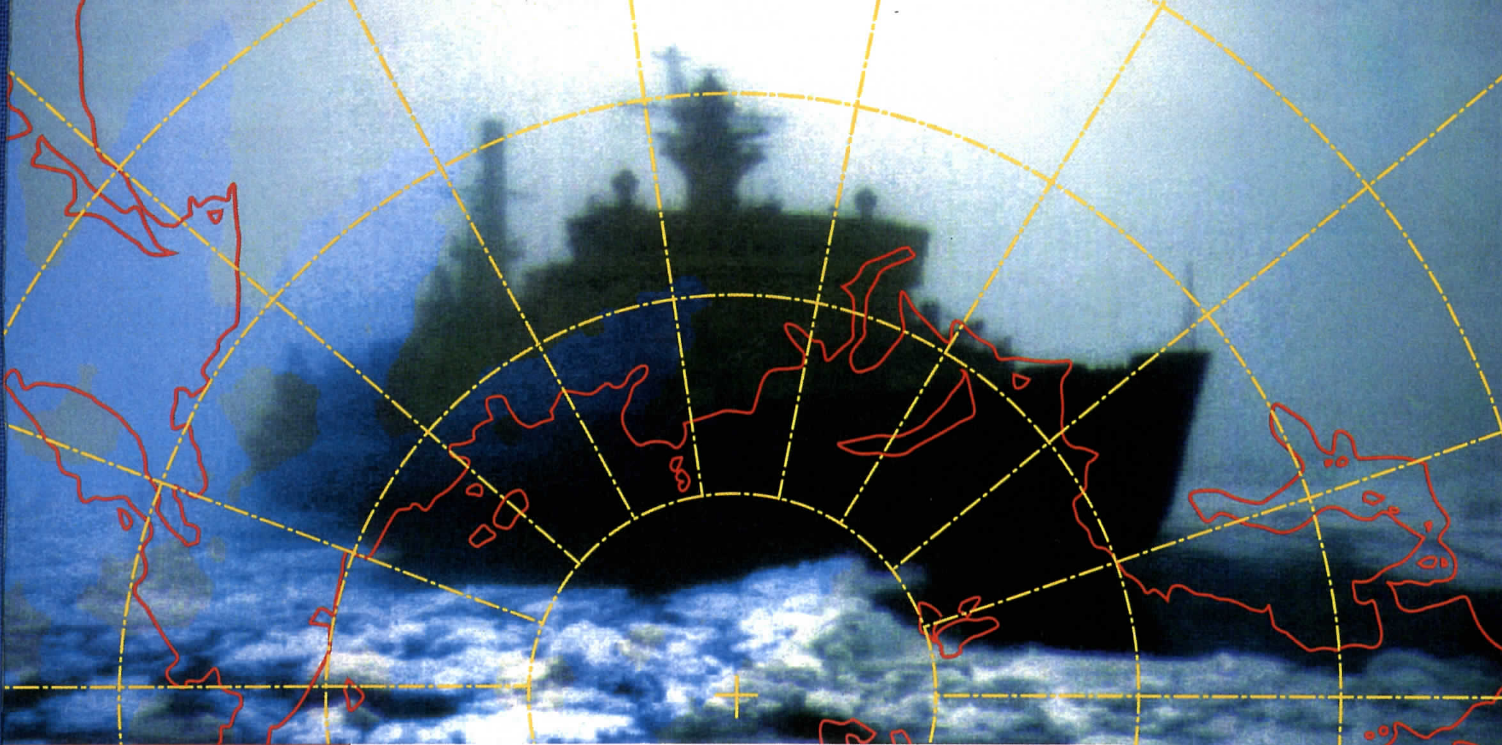

INSROP WORKING PAPER
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Linkages and impact hypothesis concerning the Valued Ecosystem Components (VEC's) Invertebrates, Fish, the Coastal Zone and Large River Estuaries and Deltas

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INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

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Ship and Ocean Foundation, Japan

International Northern Sea Route Programme (INSROP)

Central Marine Research & Design Institute, Russia | The Fridtjof Nansen Institute, Norway | Ship & Ocean Foundation, Japan

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Sub-programme II: Environmental factors

Projects II.4.1: Marine and Anadromous Fish and Invertebrates
II.4.4: The Coastal Zone
II.4.5: Large River Estuaries and Deltas

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What is an INSROP Working Paper and how to handle it:

FOREWORD - INSROP WORKING PAPER

INSROP is a five-year multidisciplinary and multilateral research programme, the main phase of which commenced in June 1993. The three principal cooperating partners are **Central Marine Research & Design Institute (CNIIMF)**, St. Petersburg, Russia; **Ship and Ocean Foundation (SOF)**, Tokyo, Japan; and **Fridtjof Nansen Institute (FNI)**, Lysaker, Norway. The INSROP Secretariat is shared between CNIIMF and FNI and is located at FNI.

