spots" in the Russian Arctic region.

Table 2.3. Initial summary of priority driver/pressure features in the Russian Arctic by rough sub-regions, corresponding "hot spots" and sources of available information
Rosgidromet: Federal Service of Russia for Hydrometeorology and Monitoring of the Environment

Sub-region	Driver/Pressure	Hot spots	Available information
White Sea basin	• Pollution (industry, urbanization, navy, power industry) • Acidification (industry, transboundary transfer) • Navigation • Agriculture (nutrient loads)	• Arkhangelsk area and North Dvina mouth and Bay	Annual data of Rosgidromet and Russian Academy of Sciences, major bibliography sources
Barents Sea basin	• Pollution (industry, mining, urbanization, oil and gas production and processing, NAVY, radioactive waste burial) • Oil spills (middle stream) • Acidification (from industry, mining, transboundary transfer) • Navigation	• Kola Bay • Nickel area • Monchegorsk area • Pechora Bay • Nenets AO • Novaya Zemlya islands	Annual data of Rosgidromet, Kola Scientific Center Russian Academy of Sciences, international lake projects "Lake Survey" and other, major bibliography sources
Kara Sea basin	• Pollution (oil and gas production and processing, industry, mining) • Acidification (industry, mining, transboundary transfer) • Damming	• Norilsk area • Yamal-Nenets AO • Ob River (upper and middle reach) and Bay • Yenisey River (upper and middle reach) and Bay	Annual data of Rosgidromet and Russian Academy of Sciences, major bibliography sources

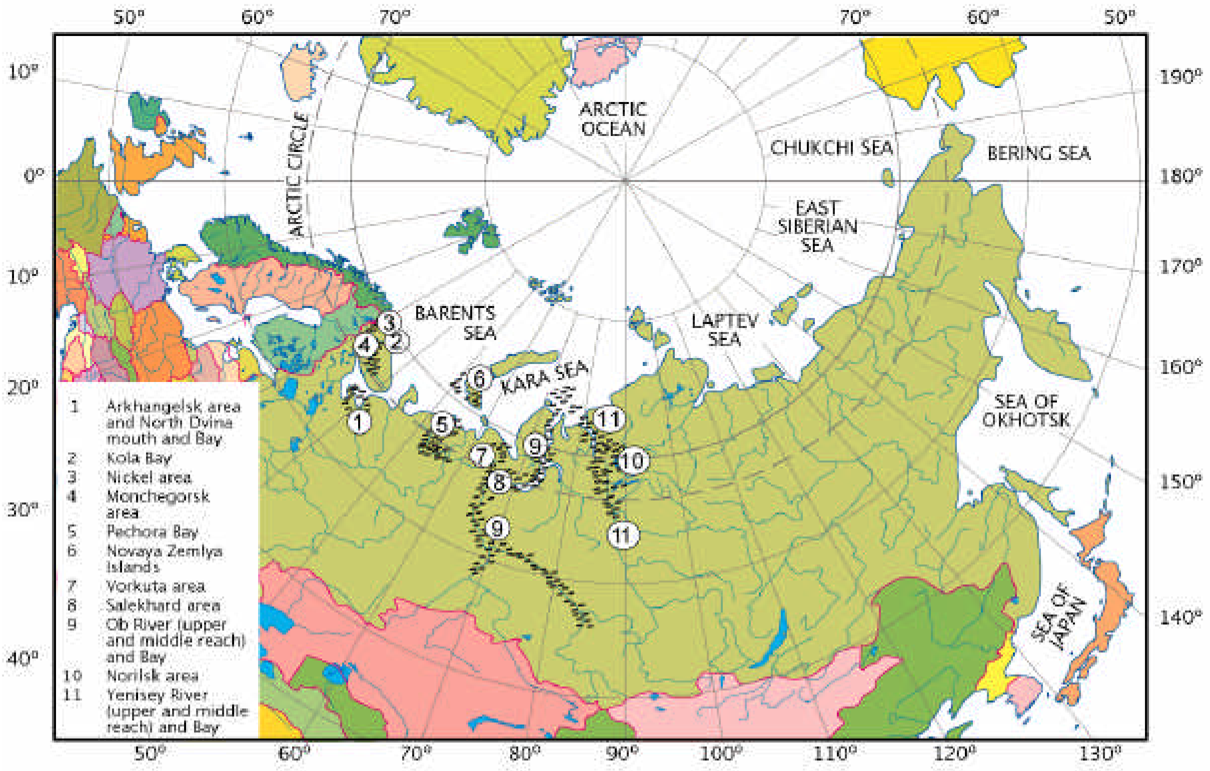

Figure 2.4: "Hot spots" in the Russian Arctic

2.3.2 Coastal issues, states, thresholds and ranking of impact (river-catchment and sub-regional scale)

To make a ranking, several different approaches can be used. A frequently acceptable one is the method using critical loads (CL). CLs determine the maximum flux of one or a few substance-pollutants entering an ecosystem without causing negative change in its most sensitive parts (Henriksen *et al*. 1994; Moiseenko 1997, 2001a). The analysis can proceed if the CLs of combined pollution for biological systems are defined and if there are models of interaction between inputs in the watershed and the corresponding concentrations of pollutants in the target ecosystems. The distance of the observed concentrations from these levels (exceeding the CLs or ranging below them) can be determined for the environmental issues given (see examples in Arthurton *et al*. 2002, Hong *et al*. 2002; Kjerfve *et al*. 2002; Lacerda *et al*. 2002). In the North of Russia, CLs were identified for sulfur fluxes, particularly in the Kola Peninsula region (Moiseenko *et al.*, 1997, Moiseenko 2001a, 2003), the Norilsk region (Myach 1996) and in the Lena River basin (Izrael *et al*. 2001).
Another criterion such as maximum allowed concentrations (MAC), which can be considered as a "single substance critical load" based on scientific information and implemented through either management response or policy targets, has also been used. However, the pollution control system based on MAC is often unable to prevent the degradation of water ecosystems satisfactorily (Nikanorov 1990; Izrael *et al*. 1991). A significant shortcoming is that considering the isolated effects of selected chemical substances without taking into account the whole complex of impacts and transformations in real ecological conditions does not reflect the real situation. Therefore in Russia, as well as abroad, the problem of ecological rating (a theory of critical loads) assumes even greater importance.

In the study of the Kola Peninsula Moiseenko *et al*. (1997) applied the index of toxicity (IT), which is a ratio of a sum of several metal concentrations to a sum of their MACs to 460 lakes on the territory to assess the degree of their pollution with heavy metals (IT critical = 1-2).

In recent work of the same research group (Lukin *et al*. 2000) studying the Pechora river an index of ecological risk (IR) was used to assess quantitatively the potencial ecological risk of a group of pollutants in the region (see also Hakanson, 1980);

$$\mathbf{IR = \Sigma_i\, Tri \times Cfi,}$$

where Tri is the coefficient of toxiticy of the substance given for the present river,
Cfi is the coefficient of pollution,
IR < 150 = low risk, 150≤ IR < 300 = moderate risk, 300≤ IR < 600 = significant risk, IR ≥ 600 = high risk.

The ranking of the coastal impacts and issues in the Russian Arctic provided here has been conducted according to their degree of importance. This referres back to a quantitative or qualitative evaluation of the present-day distance to the critical threshold of a given parameter for system functioning and is based on available data (Table 2.4).

Table 2.4. Major coastal impacts/issues and critical thresholds along the coast of the Russian Arctic

Overview and qualitative ranking of impacts: 10 = maximum; 0 = none (see appendix for more detail)

*, ** for indexing of regions and abbreviations, see footnote on page 39

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source

Pollution	**A2***. **Dvinsky Bay (and North Dvina River mouth)**	Heavy Metals (HMs)	**North Dvina delta** (in MAC): (1999) Cu - 2-4, Fe - 2-4, Zn - 2. Kuznechikha arm (in Arkhangelsk-city): Al - 6, Fe - 8, Zn - 11, Cu - 9. (2003) Cu-7, Fe- 9, Zn- 6 Bottom sediments of the river and delta (Cu, Zn, Pb, Cd, Ni, Co, Hg) at the background level. Bottom sediments near Arkhangelsk-Novodvinsk-Severodvinsk: Cr-2, Ba-2, Pb-1 Soils: Cr-7.7, Pb-3.5, Ba-4.1	5-7	**Anon. 2000**, 2005 Kukina *et al.* 1999 Petrosyan *et al.*1998 Izrael *et al.* 2001;
		Petroleum Hydrocarbons (PH)	**N.Dvina upstream** (1975-93) - 0-0.26, Average 0.04 mg l^{-1} **Mouth** (1975-93) - 0-0.56, av. 0.03-0.09 mg l^{-1} (max 11 MAC) **Dvinsky Bay** (1988-96): 0.03-0.04, Max 0.5 mg l^{-1}, MAC-3-10 Bottom sediments: 0.15-0.17 mg g^{-1}, Max 0.87 mg g^{-1}	6-8	Lebedeva 2001
		PAH	**N. Dvina**: fluoranthene - 20-45 ng l^{-1} Pyrene - 10-75 ng l^{-1} Benz(a)pyrene - < 5 ng l^{-1}.		
		POPs	**Dvinsky Bay**: α- HCB - 0.1-3.0 ng l^{-1} γ - HCB - 0.1-2.0 ng l^{-1}, max 10 **c. Verhniy Ustuyg:** a-HCB- 19 ng l^{-1}, ß-HCB- 14 ng l^{-1}, ?-HCB- 26 ng l^{-1} (MAC=10 ng l^{-1})		Anon. 2005
		Microbial pollution:	**Arkhangelsk region**: microbial quality of water samples not complying with coliform standard (% of total number of samples): 1991 - 23.9 , 1992 – 22.4	5	Abakumov 1998

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Acidification	**A2*. Dvinsky Bay (and North Dvina River mouth) continued**		Sulfate riverine flux: $6.7x10^6$ t yr^{-1}. Atmospheric component - 5 %	5	Moshiashvili 1992
Eutrophica-tion			Annual concentrations: NO_3 -84 µg l^{-1}, PO_4 -19 µg l^{-1}, TOC -23.4 mg l^{-1}. River discharge (1996): NH_4 - $4.84x10^3$ t yr^{-1}, NO_3 -$11.3x10^3$ t yr^{-1}, PO_4 -564 t yr^{-1}, P_{tot} -$2.26x10^3$ t yr^{-1}, TOC-$1.22x10^6$ t yr^{-1}. Underground discharge is 25 % of river discharge. Salinity of ground waters is unknown.	5	Gordeev *et al.* 1996; Anon. 2000 Gordeev *et al.* 1999
Radioactivity			Data on the **N. Dvina mouth** are unknown. Bottom sediments of the White Sea: ^{137}Cs < 10 Bq kg^{-1}		Aibulatov 2001a; Galimov *et al.* 1996
Sedimentation			Total sediment discharges $4.4x10^6$ t yr^{-1}, av. turbidity - 35 mg l^{-1}. There are accumulative forms in **Dvinsky Bay**. Dredging works due to navigation aims.		Mikhailov 1997

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Biodiversity	**A2*. Dvinsky Bay (and North Dvina River mouth) continued**	Assessment of aquatic ecosystems: Class I - Ecological integrity reflecting pristine environments; Class II - Ecological stress; Class III - Signs of ecological regression; Class IV - Ecological regression (loss of diversity); Class V - metabolic regression (a complete degradation of the biocoenosis)	Almost along the whole length the **N.Dvina** river is in conditions of ecological stress (Class - II). The signs of ecological regression (Class III) can be found below **Arkhangelsk city**.	5-7	Abakumov 1998

Table 2.4 continued

Coastal Impact/Issue	**Local site/Region (contributing river basins)**	**Critical substances (for system functioning)****	**Distance to critical threshold (qualitative or quantitative)**	**Impact category**	**References/ Data source**
Pollution	**B1. Kola Peninsula** (small rivers Kolos–Yoki, Nuduai, Rosta, Pechenga etc.) (without the Kola Bay); catchments near Zapoljarniy, Monchegorsk and Kirovsk.	– Heavy metals (HM): High concentrations of Ni, Cu, Cd, Pb, As, Co, Cr, Sr in lake and river waters and bottom sediments. Index of toxicity $IT_{critical}$ =1-2	30 % of the **Kola North** territory exceeds IT (up to 25). (460 lakes were studied). Bottom sediments in Imandra Lake (MAC excess): **Monche Bay** (near "Severonikel" enterprise) – Ni up to 80, Cu-25, Mn-4, Zn-2.5 **Belaya Bay** (near "Apatity") Sr-5, Al-3, Mn-2, Zn-2.5 River water in small rivers in 1997 (MAC excess): R.Kolos-Yoki (city Nikel) Cu - 5-9, Ni - 36-88, R.Nuduai (town Monchegorsk) Cu-102, Ni-87, R.Rosta (city Murmansk) Cu-6, Fe-8, R.Pechenga (near "Pechenganikel") Cu 10-13, Ni 10-13. Snow samples near Zapoljarniy, Monchegorsk and Kirovsk (MAC excess): Cu- 35-555, Ni-7-26.	9-10	Moiseenko *et al.* 1997; Moiseenko 2001(a,b); Dauvalter *et al.* 2000; Anon. 2000; Caritat *et al.* 1998
		PH	**Motovsky Bay** (1988-93): max 6 MAC in water; Pechenga R.: 1980-84 0-0.22, av.0.10 max. 4 MAC 1985-93 0-0.07 mg l^{-1}, av. 0.02 <1 MAC	5	Lebedeva 2001; Petrosyan *et al.* 1998
		POPs	**Motovsky Bay** (1988-1993): α -HCB 0.7-4.1 ng l^{-1}, <1 MAC γ-HCB 0-2.4 ng l^{-1}	2-3	Lebedeva 2001
		- Microbial pollution Coliform standard (CS): (% of total number of samples not complying with the coliform standard)	**Murmansk region**: Coli-index CS (%) 1991 - 100 1992 - 97.8	6-8	Abakumov and Talayeva 1998

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Acidification	**B1. Kola Peninsula continued** (small rivers Kolos–Yoki, Nuduai, Rosta, Pechenga etc.) (without Kola Bay); catchments near Zapoljarniy, Monchegorsk and Kirovsk.	Low pH in lake waters; Critical load (CL) -0.3 gS m^{-2} yr^{-1} for tundra and mountain regions. HCO_3 < 50 μg·eqv l^{-1}	460 lakes: 26 % - pH < 6, 11 % - pH < 5 From 1980 to 1995 total emission of SO_2 decreased from 650 x 10^3 t yr^{-1} to 450 x 10^3 t yr^{-1}. 17 % of lakes – critical threshold passed. 1990-92: 40 % of territory > 8 gS m^{-2} yr^{-1} 1995: <30 % of territory > 8 gS m^{-2} yr^{-1}	8-9	Moiseenko *et al.* 1997; Moiseenko 2003; Chernogaeva *et al.* 1998
Eutrophica-tion		DOM/P_{tot} < 1000 - dystrophic type of lakes. O_{2diss} < 4 mg l^{-1}	50-70 % of lakes belong to the distrophic type; Eutrophication only takes place in shallow, thoroughly warmed reservoirs because of agricultural and domestic discharges. Even at high concentrations of phosphorus, algal blooms do not appear – the eutrophication process is limited by low temperature and high water exchange	4-5	Moiseenko 1997; Moiseenko *et al.* 2001; Drabkova 1998
Biodiversity		Level of biodiversity loss	In 5 % of the lake's area a degradation of biodiversity is observed. Accumulation of heavy metals in organs and tissues of fishes	4-5	Kashulin 1994; Yakovlev *et al.* 1996; Moiseenko *et al.* 1997

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**B 1.1 Kola Bay** (Kola River: 3850 km^2 watershed, 1.46 km^3 yr^{-1} discharge; Tuloma River: 21,500 km^2 watershed, 7.63 km^3 yr^{-1} discharge; Murmansk area)	Heavy metals: highest concentrations in bottom sediments of Murmansk port, especially Cu and Zn	The highest content of Cu (567 ppm) in bottom sediments near **Murmansk** port. Cd 0.34, Hg 0.36, Pb 93 ppm. Port Severomorsk: Cu 54 ppm. **Barents Sea** bottom sediments: Cu 2-6 ppm. Kola Bay: Cu 30-567, Zn 80-300, As 10-25, Cd 0.11-0.34, Hg 0.13-0.36, Pb 25-93. **Air: Murmansk** Hg = 0.5-5.5 ng Hg m^{-3}, av. 2.2 **Kola Bay** Hg 0.7-3.3, av. 1.7 ng Hg m^{-3} (2 times less than in the air of the European territory of Russia)	5-6	Ilyin & Dahle 1996 Ilyin & Petrov 1994 Golubeva & Burtseva 1996
		PH the highest impact in the Barents Sea PAH chronic oil pollution POPs	**<u>Water of the bay</u>**: 1985-1992: PH = 0.02-0.1 mg l^{-1}, av. 1 MAC Maximum 1-7 mg l^{-1}, 20-140 MAC. <u>Bottom sediments (0-2 cm):</u> 1995-1996: 470-7350 mg kg^{-1} One sample max. – 50,800 mg kg^{-1} Bottom sediments: $\sum$ PAH = 240-1211 μg kg^{-1} Benz(a) pyrene = 65-513 μg kg^{-1} (10-20 MAC) 1992: Bottom sediments - α- HCB = 0.3-3.2 ng g^{-1} γ- HCB = 0.5-4.4 ng g^{-1} $\sum$ DDT = 3.3-10.1 ng g^{-1}, av. 6.1 ng g^{-1} (15 times above the Pechora Sea bottom sediments). PCB = 12.3-282.6 ng g^{-1}, av. 93.7 ng g^{-1} (**Pechora Sea** - 0.9 ng g^{-1})	7-9	Ilyin *et al.* 1996; Loring *et al.* 1995 Anon. 1993; Savinov *et al.* 1996

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Radioactivity	**B 1.1 Kola Bay (continued)**	This region has a naval bases, mooring and utilization of nuclear powered vessels, storage of exhausted nuclear fuel, ship-repairing and ship-building plants	Total discharge of artificial radionuclides into the **Kola Bay** (1989-1994): ^{90}Sr 15.7x10^6 Bq yr^{-1} ^{137}Cs 76.2x10^6 Bq yr^{-1} ^{60}Co 61.6x10^6 Bq yr^{-1} Bottom sediments: ^{137}Cs = 3-23 Bq kg^{-1}; ^{60}Co = 0.2-3 Bq kg^{-1} Near "Atomflot": ^{137}Cs = 2-40 Bq kg^{-1}; ^{60}Co = 2-27 Bq kg^{-1}	6-7	Kolomiets *et al.* 1993 Matishov *et al.* 1996
Eutrophica-tion		$O_{2diss.}$ concentration, high concentrations of nutrients in interstitial waters	$O_{2diss.}$ = 10-13 mg l^{-1}, min 60 % in winter. Surface waters: NO_2=0, NO_3=25-63 µg l^{-1}, PO_4=0. Near bottom waters: NO_2=0, NO_3 up to 55 µg l^{-1}, PO_4=0. Interstitial waters: NO_2=0-26, NO_3=20-140, PO_4=24-1020.	4-6	Pavlova 1996
Biodiversity			Existence of oppressed biocenosis in the Roslaykov Inlet and near Murmansk. Low biodiversity of bottom fauna is a result of organic pollutants. Decrease of biomass of benthos and loss of fish diversity.	5-7	Frolova *et al.* 1996 Gudimov and Frolov 1996; Karamushko *et al.* 1996