INSROP is split into four main projects: 1) Natural Conditions and Ice Navigation; 2) Environmental Factors; 3) Trade and Commercial Shipping Aspects of the NSR; and 4) Political, Legal and Strategic Factors. The aim of INSROP is to build up a knowledge base adequate to provide a foundation for long-term planning and decision-making by state agencies as well as private companies etc., for purposes of promoting rational decisionmaking concerning the use of the Northern Sea Route for transit and regional development.

INSROP is a direct result of the normalization of the international situation and the Murmansk initiatives of the former Soviet Union in 1987, when the readiness of the USSR to open the NSR for international shipping was officially declared. The Murmansk Initiatives enabled the continuation, expansion and intensification of traditional collaboration between the states in the Arctic, including safety and efficiency of shipping. Russia, being the successor state to the USSR, supports the Murmansk Initiatives. The initiatives stimulated contact and cooperation between CNIIMF and FNI in 1988 and resulted in a pilot study of the NSR in 1991. In 1992 SOF entered INSROP as a third partner on an equal basis with CNIIMF and FNI.

The complete series of publications may be obtained from the Fridtjof Nansen Institute.

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Sammendrag / Summary

The INSROP programme aims at carrying out an Environmental Impact Assessment (EIA), using the Adaptive Environmental Assessment and Management (AEAM) method. INSROP is spilt into four sub-programmes, and this report presents the Valued Ecosystem Components (VECs) that were selected in the sub-programme II projects: II.4.1: Marine and anadromous fish, II.4.4: The coastal zone, and II.4.5: large river deltaes and estuaries. Potential effects of increased traffic through the Northern Sea route (NSR) on the VECs are examined through a set of effect causing linkages and impact hypothesis. Pollution from ships and cargo is expected to have the most severe impact on the VECs , while impact of physical disturbance and noise are expected to be less significant.

Emneord:	*Key words:*
Nordøst-passasjen	Northern Sea Route
fisk	fish
evertebrater	invertebrates
kystsonen	coastal zone
elvedeltaer	estuaries

Prosjektleder / Project manager	*Kvalitetskontroll / Quality control*
Lars-Henrik Larsen	Jos Kögeler

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PREFACE.

The Subprogram II of INSROP addresses the selection and evaluation of so-called Valued Ecosystem Components (VEC's), to be used in the final environmental impact assessment. The VEC's are selected using criteria like ecological importance, data availability and vulnerability towards the Northern Sea Route activities

This working paper presents the results of the projects II.4.1, II.4.4 and II.4.5. It describes the selection and evaluation of the VEC's and the evaluating impact hypothesis (IH's).

The projects were coordinated by Akvaplan-niva, and carried out in cooperation with the Zoological Institute of the Russian Academy of Science.

The draft for this working paper was reviewed by Dr. Eike Rachor, Alfred Wegener Institutt für Polar- und Meereskunde, Bremerhaven, Germany. A copy of the main contents of the review is given in appendix 1. Comments made directly in the text were incorporated in the final document, either directly as changes in the running text, or as footnotes.

The general framework for understanding the structure and formulation of the present paper is the INSROP subprogramme II. A general outline of the full contents of the Subprogramme II is given in Appendix 2.

Tromsø 3. May 1995

Lars-Henrik Larsen Anita Evenset Boris Sirenko

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1 Introduction

The process of evaluating the potential impacts of opening the Northern Sea Route (NSR), is based on the Adaptive Environmental Assessment and Management (AEAM) evaluation system developed by Holling (1978) and modified by Hansson *et al.* (1990). This system is based on the selection and evaluation of some major parts of the ecosystem (Valued Ecosystem Components, VEC's), which are treated and analysed on a general level. A VEC is defined as a resource or environmental feature that: a) is important (not only economically) to a local human population, or b) has a national or international profile, or c) if altered from its existing status:

- will be important for the evaluation of environmental impacts of industrial developments
- the focusing of administrative efforts (Hansson *et al.* 1990).

The selection of the VEC's was carried out on an INSROP-workshop in Oslo in November 1993 (Hansson 1994). However, some adjustments were made at a workshop at Songli in November 1994. Each selected VEC is examined using a set of effect-causing linkages and impact hypotheses.

This INSROP working paper presents the Impact Hypotheses (IH's) and biological couplings acting upon and affecting the VEC's selected by the three Subprogram II projects:

- II.4.1: Marine and Anadromous Fish and Invertebrates,
- II.4.4: The Coastal Zone
- II.4.5: Large River Estuaries and Deltas.

The IH's follow the selected scenario-areas and topics suggested by Thomassen *et al.* (1994) and will form the basis for the Environmental Impact Assessment (EIA). As all three projects were managed by Akvaplan-niva, the results are presented in one comprehensive working paper.

2 Valued Ecosystem Components (VEC's) and Impact Hypotheses (IH's)

A common numbering system for all VEC's and impact hypotheses in Subprogram II, agreed upon at the Songli workshop, is used in this paper. The list of selected VEC's for the three Akvaplan-niva managed projects is shown in Table 1.

Table 1 Selected VEC's for the INSROP subprogram II projects II.4.1, II.4.4 and II.4.5 (numbering according to agreement at Songli, November 1994).

VEC	Number	Appointed by project
Benthic invertebrates	A1	II.4.1, II.4.4, II.4.5
Marine, estuarine and anadromous fish	A2	II.4.1, II.4.4, II.4.5
Plant and animal life in Polynyas	A3	II.4.1
Human settlements	D1	II.4.4, II.4.5
Water land border zone (sensitive areas)	D2	II.4.4, II.4.5

The VEC's "Plant and animal life in Polynyas" and "Water-land border zone" encompass a relatively wide geographic area, while the other VEC's of the subprogram deal with groups of organisms. This might lead to some overlap between the sub-programme projects, and also with other sub-programmes, especially subprogram IV.

The potential impacts of the traffic are expected to arise from four categories;

- Noise — Underwater noise from propellers and engines, ice being broken by ships' hulls etc. Noise from fog-horns is also considered in this context.
- Pollution — Contamination due to operational liquid and gaseous discharges from engines etc. Accidental losses of cargo and fuel.
- Physical disturbance — Pressure waves, light etc.
- Waste — Kitchen, maintenance and general rubbish etc.

Each category is separated into operational and accidental discharges, thus creating eight types of impact. A schematic flow chart, i.e. a diagram of boxes and arrows indicating the context in which the VEC appears, is presented for each VEC. The main categories of physical and biological factors (system components) and processes influencing the VEC are included in the flow chart. When a type of impact is considered to be insignificant on the actual VEC, this impact is omitted from the schematic flow chart for clarity. The relationships between the components/processes are called linkages. The linkages indicate which developments will influence the VEC directly or indirectly, via system components or processes. Each linkage is explained in a brief text proceeding the flow chart. Only the components that are in direct interaction with the VEC has been included in the flow chart. A series of impact hypotheses (IH's), i.e. hypotheses for the impacts of increased NSR traffic on the VEC, can be set up by means of these links.

The impact hypotheses are evaluated according to the assessment-system proposed by Hansson *et al.* (1990). All of the hypotheses have been listed in a standard table with the following categories:

1. *Hypothesis*: The hypothesis.
2. *Explanation*: Description of the hypothesis based on the flow chart.
3. *Category*: The placing of the hypothesis in one of the following categories:

A The hypothesis is assumed to be invalid.

B The hypothesis is valid and already verified. Research to validate or invalidate the hypothesis is not required. Surveys, monitoring and/or management measures can possibly be recommended.

C The hypothesis is assumed to be valid. Research, monitoring or baseline surveys are recommended to validate or invalidate the hypothesis. Management measures to reduce environmental damage can be recommended if the hypothesis is proved to be valid.

D The hypothesis may be valid, but is not worth testing for professional, logistic, economic or ethical reasons, or because it is assumed to be of minor environmental influence only. Monitoring, baseline surveys research and/or management measures can be recommended.

4. *Rationale*: Argumentation for the placing of the hypothesis.
5. *Management recommendations*: Measures, procedures etc. associated with the opening of the NSR to prevent or reduce harmful effects on the environment.
6. *Surveys*: The occurrence of VEC's at the relevant times/sites are surveyed, to prevent/mitigate and/or predict possible harmful effects.
7. *Monitoring*: Investigations measuring the extent of impact, or assessing the cause-effect relationship connected with the opening of the NSR.
8. *Research*: Test of a system process hypothesis, i.e. the impact of a development on a VEC or its associated components, or investigations to find the baseline measurements required for further research concerning the problems in case.

The VEC's discussed in this working paper are expected to be most vulnerable to accidental pollution from increased NSR traffic. Major discharges of oil, dispersants, cargo like chemicals, ore, fertilisers and radioactive material are expected to have the most severe impacts.