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**B2. Pechora River and Pechora Sea Coastal Zone**	Heavy metals: higher concentrations of Zn, As, Sr, Cr in the Usa River and the Kolva River due to sewage of the coal pits of the Pechora coal basin	**River water** (annual concentration, μg l^{-1}): Zn - 0.1-30, Ni - 0.05-3.1, Cu - 0.05-0.81, Cd - 0.02-0.4, Pb – 0.05-1.7, Cr - 0.1-1.7. Ust'-Tsil'ma (in MAC) (2003): Cu- 1-3 Pechora: Cu- 9-10, max 15 Nar'ayn-Mar: Cu, Zn- 2, Fe-7 Nel'min Nos: Hg- 1.9, Pb, Cd <1 (bottom sediments, μg.g^{-1}) Hg- 0.31, Pb-6.0, Cd-0.08 (all MAC<1) Suspended matter (μg g^{-1}): Zn 270, Cu 170, Pb 130, Ni 31, Cr 105 (1972) **Bottom sediments** (μg g^{-1}): Cu 5, Zn 60, Pb 17, Cd 1.5, Co 13, Ni 31(1972) Pechora Sea (bottom sediments, μg g^{-1}): Cu 21, Zn 80, Pb 19, Cd 0.07, Ni 41. **R. Usa basin** (water, μg l^{-1}): Cr 6.2, Zn 12.7, Cu 1.3, Pb 1.1, As 3.2, Cd 0.09 (max < 2 MAC for Cr, Zn, Cu).	4-6	Melnikov & Gorshkov 1999 Anon., 2005 Morosov *et al.* 1974 Loring *et al.* 1997; Lukin & Dauvalter 1997
		PH: accumulation of petroleum hydrocarbons in the Pechora Delta and the Golodnaya Inlet due to accidents in the oil pipelines. Index of ecological risk $IR_{crit.}$ > 300	**River water** (μg l^{-1}): PH = 0-60 (1999), 12-50 (2003) **Bottom sediments** (μg g^{-1}): pH = 3-20, delta and lakes PH = 360-1250 (1999), 17-30 (2003) **R. Kolva mouth**: IR - 60. Delta of R. Pechora: IR = 800-3000. Near **Narjan-Mar** City: bottom sediments - ∑ PAH = 16-500 μg kg^{-1} **Pechora Sea water**: ∑ PAH = 10-90 μg l^{-1} (1988-91) (0-2 MAC, max - 10 MAC), **Pechora River water:** S PAH=93-106 μg.l^{-1} (2003) (<1MAC) **Bottom sediments**: ∑ PAH = 55-265 mg g^{-1}	9-10 (Delta)	Wartena *et al.* 1997; Lebedeva 2001; Dahle *et al.* 1997; Anon. 2004

Table 2.4 continued

Coastal Impact/Issue	**Local site/Region (contributing river basins)**	**Critical substances (for system functioning)****	**Distance to critical threshold (qualitative or quantitative)**	**Impact category**	**References/ Data source**
Pollution	**B2. Pechora River and Pechora Sea Coastal Zone (continued)**	POPs	**River waters** (ng l^{-1}): (1991-95) a-HCH =0-6, ?-HCH =4-7 (MAC=10) DDT 0, DDE 0. (2003) a-HCH= 0.14- 0.18 **Bottom sediments** (µg kg^{-1}): Σ POP's <0.6-12.5 (1994-95) **Pechora Sea** (open water): Phenols (µg l^{-1}) – 1; (MAC is exceeded in 50 % of cases).	4-6 (Delta)	Alexeeva *et al.* 1997 Wartena *et al.* 1997 Anon. 2004 Izrael *et al.* 2001
Acidification			Sulfate flux $2.1x10^6$ t yr^{-1}, atmospheric component of sulfate = 10 %	4-5	Moshiashvili 1992
Eutrophica-tion			**Pechora River mouth** (2000): O_{2diss} - <4 mg l^{-1} (4 %). Nutrients (1979-95, µg l^{-1}): NO_3 - 74, PO_4 - 34, P_{tot} - 53.	4-5	Izrael *et al.* 2001; Gordeev *et al.* 1996
Radioactivity			**Bottom sediments of the Pechora Sea**: ^{137}Cs = 1-10 Bq kg^{-1}, max 44 near south shore of the **Novaya Zemlia** **Pechora Bay** – background (av. 8 Bq kg^{-1}).	5	Ivanov 1999
Sedimenta-tion			Total suspended matter discharge $9.4x10^6$ t yr^{-1}, av. turbidity 72 mg l^{-1}. Water exchange in **Pechora Bay** 20-30 days. Accumulation of mud in small western arms of the delta and progradation of the Big Pechora River plume are occurring.	4-6	Mikhailov 1997; Holmes *et al* 2002

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**C2. Obskaya Guba (Ob Bay)**	Heavy metals (HM) pH: Western Siberia (watersheds of the Ob and Yenisey rivers) is the region of 90 % of oil and gas production in Russia. (3-10)x10^{6} t yr^{-1} of crude oil is going to soils and water in the region. Accidents with oil spills (St. Njagan, 1993 – 420 000 t was lost) POP's	**Upper Irtysh River (Kazakhstan) (water, μg l^{-1}):** Cu-23 (23 MAC), Zn-40 (4MAC), Pb-20 (2 MAC), Mn-40 (4 MAC) **Middle Irtysh River (Russia)** (water, in MAC): Fe, Mn, Cu, Zn, Ni, Cd, Pb, Cr, Hg, Co- all below 1MAC **Middle Ob River** (water, μg l^{-1}): Cu 2.1, Zn 54, **Tomsk** (2000) Cd - 0.2, Pb - 0.8, Area Hg - 0.12 (max 2.3), Zn -5MAC, Hg -max 23 MAC. **Lower Ob River**: Cu -2.1, Zn -0.3, Ni -1.3, Pb -0.014, Hg-0.0006, Cd -0.0007 (no MAC exceeded). Suspended matter (μg g^{-1}): Cu -50, Zn -104, Pb -16, Cd -0.53, Hg -0.05. Bottom sediments (μg g^{-1}): Cu -25, Zn -83, Pb -19, Cd -0.12, As -36. pH in river waters along the whole Ob River length (1997, in MAC): upper reach - Buisk-4, Novokuznetsk - max 30-34, middle reach - Barnaul - 21, Novosibirsk - 18, Tomsk - 5-8, Nefteyugansk - 20, low reach – Salekhard - 10. Lower Ob River (2003, in MAC): 1-19 **Ob River mouth**: 0.11-3.4 mg l^{-1}, av. 0.3-0.9 (1976-1993) (6-18 MAC). (2003) (1-19 MAC) **Ob Bay**: water - 0.05-0.16 (1-3MAC) Bottom sediments - 30-60 μg g^{-1} **Ob River**: α - HCH - 0-27, av. 2 ng l^{-1}, (1997) γ - HCH - 0-86, av. 15 ng l^{-1}, DDT - 0-110, av. 13 ng l^{-1}.	5-7 2-4 8-10	Panin 2002 Gordeev *et al.*, 2004 Shvartsev *et al.* 1999 Gordeev 2001 Loring *et al.* 1997 Evseev 1996 Anon. 2000, 2005 Petrosyan *et al.* 1998; Anon. 2005 Lebedeva 2001 Anon. 2000

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**C2. Obskaya Guba (Ob Bay) (continued)**	 Phenols Microbial pollution Coli-index, coliform standard (% of samples not complying with coliform standard):	**Ob Bay**: pesticides - 0-1, max 2-6 ng l^{-1} $\sum$ HCB - 4.1 ng l^{-1}, PCB - 4.3 ng l^{-1}, max 11. **Ob River**: middle reach - 0-40, av. 9 $\mu g\ l^{-1}$ (1976-1993) mouth - 0-13, av. 2-4 $\mu g\ l^{-1}$ (2-9MAC) *E. coli*-index: 1991 1992 **Novosibirsk area** 91.8 81.5 **Tomsk** 91.3 84.7 **Omsk** 100 100 **Tumen’** 100 394 Samples not complying with the coliform standard (% of total number of samples)	9-10	Petrosyan *et al.* 1998 Abakumov 1998
Acidification		Deposition of sulfur	The Arctic coastal zone and the North and the central part of West and East Siberia in 1999-2000: SO_4 in wet deposits av. 3-11 mg l^{-1}, av. deposition of S 0.8-0.9 g $m^{-2} \cdot yr^{-1}$.	4-5	Izrael *et al.* 2001

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Eutrophication	**C2. Obskaya Guba (Ob Bay) (continued)**	Concentrations of $O_{2diss.}$, nutrients, fish mortality.	$O_{2diss.}$ In the **Ob River basin** in 1996-97 average 9.5-10.0 mg l^{-1}. In winter minimum concentrations were detected in the **Irtysh and Tobol rivers** (down to 0.8 mg l^{-1}) and in the Ob River (2.1 mg l^{-1}). Groundwater from swamp watershed with low content of $O_{2diss.}$ / fish mortality. Underground water discharge $76x10^{12}$ l yr^{-1} (17.7 % of river discharge). Very high NH_4 0.03-2.6 mg l^{-1} (up to 5 MAC), NO_3 0-4.8 mg l^{-1}, NO_2 0-0.14 mg l^{-1}.	4-7	Anon. 2000 Gordeev *et al.* 1999
Radioactivity		Major sources of radioactivity located in the Ob River basin: the "Mayak" chemical enterprises (Ozersk town) (processing of nuclear fuel for atomic power stations and atomic submarines), Siberian group of chemical enterprises Tomsk-7 (Seversk town) (processing of U and Pu)	The **Ob River Bay** (bottom sediments): ^{137}Cs <10-50 Bq kg^{-1}, av. ≤ 10 Bq kg^{-1} The **Kara Sea**: sediments of the main part of the sea ^{137}Cs < 10 Bq kg^{-1}, high concentrations to north from the Yugorsky Peninsula, Novozemelskaya deep. "Yugorsky" spot: 1984 = 245 Bq kg^{-1}, 1993 - 95 = 27-31 Bq kg^{-1}: decreased by a factor of 7.	8-10 (South Ural) 5-6 (delta and sea)	Cocran & Norris 1993; Matishov *et al.* 1996; Aibulatov 2001a; Champ *et al.* 1994; Galimov *et al.* 1996
Sedimentation		In the Ob River basin there are 8 dams with total volume 75.2 km^3 of water	Influence of dams is not significant. Dredging works on bay-mouth bars of the Ob, Pur and Taz rivers. Total suspended matter discharge – $15.5x10^6$ t yr^{-1}, av. turbidity 37 mg l^{-1}. Anthropogenic decrease of water discharge (403 km^3 yr^{-1}) is less than 3 %.	5-6	Mikhailov 1997; Zalogin & Rodionov 1969; Holmes *et al* 2002

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**C3. Yenisey River and Yenisey Bay**	Heavy metals: low concentrations in water, suspended matter and bottom sediments of the Yenisey bay. There are few deeps with higher heavy metals concentrations due to natural processes.	**Yenisey Bay**: Water (µg l^{-1}): in 1989-1993 Cu 1.6, Zn 1.5, Pb 0.01, Ni 0.54, Hg 0.0003. Suspended matter (µg g^{-1}): Cu 144, Zn 220, Pb 30, Cd 2.2, Ni 75, Hg 0.05. Bottom sediments (µg g^{-1}): Cu 45, Zn 108, Pb 15, Cd 0.11, Ni 61, As 21. One deep in the Yenisey Bay (30 m, 3 ‰): O_{2diss} < 4 mg l^{-1}, pH - 7.3, H_2S traces, Cu 2.0, Zn 3.5, Pb 0.4, Cd 0.1 (this deep is a trap of organic matter, low exchange of water, flux of dissolved metals from interstitial waters).	2-3 (Bay)	Dai & Martin 1995; Kravtsov *et al.* 1994; Gordeev 2001; Loring *et al.* 1997
		The Norilsk mining-metallurgical complex (NMMC) is situated in the lower Yenisey River basin. Emission to the atmosphere were extremely high in 1960-70-s (up to 22.4x10^6 t yr^{-1}), in 1995 down to 1.95x10^6 t yr^{-1}.	Yenisey River (water, in MAC): 1997 — Cu, Zn, Fe Sayanogorsk (3013 km from sea) 3, 3, 1.5 Abakan (2887) 6, 3, 1.5 Divnogorsk (2500) 3, 4, 2 Krasnoyarsk (2480) 7, 4, 4 Igarka (711) 3, 2, 2 2003 Dudinka (435 km) Pb <1, Cd<1, Hg-1.7 Upper Yenisey River Cu-4-11, Zn-2-6 Krasnoyarsk (2480) Cu- max 25, Zn- max 34	6-7 (upper and middle reach)	Anon. 2000 Evseev 1996 Anon. 2005
			Soils in the **Norilsk area** (70-100 km from the source, µg g^{-1}): Cu 1400-1700, Ni 250-500, Pb 30, Cd 3-5 (up to 50 x background). Near the industrial zones up to 150-200 MAC.	10	Anon. 2000

Table 2.4 continued

Coastal Impact / Issue	Local site/Region (contrib. river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References / Data source
Pollution	**C3. Yenisey River and Yenisey Bay (continued)**	PH: similar situation to the Ob River (see above). In 2003 PH pollution decreased by a factor of 1.8 in comparison to the previous years.	**Yenisey River** (1975-93) (mg l^{-1}) Upper reach – av. 0.17-0.94, max 2.6 (52 MAC) middle reach – av. 0.37-0.50, max 1.2 (24 MAC) lower reach – av. 0.17-0.20, max 0.6 (12 MAC) (1996-97): Yenisey R. - 0-1.19 Angara R. - 0-0.84 Kacha R. - 0-0.64 **Whole Yenisey basin** - 0-1.42, av. 0.20 (4MAC) **Tebusey Bay** (bottom sediments, µg g^{-1}): < 1.19-149. **Yenisey Bay** (2003) (water, mg.l^{-1}): av.0.032 (max 1.2MAC) PAH: **Yenisey River, Dudinka**(2003) (water, ng.l^{-1}) S PAH=226-258 (bottom sediments, µg.g^{-1}) S PAH=56-71 Yenisey Bay (2003) (water, ng.l^{-1}) SPAH=29	8-10 (1975-1993) 3-5 (2003)	Dahle *et al.* 1997 Petrosyan *et al.* 1998 Anon. 2000, 2005. Anon. 2005
		POPs	**Yenisey River** (1991-95, water, ng l^{-1}): a- HCH - 0-14, ?- HCH - 2-12, DDT - 0, DDE - 0. Dudinka (2003): SHCH=0.21-0.36, DDT=0.29-0.41, CBz (Chlorinated benzene)=0.17-0.21, SPCB=0.93-1.54 (all below 1MAC) (bottom sediments, ng.g^{-1}): SHCH= <0.05-0.14, DDT=0.52-0.73, SPCB=1.66-1.92 **Yenisey Bay** (1992-95, bottom sediments, ng g^{-1}): ∑ HCH - 0.1-0.5 (water, ng.l^{-1}, 2003): a-HCH=0.75, ?-HCH=0.89, DDT=0.41, DDD=0.14, DDE=0.21, SPCB=3.1 (all below 1MAC) **Kara Sea shelf** (1992-95, bottom sediments, ng g^{-1}): ∑ HCH - 0.1-2.3. Phenols: **Yenisey River** (1975-93, ng l^{1}): middle reach - 0-12, av. 3.5. Dudinka (2003): 0.9-1.1 (max 1.1 MAC) (bottom sediments, µg.g^{-1}): 0.96-3.1	6-8 (1991-1995) 2-4 (2003)	Anon. 2004

Table 2.4 continued

Coastal Impact / Issue	Local site/Region (contrib. river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References / Data source
Pollution	**C3. Yenisey River and Yenisey Bay (continued)**	Microbial pollution	**Lower Tunguska River**: 0-25, av. 6 **Angara River**, mouth: 0-23, av. 6 **Irkutsk Reservoir**: 0-6, av. 1. **Yenisey River** basin (1996-97): 0-39, av. 1 (av. 1MAC). Samples not complying with the coliform standard (% of the total number of samples): 1991 1992 **Krasnoyarsk region** 13.9 12.3 **Irkutsk region** 5.0 33.9	4-5	Abakumov & Talayeva, 1998

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Eutrophica-tion	**C3. Yenisey River and Yenisey Bay (continued)**		O_{2diss} in the **Yenisey River** basin in 1996-97 was on average 10.5 mg l^{-1}, in the lower reach of the Yenisey River - min 6.17 mg l^{-1} (723 samples). **Lower reach of the Yenisey River** (1985-95) (µg l^{-1}): NO_2 - 3, NO_3 -41, PO_4 -13, P_{tot} -49.	2	Anon. 2000; Gordeev *et al.* 1996
Acidification			Riverine sulfate discharge $9.2x10^6$ t yr^{-1}, atmospheric input is 25 % of this discharge. **Norilsk area**: air - 0.3-0.5 mg S m^{-3} (damage to coniferous forest,10 backgrounds) (> 5MAC, up to 70MAC); Soils: 2-7 gS kg^{-1}, Snow: 30-40 mgS l^{-1}. Area of acidified atmospheric deposits near Norilsk – 400,000 km^2. S deposition in Norilsk city: 1999 - 16 gS $m^{-2}\cdot yr^{-1}$, 2000 - 15.6 gS $m^{-2}\cdot yr^{-1}$. Deposition of S and N in the NMMC area: Critical Loads CL ≥ 6 for S, CL ≥ 1.2 for N.	10	Moshiashvili 1992 Evseev 1996 Myach 1996
Radioactivity			**Yenisey Bay** (bottom sediments, Bq kg^{-1}): ^{137}Cs 50-70, max 100 in 1993 ^{60}Co 2-6.	5-6	Aibulatov 2001a; Matishov *et al.* 1994; Champ *et al.* 1994

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Water withdrawal	**C3. Yenisey River and Yenisey Bay (continued)**		Total loss of water in the **Yenisey River** in 1995 8.7 $km^3\ yr^{-1}$, consumption - 4.9 $km^3\ yr^{-1}$. Expected in 2025: 12 and 7 $km^3\ yr^{-1}$ accordinally, i.e. 1.2-2.0 % of river discharge.	1	Shiklomanov *et al.* 2000
Sedimenta-tion			Low activity of erosional processes in the basin, av. turbidity – 20 mg l^{-1}. There are 8 big dams in the Yenisey basin. After the Krasnoyarskaya dam construction (1967) sediment flux in Divnogorsk (just downstream of the dam) dropped from 6.3 to $0.2x10^6$ t yr^{-1}. Annual flux of sediment near the Yenisey mouth (Igarka) decreased from 13.2 to $4.7x10^6$ t yr^{-1}. In winter river water discharge increased 50-60 %, and during flood decreased 10 %.	2	Lisitzina 1974 Mikhailov 1997

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**D2. Khatanga River**	Heavy metals	**Water** (mid of 1980's-beginning of 90's)($\mu g\ l^{-1}$): Cu 0.2-15 (max 15MAC), Zn 1.1-18 (1.8 MAC), Pb 0.08-0.3, Cd 0.03-0.2, Ni 0.1-0.9 (<1MAC) In 2000 Fe, Cu, Ni exceeded 1.1-2 MAC in 18-24 % of samples analyzed (2003) Hg 0.027 (2.7MAC), Pb 3.2, Cd 0.047 (both <1MAC) Suspended matter ($\mu g\ g^{-1}$): Cu 82, Zn 104, Pb 12, Cd 0.22, Ni 84, Sn 1.6, As 9.3.	4-6	Melnikov and Gorshkov, 1999 Melnikov *et al.* 2001 Anon. 2004 Rachold 1999
		pH	**Khatanga Bay (2000)**: water- 40 $\mu g\ l^{-1}$ (0.8MAC) Settlement Khatanga: soils - PH 4-6MAC Khatanga River (2003): (water, $\mu g l^{-1}$) 5.9-47.9 (<1MAC) SPAH= 117-143 $ng.l^{-1}$ (bottom sediments, $\mu g.g^{-1}$) 10.8-18.9 SPAH= 128-140 $ng.g^{-1}$	5-7 (2000) 2-3 (2003)	Melnikov *et al.* 2001 Anon. 2004
		POPs	Khatanga River (2000, water) ∑ HCB - 6 $ng\ l^{-1}$ DDT - 3.6, PHB - 6.1 Phenols - 1.3 $\mu g\ l^{-1}$ (1.3 MAC). (2003, water,$ng.l^{-1}$) SHCH = 0.21-0.31, SDDT = 0.46-0.79, CBz =0.20-0.32, SPCB= 1.12-1.58 (all below 1MAC) (2003, bottom sediments, $ng.g^{-1}$) SDDT= 0.72-0.92, SPCB= 1.28-1.75, SHCH= 0.06-0.11	2-3	