Several of the possible disturbances pointed out by Thomassen *et al.* (1994) for the INSROP EIA are expected only to have marginal effects. For instance, noise from passing ships is not expected to affect the VEC Benthic invertebrates to any measurable extent.

3 VEC A1: Benthic invertebrates

3.1 Background

The VEC A1 "Benthic Invertebrates" comprises invertebrates living buried in or on soft bottom sediments and those attached to hard bottom substrates. This VEC therefore include sediment eaters, such as scallops, blue mussels, benthic crustaceans and starfish, as well as hardbottom groups, such as bryozoans and hydroids, and soft bottom groups, such as the infaunal molluscs and polychaetes.

The arctic invertebrates play a major role as food for organisms at higher trophic levels, e.g. walrus preying on bivalves (Griffiths *et al.* 1987). Benthic invertebrates also play a major role as consumers of detritic material, which is converted to accessible food for organisms at higher trophic levels.

Assessment of invertebrate infaunal populations serve as a useful tool for monitoring human impacts on the environment in the Arctic as well as elsewhere. Invertebrate infauna lives in soft sediments, and can be collected quantitatively. Human impacts, e.g. pollution, will cause changes in both species composition and population densities. These differences are expected to be longer lasting in the Arctic, where growth is slow and generation time is generally expected to be long. Benthic invertebrates as indicators of anthropogenic impact are widely used in environmental monitoring.

Invertebrates are also often used for monitoring levels of organic and inorganic pollutants (PAH, PCB, heavy metals, radionuclides), as they have a relatively limited ability to excrete such compounds, thus accumulating a body burden that is higher than that in the water or sediment. This problem may assume more importance in the Arctic, where the often larger size of the individuals indicates a longer lifespan, and thus longer exposure time to contaminants.

The species composition along the NSR has been investigated by Russian scientists for more than 100 years, and several regions have been identified, classified and described according to the biomass and species composition in the invertebrate communities (e.g. Golikov & Scarlato 1989). At least 1580 species of benthic invertebrates, both infaunal and epifaunal, have been recorded from the Kara Sea, and some 1000 species are known from Laptev, East Siberian and Chucki Seas (Fig. 1). Among the known invertebrates in the Eurasian Arctic shelf area, the macrobenthic species dominate (68 %) while microbenthic species comprise 26 % and planktonic species only 6 % (Sirenko & Piepenburg 1994). However, the microbenthos is at present a relatively insufficiently studied group, and might deserve some more attention.