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contrib. river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**D4. Lena River and Delta**	Heavy metals: Reliable data on concentrations in water and suspended matter in lower Lena River and its delta reveal that this river is among the most pristine great rivers pH	**Water** (μg l^{-1}): Cu - 0.8, Zn -0.4, Pb -0.04, Cd -0.006, Ni -0.3, Hg -0.001, As-0.15. **Suspended matter** (μg g^{-1}): Cu -28, Zn -140, Pb -24, Cd -0.6, Ni -34, As -9, Hg -0.12. **Bottom sediments** (μg g^{-1}): Cu - 8-19, Zn 56-108, Pb 12-19, Cd 0.03-0.13. **In upper and middle reaches** (from Peleduy to Zhigansk) high Fe, Cu and Zn concentrations detected in 1999 (up to 16 MAC for Cu and Zn and 38 MAC for Fe) (2003, in MAC): Kirensk Cu- 1-2, Olekminsk Cu-3-4, Zn-1 Yakutsk Cu<1, Mn<1 Jigansk Cu-4, Fe-2, Zn-2 Kiusiur Cu-4, Fe-3 **Lena River** (water, mg l^{-1}) (1975-1993) **Upper reach** 0-0.84, av. 0.02-0.12 **Mouth** 0-0.12, av. 0.04-0.06. **Lena delta** (1996-97): 0-2.30, av. 0.03 (0.6MAC) **Lena River basin**: 0-4.19, av. 0.05 (1MAC) **Port Tiksi**: 0.07 (1.4MAC) **Buor-Khaia Bay**: 0.10 (2MAC). (2003): Jigansk (765 km from the sea) -1MAC Kiusiur (320 km)- 2MAC St. Khabarova (111 km)- 2MAC	2 (delta) 3-5 (upper and middle reaches) 2-4	Martin *et al.* 1993; Gordeev 2001; Gordeev & Shevchenko 1995; Rachold *et al.* 1999 Anon. 2000, 2005 Anon. 2000, 2005

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contrib. river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**D4. Lena River and Delta**	POPs	**St. Khabarova** (111 km)- 2MAC **Lena River delta** (1993, ng l-1): ∑ HCB - 6.4 (1993) DDT - 0.01-2.7, av. 0.2; PCB - 1.8 **Buor-Khaya bay**: ∑ HCB - 0.9 (all < 1MAC). Bottom sediments of the **Laptev Sea** (ng g-1): DDT 0.1-0.45, av. 0.14; PCB 0.07 Phenols (water, μg l-1): (1975-1993) upper reach 0-15 av. < 1-2 mouth 0-13, av. 1-5 (1996-97) Lena delta: 0-36, av. 3 (up to 13 MAC) Lena basin: 0-58, av. 3 (max 116 MAC). 2003: Olekminsk- 2-3 MAC Yakutsk- 2 Jigansk- 2 Kiusiur- 3	2-4	Anon. 2005

Table 2.4 continued

Coastal Impact/Issue	**Local site/Region (contributing river basins)**	**Critical substances (for system functioning)****	**Distance to critical threshold (qualitative or quantitative)**	**Impact category**	**References/ Data source**
Acidification	**D4. Lena River and Delta (continued)**		Sulfur deposition (1999-2000): 0.2-0.4 gS m^{-2} yr^{-1}, nitrogen deposition: 0.15-0.30 gN m^{-2} yr^{-1} (< CL).	3-4	Izrael *et al.* 2001
Eutrophication			In 1996-97 in the **Lena River** waters O_{2diss} = 6.3-13.9, av. 9.5 mg l^{-1}; in the **Lena River** 0.90-16.5, av. 10.0 mg l^{-1}. Av. nutrient concentrations in the Lena delta (µg l^{-1}): NO_3 40, NH_4 40, PO_4 8, TOC 10.1 mg l^{-1}. C_{org}/N_{org} = 20-40 (main origin of OM in the river is terrestrial vegetation).	3-4	Gordeev *et al.* 1996 Cauwet & Sidorov 1996
Radioactivity			^{137}Cs in bottom sediments of the Laptev Sea - background level.	3-4	Matishov *et al.* 1994
Coastal erosion		Coastal erosion (CE) is very significant source of material to the sea	Thermal abrasion: mean rates of retreat - 2-6, av. 2.5 m yr^{-1}. Total mass of abrasion material along 2400 km of the **Laptev Sea** coastal zone is evaluated as $60x10^6$ t yr^{-1}. Riverine TSM discharge - $25.1x10^6$ t yr^{-1} (CE/Riv. TSM = 2.4).	6	Are 1980 Grigoriev 1996; Rachold *et al.* 2000
Sedimentation		Lena delta (32,000 km^2) is the biggest one in Russian Federation. Two dams are located in the upper reach of the Lena River (2,360 km^2, 40.4 km^3)	Av. concentration of river suspended matter - 34 mg l^{-1}, 7.1 t $km^{-2}\cdot yr^{-1}$ Influence of the dams on suspended sediments and water discharge in the lower Lena River course is not significant. During last 5,000-7,000 years the river fan has prograded 120-150 km. Dredging works in the Bykovskaya arm for navigation.	4-6	Mikhailov 1997; Korotaev *et al.*1998
Water withdrawal			Mid 1980s: av. $385x10^6$ m^3 yr^{-1}, i.e. 0.08-0.09 % of river discharge; 2000 - 310-330, 2010 - 570-635.	1	Magritsky, 2001

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)* *	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**D5. Yana River**	Heavy metals pH POPs	In 1997 discharge of untreated wastes to the **Yana River** (Nijneyansk) was 1200 m^3 yr^{-1}. Concentrations of dissolved Fe - max 18MAC, Zn - 9MAC (Verkhoyansk, middle reach) Suspended matter (µg g^{-1}): Cu - 30, Zn - 130, Pb - 23, Cd - 32, Ni - 39, As 27 (background level) (2003) Middle reach,St.Jubileinaya: Cu,Zn>1MAC in 77-100% of cases, Fe-max 20MAC **Yana River** (2003, water, mg.l^{-1}): >1 MAC in 77-100% of cases **Yana Bay** (mg l^{-1}): 0.04-0.07 (0.8-1.4MAC) Phenols (1997): up to 11MAC	5-7	Anon. 2000 Rachold 1999; Anon. 2000, 2005
Eutrophication			Multiannual average (µg l^{-1}): NO_3 -50, PO_4 -9, P_{tot} – 12		Gordeev *et al.* 1996
Sedimentation			Total suspended matter discharge - 4x10^6 t yr^{-1}, average turbidity 130 mg l^{-1}. From 1973 dredging works have removed an average 350,000 m^3 yr^{-1} of sedimented material (up to 600,000 m^3 yr^{-1}). Elevated turbidity is detected in 3-5 km zone and for a few hours. Negative result – intrusion of saline waters to the mouth of the **Glavnoe Gorlo** arm: 1) problems with freshwater supply in c. Nijneyansk; 2) destruction of vegetation.	6	Holmes *et al* 2002 Korotaev *et al.* 1998
Water withdrawal			Mid 1980s: 8x10^6 m^3 yr^{-1}, i.e. 0.02-0.03 % of river discharge	1	Magritsky 2001

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**E1.Indigirka River**	Heavy metals:	Multiannual dissolved concentrations (µg l^{-1}): Cu 0.7-2.6, Zn 0.6-8.2, Pb 0.16-0.20, Cd 0.06-0.14, Ni 0.5-0.9. Suspended matter and bottom sediment - no data.	3-5	Melnikov & Gorshkov, 1999
		pH:	Central part of the **East-Siberian Sea** (mg l^{-1}): 0.03-0.04 (1990-93); 0.03 (2000) Cheshskaya bay (v. Pevek) - 0.03 (<1MAC)	2-4	Lebedeva 2001; Izrael *et al.* 2001; Anon. 2000 Anon. 2005
		POPs	**East-Siberian Sea** (1990-1993) ∑ HCB - 1.4-1.8 ng l^{-1}, DDT - 0.5-1.0, PCB - 0.5-6.5 **Cheshskaya bay**: ∑ HCB - up to 5.3, DDT - up to 3.2. Phenols: 3MAC (50-100 % of samples). **Indigirka River** (2003): up to 12 MAC	4-6	
Euthrophi-cation			Multiannual average concentrations (µg l^{-1}): NO_3 - 50, PO_4 - 8, P_{tot} - 17.		Gordeev *et al.* 1996
Sedimentation			Total suspended matter discharge – 11.1x10^6 t yr^{-1}, av. Turbidity – 207 mg l^{-1}. Dredging works in the main stream. Intrusion of saline waters to the lower part of the Srednyay arm.		Mikhailov 1997; Holmes *et al* 2002
Erosion of the coastal zone			The rates of retreat due to thermal abrasion - 1-15 m yr^{-1} Please score (if possibl.) thermal abbrasion		Korotaev *et al.* 1998
Water withdrawal			In mid 1980s: 10x10^6 m^3 yr^{-1}, or 0.02-0.03 % of river discharge.	1	Magritsky 2001

Table 2.4 continued

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical substances (for system functioning)**	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	**E2 Kolyma River**	Heavy metals: pH POP's	Multiannual concentrations (µg l^{-1}): Cu 0.05-2.1, Zn 0.1-10.4, Pb 0.02-0.35, Cd 0.01-0.4, Ni 0.1-1.8. Suspended sediments (µg g^{-1}): Cu 100-1000, Zn 100-250, Pb 80-260, Cd 1-20, Ni 30-350. **Upper reach (Kolymskoe reservoir, 1997)** - Fe = 10 MAC, Cu = 10 MAC, Zn = 8 MAC. (2003): Cu,Fe, Pb,Mn- 3-10MAC **Kolymskoe reservoir** (1996-97): 0.0-1.38 mg l^{-1}, av. 0.15 (3 MAC max 15MAC) (2003): >1MAC in 50-100% of cases **Kolyma River** (Srednekansk, 2003): av.2, max 7 MAC **Chaunskaya bay**: 0.02-0.04, max 0.11 (2 MAC). Phenols (1996-97): 0.0-27, av. 2 µg.l^{-1} (2 MAC). (2003): 3-10MAC	5-7	Melnikov & Gorshkov,1999 Anon. 2000, 2005 Anon. 2000, 2005
Eutrophication			O_{2diss} in waters of the **Kolyma River**: 1996 - 1.17-13.4, av. 9.63 mg l^{-1} 1997 - 7.06-16.4, av. 11.3 mg l^{-1} 1984-94 (µg l^{-1}): NO_3 46, NH_4 63, PO_4 9.5, P_{tot} 14.	2-3	Anon. 2000; Gordeev *et al.* 1996
Sedimentation			**Kolyma delta** – 3250 km^2, 120 km length. total suspended sediment discharge - 10.1x10^6 yr^{-1}, av. Turbidity – 83 mg l^{-1}. Kolymskaya dam (1983): decrease of sediment discharge in Srednekolymsk - 5-10 %. Dredging works.		Gordeev *et al.*1996; Holmes *et al* 2002
Water withdrawal			In mid-1980s: 110x10^6 m^3 yr^{-1}, or 0.1 % of river discharge. In 1999 sharp reduction - 5x10^6 m^3 yr^{-1}, or 0.004 %.	1	Magritsky 2001

* Indexation of the subregions see in Figure 2.3;

** Accepted abbreviations: HMs- heavy metals, PH- petroleum hydrocarbons, PAHs- polyaromatic hydrocarbons, HCB- hexachlorobenzene, HCH- hexachlorocyclohexane (organochlorine insecticides, including the γ-HCH isomer, lindane), PCB's- polichlorinated biphenyles, DDT- organochlorine pesticides, POPs- persistent organic pollutants, DOC, POC and TOC- dissolved, particulate and total organic carbon, DOM, POM and TOM – dissolved, particulate and total organic matter, CS- coliform standard, CE- coastal erosion;

MAC- maximum allowed concentration: for HMs (in $\mu g\ l^{-1}$)- Hg-0.01, Cu-1, Cd-1, Zn-10, Ni-10, Mn-10, Pb-30, As-50, Fe-100 (figures behind chemical element symbols show the ratio of their actual concentration in water to their MAC values (or excess above MAC); MAC for PH-50$\mu g\ l^{-1}$,

HCB- 10 ng l^{-1} (for example: if the actual concentration of HCB in water is 25 ng l^{-1}, then its MAC is 2.5 (25/10) and so on)

IT-index of toxiticy, $IT=\Sigma_i\ C_i/MAC_i$ (ITcritical=1-2);

IR-index of ecological risk (IR critical = 300);

CL-critical load, it is the maximum flux of one or a few substance-pollutants entering an ecosystem yet without causing negative change in its most sensitive parts. (see Section 2.3.2 for more explanations).

As is shown in Table 2.4, the most significant coastal issues originate in industrial land and sea use, incl. mining, resulting in oil and radioactive pollution, acidification, and to a lesser degree eutrophication, erosion/sedimentation, biodiversity can be observed. These pressures have already caused measurable impact on some local and sub-regional coastal zones in the Russian North. Biodiversity information, however, which is an important indicator of ecosystem health, except for the White Sea subregion, is practically absent. The Driver/Pressure issues are dealt with in detail:

Pollution

The great remote region of the Arctic, which only recently was considered pristine, became an object of pollution impact during the last few decades from local and distant sources (Yablokov 1996; Gordeev 2002).

Among the most important pollutants in the Russian Arctic are heavy metals, oil products, sulfur and nitrogen oxides and organic micropollutants. Air-borne wastes produced by metallurgy smelters, cement plants and mining, strongly affect natural ecosystems within several industrial regions in the Kola Peninsula (B1), Arkhangelsk (A2), Vorkuta (B2) and Norilsk (C3) areas (Figure 2.3). The situation in the Norilsk region is especially serious, featuring a real hot spot of apassed threshold concentrations. Due to pollutants emitted by the Norilsk mining/metallurgical plant (NGMC), concentrations of some heavy metals in the soil and moss exceed the MAC by 150-200 times (soil Cu - 0.4 %, Ni - 0.4 %, Co - 0.02 %; moss Cu - 700-1400, Ni - 250-500 $\mu g\ g^{-1}$).
At the beginning of 90ies, the emission to the atmosphere from the NGMC ($22.4x10^6\ t\ y^{-1}$) has exceeded the total emission in the Russian federation in 2004 ($20.5x10^6\ t\ y^{-1}$). In 2004, emission has been reduced down to $2.068 \times 10^6\ t\ y^{-1}$. Total discharge of untreated and partially treated waste waters from the NGMC was $85.4 \times 10^6\ m^3$ in 2003.

In the Murmansk region (B1), the metallurgy smelters “Pechenganikel” (Monchegorsk) and “Severonikel” (Zapolyarnyi and Nikel) emit about 3000 t of Ni, 2000 t of Cu, 100 t of Co annually (Myach 1996).
In snow meltwater near Monchegorsk concentration of Cu was up to 2190 $\mu g\ l^{-1}$ (av. 555), Ni – 209-708 $\mu g\ l^{-1}$ (av. 258) (Caritat *et al.* 1998). In the water of Imandra Lake near the “Severonikel” smelter, concentrations of dissolved Ni were 180 $\mu g\ l^{-1}$ (18 MAC) in 1986 and 63 $\mu g\ l^{-1}$ (6 MAC) in 1996; Cu was 21 $\mu g\ l^{-1}$ (21MAC) in 1986 and in 1996 (Moiseenko 1997). In bottom sediments of Imandra Lake (Monche Bay) Ni and Cu contents exceed MAC by 80 and 25 times, respectively.

New, reliable data on dissolved heavy metals in the mouth areas of the Ob, Yenisey and Lena rivers, however, are much lower than previous figures (Martin *et al.* 1993; Dai and Martin 1995). According to these studies, the great Siberian rivers are among the most pristine big rivers in the world (the Lena River especially). Irrespective of this, in the upper and middle reaches of the rivers heavy metals concentrations may still be quite high (Shvartsev *et al.* 1999; Rachold 1999; Panin and Sibirkina 2000; Panin 2002; Gordeev *et al.* 2004 and others).

Mining leads to pollution over hundreds of sqare kilometres at a distance 30-100 km and more from the sources. The most typical example is the “Apatity” mining complex in the Kola Peninsula region. “Apatity” accumulates annually about $30x10^6$ t of waste ores and emits about $70x10^3$ t of dust. The maximum concentration of Sr in the air was 170 $ng\ m^{-3}$, i.e. 100 times above background level.

Rivers and lakes within gas and oil extraction regions (mainly in eastern European and north-western Siberia) are heavily polluted by crude oil: 3 to $10x10^6$ t of oil are spilled annually in 300 large (over 10,000 t) and 11,000 intermediate accidents from pipelines and oil extracting facilities (Yablokov 1996). One study (Bratsev 1989) has shown that one derrick emitted about 2 t of hydrocarbons and soot, 30 t of NO_2, 8 t of CO_2, 5 t of SO_2.

Oil pollution leads to significant change in the diversity of the local fauna. The number of species and quantity of birds in the territory of oil outputs decreased significantly in comparison with unpolluted areas: water-fowls have disappeared completely while the number of sinantropous species (following or adapted to human civilisation) increases.

Persistent organic pollutants (POPs) are among regularly detected substances in the water, sediments and biota of the Arctic region. The main contaminants of concern are: organochlorine pesticides (e.g. HCH) and their metabolites, industrial chemicals (PCBs), and anthropogenic and natural combustion products (dioxin/furans and PAHs). For example, in 1995-1997 recurrence (in %) exceeding 1MAC of phenol concentrations in waters of the North Dvina River basin was in the range 35-51 %, in the Ob River basin 44-46 %, in the Yenisey river basin 28-31%, and in the Lena River basin 61-72 %.

Acidification

Anthropogenic acidification of waters is occurring due to atmospheric deposition of sulfur dioxide and nitrogen oxides in the watershed areas. For anthropogenic acidification of surface waters, two factors are generally necessary: the occurrence of acid precipitation and the natural sensitivity of the land to acidification.

In the Murmansk region (B1), two metallurgic smelters “Pechenganikel” and “Severonickel” emit 86 % of sulfur dioxides (another 14 % comes from local power and wood-pulp and paper plants). At the same time the transboundary transfer of sulfur from Western Europe and even from the American continent is a significant source of sulfur import in the Russian Arctic.
The NGMC remains the most significant source of sulfur dioxide. In 2003 its emission to the atmosphere was $1.5x10^6$ t y^{-1} of sulfur dioxide, $120x10^3$ t y^{-1} of carbon oxide and $50x10^3$ t y^{-1} of nitrogen oxide.

Comprehensive studies of the pollution of the Kola Peninsula have been carried out by the Institute of Industrial Ecology Problems of the North (Kola Science Center, Russian Academy of Sciences). They determined the critical loads for sulfur deposition on the Kola Peninsula territory (Table 2.4). On broader scale, information on the rest of the Arctic zone apart from North Fennoscandia and the Kola Peninsula is too limited to draw reliable conclusions about the level of acidification in the Russian Arctic (Moiseenko 1997; Khublaryan and Moiseenko 2000).

Radioactive pollution

Sources of artificial radionuclides in the Russian Arctic Seas include the Novaya Zemlya nuclear weapon tests (1950s – 1960s), globaly transferred input from other tests, the Chernobyl accident, mining-chemical plants in Russia, radiochemical plants in western Europe, dumping of solid and liquid radioactive wastes in the Barents and the Kara seas, and the northern military marine and atomic icebreaker fleet “Atomflot” (Aibulatov 2001a). Located in the river basins, Russian chemical plants of the military-industrial complex are powerful sources of radioactive pollution of the seas. According to official data (Yablokov *et al*. 1993), 1100 Tbq (30,000 Ci) were transferred to the Arctic Ocean through the Ob and Yenisey rivers between 1961 and 1989. However, the general degree of water radioactive contamination of the Arctic seas differs little from background (~6 Bq l^{-1}), except for several localized areas. The input of the Ob and Yenisey liquid discharge is not significant at present.

The activity of ^{137}Cs for the Barents Sea bottom sediments generally does not exceed 10 Bq kg^{-1}. The anomalous high content of technogenic radionuclides is due to the vicinity of the southern Novaya Zemlya polygon (Chernaya Inlet and others). The distribution of artificial nuclides in the Kara Sea bottom sediments is irregular. High concentrations were detected in the Yenisey and Ob estuaries and in the Novozemelsky trench. The Yenisey and the Ob (less obvious) should be considered as arteries through which technogenic radionuclides reach the ocean water (Aibulatov 2001a). The fact that high ^{137}Cs concentrations have not been registered in the Novaya Zemlya coastal zone indicates that solid radioactive waste dumping has not yet influenced the contamination of the open Kara Sea. Obviously monitoring of the Ob and Yenisey estuaries is necessary.

Eutrophication

Eutrophication in the Arctic does not attract priority scientific attention. Despite the existence of anthropogenic drivers for excess nutrient supply the hydrological and biogeochemical system settings regulating water formation in the Arctic basin may actually prevent the development of eutrophication. Among those factors are a significant precipitation, good water exchange and a weak soil-vegetation cover (Moiseenko 1997).