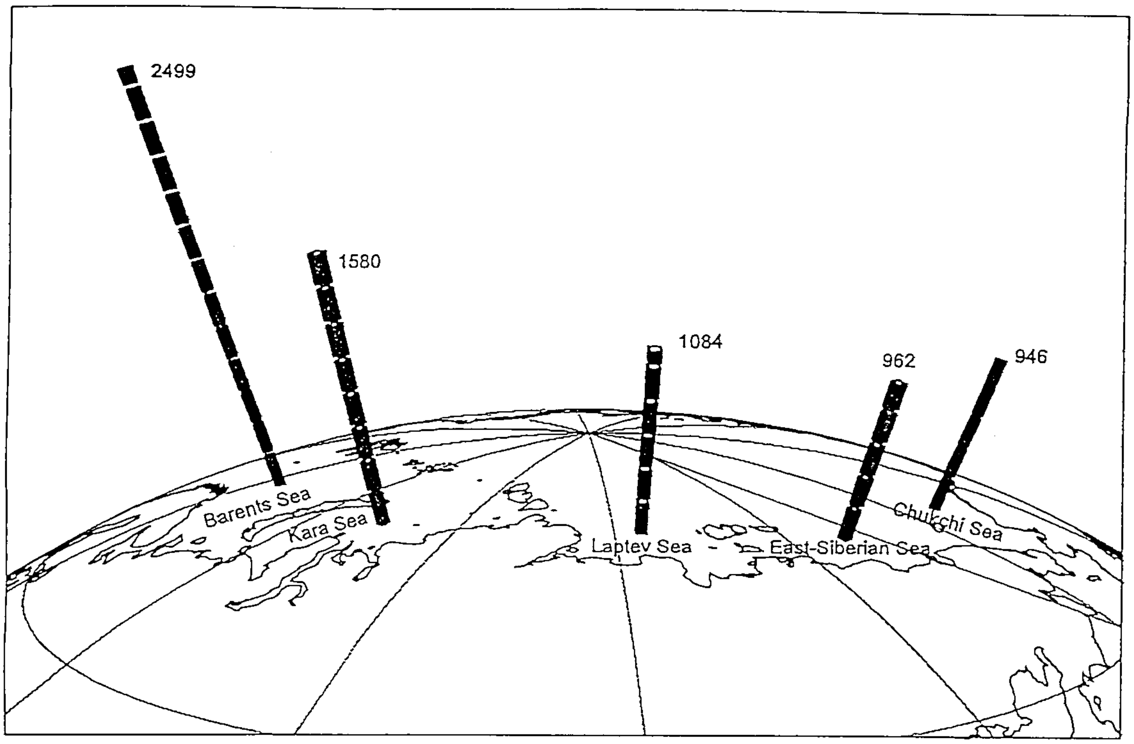

Figure 1. Number of species of benthic invertebrates known from the Russian Arctic Seas (Sirenko in press).

In most of the area along the NSR, the benthic invertebrate fauna is constantly exposed to sub-zero temperatures, and permafrost below the sea-bed is common (Keck & Wassmann 1993). The significance of the benthic invertebrate communities along the NSR arises mostly from their important role in providing food for higher trophic levels, but even the most serious accident is unlikely to cause more than local damage to the invertebrate VEC itself[1].

The epifaunal hard-bottom invertebrates are entirely dependent on the presence of a firm, hard and stable substrate (not displaced by tides or ice scouring) to which they can attach. Free living forms like crustaceans and brittle-stars are less dependent on a specific substrate.

Hard substrate mostly occur in shallow water areas with either moderate to strong currents or wave action. Particle bound pollutants will bypass such habitats and end up sedimentating in low energy, soft bottom areas. Therefore, it is expected that hard bottom fauna is less vulnerable to particle bound pollutants than soft-bottom fauna. However, filtrating hard-bottom organisms will actively remove polluted particles from the water, and thus become exposed.

Invertebrate hard-bottom epifauna is adapted to relatively strong currents and wave actions. Many of the organisms depend on filtration or grazing as feeding mechanism. They are very vulnerable to alterations in the substrate. Dumping of dredging material in hard bottom areas may eradicate a large part of the epifauna, due to clogging of

[1] Rewiever comments that in severe cases of oil spill, the damages might have more than local extent.

filtration organs, even though the material eventually will be transported away by the currents.

Most benthic invertebrates reproduce once a year. Many species simply release eggs and sperm to the water column, leaving the rest to Nature. The first stages in the life cycle are thus pelagic, and this is the period when the species are distributed to new habitats. At a certain time, the pelagic larvae settle to the bottom. During settlement it is essential that the substrate is of a suitable texture, and that there is not too much competition for space or too many predators present. The lack of suitable substrate is often a limiting factor during the settlement period of hard-bottom organisms. Available, hard and stable substrates are thus rapidly covered by epifaunal organisms, in competition with marine algae (in shallow areas) which also use the pelagic system for spreading. However, among the polychaetes (Wilson 1991) and in all peracarides (Rachor, E. pers. comm.), a wide range of brooding behaviours are exhibited, where the duration of the planktonic phase is limited or even absent.

3.2 Linkages

Possible effects of increased NSR traffic on the VEC "Benthic invertebrates" are here described through a set of impact causing linkages. A scematic presentation of the linkages is given in figure 2.

1 Accidental and operational pollution will cause direct mortality in benthic invertebrates at the site of an accident. Also, mortality may be encountered spread over a larger area, resulting from for example abrading of anti-fouling agents from ships' hulls during passage through the ice.
2 Chronic, long term discharges of pollutants from ships can alter the species composition of benthic invertebrate communities.
3 In shallow areas, turbulence caused by ships can cause changes in sediment composition and distribution, thereby affecting survival and species composition in invertebrate communities (see also VEC D2).
4 Pollution can reduce the amount and quality of accessible food for benthic invertebrates, causing changes in species composition and benthic productivity.
5 Traffic can disturb predators (fish and mammals), leading to reduced predation pressure on invertebrates, thus changing survival conditions for such invertebrate prey.
6 At certain times of the year, pollution from ships can reduce the survival of pelagic larvae of invertebrate fauna, thereby affecting recruitment.
7 Pollutants accidentally or operationally discharged from ships can accumulate in invertebrate fauna, eventually resulting in increased mortality.
8 Waste from ships may serve as artificial substrates for hard-bottom dwelling invertebrates.
9 Particulate organic waste can serve as food for benthic invertebrates.
10 Pollution components can accumulate in bottom sediments and affect benthic invertebrates.