Among those characteristic signals of eutrophication the following can be detected only locally, increasing nutrient concentrations, intensive algae bloom with prevailing blue-green and green phytoplankton species and subsequently decreasing concentrations of dissolved O_2. However, the periodicity of appearance of low dissolved O_2 (< 4 mg l^{-1}) in waters of big Arctic river basins is very low (Table 2.4).

Levels of nutrient concentrations in waters of rivers, lakes and reservoirs are important in regard to the eutrophication process. There are long series of nutrient data for many Arctic rivers in the Rosgidromet database. However, data for ammonium nitrogen are considered unreliable due to analytical problems (Holmes *et al*. 2000, 2001). But the very high NH_4 concentrations (in the Ob and Yenisey rivers especially) might be an indicator for eutrophication in these basins.
In general, eutrophication is significant in some small rivers and reservoirs but is not a real problem for the big Arctic rivers and their receiving water bodies as a whole.

Coastal geomorphology

Damming is seriously affecting the erosion - accretion equilibrium in the basins of some big Arctic rivers. The detailed consideration of the recent trends in sediment yields of the Arctic rivers shows that "changes in suspended sediment yields depend more on man's activity than on climate change" (Bobrovitskaya *et al*., 2003).
There are 13 dams and reservoirs in the Ob River basin (total volume 75.2 km^3), 8 dams and reservoirs in the Yenisey River basin (473.9 km^3), and a few dams with reservoirs in the Lena and Kolyma basins (Voropaev and Avakyan 1986). The most important changes in the suspended matter discharge have happened in the Yenisey basin. After construction of the Krasnoyarskaya dam and hydro-electric power station in 1967 (73.3 km^3), sediment discharge in Divnogorsk (just below the dam) dropped sharply from $6.3x10^6$ t yr^{-1} to $0.24x10^6$ t yr^{-1}, and in Igarka (few hundred km from the mouth) it decreased from $13.2x10^6$ to $4.7x10^6$ t yr^{-1} (turbidity was reduced from 24 mg l^{-1} to 10 mg l^{-1} (Mikhailov 1997)).

In the Ob River basin, the water and sediment fluxes at Salekhard show no statistically significant trends. After construction of the Novosibirskaya dam, the sediment discharge in Novosibirsk decreased from 14.0 to $5.1x10^6$ t yr^{-1}. However, observations in Belogorie (about 700 km upstream of Salekhard) demonstrated a positive trend from $19.2x10^6$ t yr^{-1} (1941-1964) to $28.4x10^6$ t yr^{-1} (1956-1990) due to a siginificant impact of human activity. Bobrovitskaya *et al*. (2003) consider that the main reason of stable regime of sediment flux at Salekhard is a wide flood plain downstream of Belogorie. A huge amount of sediments (about 59%) is deposited and exchange between river and the flood plain occurs. Insignificant changes were found in the Lena and Kolyma basins after construction of the dams in their basins. The river discharge for the Kolyma River at Ust-Srednekan for the period 1941-1988 shows no significant trend. At the same time, the sediment flux record shows clear evidence of increase – at least double since the mid-1960s (Walling and Fang, 2003). The increase from $1.9x10^6$ t yr^{-1} (1941-1964) to $3.7x10^6$ t yr^{-1} (1964-1988) may be explained by gold mining in the Kolyma river basin (Bobrovitskaya et. al. 2003).

In general, recent investigations have shown that the contribution of coastal erosion to the material budget of the Arctic coastal seas is significant. Are (1999) suggested that the amounts of sediments supplied to the Laptev Sea by rivers and shoreline erosion are at least of comparable order, maybe even that the coastal erosion input is likely to exceed the riverine one. The total mass of abrasion material along 2400 km of the Laptev Sea coastline was $60x10^6$ t yr^{-1} (Rachold *et al*. 2000). This is indeed 2.4 times the discharge of riverine suspended sediment in the Laptev Sea basin ($25.1x10^6$ t yr^{-1}; Gordeev 2000). This is a result of high erosion rates (2-6 m yr^{-1} retreat) due to high cliffs and seasonal ice melting. The opposite is taking place in the Canadian Beaufort Sea: riverine sediment discharge is $64.45x10^6$ t yr^{-1} and coastal erosion sediment input is only $5.6x10^6$ t yr^{-1} (erosion/ riverine ~ 0.09) (Macdonald *et al*. 1998). Significant abrasion was detected in the eastern White Sea coastal zone (13-17 m retreat), and in the East-Siberian Sea (4-30 m retreat; Aibulatov 2001b).
These pronounced regional differences in the riverine and coastal erosion sediment input have to be considered when establishing budgets of the Arctic seas. Recent publications (Brown *et al*. 2003; Grigoriev and Rachold, 2003; Rachold *et al*. 2003b) indicate that coastal erosion forms a major source not only of the sediment input but also of the the total organic carbon (TOC) input to the Arctic seas.
Figure 2.5 shows the comparison between riverine and coastal TOC input in the Arctic coastal basin. It has to be noted that that the data given in the figure are the best currently available estimates, but may include errors ranging from ca. 30 % for the Laptev and East Siberian seas to one order of magnitude for the other seas (Rachold *et al*. 2003a).

Biodiversity

Increasing pollution of the lakes, rivers and coastal zones of Arctic seas by oil products, heavy metals, pesticides and other pollutants leads to loss of biodiversity - reduction of biomass and change in structure of plankton community, loss of biomass and diversity of bottom fauna and especially loss of habitats and significant loss of fisheries.

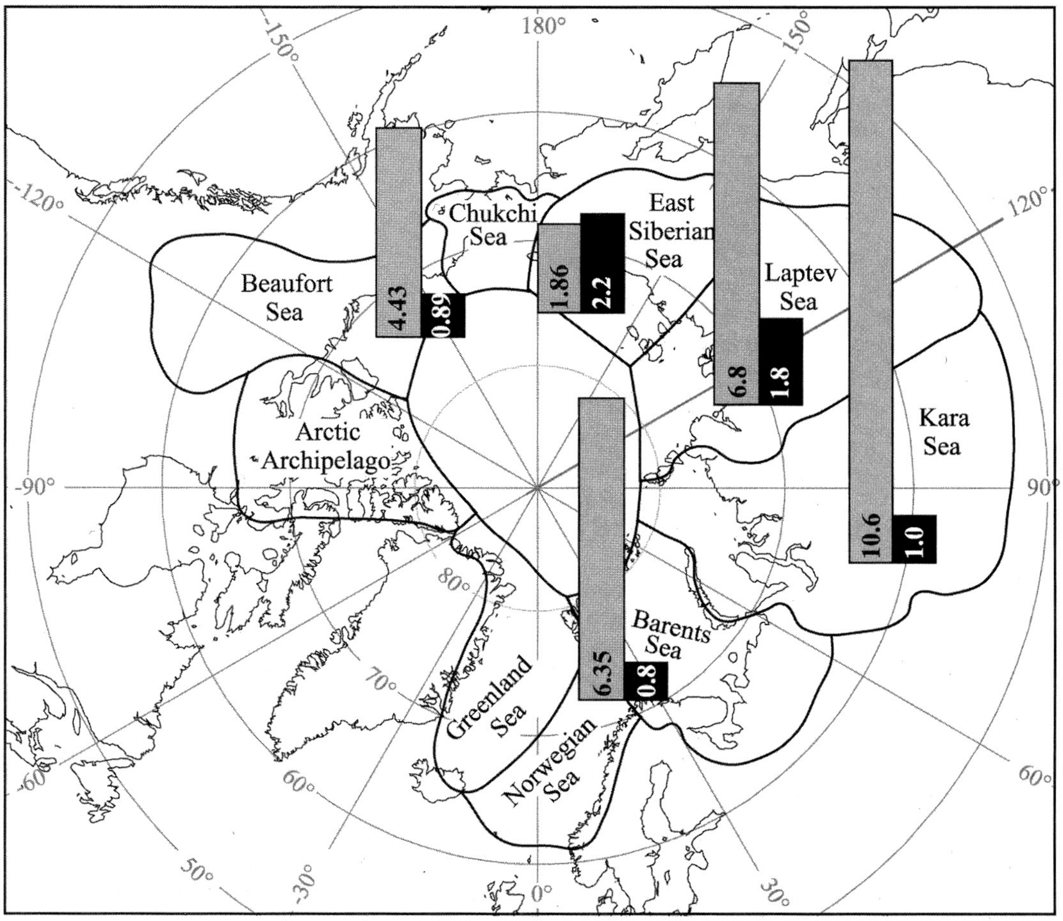

Figure 2.5: Riverine and coastal TOC fluxes to the Arctic Ocean (in mio. t C yr^{-1}). Gray bars refer to river input and black bars to coastal input. Note that the sum is shown for Beaufort and Chukchi Sea and that Barents Sea input data include the White Sea. (Rachold *et al* 2003a).

The White Sea and the Barents Sea were the richest in food-fish stocks. However, major exploitation of these resources occurred in the mid-20th century. The combination of overfishing and pollution led to sharp reductions in fish population and fish catches. In the North Dvina basin, catch volumes of salmon and Siberian White fish has dropped by a factor of 4 between 1985 and 1990 (Mokievsky 1996). In the Pechora basin reduction of fish catches by 3-4 times in the early 1990ies was due to industrial wastes floatage, dredging and oil pollution.

In the Ob River basin, fish catch was about 34,000 t at the end of the 1930s, 80,400 t in the mid-1940s, but by 1993 it was down to about 400 t yr^{-1} in the Ob mouth and bay and 14,500 t yr^{-1} in the Ob basin (Mokievsky 1996).

Fish catches in the Yenisey River basin are more or less stable, reducing 20 % from the 1940s to the 1990s. In the Lena basin the highest catch, 9960 t, was recorded in 1944; by 1964 in the lower Lena River it was down to 1,100 t yr^{-1}.

Significant decreases of fish populations results in reduction of numbers of birds, seals and walruses. Overfishing of capelin in the Barents Sea in the 1970s (3x10^6 t) resulted in degradation of seashore colonies of birds (Krasnov *et al.* 1995). In 1986-87, 90% of the Murmansk (Barents Sea) population of common guillemote and 50% of thick-billed guillemote have been lost. The problem of biodiversity preservation in the Arctic with its relatively low biota composition and extreme sensitivity of ecosystems to anthropogenic impacts is of high priority.

2.4 Driver/pressure state change relationships

A matrix of causes and effects (Table 2.5) provides an overview of the major drivers affecting drainage basins, the mechanisms whereby the resulting pressures affect the coast, the specific state changes and impacts observed, and timing of these. In principle the very long Arctic coastal zone in Russia is tectonically passive, although the boundary between the Eurasian and North American tectonic plates passes along the Lena River channel. Thus anthropogenic and climatic drivers of change dominate as compared to geotectonical incidents.

In the huge Arctic basin there are many small rivers inflowing to the coastal seas. However, due to the very low density of population, the overwhelming majority of them, with the exception of small rivers of the Kola Peninsula and probably of the White and Barents seas, are practically pristine and are not considered here.

Table 2.5. DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the Russian Arctic coastal zones *versus* catchment size class. Time scale: p - progressive, d - discrete.
State change dimension: major, medium, minor, no impact, insufficient information

Driver	Pressure	State change (qualitative index) Large basins (> 200,000 km^2)	Impact on the coastal system	Time scale
Industry including mining and oil/gas production	- Waste and heat effluent - Water extraction - Pollutant loads increase - Increase in sediment Transport	Major (also applicable for small catchment basin coast systems in the Kola Peninsula)	- Pollution (heavy metals, petroleum hydrocarbons, sulfur, POPs, heat) - Increasing anoxia - Loss of biodiversity	p
Navigation	- Waste influence - Increasing sediment transport due to dragging - Increasing demand for coastal engineering works	Medium	- Pollution - Sedimentation - Salinization	p
Damming	- Decreasing sediment transport - Changing seasonal water flow regime (decreasing spring flood and increasing winter runoff)	Medium	- Coastal erosion	d
Agriculture	- Waste/nutrient (excess of fertilizer) effluent - Water extraction - Increasing sediment transport	Minor	- Pollution with heavy metals and pesticides - Eutrophication - Increasing anoxia	p/d
Urbanization	- Increasing waste effluents - Increasing water extraction	Minor	- Pollution (heavy metals, organic, nutrients)	d/p

			- Eutrophication	

As shown earlier in Table 2.4, the small rivers of the Kola Peninsula (Kola, Tuloma, Patsa-Joki and others) are subject to high pressure by pollution and eutrophication due to effluent discharge from industrialization, urbanization and agriculture within their catchment areas.

The timing of changes in the coastal zone is another significant aspect of driver-pressure-state change relationships. With the exception of damming, all other environmental changes will be progressive in the coastal zone and will need to become subject of long-term monitoring to understand and manage effectively the Arctic coastal zone.

2.5 Assessment of impacts by land-based drivers

Land-based drivers and their related coastal impacts are considered and ranked according to relative scale categories. The ranking follows the LOICZ-Basins approach (Kremer *et al*. 2002, Hong *et al*., 2002), taking into account the present dimensions of impacts and their expected evolution based on existing data and expert judgement. In general, in the Russian Arctic, although of predominatly local and / or sub-regional scale, the most concerning coastal issues are caused by pollution originating mainly from industrialization and navigation, acidification, radioactive pollution and erosion. The latter can be attributed largely to climate change affecting the hydrological cycle, run off, ice-cover patterns and permafrost conditions. (Hassol, 2004)

2.5.1 Catchment scale synthesis

Pollution by petroleum products, heavy metals and organic micropollutants remains the most significant problem in the Russian Arctic. The economic recession of the 1990ies in the Russian Federation interrupted the further increase of pollution increase in the industrialized western Arctic, and at present there is a more or less stable situation in the Kola Peninsula, Arkhangelsk and other regions (Andreeva, 1998b). At the same time, however, we expect increasing activity of national and multinational oil, gas and coal companies in exploitation of and elevated output from numerous new deposits in the Arctic basin. Further development of all these activities will necessarily require extended infrastructure for land transport and growing navigation in the region. A significant increase of related pressure on the environment is anticipated.

Acidification is a major problem in some local areas of the Kola Peninsula, the Arkhangelsk region and the Norilsk region where the critical threshold has been passed. However, at present stabilization or even a decrease of sulfur deposition in these regions can be observed. At the large scale of the huge Arctic coastal zone territory the problem of acidification is of minor importance.

Technogenic radionuclide pollution of the Arctic environment remains among the most significant problems in the Russian Arctic. Maximum pollution took place in the 1960s-70s during and after the period of nuclear weapons tests. There are indications of a stabilization of the situation, but due to the long life span of many nuclides the problem will persist for some time in the future.

In the former Soviet Union many very large dams were constructed in Arctic river basins. However, significant influence of damming on the annual hydrological regime and suspended matter discharge was observed only in the Yenisey River. For example, after construction of the Krasnoyarskaya dam (1967) suspended matter discharge decreased by a factor of 2-3 during the subsequent few years.

Water withdrawal is not a problem in the Arctic due to very high volumes of river water discharges and relatively low regional consumption of freshwater. Even looking to the future (2025+) the total water withdrawal in Arctic river basins for industry, agriculture, public services and other uses, together with water loss by evaporation from reservoirs, would linkely not exceed 1-2 % of the river runoff.

A synthesis of river-monitoring data reveals that the average annual discharge of fresh water from the six largest Eurasian rivers (N.Dvina, Ob, Yenisey, Lena, Kolyma, Pechora) to the Arctic Ocean increased by 7 % from 1936 to 1999. The average annual rate of increase was 2.0 ± 0.7 km^3 yr^{-1}. Consequently, average annual discharge from the six rivers is now about 128 km^3 yr^{-1} higher than it was when routine measurements of discharge began. Discharge was correlated with changes in both the North Atlantic Oscillation and global mean surface air temperature. The observed large-scale change in freshwater flux has potentially important implications for ocean circulation and climate (Peterson *et al*. 2002)
In a recent paper (Gordeev, 2006) the attempt was made to estimate the sediment flux increase over the next 100 years. A stochastic model for the simulation of sediment discharge (Morehead *et al*., 2003) predicts that there will be a 30% increase in sediment load for every 2 $^{\circ}$C of warming in the drainage basin and a 20% increase in water discharge will result in a 10% increase in sediment transport. The Intergovernmental Panel on Climate Change (IPCC, 2001) projects a global surface air temperature increase between 1.4 and 5.8 $^{\circ}$C by 2100. Peterson *et al*. (2002) consider that, on this basis, the discharge of the six largest Eurasian arctic rivers would increase by 18-70 % by 2100 which would mean that the sediment flux of these six rivers would increase from 30 to 122 % by 2100.

The ranked importance of impacts on coastal areas by basin activity and their trend expectations are given in Table 2.6.

Table 2.6. The link between coastal issues/impacts and land based drivers in the Russian Arctic - coastal zone - Overview and qualitative ranking on local, catchment or sub-regional scale:
Category: 1 = low; 10 = high. (1= no impact, 10= very serious impact.) Trends: ⇒ = stable, ⇑ = increasing, ⇓ = decreasing.

Coastal impact/issue	Drivers	Local catchment		Trend expectations	Reference/Data sources
		River	Category		
Pollution	Industrialization	A2*. North Dvina R. B1. Small rivers of the Kola Peninsula (Kola, Tuloma, Pechenga and other) B2. Pechora R. C2. Ob R. and bay C3. Yenisey R. and Bay C3. Yenisey basin (Norilsk area) D4. Lena R. and delta	9 8-10 8-9 4-6 4-6 10 3-5	⇑ ⇑ ⇑ ⇒ ⇒ ⇒ ⇒	Yablokov 1996 Matishov *et al* 1996; Moiseenko 1997 Lukin *et al*. 2000 Izrael *et al*. 2001; Dai and Martin 1995 Izrael *et al*. 2001; Gordeev 1997 Yablokov 1996 Anon. 2000; Martin *et al*. 1993
	Navigation	A2. North Dvina R. B2. Pechora R. D4. Lena R. D5. Yana R. All other local sites	6 5 3 4 2	⇑ ⇑ ⇑ ⇑ ⇑	Samoilov 1952; Zalogin and Rodionov 1969; Mikhailov 1997
	Urbanization	A2. North Dvina R.	8-9	⇑	Yablokov 1996
Acidification	Industrialisation	A2. North Dvina R. (Arkhangelsk) B1. Kola Peninsula (industrial centers – Monchegorsk, Apatity, Nikel) C3. Yenisey R. basin (Norilsk)	8-9 9-10 10	⇒ ⇒ ⇒	Yablokov 2001 Moiseenko 2003; Izrael *et ai* 2001 Yablokov 2001

Table 2.6 continued

Coastal impact/issue	Drivers	Local catchment		Trend expectations	Reference/Data sources
		River	Category		
Radionuclides pollution	Nuclear-power engineering, nuclear industry, NAVY	B1. Kola bay (NAVY bases, places of nuclear spent fuel storage, ship- repairing and ship-building plants)	7-8	⇒	Matishov *et al.* 1996; Aibulatov 2001a
		Guba Chernaya (Black Bay), south of the Novaya Zemlya Islands	10	⇒	
		C3. Yenisey Bay	5-6	⇒	Sapojhnikov *et al.* 1995; Galimov *et al.* 1996
Erosion	Damming	C3. Yenisey R. E2. Kolyma R.	2 1	⇒	Mikhailov 1997 Magritsky 2001
	Thermoabrasion	Laptev Sea coastal zone	6	n.o.	Rachold *et al.* 2000
Sedimentation	Navigation	All sub-regions	2-3	⇑	Mikhailov 1997

* Indexation of the subregions refer to Figure 2.3

2.5.2 Sub-regional and regional scale

The administrative regions of the Russian Federation correlate closely with large water basins. This allows to make a sub-regional division relevant to the Arctic seas and to assess the situation of management response in the framework of existsing administrative borders of the Russian Federation (Figure 2.3).

A The White Sea sub-region
A1 The Onega River catchment basin
A2 The North (Severnaya) Dvina River catchment basin
A3 The Mezen and Kuloy River catchment basin

B The Barents Sea sub-region
B1 The Kolsky peninsula coast
B2 The Pechora River catchment basin

C The Kara Sea sub-region
C1 The Yamal peninsula coast
C2 The Ob River catchment basin
C3 The Yenisey River catchment basin

D The Laptev Sea sub-region
D1 The Taymyr peninsula coast
D2 The Khatanga River catchment basin
D3 The Olenek River catchment basin
D4 The Lena River catchment basin
D5 The Yana River catchment basin

E The East Siberian Sea sub-region
E1 The Indigirka River catchment basin
E2 The Kolyma River catchment basin

F The Chuckchee Sea sub-region
F1 The Chuckchee Sea coast

The White Sea sub-region (*A in Figure 2.3*)

Arkhangelsk region

This region includes the basin of the Severnaya Dvina River and the coastal area of the White Sea. The area is situated in an intermediate position between the crystalline Baltic shield and the flat Russian platform. Ecologically the White Sea is subdivided into two large parts – the eastern part, practically clean, washed by tidal waters with strong destructive processes on coasts due to marine abrasion, and the western part or internal basin of the sea with bays where natural conditions are favorable for accumulation of pollutants. The main resources of the sub-region are forests, fish and river-marine transport routes (Figure 2.6). Exploitation of these resources, particularly chemical processing of timber and dumping of poorly treated polluted waters into natural water systems create the main environmental problems and anthropogenic impacts on coastal zone. The sources of pollution are located on adjacent land areas - timber industry, pulp and paper industry, communal and local industry sewage waters. The local fleet is also an important source of polluted waters. All main sources of pollution are located on the coastal zone of the western part of the sea, in the Dvinsk Bay, Onega Bay, and to a lesser extent on the Karelian part of the Kola Peninsula, while the eastern and northern parts of the sea are practically clean. However, the eastern part of the White Sea is under strong impact of marine abrasion. The rates of coastal destruction may reach 13-17 m in a year on the Tersky coast (eastern Kola Peninsula) and the Kaninsky coast. As a result about $60x10^6$ tonnes of sediments come to that part of the sea, mainly aleurit and pelit fractions.

Figure 2.6: Arkhangelsk port, North Dvina river (courtesy: V.P. Shevchenko)

As part of a systematic assessment of surface water quality in Russia, hydrochemical observations are carried out by Rosgidromet against 35 water objectives at 53 points in the catchment of the Severnaya Dvina River. The main source of pollution in the region are the pulp and paper mills "Arkhangelskiy CBK", c.Novodvinsk, "Kotlasskiy CBK", c.Koryazhma, "Solombalskiy CBK", c.Arkhangelsk and the enterprises of timber and woodworking industry, and also the heat-power stations and housing and communal services. Total emission to the atmosphere in 2000 was about $268x10^3$ t y^{-1} and in the following years the situation was practically not changed (Table 2.7). The discharge of the untreated and partially treated waste waters (65-70 % of total waste water discharge) has been sligthly reduced. Typical for the North Dvina pollutants are lignosulphates, phenols, petroleum products, Al, Fe, and Cu in river water and soils.

One of the main ecological problems of the Arkhangelsk region is the situation of the nuclear and radiation-dangerous objects such as the Northern Military Marine with its numerous bases and ship repair facilities and civil atomic fleet "Atomflot". A specific problem is the ecological rehabilitation of the "fields of falls" of the separated parts of the rocket-carriers and its fuel at the realization of the rocket-cosmic activity on the cosmodrom “Plesetsk”. The residents of coastal communities combine marine hunting and fishing with coastal fishing. For these people, the state of the marine ecosystems plays a crucial role in their life support system (fish is a main source of protein) and the possibility to work in their traditional economy. Apart from industrial sites in urban areas, there are numerous rural communities involved in coastal fisheries. Their activity has strict rules and centuries-old traditions. Now commercial fisheries and industrial development impact these subsistence users of biological resources, and local communities face the problem of how to maintain and protect their traditional economy: through illegal catch or self-management of natural resources (Cetlin 2000).

Table 2.7 Annual emission to the atmosphere (in 10^3 t y^{-1}) and discharges of untreated or partially treated waste waters to the water bodies (in 10^6 m^3 y^{-1}) in the administrative regions of the Russian Federation (Anon. 2001-2005)

Territory	2000	2001	2002	2003	2004
White Sea/Barents Sea sub-region					
Arkhangelsk region:					
- emission to atmosphere	268	278	261	259	272
- waste water discharge	540	537	513	477	454
Murmansk region:					
- emission to atmosphere	373	367	334	316	315
- waste water discharge	429	370	366	339	374
Kara Sea sub-region					
Nenets Autonomous Okrug:					
- emission to atmosphere	21.9	17.8	15.1	36.8	63.0
- waste water discharge	1.1	1.0	1.0	1.2	1.2
Khanty-Mansi Autonomous Okrug:					
- emission to atmosphere	1160	1730	2550	2440	2970
- waste water discharge		483	318	510	635
Yamal-Nenets Autonomous Okrug:					
- emission to atmosphere	576	587	725	914	1088
- waste water discharge	27.7	33.2	33.1	31.9	32.5
Taymyr (Dolgano-Nenets) Autonomous Okrug:					
- emission to atmosphere[1]	16.0	12.4	12.1	14.7	15.1
- waste water discharge	95.8	95.9	94.1	93.3	96.8
Laptev Sea sub-region					
Republic of Sakha-Yakutia:					
- emission to atmosphere	134	130	131	134	154
- waste water discharge	85.3	86.8	82.9	86.5	79.2
Chuckchee Sea sub-region					
Chuckotsky Autonomous Okrug:					
- emission to atmosphere	35.5	31.9	28.4	38.2	38.1
- waste water discharge	5.3	5.2	5.7	4.4	4.8

1) emission from the Norilsk mining-metallurgical complex is not included.

The approach to resource management for sustainable development is a key mechanism in the international program “Complex Studies of the White Sea”, launched in 2000 as a sub-project of LOIRA (Land-Ocean Interaction in the Russian Arctic). The White Sea is a shelf water body situated in the subpolar physico-geographical zone of the northern European part of Russia. In spite of the large extent of this water body lying to the south of the Arctic Circle, the White Sea belongs to the arctic-boreal category of seas due to peculiarities of its climate, hydrology, flora and fauna (Berger *et. al*., 2001). The system approach uses, for a comprehensive study of the White Sea ecosystem functions (Lisitzin *et al*., 2003), investigations of the whole system of oceanology (physics, chemistry, biology and geology) in their dynamics and interaction in space and time (four-dimensional approach). Beginning in 2000, more than 30 expeditions on the R/Vs "Professor Shtokman", "Ivan Petrov", Professor Vladimir Kuznetsov", "Kartesh", "Ecolog" and other smaller ships were conducted.

The Barents Sea sub-region (*B in Figure 2.3*)

Murmansk Region

In the far north-western part of the Russian coastal zone, washed by the Barents Sea, lies the Murmansk region. It has 1730 km of diversified coastline with numerous fiords and bays. Geologically it consists of a Baltic crystalline shield with radial tectonic breaks. The Kola Fiord is the largest, with water depths up to 300 m. The Kola River enters the Kola Fiord and, together with other rivers of the Kola Peninsula (including the Patso-Yoki, Zapadnaya Litsa, Tuloma, Vorjema, Pechenga) - brings only 10 % of the total sediment load to the Barents Sea. Anthropogenic impact of Kola Peninsula industry on the environment is the highest in the Russian North. It is associated with mining and manufacturing industry complexes that were the pioneers of the industrial era in Soviet times. Now the work of these enterprises is assessed as "non-effective development with wrong management methods" (unplanned intensification, ignoring largely the principles of sustainability and nature conservation; Matishov *et al*. 1996). Coastal areas of the Murmansk Region have strong impacts from industrial development, transport facilities and commercial fisheries. During the 1990s the area received a new stimulus for industrial development: ten oil and gas fields were discovered in the Barents Sea in hydrocarbon-rich structures at different depths in both ice-covered and ice-free conditions. Without doubt this region may be considered as a first "hot spot" in the Russian arctic coastal zone in terms of anticipated grwoing pressures due to intense growth of land and sea use (Figure 2.7).

Figure 2.7: Oil base at Varandey, Barents Sea (courtesy: S.A. Ogorodov)

Biologically the Barents Sea is the richest part of the Arctic Ocean. All forms of life are supported by advection of the warm Gulf Stream water masses. Meeting with cold Arctic masses they create diversified favorable conditions for numerous biological cycles. Together with the key role played by floor relief the southern (coastal) part of the sea, the year-round ice-free conditions are favorable for bioproduction. The Barents Sea provides 10 % of the world's catch of marine fish (cod, haddock, perch, etc). During recent years, this region has also received great attention for development of non-traditional fisheries (scallop, *Laminar saccarina*, sea cucumber, king crab). (Matishov *et al*. 1996).

The Federal Service of Russia for Hydrometeorology and Monitoring of the Environment (Rosgidromet) is conducting annual monitoring of the terrestrial water quality. The results are published in annual reports. In the Murmansk region, 38 water bodies are included in a permanent net of observations. Along with rivers strongly impacted by mining, chemical, metallurgical and timber industries, other rivers which experience little anthropogenic impact are also taken into assessment. Some natural ecosystems show loads of Cu, Fe and phenols beyond the maximum allowable concentrations (MAC), which originate from natural sources.
The total emission to the atmosphere in the Murmansk region including the Kola Peninsula has been slightly reduced in the period from 2000 to 2004 (from $373x10^3$ t y^{-1} to $315x10^3$ t y^{-1}, Table 2.7). About 80-85 % of this volume was treated (catched and rendered). The same trend is observed for the discharges of untreated and partially treated waste waters – from 429 to 374 x 10^6 m^3 y^{-1} (60 - 75 % of total waste water discharge).
The gross output of the Murmansk region was increased by 31 %, the industrial output by 24 % during the last three years. A slight decrease of the anthropogenic impact on the environment during an increase of gross and industrial output testifies positive results for the ecological policy of the local administration.
A specific feature of the region is the existence of many sources of nuclear danger. These are the Central Nuclear Polygon on the archipelago Novaya Zemlya, the Northern Military Marine and its bases, solid and liquid radioactive waste dumping in the Barents Sea, atomic submarine construction and maintenance facilities and Atomflot (atomic fleet) of the Murmansk Shipping Company. In 2003, around $1x10^6$ Ci of radioactive wastes were accumulated in the region.

Kola Peninsula
The best-investigated area of the Russian coastal zone is undoubtedly the Kola Peninsula. This area is the most industrially developed and populated in the Russian North. Around 60 % of the region's population, which is 90 % of the urban population, are concentrated in the coastal zone. There is also an active scientific center – the Kola Science Center of the Russian Academy of Sciences. This center includes such famous research institutes as the Murmansk Marine Biological Institute, the Institute of Industrial Ecological Problems, the Institute of Economical problems and the Knipovich Polar Research Institute of Marine Fisheries. The center has good cooperative links with research institutes in Scandinavian countries. During recent years the Russian institutes carried out several large programs of comprehensive studies aimed at the functions of natural ecosystems and processes of the Kola Peninsula, and anthropogenic impacts connected with the mining industry. One of the results is the "Ecological Atlas of the Murmansk region" (Apatity 1999). The detrimental impacts of industrial enterprises located in such places as Apatity, Nickel, Monchegorsk and Murmansk created many environmental problems not only for the Murmansk region, but also for neighbouring countries – Norway, Finland and Sweden. The joint programs are aimed at radical changes to the environmental situation on the Kola Peninsula. All these countries, including northern regions of Russia, are members of a new international organization "Barents-Region" which elaborated long term research programs where ecological issues are of first priority.

In order to protect the region's natural resource base and fragile ecosystem and to improve socio-economic conditions, one such program was initiated by United Nations Development Program (UNDP)-Capacity 21. The main goal of the "Murmansk Region-Barents Sea Sustainable Development Project" was to strengthen the capacity of institutions to effectively plan and implement environmentally sustainable economic development policies and programs. The first stage of this work had been finished in 2000 and now another part of the "Barents-Region" – Nenets autonomous okrug (NAO) – is the subject of the sustainable development program. It will be represented in more detail below.

The Kara Sea sub-region (*C in Figure 2.3*)

The Nenets Autonomous Okrug

The south-eastern part of the Barents Sea has its own name – Pechora Bay, or the Pechora Sea, from the associated river. The Pechora River is the largest river of the lowland north-eastern part of Russia. Its water runoff to the Barents Sea is 130 km^3 y^{-1} or 80 % of all river runoff. The lowland is a deep sedimentary basin covered by thick layer deposits of complex marine and continental origin. The rivers are all young, having attained their present flow features after the end of the last glaciation (Lavrinenko *et al*. 2000). Two macro-scale relief zones may be distinguished: South of 67 ° N, the landscape has a gentle topography, extended swamps and occasional lakes, while to the north, glacial landscapes dominate – ice-pushed ridges, hill and trough pairs, kames and hummocks, and numerous dissected lakes (Astakhov 1994).

The region's unique natural landscape complexes are determined by the Pechora River and by the geological history of the territory. Although this is a tundra zone, there are relict islands of boreal forests, at the extreme northern boundary of their distribution. Many water-bird species wintering in Western Europe breed in this area, and the major spawning route of Atlantic Salmon passes through here. All this contributes to the profound biodiversity of the Pechora catchment basin, with Siberian and European faunal aspects (Lavrinenko *et al*. 2000).

Anthropogenic pollution of the Pechora catchment basin began in the mid-1950ies. It was driven by the industrial development of the Komi Republic, located to the south of the Nenets Autonomous Okrug (NAO). More than two-thirds of the economic potential of the Komi Republic is situated in the Pechora River basin, so that industry and domestic as well as agricultural use of floodplains are the main driving forces in changing the natural environment. All types of oil industry, from exploitation of fields to chemical processing of oil and gas, produce heavy impacts though chronic environmental pollution and emergency emissions of petroleum, as well as by oil products and heavy metals (Andreeva 1998c). Regular release of non-treated communal wastes and domestic sewage exacerbate the situation.

Particularly the tributaries of the Pechora River – Izhma, Ukhta, Vorkuta, Nibel, Voy-Vozh, Yarega and Kharjaga – appear to be heavily impacted by industrial pollution. Among them are the two big coal-mining centers of Vorkuta and Inta. A specific feature of pollution of river waters in coal mining areas is the input of large volumes of cleared and polluted mine-water, resulting in high levels of mineralisation, a prevalence of chloride and sulfate, and significant loads of suspended matter, phenols, petroleum hydrocarbons and heavy metals. Already in the 1960ies some tributaries had lost their economic "service" category as high fish-producing rivers (Andreeva *et al*. 2003).

The expansion of oil exploration and drilling activities not only in the Komi Republic but also to the north, in the Nenets autonomous region, in the 1980ies-90ies generated increasing anthropogenic impact. In the northern part of Timan-Pechora oil-gas province, 82 oil and natural gas fields have been discovered, of which five are under exploitation. A significant number of coastal and marine oil fields will soon be accessed for further exploration and development.

Extraction of oil in the Nenets AO has increased from 3.4 in 1998 to $12x10^6$ t y^{-1} in 2005. The emission of pollutants to the atmosphere increased from 21.9 x 10^3 t y^{-1} in 2000 to 63 x 10^3 t y^{-1} in 2004, and practically all this additional volume of emission was connected with oil extraction. Sharp change for the worse is expected in the nearest future when many new deposits will be developed, especially the Shtokmanovskoe gas deposit in the Pechora Sea (stock ~$2.8x10^{12}$ m^3 of gas) and the Prirazlomnoe oil deposit (60 km from the shore in the Pechora Bay – stock ~100 x 10^6 t).

The upper Pechora River (western slopes of the Ural Mountains) is not navigable for shipping, but the middle and lower reaches of the river are intensively used for transport of people and cargo as this area has no ground transport infrastructure. River transport routes are mainly used during warm seasons. The small vessels used are a major source of water pollution. For many decades timber rafting was common in the Pechora River basin and this changed the natural chemistry of the aquatic ecosystems. The catchment basin also gathers wastes from agriculture, such as pesticides and excess fertilizers used in large quantities on these poor northern lands. Among all polluting agents, however, the most important ones are contaminants such as phenols, hydrocarbons, Zn, Cu and pesticides. Concentrations may exceed maximum allowed concentrations by manyfold (Lukin *et al.* 2000).

The lower part of the river and the delta are very slow-flowing. As a result, all pollutants from upper streams accumulate in bottom sediments. Thus, water and sediment samples of the mouth and coastal areas show maximum pollution levels. In the first instance, observed effects are on fish resources in several parts of the catchment. The delta is occupied by typical boreal species of the Arctic plain (Roach *Rutilus rutilus*, Ide *Leuciscus idus*, Crician Carp *Carassius auratus gibelio*, Perch *Perca Flavescens*, Pike *Esox lucius*, Stickleback *Gasterosteus aculeatus*), while the brackish Pechorskaya Bay and other bays with salt water inlets are the habitat of estuarine species typical for the marine Arctic ecosystems such as navaga, four-horned bullhead, Arctic flounder and several species of salmoniform fish: Atlantic salmon (*Salmo salar*), Arctic salmon (*Savelinus alpinus*), Lake salmon (*Salmo solar sebago*). The anadromous Atlantic salmon has its feeding ground at sea entering upper catchment regions during the spawning migration; Siberian White Salmon (*Stenodus leucichtys nelma)* uses estuaries and bays for feeding before migration.

The Pechora region is now the second most important economic area in the Russian North. This area is open to the southeastern part of the Barents Sea and is part of the Barents Region Organization area. Due to its richness in natural oil and gas resources and its close vicinity to European markets, this area has attracted various industries. In accordance with industrial development plans to 2010-2020, this area will face a transition to the second largest oil and gas producer following Western Siberia. Naturally such large-scale development is likely to result in increasing pressure on and negative changes of ecosystems and their natural resources which often carry traditional forms of regional economy. It is anticipated that the coastal and shelf areas of Pechora Bay will be the first places in Russia where new technology for exploitation of oil fields and pipeline-construction in the Arctic Sea will be applied. Already nowadays the shelf areas accommodate considerable amounts of oil tanker traffic as well as large-scale constructions of terminals in offshore and onshore locations.

It is highly recommendable to conduct a comprehensive investigation of Pechora Bay and adjacent areas prior to the onset of such a large-scale economic developments and which have potential to turn the coastal areas of the Pechora Sea into a new “hot spot” in the Russian Arctic. Previous discrete studies have been considerably augmented by the results of the Russian-Dutch project “Pechora Delta. Structure and Dynamics of Pechora Delta ecosystems” (1995-1999), carried out by the Institute of Biology (Syctyvcar, Komi Republic) and RIZA, Institute for Inland Water Management and Waste Water Treatment (Ministry of Transport, Public Works and Water Management, Lelystad, The Netherlands). Later in 2000 a new project was launched: “Sustainable Development of the Pechora Region in a Changing Environment and Society” (SPICE, 2000-2003). Scientists from Russia, Finland and Great Britain conducted this multidisciplinary research project. One of the aims of the study was to investigate the distribution, transport and effects of pollutants on terrestrial, freshwater, deltas and coastal environments.

Western Siberia (Tymen region, Khanty-Mansi and Yamal-Nenets Autonomous okrugs)
Some of the largest rivers of Russia, Ob, Pur, Taz, Yenisey and Pjasina, discharge into the Kara Sea. Together they form one of the most complex delta-estuarine areas in the world, with a combined area of more than 55,000 km^2. These rivers contribute 41% of the total Arctic Ocean’s river runoff, or 56 % of the Siberian sector of the Arctic Ocean. The Ob River alone contributes 27 % of the runoff to the Kara Sea, equalling 1480 km^3 per year. The construction of dams on the Ob River had no significant impact on the volume of river flow, decreasing it by only less than 3 %.

The geological history of Western Siberia includes several marine transgressions and regressions that brought about accumulation of huge volumes of organic and organic-mineral sediments. Poor drainage of the plain and the numerous lakes and rivers further contribute to the extremely wet character of the region. Concentrations of pollutants are due not only to the volume of wastes but also to the unfavorable hydrological regime. Soils for example have a strong impact on the chemical regime of the Ob River. Widespread bogs and marshes are typical for the whole region; they become increasingly massive from north to south because of the growing thickness of the underlying permafrost in high latitudes. In the far northern part of the river catchment, permafrost thickness can reach more than 100 m in coastal areas, but close to river channels it has a discrete character. Geomorphologically, Western Siberia is one of the greatest plains of the world, with clear latitudinal zonal differentiation of landscapes from steppes in the south to subarctic tundra in the north.