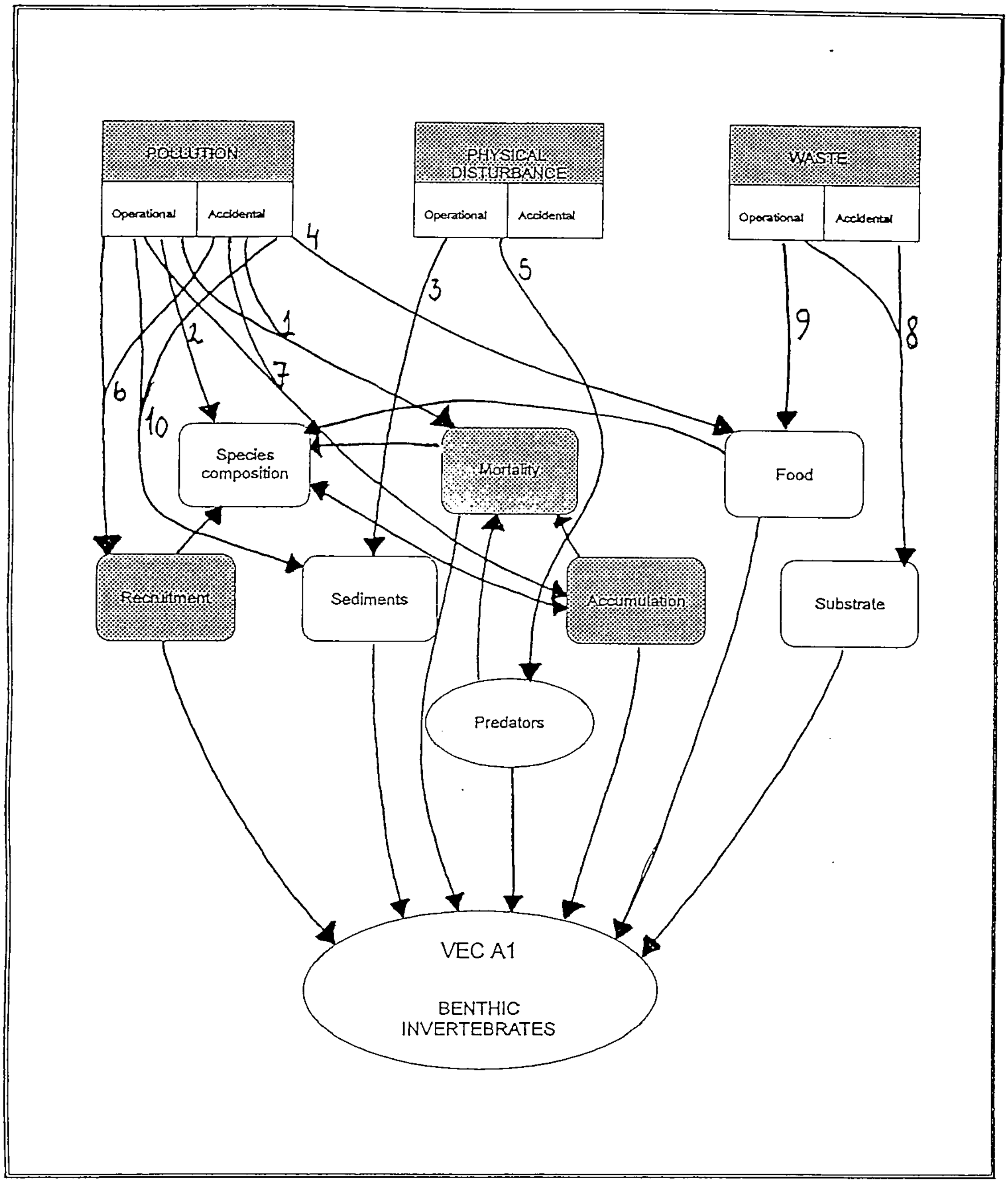

Figure 2. Schematic flow chart for the VEC benthic invertebrates. The shaded boxes represents processes, while the white boxes represent system components.

3.3 Impact Hypotheses (IH's)

Only impact hypotheses directly concerning the benthic invertebrates are treated in this context. Indirect effects on other parts of the eco-system, affecting VEC's of other projects, are dealt with in the respective working-papers.