The catchment basin of the Ob River gathers water from the territories of seven administrative regions of Russia, which form the Western Siberia macro-region with a population 16.74 million people (Municipal Russia 2000). The Yamal-Nenets Autonomous Okrug, the northernmost region, opens to the Kara Sea where the Ob River enters the Obskaya Guba (Ob Bay). The river basin is highly industrialized, with oil and gas activities dominating. The central and southern regions of Western Siberia contain a diversity of industry, including materials processing, coal-mining, agriculture, transport, building materials manufacture, pipeline construction and military enterprises. The process of pollution starts upstream in the Altay region and continues along the whole length of the Ob River to the Kara Sea. The central part of the basin (corresponding to the Khanty-Mansi Autonomous Okrug) is a major oil producer (around $170x10^6$ t oil and $18x10^9$ m^3 of natural gas per year). The northern part, the Yamal-Nenets Autonomous Okrug, is a major producer of natural gas ($535x10^9$ m^3 of natural gas and $30x10^6$ t of oil per year. The oil industry continues to increase its output while a few gigantic fields of natural gas are ready for exploitation on the Yamal Peninsula and in shelf waters of the Kara Sea. The main problem for natural resource users is a conflict between local indigenous peoples in Yamal Nenets and Khanty-Mansi and oil and gas companies. The traditional economy of the Khanty-Mansi people has been almost destroyed - they have lost access to many areas for reindeer breeding, hunting and fishing. The Yamal Nenets are fighting for their rights and are looking for other ways of co-existence with industrial development. The new federal laws relevant to indigenous people's status and rights were adopted only within the last few years. Implementation of these laws can change the situation but the poor economic state of the indigenous tribes is forcing them to compromise with companies.

The Ob River catchment basin and its observation points are part of the State System of Environmental Monitoring. The hydro-chemical observations have been conducted by Rosgidromet at 236 points on 114 rives of the Ob River catchment basin, as well as in 8 reservoirs and at one point on Obskaya Bay. The current ecological situation in this catchment is assessed as critical. Moreover, in the southern industrial areas, the wastes from coalmining, processing industries and agricultural enterprises has led to very serious state changes or even ecological disaster. The middle and northern reaches of the Ob River and its tributaries have chronic pollution from crude oil and its products. Together with heavy metals Fe, Cu, Zn and phenols, oil hydrocarbons are the main persistent pollutants in lower reaches and the Obskaya Guba (Anon. 1999).

In the course of the forthcoming gas development in the Yamal Peninsula and on the Kara Sea shelf, ecological research and technological studies addressing the numerous operational issues were undertaken during the 1990ies. Over 60 research projects were undertaken involving researchers from more than one hundred Russian institutions. The results of these studies are available from the Institute of the holding GASPROM "VNIIGAS", in the Arctic and Antarctic Research Institute, AARI, Murmansk Marine Biological Resources Institute, Moscow State University and others.

An approach based on integrated resource management is practically nonexisting for the Kara Sea coastal zone, although this problem obviously needs special attention from federal structures and regional administrations.

Eastern Siberia

Krasnoyarsky Kray, Evenkysky, Taymyr (Dolgano-Nenets) Autonomous okrugs

The largest river of Russia, the Yenisey River and its tributaries, drains this area. The area of the catchment basin is 2.59 x 10^6 km^2 (not including the basin of the largest tributary, the Angara River). Dams with the two largest reservoirs, the Sayano-Shushenskoe and the Krasnoyarskoe, regulate the river discharge. From its upper reach to its delta, the Yenisey flows more than 3000 km from south to north. The mouth area of the river is an estuarine delta and it is still forming. The valley is asymmetrical, with a narrow, low western part and a well-developed mountainous eastern part where most of the tributaries originate. The coastal area of the Yenisey River consists of a delta with numerous channels, Yeniseyskaya Guba and the semi-enclosed Yenisey Bay: these cover 20,000 km^2.

The Yenisey River flows through the administrative region of Krasnojarsky kray (with two autonomous okrugs (autonomous districts, AO): Evenkiysky AO and Dolgano-Nenets or Taymyrsky AO) while the whole catchment basin, together with the main tributary, the Angara River, embraces another four regions of the Russian Federation. Krasnojarsky kray has the one of the lowest population densities, with 1.3 person km^{-2} but regionally there are great variations in population and economic development. The southern part of the region is the most heavily populated (more than 3 million people) and has a diversified industrial and agricultural structure. The most important anthropogenic drivers are industry (mining, non-ferrous metallurgy, chemical plants, timber, pulp and paper production) agriculture, local fleet, housing and communal holdings. Due to the high level of pollution of the southern upper reach, the environmental state of the whole river is assessed as rather critical (4th class of pollution in accordance with Rosgidromet classification).

The middle reach of the river includes the poorly developed areas of the Evenkyisky AO, where the population density is lower than 1 person km^{-2}.

Further north, the area is served by two sea ports – Igarka and Dudinka, which are connected with the main Arctic transport line, the Northern Sea Route. Timber and the timber-processing industry, local fleets and port facilities impact the lower reach of the river, so that persistent pollution of the water with phenols, oil products, Cu, Zn and Fe is common. Moreover, the world-famous non-ferrous metal mining and metallurgical complex at Norilsk (with a population of more than 300,000) is situated close to the northern part of the Yenisey River basin. This is a major nickel production area in Russia, with associated processing and other industries. The contribution of air pollution from industrial complexes in Norilsk amounts to 77 % of the whole volume of air pollution in the Krasnoyarsky kray. Pollutants include Ni, Cd, Zn, Cu, H_2S and Pb. This industrial complex influences mainly the surface waters of Lake Pyasina and the Pyasina River, which flows into Pyasina Bay and then the Kara Sea, east of the Yenisey River. The impact of this industrial area is the most devastating in the Russian Arctic and definitely a "hot spot". Krasnoyarsky kray ranks first in Eastern Siberia for its volumes of pollutants, particularly air emissions (66 % of all gaseous refuse), and second for liquid (32 %) and solid wastes.

Krasnoyarsky kray is one of 10 economic regions where the Rosgidromet has monitored the water discharge and hydrochemistry. Intensive ecological research had been carried out in the Taymyr and Norilsk areas by academic institutes including the Institute of Geography RAS, and Arctic and Antarctic Research Institute (AARI). An interesting comparison with other Arctic region, the Kola Peninsula, had been made by the Institute of Industrial ecology of the Kola Scientific Center. In both regions similar industrial enterprises ("Severonikel", Pechenganikel in the Kola Peninsula and Norilsknikel in Eastern Siberia) produce Ni, Cu, Co, Ag, Pt and Se, which impact strongly on the natural environment and are sources of acidification of soils and waters. This has led to deforestation of adjacent areas in Norway and Finland, a major teleconnection problem for these countries.

The Laptev Sea sub-region (*D in Figure 2.3)*

Republic of Sakha-Yakutia

The Laptev Sea washes the coastal zone of the administrative region Republic of Sakha-Yakutia. The big rivers that flow into the Laptev Sea, including the Khatanga, the Lena, the Olenek and the Jana rivers, generate the major freshwater input to the sea. The total annual runoff of these rivers is 673 km^3, of which the four biggest rivers contribute 91%. Ice transgressions and modern tectonic movements of three large structures determine the geological history of the basin: the Siberian platform, Lake Baikal and the Verkhoyano-Kolymsky mountain-folded areas. Permafrost is widespread and forms a confining layer. The coastal zone is presented by a narrow strip of tundra that further south becomes forest-tundra and taiga forests. Surface waters feature a low level of mineralisation.

The catchment basin of the Lena River is one of the largest in Russia, $2.49x10^6$ km^2, and the river is 4400 km long. The Lena River delta is the largest in Russia, with a very complex configuration. Strong flows of river sediments have formed numerous channels and islands. The delta consists of 6089 channels, 58,728 lakes, and 1600 islands with a total area of 32,000 km^2.

The population of the area is a little more than one million. Rivers are still the main transport lines so the local fleet is one of the primary sources of water pollution. Due to the large runoff and relatively dispersed industrial development, water is reasonably clean at many observation points. Nevertheless, industrial development such as coal mining, gold-dredging, timber and shipyards produce considerable volumes of sewage, polluted by oil products, phenols and heavy metals. The main problem of liquid wastes is insufficient purification. Only 27 % of wastes satisfy the environmental standards. This situation applies especially to the Olenek River (length 2270 km, catchment area 219,000 km^2, water runoff 32.8 km^3 yr^{-1}) and to the Yana River (catchment 225,000 km^2). The water quality of these rivers may vary from "practically clean" to "very dirty". It comes from dumping of industrial liquid wastes and communal sewage directly on soil or into water. Near the settlements and mining complexes, pollution of water with phenols, oil products, Cu, Zn and Fe may reach 6-12 times MAC (Anon. 2000).

The hydrological regime is highly seasonal, with peaks in May-June, when pollution inflow entering the main stream from flooded lands also peaks. Even the natural background of the river shows high levels of Cu and Zn, which together with the anthropogenic heavy metal contamination creates a critical ecological situation at least in small tributaries and lakes.

Rosgidromet has conducted observations of the hydrochemical regime in 47 water bodies, for 66 points. The Lena River mouth and coastal zone have been investigated for many years by the Arctic and Antarctic Research Institute and Department of Geography of the Moscow State University. The International Laptev Sea Program has been running since 1996.

The East Siberian Sea subdivisio*n (E in Figure 2.3)*

Other large rivers, the Indigirka River and the Kolyma River, which enter the East-Siberian Sea, drain the eastern part of the Republic of Sakha-Yakuta. This sea is very shallow (the shelf covers 866,000 km^2 of the 889,000 km^2 total area); tidal activity is significant because of the very narrow strip of water free of ice, with severe ice conditions for shipping and intensive thermo-abrasion of shores due to the high content of ice (up to 90 % of rock mass). Annually the shoreline recedes at a rate of 4-30 m; in total approximately 10-50 km have been lost since the shoreline stabilised during a period of some 5 to 6000 years (Aibulatov 2001b).

Two rivers deliver most of the water to the sea: their share is 75 % of the total runoff. However, freshwater affects only 6 % of the sea. The Indigirka River originates in a mountainous area and in its lower reach it passes through easily-eroded quaternary rocks, so it brings high loads of sediments (11.2 x 10^6 t yr^{-1}). The Kolyma River drains lowland areas and brings 10.1 x 10^6 t yr^{-1}. The construction of the Kolymskaya hydroelectric station in 1993 reduced the sediment load by 5 % (Mikhailov 1997).

The main anthropogenic forcing affecting and changing the state of the natural waters are dam construction, industrial effluents (gold mines and other non-ferrous metal mining complexes), and agricultural and domestic wastes. Again the situation is exacerbated by low-level purification of liquid wastes in settlements and industrial enterprises. This situation impacts on natural waters, particularly in flood season. As a result, in such places the observation points registered high levels of pollution by oil products (7-13 times MAC), heavy metals (Cu, Fe), phenols and ammonium nitrogen. Particularly widespread pollutants are Cu compounds (5-10 times MAC, up to 39 MAC). The maximum levels of contamination are typical for small tributaries of the Kolyma and Indigirka rivers, where river water is less able to mitigate pollution volumes. Despite comparatively low population densities, some parts of such rivers show rather high indicators of pollution: from 3rd class (polluted) to 4th class (dirty), in the Rosgidromet classification (Anon. 2000).

The monitoring service of Rosgidromet has observation points on 13 water objectives in the Kolyma River catchment basin, and on 8 water objectives in the basins of the Olenek, Yana and Indigirka rivers. Hydrological and hydrochemical studies in the catchment basins of the Indigirka and Kolyma rivers were carried out by the Arctic and Antarctic Research Institute in 1960-80s and published in regular issues of proceedings of AARI "Problems of the Arctic and Antarctic" as well as by scientists of the Department of Geography of the Moscow State University (Burdykina 1967; Bogomolov *et al*. 1979; Gilyarov 1967; Turanov 1960). In the recent period of 1980-2000 more attention was paid to the anthropogenic impact on the processes in the river basins: 1) the hydrologo-morphological processes in the river mouths, their anthropogenic variability; 2) an assessment of local human activity influence on the regional resources, the problem of protection and rational landuse; 3) an assessment of the consequences of hydro-power constructions (Malik 1990); 4) an assessment of the sediment flux variability due to human activity in the river basins and under anthropogenic disturbance of the conditions of its transportation (Alekseevskiy and Sidorchuck 1992; Babich *et al*. 1992).

The biggest river in the Chukchi Sea basin (without the Alaskan part) is the Amguema River (discharge of water and suspended matter 9.2 km^3 and $0.05x10^6$ t yr^{-1}, respectively). Total water and suspended matter discharge in the basin are insignificant (20.4 km^3 and 0.7x 10^6 t yr^{-1}) (Gordeev *et al* 1996).
Although there are 10 points of observation in the basin at present (Anon. 1999), information on ecological situation is very scarce. The traces of anthropogenic pollution of water and bottom sediments on the Chukchi Sea shelf by heavy metals are practically absent (Kolobokova and Manyakina 1992; Naidu *et al* 1997).

2.5.3 Summary across the sub-regions A-E – a nearly sub-continental view

At full regional scale we can distinguish between two major sub-regions, the Western Arctic and Eastern Arctic. The boundary between these two large sub-regions crosses the Laptev Sea basin and coincides with the boundary between the Eurasian and North American tectonic plates. There are considerable distinctions in the geological structure of the two basins, their elevation and climate. The rivers of Eastern Siberia exhibit lower runoff, higher turbidity and significantly lower water mineralization, organic matter and nutrient concentrations than the rivers of the western part of the Russian Arctic. The Eastern Siberian rivers (Yana, Alazeya, Indigirka, Kolyma) are more similar to the North American Arctic rivers than to the rivers located westward of the Lena River (Gordeev *et al.* 1996).

Based on the existing data and information given above a large scale almost sub-continental synthesis can be found in Table 2.8. It provides a ranking of the importance of the impacts on coastal areas driven by catchment-based activities and their trend expectations.

Table 2.8. The link between coastal issues/impacts and land-based drivers in the Russian Arctic coastal zone. Overview and qualitative ranking on full regional/sub-continental scale.
Category: 1 - low; 10 - high; trends: ⇒ - stable, ⇑ - increasing, n.o. - not observed.

Coastal impact/issues	Driver	Full regional		Trend-expectution	Reference/ data sources
		Coast*	Category		
Pollution	Industrialisation	Western Russian Arctic (WRA) coast Eastern Russian Arctic (ERA) Coast	6-8 4-5	⇑ ⇒/⇑	Table 2.4, Table 2.5, Table 2.6
	Navigation	WRA coast ERA coast	5-6 2-3	⇑ ⇑	Table 2.5, Table 2.6
	Urbanization	WRA coast ERA Coast	5-6 2-3	⇑ ⇑	Table 2.5, Table 2.6
Acidification	Industrialisation	WRA coast ERA coast	6-7 3-4	⇒/⇑ ⇑	Table 2.4, Table 2.5, Table 2.6
Radioactive pollution	Nuclear-power Engineering, nuclear industry, Navy	WRA coast ERA coast	5-6 3-4	⇒ ⇒	Table 2.4, Table 2.5, Table 2.6
Erosion	Damming	WRA coast ERA coast	2 1	⇒ ⇒	Table 2.4, Table 2.5, Table 2.6
Sedimentation	Navigation	WRA coast ERA coast	1-3 2-3	⇒ ⇒	Table 2.4, Table 2.5, Table 2.6
Loss of biodiversity	Fisheries, damming	WRA coast ERA coast	1-3 n.o.	⇒	Table 2.5, Table 2.6

* The Lena River, located at the boundary between the Eurasian and North American tectonic plates, divides the Western Russian Arctic (WRA) and the Eastern Russian Arctic (ERA). Left side Lena River basin is related to WRA, right side to ERA.

Table 2.8 indicates that practically all coastal issues and land-based driven impacts are more important (ranking higher than 6) for the Western Russian Arctic than for the Eastern Russian Arctic. Trend expectations anticipate increasing impact because of economical demands, and again they are more pronounced in the Western Arctic. Wide ranging effects can also be anticipated from recently published climate change scenarios (Hassol 2004), which will affect the material transport and cycling in the Arctic coastal Sea. Changes in permafrost coverage and seasonality and spatial scale of ice cover in tandem with changing run off characteristics will parallel the growth of new forms of land and sea use. This is being addressed in various upcoming activities under the IPY umbrella.

2.6 Scientific and/or management response

This section of the Russian Arctic Basin desk study, RusABas, revealed quite specific and interesting results. Due to long-term studies conducted by academic institutes of the Soviet Union and later Russia, information on river basins and much of the Arctic coastal zone can rely on rather extensive databases. These databases are available and can be used for elaboration of comprehensive regional programs for sustainable development of coastal zones and adjacent areas. Nevertheless, the current state of implementation of Integrated Coastal and River Basin Management approaches in policy and administartive institutions doesn't meet the state of the art requirements of sustainable development in the socio-ecological system context (see EU Recomm. 2002; http://ec.europa.eu/environment/iczm/). This indicates that likewise with many other regions in the world the understanding among governance circles and stakeholders of the high values of coastal zone areas and their vulnerability and the appropriate exploitation of available scientific information is rather insufficient. This situation applies to Arctic coasts as well as to other regions of Russia, as can be taken from other desk studies devoted to western, southern and eastern sectors of the Russian coastal zone. It also highlights the problem of converting academic data and information into electronic databases, accessible for work on all levels of regional planning and management. Moreover, a principle shortcoming in science-user communication likewise with multiple other regions worldwide also applies to Russia. This in turn means a great challenge to scientists to make their results clear enough to be understood and applicable for decision support in practical management problems. This task may be solved more successfully by active cooperation between natural and social scientists involving also regular stakeholder participation (Ledoux *et al*. 2005). The EU Water Framework directive and the Recommendations of the Commission to the Parliament on a "Coherent Strategy for Integrated Coastal Zone Management" (see above) try to pave the way to this complex approach at least on European scales though including the new independent States of the East.

In our regional context one experience of such cooperation was the Barents Sea Region Sustainable Development Program, conducted in the Murmansk region by Russian and American scientists together with the local Administration. The continuation of this project is connected with the Nenets Autonomous Okrug, also a member of the "Barents Euro Arctic Region". This work is particularly timely, taking into account the current plans of industrial companies for future expansion of onshore and offshore oil development.

Another important attempt to extend a vision on the arctic coastal zone as on a complex system where natural and anthropogenic processes interact and where growing resource use call for a special integrated management approach was the comprehensive academic project "Land-Ocean Interactions in the Russian Arctic" (LOIRA). This project has been carried out since 1996. LOIRA has basically used the ideas and approaches of two international projects "Land-Ocean Interactions in the Coastal Zone" (LOICZ) (as an IGBP/IHDP Core Project) and "European Land-Ocean Interaction Studies" (ELOISE). The main task of LOIRA was to adapt the objectives and frameworks of these international projects to the Russian Arctic on the base of the Russian scientific and national socio-economic priorities (Andreeva 1998a). Since its beginning, LOIRA was supported by the International Arctic Science Committee (IASC). The project included a wide circle of natural and social economic studies on the coastal zones of the White Sea and the Pechora Sea during the years 1997 – 2004. The results were published in many articles and two monographies. Some of the LOIRA results are given in chapter 2.5.2 "The White Sea Subregion".

The primary objective was to obtain a comprehensive scientific understanding of the fundamental physical, chemical, geological and biological processes in the Russian Arctic under influence of global change and anthropogenic impact. The goal was to develop the scientific and socio-economic bases for integrated management of the coastal environment. LOIRA promoted the development of an integral approach that for the first time combined the efforts of natural and social scientists. In addition to global change issues, LOIRA responded to the "precautional principle" by recognizing the urgent need to study the natural processes in the estuarine zones of the great Arctic rivers before the onset of industrial large-scale exploitation. This was aimed to enable prognoses of its anthropogenic impacts and the development of scenarios. Another extremely important aspect was to study, predict and to feed into the scenarios the socio-economic consequences of Arctic coastal zone development in relation to exploitation of non-renewable (mainly oil and gas) resources.

For the first stage of the project, the key study areas were the basins of the White and the Barents Seas with special focus on the Pechora Sea as its south-eastern part. The LOIRA project was a long-term research study providing a good opportunity to concentrate fieldwork in the Arctic coastal zone and exchange of results of complex studies at the annual workshops. Due to its links to the global change projects, results which are being published in the form of proceedings of these international meetings are immediately exposed to exchange and discussion with the global community of scientific peers. Ultimately, LOIRA aimed to prepare the scientific base for regional programs on Integrated Coastal Zone Management and to facilitate the cooperation of scientists and resource managers. The project finished in 2006, but the main problems formulated during the studies have been transferred into new project applications of the International Polar Year program.