A1-IH1 *Accidental discharges of pollutants will affect benthic invertebrates.*

A1-IH2 *Pollution from ship traffic will affect survival of pelagic larvae of benthic invertebrates at certain times of the year.*

A1-IH3 *Chronic pollution will cause accumulation of pollutants in benthic invertebrates.*

A1-IH4 *Hard-bottom epifaunal organisms can access new substrates by colonising the surface of dumped waste.*

3.4 Evaluated Impact Hypotheses (IH's)

VEC A1: **Benthic Invertebrates**	**A1 - IH1**

HYPOTHESIS: *Accidental discharges of pollutants will affect benthic invertebrates.*

EXPLANATION:
Being immobile, the invertebrate bottom-dwelling fauna can suffer increased mortality after a discharge of pollutants. Increased mortality and changes in community structure are caused by direct toxicity of e.g. oil, but also by clogging of feeding and respiratory organs. Sublethal effects like reduced fecundity and reduced production are likely to occur at some distance from an accident (Wells & Percy 1985).

CATEGORY: B

RATIONALE:
A long series of investigations following accidental oil spills world-wide (Rice *et al.* 1993) have documented the above expected series of effects. In addition, different types of cargo accidentally released from ships (ore, fertiliser, timber etc.) are documented to have an effect on invertebrate fauna (see review of sources and effects in Clark 1989).

MANAGEMENT RECOMMENDATIONS:
Oil spill contingency plans. Strict specification of hull-requirements for ships using the NSR. A register of cargo transported on each ship should be kept. Restrictions on types of cargoes transported during environmentally sensitive periods can be enforced.

SURVEYS:
Quantitative mapping of invertebrate communities in areas with insufficient data coverage are recommended, in order to expand the basic knowledge before activities are initiated.

MONITORING:
In the case of an accident, a monitoring programme must be directed towards the effects of the ship's cargo and fuel. Any synergistic effects should also be assessed.

RESEARCH:
Specific effects of cargo types that will be transported along the NSR should be investigated through laboratory and field experiments on arctic fauna.

VEC: **A1 Benthic Invertebrates**	**A1 - IH2**
HYPOTHESIS: *Pollution from ship traffic will affect survival of pelagic larvae of benthic invertebrates at certain times of the year.*	
EXPLANATION: Accidental discharges from ships are usually released to the pelagic system or the sea surface. Pelagic larvae are more sensitive to pollutants than adult bottom-dwelling organisms and can come in contact with higher concentrations following a discharge incident. This will in turn lead to increased mortality and subsequently reduced recruitment. Oil and chemicals are considered to be most harmful to the egg and larval stages of fish and benthos. An oil spill occurring in the spawning season or immediately afterwards may therefore affect recruitment. However, this hypothesis is difficult to test under natural conditions.	
CATEGORY: C	
RATIONALE: Toxicity tests and investigations have been carried out on pelagic juveniles of many species. Following major oil-spills, the effects on recruitment in invertebrates have always been of a temporary nature.	
MANAGEMENT RECOMMENDATIONS: Oil spill contingency plans. Strict specification of hull-requirements for ships using the NSR (See also VEC A1-IH1). "Free of charge [2]" delivery systems for waste products in the harbours is encouraged.	
SURVEYS: Same as VEC A1-IH1, but considering the season.	
MONITORING: Same as VEC A1-IH1, but considering the season.	
RESEARCH: Testing of the toxic effects of oil, chemicals and cargo on the egg and larval stages of benthic animals. Investigations of temporal distribution of pelagic invertebrate larvae will reveal the time-scale of the period of maximum density. Mapping of the vertical distribution of pelagic larvae will reveal the expected degree of exposure to surface oil slicks and other chemicals.	

2 "Free of charge" delivery systems in harbours is a disputed matter. The intention of the facility is to reduce the temptation for improper disposal of waste off-shore, and to reduce the risk of pollution in case an accident. If waste disposal systems are poorly developed, accidents involving ships carrying large amounts of waste, can happen. A deposit system might be introduced.

VEC: **A1 Benthic Invertebrates**	**A1-IH3**

HYPOTHESIS: *Chronic pollution will cause accumulation of pollutants in benthic invertebrates.*

EXPLANATION: Most benthic organisms have a very limited capacity to break down and excrete organic pollutants. If they are exposed to such pollution they will accumulate high concentrations in their body tissues. The acute effect of high body-burdens of different pollutants in invertebrates is assumed to vary according to species, sex, age etc. The most severe ecological effects are registered when the contaminated animals are eaten by predators, or if predators are forced to switch to more tolerant, but less accessible prey.

CATEGORY: B

RATIONALE: It is well documented that invertebrates have a limited capacity to excrete organic contaminants (Lee 1981, James 1989, Kvernheim & Brevik 1992). Due to their relatively long life-span, arctic invertebrates may accumulate higher body-burdens of contaminants than comparable species from temperate areas. Higher concentrations increase the risk of sub-lethal and lethal effects. Since pollutants may be transferred to the eggs, early embryonic development may be affected.