Strong seasonality of meteorological, hydrological, hydrochemical, biological and geochemical processes is reflected in the seasonality of sedimentary matter supply and vertical particle fluxes (Lisitzin *et al*., 2003). From 2003 onwards, the studies of vertical particle fluxes were continued using sediment traps. In the river-sea barrier zone (The North Dvina, Onega and other rivers of the White Sea basin), more than 90 % of riverine suspended matter (including pollutants) is deposited. There are many similarities in functioning of marginal filters of the White Sea and other Arctic Seas, but also some peculiarities (Dolotov *et al*., 2002; Lukashin *et al*., 2003).

Simultaneous remote sensing observations (SeaWIFS and other satellites), suspended matter and chlorophyl sampling, hydrooptical studies and sediment trap measurements give possibility to begin 4-D researches of material fluxes (Lisitzin *et al*., 2003; Pozdnyakov *et al*., 2003). Development of new algorithms for interpretation of satellite data has made possible a simultaneous determination for the entire sea of chlorophyl a concentration, and - after verification - of phytoplankton primary production, suspended material and dissolved organic matter (yellow substance). All these data were verified during expeditions in the sea in summer and autumn months.
Multidisciplinary studies in the White Sea in the frame of the LOIRA project give a good possibility for the development of a new generation in monitoring (four-dimensional) of the Arctic environment.

Arctic Coastal Dynamics (ACD; http://www.awi-potsdam.de/acd/) is an affiliated LOICZ project the first phase of which finished in 2006. The second phase is about to start. ACD I followed a multidisciplinary, multinational project of the IASC and the IPA (International Permafrost Association; Rachold *et al.* 2003b). The project elements for ACD were formulated at a workshop in Woods Hole, Massachusets in November 1999. The international workshop, held in Potsdam (Germany) in October 2000, produced a phased, five-year Science and Implementation Plan (2001-2005). The ACD project office was established in Potsdam at the Alfred Wegener Institute.

The overall objective was to improve our understanding of circum-Arctic coastal dynamics as a function of environmental forcing, coastal geology and permafrost and morphodynamics behavior.

It is planned to establish the rates and magnitudes of erosion and accumulation of Arctic coasts, to develop a long-term monitoring, to identify and undertake focused research on critical processes, to develop empirical models to assess the sensitivity of Arctic coasts to environmental variability and human impacts, and to refine and apply an Arctic coastal classification in digital form (GIS format) and produce a series of thematic and derived maps (Rachold *et al*. 2003a).

The first phase of the ACD I project has been directed towards the assessment and synthesis of existing information on Arctic coastal properties and dynamics. A network of long-term monitoring sites has been established. The metadata information for these ACD key sites is available on the ACD website. During the second phase of ACD I research, until 2005, emphasis was on critical processes. This focused on the transport and fate of eroded organic material and on the most critical and poorly understood transition between onshore and offshore permafrost.

A key issue is also to strengthen the federal legal base regarding coastal zone management for the special and very valuable subject of sustained natural ecosystem goods and services, i.e. natural as well as social capital. Such a response was raised by the Russian Federal Ministry of Science and Technology in 1997 (now Ministry of Industry and Science). A multidisciplinary group of scientists from Moscow, Murmansk and Krasnodar was elaborating the scientific background for a new federal law on coastal zone management for the purposes of rational use of space and natural resources. The first draft of such a law, with a comprehensive analysis of the situation and the efficiency of the existing legislative base, has been submitted for consideration at ministerial level. Meanwhile this work is continuing, and special emphasis will be placed on the interrelations of natural resource users and mitigation of conflicts between them.

Along with rich material from academic institutes, the Federal Service of Hydrometeorology and Monitoring of Environment provides databases on surface water quality in river basins based on long-term studies. It enables analysis of the dynamics of changes and assessment of the current situation regarding pollution and environmental quality in different parts of the river basins. The land-based sources of contamination have uneven distributions over vast areas of the river catchment basins, but there are some places where anthropogenic impact exceeds the maximum allowed loads. These places include the Kola Peninsula, the mouth of the Ob River, the lower reach of the Yenisey River and the Pyasina River. These areas can be referred to as “hot spots” in the coastal zone of the Russian Arctic (Figure 2.4). The coastal zones of some other Arctic rivers also show poor environmental conditions due to permanently high contamination of waters by sewage and wastes from mining, timber and the shipping industry, dumped without or with insufficient levels of purification.

Anthropogenic impacts are usually connected with industrial development and exploitation of natural resources and urbanization of the western part of the Arctic. There is a likelihood of further economic growth of this sector of the Russian arctic coastal zone in the near future. Although these regions can draw on a higher level of scientific investigations allowing a more advanced understanding of anthropogenic impacts, real progress refers more to scientific response than to the management and policy sphere on both regional and catchment scales. The following table (Table 2.9) summarizes the scientific and management related responses addressing the Russian Arctic coastal and riverine issues on sub-regional and regional scale.

Table 2.9. Scientific and/or management response to coastal impact/issues in the Russian Arctic Coastal zone on catchment, sub regional and regional scale.

River catchment	**RESPONSE Catchment scale**		**RESPONSE Sub regional /Country Scale**		**RESPONSE Regional Scale**	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
Barents Sea Murmansk region Kola River Tuloma River Kola Peninsula coast Lakes of Kola Peninsula	Systematic ecological studies on population, biological and hydrochemical research on anthropogenic impact are carried out by Murmansk Marine Biological Institute (MMBI), Institute of Industrial Ecological Problems, Polar Research Institute of Sea Fisheries and Oceanography (PINRO)	38 water objectives of the Kola Peninsula are included in the state system of surface water quality monitoring (39 points and 47 profiles) (Rosgidromet)	**Program of Ecological- Economic regionalization of Barents region for** purpose of sustainable development (MMBI)	**The Barents Sea Region Sustainable Development.** Program was sponsored by UNDR (1995-1999), managed by Education Development Center, Inc. (EDS) and Murmansk Province State Committee on Environmental Protection and Natural Resources (in frame of **Barents Euro-Arctic Region Program, BEAR)** Main task: to develop a strategy to incorporate principles of environmental governance and sustainable development into the policies, programs and planning process of key agencies in the region	**The Barents Sea - physical oceanography research** 1991-1995. By the Institute of Marine Research (Norway) together with Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) **Barents Sea Impact Study (BASIS) –** international program sponsored by EU Stage I 1997-2001. Stage II 2001 to date	**Arctic Monitoring and Assessment Program (AMAP)** began 1991, includes 8 Arctic countries, provides ministers with assessment of levels of anthropogenic pollutants of the Arctic environment. The results of the first 6-year term of the program were published in AMAP 1997: Arctic Pollution Issues: A state of the Arctic Environment Report. **Protection of the Arctic Marine Environment Program (PAME)** began 1993, focuses on marine pollution and effects on the environment from land-based and sea-based sources. All Arctic countries participate

Table 2.9 continued

River catchment	**RESPONSE Catchment scale**		**RESPONSE Sub regional /Country Scale**		**RESPONSE Regional Scale**	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
White Sea Arkhangelsk region Northern Dvina River	Ecological studies of deforestation, depletion of fish stocks, contamination of natural waters in catchment basin (Institute of Northern Ecology, Arkhangelsk	State monitoring system of surface water quality (35 water objectives at 53 points, 70 profiles)	**BEAR Program, International Program Complex studies of the White Sea** 2000-04 (Russian – German Project)		**BASIS**	AMAP **PAME**
Kara Sea Nenets Autonomous okrug Pechora River	Ecological Study of the Pechora River Distribution of heavy metals, Al, hydrocarbons in sediments, fish in the P.R. basin (1997-2000)	Local Administration Program “Zones of limited economic activity” (coastal zone, rivers & lakes shores – since 1997)	Pechora Delta, Structure and Dynamics of Pechora Delta ecosystems (1995-1999) Russian-Dutch project	Environmental impact assessment of oil development off-shore & in coastal zone of Pechora Sea, 1996-2001	**BASIS** 1997-2000 **LOIRA** **Land Ocean Interaction in Russian Arctic**	**AMAP** PAME

Table 2.9 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub regional /Country Scale		RESPONSE Regional Scale	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
Kara Sea continued		State monitoring system of surface water quality by Rosgidromet (17 water objectives of the Pechora River catchment basin, 26 points, 35 profiles)		INSROP (Impact of Northern Sea Route on regional development & indigenous people.	1996-2005: ACD **Arctic Coastal Dynamics** 2001-2005 Main task: to determine role of coastal seas in land - ocean interactions: carbon cycle, coastal erosion and riverine and direved from erosion fluxes of sediments and organic carbon, regional and global consequences of human impact through pollution, eutrophication and physical disturbance. Strategic approach to management of sustainable coastal development and resource use.	

Table 2.9 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub regional /Country Scale		RESPONSE Regional Scale	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
Kara Sea Tymen Region Khanty-Mansi Yamal - Nenets AO. Ob River, Yamal Peninsula coast	Environmental studies: Dynamics of tundra ecosystems, permafrost, Biochemical, biophysical and hydrochemical research of the Ob R. mouth, Ob Bay and the Yamal Peninsula coast, 1990-2000 (connected with gas development on Yamal Peninsula) Determination of contaminant contents in coastal waters from Vaygach island till the Laptev Sea water bodies (INP&SNU)	State monitoring system of surface water quality (236 points on 114 rivers of the Ob River basin, 314 profiles)	Russian-American Expedition to the Siberian River Deltas (GosNIIPAS, ZIN RAS), 1994. Complex investigation on the hydrology and hydrobiology of deltas and estuaries Hydrochemical regime of estuarine and deltas of Ob, Yenisey, Kara Sea (AARI, 1990-1993). Radioactive contamination of the Kara Sea through the Ob River basin (1993, Arkhangelsk)		Russian-Norwegian expedition in the Kara Sea (AARI) – studies oceanology, hydrobiology (1995-1996)	
Taymyr (Dolgano-Nenets autonomous okrug, (AO) Evenky AO Krasnoyarsky kray Yenisey River, Pyasina River	Biological diversity of Taymyr Peninsula, coastal waters productivity (VNIIpriroda, PINRO,) Geographical Dept. Of Moscow State University	State monitoring system of surface water quality (124 points on 79 rivers in the Yenisey basin, 179 profiles)				

Table 2.9 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub regional /Country Scale		RESPONSE Regional Scale	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
Laptev Sea Republic of Sakha-Yakutia Lena River Yana River	Ust-Lensky State Reserve (formed in 1983) – studies of the Lena River delta and adjacent area – biological, biochemical research (1990s) Anthropogenic contamination of the Lena River delta (AARI)	State monitoring system of surface water quality (66 points on 47 water objectives in the Lena River basin, 85 profiles)			Laptev Sea System Complex Russian-German Research Project 1994-1998. (AARI) ACD 2001-2005	
East Siberian Sea Republic of Sakha-Yakutia Indigrka River Kolyma River	Environment-transport conditions in the mouth of the Kolyma River (AARI, 1970s). Ecological studies in Chukchi and East Siberian Sea, Kolyma Mouth (anadromous and freshwater fishes, water fowl, breeding biology) on bases of permanent stations 1980s-90s (Institute of Biological Problems of the North, Far-East Dept RAS)	State monitoring system of surface water quality (17 points on 13 water objectives in the Kolyma River catchment basin, 17 profiles)	Ecological and biological studies of the Laptev Sea and Eastern Siberian Sea (Institute of Biology of the Yakut Branch of the Northern Department RAS) 1990s		ACD 2001-2005	

Table 2.9 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub regional /Country Scale		RESPONSE Regional Scale	
Sea/Subject of RF	***Scientific***	**Management**	**Scientific**	**Management**	***Scientific***	***Management***
Chukchi Sea Chucotsky Peninsula coast			Ecological and biological studies of Chukchi Sea – biodiversity, catalogues on sea mammals, fishes, invertebrates (TINRO, 9 expeditions, 1970s-1990s)		**Bering Sea Impact Study (BESIS)** 1995-2001 Coastal zone of eastern part of Chukotsky Peninsula – Western Alaska Studies of global change consequences on physical, biological, social systems. USA, Canada, Russia, Japan, China	

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3 ANNEX

Human dimensions of land-based fluxes to the coastal zone: the LOICZ-Basins approach

(from Kremer et al. 2002)

This appendix provides an introduction in methodology of the regional assessment and synthesis of human dimensions of land-based fluxes to the coastal zone as performed in the LOICZ-Basins core project. In using a common methodology, harmonized assessment protocols and project designs for research on global scales, the LOICZ-Basins framework aims to assist in interregional exchange and acquisition of funding opportunities on local, sub-regional and regional scales.

Background

Coasts worldwide are subject to many pressures which are expected to continue or increase in the future. Natural flows of water, nutrients and sediments to the coast are largely and increasingly influenced by past and planned physical changes in rivers (e.g., damming). In addition, the increase in tourism, fisheries, urbanization and traffic will offer challenges for the coastal zone managers and regulators. The management issues and their solutions require an integrated approach of the natural and socio-economic sciences (Turner *et al*. 1998; Salomons *et al*. 1999). Numerous studies (often mono-disciplinary) have been conducted to deal directly with these issues but could benefit from more integrated assessment. This integration of the results of past studies requires a simple and harmonized framework for assessment and analysis. For the integration LOICZ-Basins uses the DPSIR framework:

LOICZ-Basins faces three major challenges:

1. to determine the time delay between changes in land-based material flows (due to socio-economic activities, morphological changes or regulatory measures) and their impact on the coastal zone system.
2. to generate an improved understanding of the complexities of the coastal sea environments and to derive from this complex environment the "critical loads".
3. to consider the multiplicity of interests and stakeholders affected by transboundary issues, particularly when local, regional, national, and multi-national governmental bodies with conflicting interests are involved.

The DPSIR framework

The Driver-Pressure-State-Impact-Response or DPSIR scheme (Turner *et al*. 1998; Turner and Bower 1999) provides a standardised framework for site assessment and evaluation. It enables the calculation and modelling of the impacts of change on the delivery and use of environmental goods and services expressed in scientific and monetary terms. The scheme sets up a platform for independent review and evaluation of political and managerial response and options. The elements of this framework are:

Drivers: resulting from societal demands, sectoral activities with consequences for the coastal zone include:

- urbanisation
- aquaculture
- fisheries
- oil production and processing

- mining
- agriculture and forestry
- industrial development
- land use change.

Pressures: processes affecting key ecosystem and social system functioning (i.e., natural and anthropogenic forcing affecting and changing the state of the coastal environment):

- damming and other constructions
- river diversion, irrigation and water abstraction
- industrial effluents (industrialisation), agricultural and domestic wastes (urbanisation)
- navigation and dredging
- sea-level rise induced by land-based activities and affecting the coastal zone (e.g., decrease of riverine sediment load leading to instability of coastal geomorphology)
- other forcing functions (not primarily anthropogenic) such as climate change.

State and State change: the indicator functions and how they are affected:

- water, nutrient and sediment transport (including contaminants where appropriate) observed in the coastal zone as key indicators for trans-boundary pressures within the water pathway. Indicators are designed to give an overview of the environmental status and its development over time and to enable derivation of critical load information
- geomorphologic settings, erosion, sequestration of sediments, siltation and sedimentation
- economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity including the valuation of natural resources, goods and services.

Impact: effects on system characteristics and provision of goods and services:

- habitat alteration
- changes in biodiversity
- social and economic functions
- resource and services availability, use and sustainability
- depreciation of the natural capital.

Response: action taken on political and/or management level:

- scientific response (research efforts, monitoring programs)
- policy and/or management response to either protect against changes such as increased nutrient or contaminant input, secondary sea level rise, or to ameliorate and/or rehabilitate adverse effects and ensure or re-establish the chance for sustainable use of the system's resources.

The pressures are manifold, so we narrow them down within the LOICZ context, which deals with changes in biogeochemical cycles as major indicators. The LOICZ-Basins project therefore deals with the impact of human society on the material transport such as water, sediments, nutrients, heavy metals and man-made chemicals to the coast. It assesses the loads and their coastal impact and tries to provide feasible management options together with an analysis of success and failure of past regulatory measures. Since changes in fluxes are mostly land or catchment-based, the catchment–coastal sea system is treated as one unit – a water continuum. In applying this scale to loads and coastal change phenomena this means that beyond activities from agriculture, fisheries, urban development, industry, transport, tourism also morphological changes made to a catchment (e.g. damming) have to be taken into account.

In particular the following parameters will be assessed:

- material flow of water, sediments, nutrients and priority substances (past, current and future trends);
- socio-economic drivers which have changed or will change the material flows;
- indicators for impacts on coastal zone functioning; and to derive from them
- a "critical load" for the coastal zone and "critical thresholds" for system functioning.

Linking coastal response to socio-economic drivers

This critical load and threshold concept being developed within the UN/ECE CLRTAP convention will develop this link. The United Nations Economic Commission for Europe's convention on Long-Range Transboundary Air Pollution has held several workshops and produced handbooks on the critical load concept for terrestrial and freshwater systems. In LOICZ-Basins these concepts are extended to the marine environment. In a systems approach it can be used (as has been done for atmospheric pollution abatement) for a cost-benefit analysis of management options. Scenario-building is an integral part of this analysis. Critical loads provide key information for the development and application of indicators for monitoring purposes as required, for example for the implementation of the Coastal Global Observation System, C-GOOS, of UNESCO's IOC.

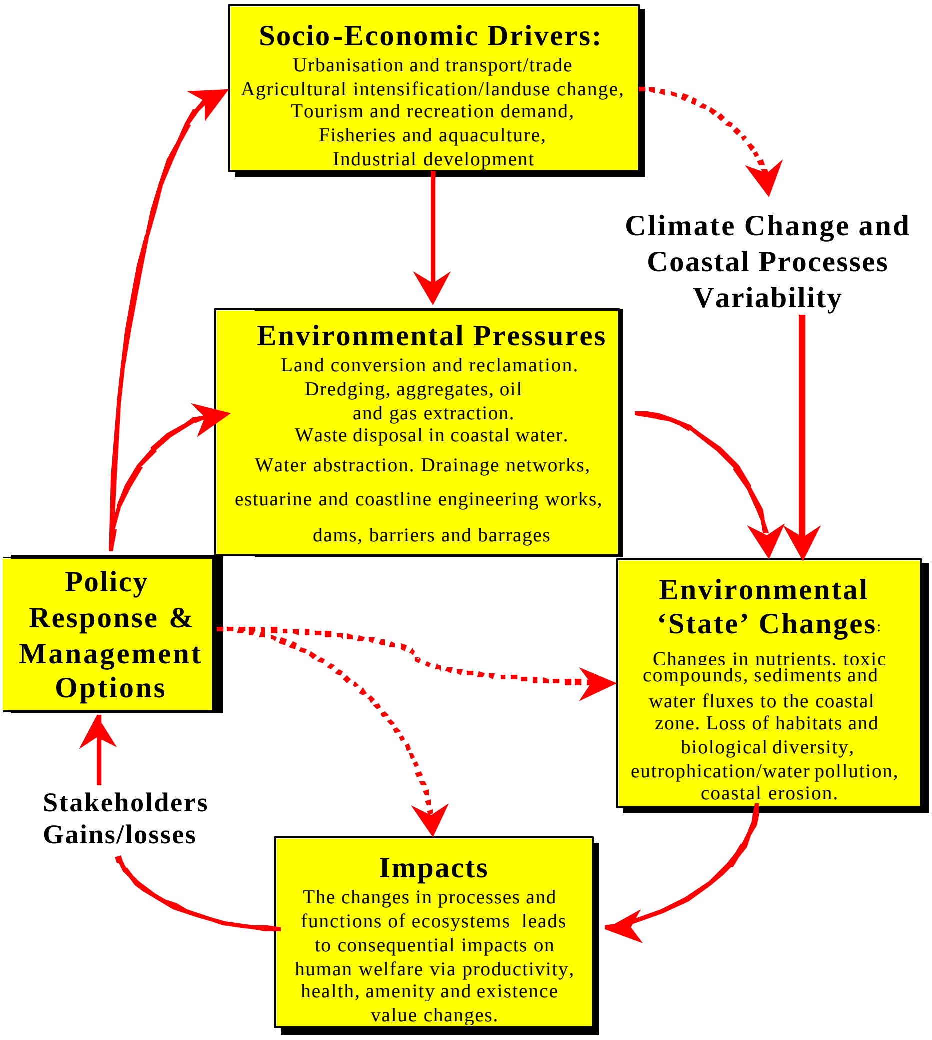


Figure 3.1: Description of the Driver-Pressure-State-Impact-Response

LOICZ-Basins employs different approaches to identify **targets and indicators** for the coastal response:

- The simple "policy-oriented" approach takes the critical loads agreed upon in international treaties (e.g., the 50% reduction scenario within the Rhine Action Plan, also adopted for the North Sea).
- The "ecosystem" approach uses historical data on the response of the coastal system to changing loads and identifies indicators. This approach will attempt to discriminate between natural states and anthropogenically altered states.
- The "regional management" approach is based on consultation with local authorities and identifies their criteria for indicators or critical loads. This incorporates other indicators than those based on scientific arguments alone.

The indicators and targets are used to derive critical concentrations. Taking into account transformations and dispersion in the coastal environment, a critical load to the coastal zone can be calculated. This critical load, the **critical outflow** of the catchment, is a combination of inputs by socio-economic activities and transformations in the catchment and its delta/estuary. Once these links and the transformations of the loads have been established it will be possible to carry out scenarios for cost-benefit analysis and trade-offs. This will require the integration of existing modelling tools from the natural and social sciences.

The DPSIR framework is applied to determine critical loads of selected substances under various development scenarios with diverse biophysical and socio-economic settings, triggering discharges into the coastal seas. It provides an interdisciplinary platform for joint approaches of natural, social and economic scientists, and to incorporate stakeholders - industry, agriculture, environmental organizations and citizens.

Large catchments seem to be obvious examples to be addressed within a global LOICZ synthesizing effort (e.g., Amazon, Nile, Yangtze, Yellow, Orinoco), and East Asia is dominated by big streams. However, from the perspective of coastal change on regional and global scales, considerable if not major influence from land-based flows is generated in small to medium catchments with high levels of socio-economic activity. Changes in land cover and sectoral use need much shorter time-frames to translate into coastal change and usually exhibit more visible impacts in smaller catchments than in large catchments where the "buffer capacity" against land-based change is higher simply as a function of catchment size. Thus, small and medium catchments are in principle of equal priority to the global LOICZ-Basins assessment. They dominate the global coastal zone (in Vietnam, for example, they characterize extensive parts of monsoon-driven runoff to the South China Sea). In island-dominated regions such as the South Pacific or the Caribbean – or in East Asia the island of Taiwan and the Japanese Archipelago - frequently whole islands can be considered as one catchment affecting the coastal zone and influences are generated by both anthropogenic drivers and global forcing.

The approach

Regional networks, assessment workshops/desk studies

Through two-stage regional workshops, LOICZ-Basins builds up regional multidisciplinary networks of scientists who bring their experience and existing information into the synthesis process. The first workshop identifies the pertinent regional issues and provides a first ranking order of current and predicted impacts with trend analysis, based on expert judgement and published scientific information. A second workshop finalizes the regional synthesis, improves the geographical and thematic coverage and assists in preparing research proposals for local and regional funding. Emphasis is given to close coupling of biogeochemical and physical sciences with human dimensions. Workshops have been held and networks established in Europe, Latin America, East Asia (this report) and Africa, while desk studies cover the Caribbean, Oceania and the Russian Arctic. (The East Asia Basins assessment was run as a single workshop. This was possible through the broad scientific and geographical coverage provided by the network. However, the two-step approach is preferable).

In February 2001 the European Catchments (EuroCat) project, funded by the European Union, started as a direct result of a LOICZ assessment (http://www.iia-cnr.unical.it/EUROCAT /project.htm). The EuroCat design, objectives and modelling approaches serve as templates for the development of other regional catchment-coastal zone projects currently being developed for Africa (in implementation with support from START as a pilot study phase 2002/03 – four catchments), and Latin America. In East Asia a similar development is foreseen for the near future.

A **LOICZ-Basins** web-page is now available at the GKSS Research Center, Geesthacht, Germany, (http://w3g.gkss.de/projects/loicz_basins/) and through the LOICZ web-site (http://www.loicz.org). It is updated continuously and provides pdf copies of reports.

Proposals and projects that develop from regional LOICZ-Basins efforts contribute to the global LOICZ assessment. They also contribute to the Integrated Coastal Area Management initiative, ICAM, as well as to the Coastal GOOS "Global Ocean Observing System" of UNESCO/IOC. Links to the typology up-scaling effort considering global river run off and coastal biogeochemistry (a joint project of LOICZ and BAHC through the University of New Hampshire, are being pursued [http://www.kgs.ukans.edu/Hexacoral/Tools/tools.htm]). Watching briefs exist with other global efforts such as GIWA, the WWAP and Millennium Assessment. Increasing the links with the Regional Seas initiatives under UNEP and the GPA is under consideration.

The framework for LOICZ-Basins synthesis and project development

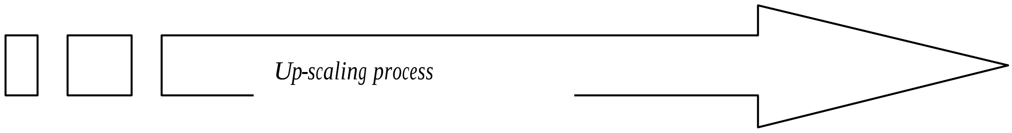
Since LOICZ-Basins workshops have a regional focus, assessment and ranking follow a hierarchy of scales finally allowing a full regional picture to be generated. The scales increase from:

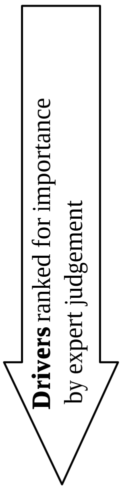
- local catchments via
- sub-regional or provincial scales up to
- regional scale which could be a country (e.g., continental China) or a sub-continent or continent.

To facilitate thinking and to guide the evaluation of existing information, the Driver-Pressure-State-Impact-Response scheme (DPSIR) has proven to be an appropriate descriptive framework. The steps taken are:

1. set up a **list of coastal change issues** of and **related Drivers** in the catchment (plenary-task).
2. characterize and rank the various issues of change based on either **qualitative information** (i.e., expert judgement - if there are no hard figures) or **hard data** coming from investigations or archived material; this includes identifying **critical load** and **threshold** information for system functioning.
3. derive a list of current or prospective **"hot spots"** representative of a type or class of catchment-coast system, from which to develop a **proposal** for future interdisciplinary work.

LOICZ-Basins aims to provide an **expert typology** of the current state and expected trends of coastal change under land-based human forcing and natural influences. The assessment follows a set of key questions which cover the various aspects and scales of the DPSIR analysis and follow a sequence of **assessment tables**; participants are asked to fill in prior to the workshops. A generic scheme is shown below. All major assessment tables closely follow this scheme, and allow intra- and inter-regional comparison within the global LOICZ-Basins effort, although the entries to the tables can be different.





Coastal issues	***Drivers****	**Local catchment level (allowing within- and between-catchment comparison)**		***Sub regional level*** **(e.g. by country or considering open** ***versus*** **enclosed seas)**		**Region level (e.g., Asia)**
Eutrophi-cation	Damming	River A	Trends or Ranking	Sub-region 1 (Rivers A-D)	Trends or Ranking	
Erosion	e.g. Water Abstraction	River B				
Loss of Biodiversity						

***** = see comments on this driver identification and ranking on the following pages.

Figure 3.2: Basic schema of assessment tables.

Ranking and classification

The OSPAR 2000 quality status report (http://www.ospar.com) lists human pressures on the coastal sea in a ranking order with four classes according to their relative impact on the regional ecosystem - including sustainable use. Pressures are attributed to various drivers or pressure classes.
Table 3.1 shows some examples compiled along the OSPAR guidelines, adapted to fit the LOICZ-Basins concept. It focuses on issues which link to land-based activities.

From these and other examples, adapted to the LOICZ needs and relying strongly on regional expert judgement and - if available - regional quality standard protocols and agreements, the LOICZ-Basins task group has developed a set of **LOICZ-Basins Regional Assessment tables** for global application.

LOICZ-Basins Regional Assessment Tables (Table 3.1-Table 3.8) and key questions for workshops, synthesis and project development

The tabulated DPSIR analysis has proven to be an appropriate descriptive framework for this purpose. The questions leading through the tables have usually been addressed in the first phase of the LOICZ-Basins workshops. The tables ensure a standardized approach within the global LOICZ-Basins effort. They allow integration of the regional assessments and expert typologies into the global scales and help to fill gaps and harmonise the synthesis. Data included in the first workshop are reviewed and confirmed in light of new information delivered to the second workshop. Detailed source references for data or critical load information is included wherever possible (they can, however, also rely on expert knowledge to a considerable extend). The steps taken are outlined in the accompanying Regional Assessment tables.

Table 3.1 Examples of impacts, pressures and driver/pressure settings in the LOICZ context.

Impact priority	Priority classes of human pressures	Driver/pressure settings - sectoral; land- or catchment- or sea-based
A (highest impact)	Input of organic contaminants – land-based	Various economic sectors
	Inputs of nutrients – land-based	Various sectors, urbanization, (wastewater, agriculture)
B (upper intermediate impact)	Input of oil and PAH – land-/sea-based	Oil industry/Shipping
	Input of other hazardous substances – land-/ sea-based	Industry/Shipping/various sectors
C (lower intermediate impact)	Input of nutrients, organic material, antibiotics etc.	Mariculture
	Mineral extraction – land/ sea based	Engineering, Mining
	Inputs of radio nuclides from land	Energy and other sectors
D (lowest impact)	Input of waste/litter	Recreation, Tourism

Table Input

Major data needed for the assessment are material flows and loads (historic data and those of relatively unimpacted systems if possible). Fluxes to be considered are:

- Water
- Sediments
- N, P, C (Si)
- Contaminants

The trend information on expected changes in the DPSIR scenarios across the various scales (how will drivers change and will this affect the loads to the coastal sea?) provide preliminary assessment that sets the stage for dynamic scenario analysis.

The critical thresholds information can be derived from: ecological (State/Impact relationship) as well as political and managerial information (Response) which refers to environmental quality standards, regulations, water directives and other comparable instruments.

Table 3.2 Major coastal Impacts/issues and critical thresholds in coastal zones – Overview and qualitative ranking based on change in the region following the key questions:

- What are major impacts (coastal issues) along the coastal zone?
- How close are they to a critical threshold of system functioning?

Coastal impact/issue e.g.	**Local site/region (contributing river basins) e.g.**	**Critical Threshold (for system functioning) e.g.:**	**Distance to Critical Threshold (qualitative or quantitative) e.g.:**	**Impact category (Impact code and rank of importance 1- 10)**	**References/ data source**
Erosion (coastal geomorphology)	River ABC - Delta	For coastal stability; Sustained delivery of xy t per year …..	Qualitative or quantitative information. about the amount needed for coastal security. (e.g., no distance since the sediment delivery due to damming has been reduced to such a level that coastal erosion becomes a continuos process)	Erosion - 10	Database xyz, Reference abcd, 19...…
Eutrophication (habitat loss)	Bay ACEF – (rivers draining into the Bay a,b,c,…)	Seagrasses show signs of destruction; Occurrence of anoxia or low oxygen in estuaries; Nutrient load is at the threshold.	Further increased nutrient load by 20-30% will change the system	Eutrophication – 8	
Pollution	Rivers XYZ				

Notes for use

This table is a first priority list of issues for the regional coast based on riverine (i.e. catchment-based) forcing. It serves to compile as much information as possible on critical fluxes, loads and thresholds for systems functions. It provides a first overview of a remaining capacity for material input or withdrawal that a target ecosystem might be able to handle without observable change. This can refer to a single function such as the stability of a coastal area against erosion. It can also refer to a multicausal impact affecting for example fisheries or water quality. These critical load and threshold estimates return in Table 3.8 as part of the "hot spot" and response assessment.

The ranking involves 4 main categories: values 1-3 no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value 10 = critical.

Table 3.3 DPSI matrix characterizing major catchment-based Drivers/Pressures and a qualitative ranking of related coastal State changes impacting the coastal zone *versus* catchments size class.
State change dimension: major; medium; minor; no impact; ? = insufficient information.
Time scale: p = progressive (continuous); d = discrete (spontaneous) n.a. = not applicable

Key questions and examples:

- What are the major (max. 10) driver / pressure settings on river catchment level causing coastal change?
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues?

Driver	**Pressures**	**State change (qualitative index)**				**Impact on the coastal system**	**Time scale**
		Large basins	**Medium basins**	**Small basins: active coast**	**Small basins: passive coast**		
Agriculture	Waste/nutrient (excess fertilizer) Increasing sediment transport Water extraction	**minor**	**medium**	**major**	**major**	Eutrophication; Contamination; Siltation, etc….	**p**
Damming	Nutrient and sediment sequestration Changing hydrological cycles	**?**	**major**	**n.a.**	**medium**	Coastal erosion; Nutrient depletion; Salinization	**d**
Deforestation	Sediment budget alteration …..	**minor**	**major**	**major**	**major**	Siltation; Sediment accretion/ Erosion	**p**
etc	**etc**					**Etc**	

Notes for use
Please refer to the basins in your sub-region or for which you have information and make a judgement on how intense the effects of the various drivers on these catchments are and to what extent this may impact on the coastal zone. Ranking is in three categories (also used in tables 2 and 4-6); those are: minor importance equals 1-3, medium importance equals 4-6, major importance equals 7-10.
State changes in coastal zones driven by a catchment – based prozess will vary according to catchment size, for example: Deforestation even on large scale if conducted in a huge catchment such as the Yellow or Yangtze will cause a rather moderate if any coastal signal as compared to effects originating from pressures on small catchments where even minor deforestation can dramatically influence the sediment budget in the coastal zone. So, deforestation in some large catchments could be scored a "minor" while in a small catchment it could go score a "major" ranking. Where your information is referring to only one catchment type or class (e.g., large >200.000 km^2, medium 10.000 – 200.000 and small <10.000 km^2), delete or ignore the other columns.

Active/passive coast refers to geomorphology, tectonics and climate. Small rivers along the Vietnamese coast for example are in a tectonically rather passive area with high seasonality in runoff (monsoonal influence) while small rivers draining to other coastal areas e.g. the Island of Taiwan or the Japanese Archipelago are located in a tectonical rather active area exhibiting high slopes but they also feature high amplitiudes of seasonal runoff variation on a yearly time-scale.

Table 3.4 Linking coastal issues/Impacts and land based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on local or catchment scale.

Key questions:

- What are the major pressure/driver settings at catchment level causing coastal impacts?
- What are the future trends (based on hard data or expert judgement)?

Coastal Impact/issues	Drivers	**Local catchment (allowing within and between catchment comparison)**		**Trend expectations**	References/ **data sources**
		River A	Category (1 low – 10 high)		
Erosion	Damming	Area… Volume… Runoff reduction… …..	10	Increasing	XYZ, 2000
	Deforestation	Area… Residual TSS production… …..	8	stable	
	Diversion	Little, area; effect on water flow… …..	4	decreasing	
Erosion total	All drivers	In River A	Ranking weighted from information above	Overall trend	
		River A	Category		
Eutrophication	Agriculture	Residual nutrient production…	9		
	Mariculture	Local residual nutrient production…	5		
	Municipal waste	Local urbanisation areas… ; xy t/tear residual production	10		
Eutrophication total	All drivers	In River A	Ranking weighted from information above	Overall trend	
Further issues					
etc					

Notes for use:

After finishing River A, continue with River B,C etc. Where possible please treat pollution separately from eutrophication.

The ranking involves four main categories: values 1-3 = no or minor importance; values 4-6 = medium importance; values 7-9 = major importance and value 10 = critical.

Table 3.5 Linking coastal issues/Impacts and land-based drivers in coastal zones – Overview, qualitative ranking and trend expectations on <u>country or sub-regional</u> scale.

Key questions and example:
- What are the major pressure/driver settings on <u>country or sub-regional level</u> causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	**Sub-regional (i.e. by country or comparing open versus enclosed seas)**		**Trend-expectation**	**References/ data sources**
		Sub Region A	Category (1 low – 10 high)		
Erosion	Damming	• Catchments involved • Area… • Volume… • Run off reduction…	5	stable	
	Deforestation	Area… Residual TSS production…	8	increasing	
	Diversion	Little, area…; effect on water flow…	4	increasing	
Erosion (total in sub-region A)	All drivers and rivers weighted	Sub Region A	Ranking weighted from information above		
Eutrophication	Agriculture	Residual nutrient production…	9		
	Mariculture	Local residual nutrient production…	5		
	Municipal waste	Local urbanisation areas… ; xy t/year residual production	10		
Eutrophication (total in sub-region A)					
etc.	**etc.**	**etc.**			

<u>Notes for use:</u>
If you have information about more than one sub-region e.g. north-west Africa or north-east Brazil, please treat them separately. Information involved here should summarize the coastal issues for the whole region and consider all the rivers reaching the coast.
The ranking involves 4 main categories: values 1-3 = no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value10 = critical.

Table 3.6 Linking coastal issues/Impacts and land-based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on whole regional or continental/sub-continental scale.

Key questions**:**

- What are the major pressure/driver settings at whole regional, continental/sub-continental level causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	***Full regional*** (continent or sub-continent)		**Trend-expectation**	**Reference/ data source**
		e.g. Asia or East Asia	Category (1 low – 10 high)		
Erosion	Damming	• Sub-regions involved • Area… • Volume… • Runoff reduction…	2	increasing	
	Deforestation	• Area… • Residual TSS production…	8	stable	
	Diversion	Little, area; effect on water flow	4	increasing	
Erosion (total in the region)	All drivers and rivers weighted	Full region scale	Ranking weighted from info above		
Eutrophication	Agriculture	Residual nutrient production…	4		
	Mariculture	Local residual nutrient production…	5		
	Municipal waste	Local urbanisation areas… ; xy t y^{-1} residual production	10		
Eutrophication (total in the region)					
etc.	**etc.**	**etc**.			

Notes for use:

This table should be filled in during the workshop since it will help synthesising the working group discussions on up-scaling individual catchment and sub-region based information.

The ranking involves 4 main categories: values 1-3 = no or minor importance, 4-6 = medium importance, 7-9 = major importance and 10 = critical.

Table 3.7 Scientific and/or management Response to coastal impact/issues in (continental region) coastal zones on catchment, sub-regional and regional scale.

Assessment of scientific and/or management Response on the various scales: overview of monitoring programmes and scientific investigations as well as (if applicable) management interventions, environmental quality standards, legislation, river and other commissions).

Key questions:

- What is the current status of response taken at scientific policy and/or management levels against the major coastal issues in the region?

River catchment	**RESPONSE catchment scale**		***RESPONSE Sub-regional/ country scale***		**RESPONSE Regional scale**	
	Scientific	**Management**	**Scientific**	**Management**	**Scientific**	**Management**
River A	e.g. monitoring programme 19-- 2001, Data: …; Source:	e.g. commission established; thresholds set; legislation in place… Source:	e.g. (combining catchments A-B-… Programs? Data? Source:	e.g.…	e.g. UNEP Regional Seas programme Source:	e.g. quality criteria for the regional waters? Source
River B						
River C						
River D						
River E						

Notes for users:

This table describes the current activities dealing with the issues on either a scientific or a policy level. This can include databases and monitoring efforts, local GOOS networks or simply investigations. On policy and management levels, this focus can be on guidelines, threshold values and environmental standards (political critical loads). The scale to which these measures are being applied or should apply should be mentioned.

The information and ranking of DPSIR scenarios (tables 1-5) together with this "Response" information should lead to the identification of "hot spots" to be listed in Table 7.

Table 3.8 "Hot spots" of land-based coastal impact and gaps in understanding; a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

Key questions:

- What are the major gaps in our current understanding of river catchment - coastal sea interactions?
- Which "hot spots" should be addressed in a future integrated scientific effort (natural and socio economic disciplines)

River catchment	**"Hot spot" catchment scale**		***"Hot spot" sub-regional/ country scale (e.g. Yangtze River or Bohai Sea)***		**"Hot spot" regional scale**	
	Key issues, trend and gaps	**Scientific approach**	**Key issues, Trend and gaps**	**Scientific approach**	**Key issues, Trend and gaps**	**Scientific approach**
River A	…	Biogeochemical studies Residual calculation by economic sectors Critical flux investigation Stakeholder and scale analysis ACTION ….		e.g.…	…	…
River B						
River C						
River D						

Notes for use:
This table extracts from the regional assessment the potential demonstration sites, which can be included in a proposal for a future Regional Catchment/Coast Assessment Project - "…Cat". Ideally the sites should represent different settings which are typical for a special sub-region. This would allow up-scaling of the findings to comparable "classes" of catchment/coastal systems at a later stage. An accompanying note may be given informing about ongoing activities, link suggestions and key contact persons.
Emphasis should be on the human dimensions of catchment–coastal sea interaction considering the co-evolution of natural and societal systems (i.e. involving natural and socio-economic sciences).