MANAGEMENT RECOMMENDATIONS: Discharges must be avoided. Alternatively strict limitations on concentrations in emissions should be imposed. Anti-fouling agents should be tested and approved before use. "Free of charge" delivery systems for waste should be available in the harbours, not only along the NSR, but also in the neighbouring harbours, e.g. Murmansk or Archangel.

SURVEYS: Levels of pollutants in invertebrates along the NSR are poorly documented, and a baseline survey is recommended.

MONITORING: General monitoring of pollutant levels is initiated through the AMAP programme. Specific monitoring in the NSR area will have to be adjusted to findings and registrations by AMAP

RESEARCH: Ecotoxicologial studies on arctic animals at different trophic levels should be encouraged.

VEC: **A1 Benthic Invertebrates**	**A1 - IH4**
HYPOTHESIS: *Hardbottom epifaunal organisms can access new substrates by colonising the surface of dumped waste.*	
EXPLANATION: In the marine environment, the availability of hard, stable substrates is a limiting factor for settling of pelagic larvae of hard-bottom organisms. Thus, new substrates will rapidly be colonised.	
CATEGORY: D	
RATIONALE: Underwater installations, solid dumped material etc., retrieved from the sea, always contain some epifaunal and epiphytic organisms. Waste, acting as artificial substrates will increase the range and distribution of such organisms by increasing the area of potential habitats.	
MANAGEMENT RECOMMENDATIONS: None.	
SURVEYS AND MONITORING: None.	
RESEARCH: Studies of colonisation of dumped waste will reveal which organisms are able to use such substrates.	

4 VEC A2: Marine, estuarine and anadromous fish

4.1 Background

The fish fauna along the NSR consists of relatively few species, but the relatively low number of species is often compensated for by high numbers of individuals. Nevertheless, species with all major life strategies are represented, from marine to anadromous and pure freshwater species. However, on a global scale the fish stocks of the NSR area are of minor importance. Zenkevitch (1963) mentioned 39 species of marine and anadromous fish from the Laptev Sea, and 37 from the Chucki Sea. In the Kara Sea including the Yenisei river estuary, 64 fish species are reported to occur (Neyelov 1994, present INSROP project). Pelagic shoaling fish and species adapted to life close to the ice edge such as the Arctic cod, *Boreogadus saida,* constitute an important food item for birds and mammals.

The most efficient means of storing energy is in the form of lipids, and the arctic fish fauna build up lipid stores during an intensive feeding period in spring and summer, allowing them to cope with food shortages during winter. Such a life strategy makes arctic fish vulnerable to reductions in the available food resources in summer, and arctic fish may be more exposed to lipid soluble pollutants like PAH or PCBs than comparable species from temperate areas, due to their high body lipid content.

The arctic food chains are short, often with only two or three steps from the primary producers to the top predators. This makes the entire system vulnerable to disturbances, as each link often is made up of only one species.

Besides the toxic/accumulative effects of pollutants, increased NSR traffic will cause increased risk of accidents, not only in open sea but also in harbours or during reloading operations. One possible NSR scenario is the transport of oil and goods on river barges, and reloading to NSR ships in the estuaries of the large rivers. The latter activity might cause oil-spills in these areas, placing spawning grounds and migration areas for anadromous fish at risk of contamination.

4.2 Linkages

Possible effects of increased NSR traffic on the VEC "Marine, Estuarine & Anadromous fish" are here described through a set of impact causing linkages. A scematic presentation of the linkages is given in figure 3.

1. Continuous breaking up of ice may exclude fishermen from traditional fishing grounds, leading to reduced mortality and increased recruitment to fish stocks.
2. Noise from ships can affect migration of anadromous fish during certain parts of the year.
3. Pollution and substrate alterations can reduce the number and quality of pelagic and benthic invertebrate prey available to fish, and thus increase fish mortality.
4. Chronic pollution of invertebrates can cause higher body burdens in fish due to ingestion of contaminated prey, and increase mortality in juvenile and adult fish.
5. Dumping of waste can render areas inaccessible for certain types of fishing gear, relieving the fishing pressure on some species.
6. The anti-fouling agents on ship-hulls can be abraded by water and ice and thereby release toxic substances to the ice/water environment. This might in turn increase mortality in fish.
7. Major human activities in connection with accidents (clean up), dredging or harbour construction will locally affect fishing activity.
8. Noise from ships, combined with the turbulence of the water from the moving propeller, is often observed to make fish jump out of the water, and onto the ice.
9. Accidental pollution will affect fishing activity.

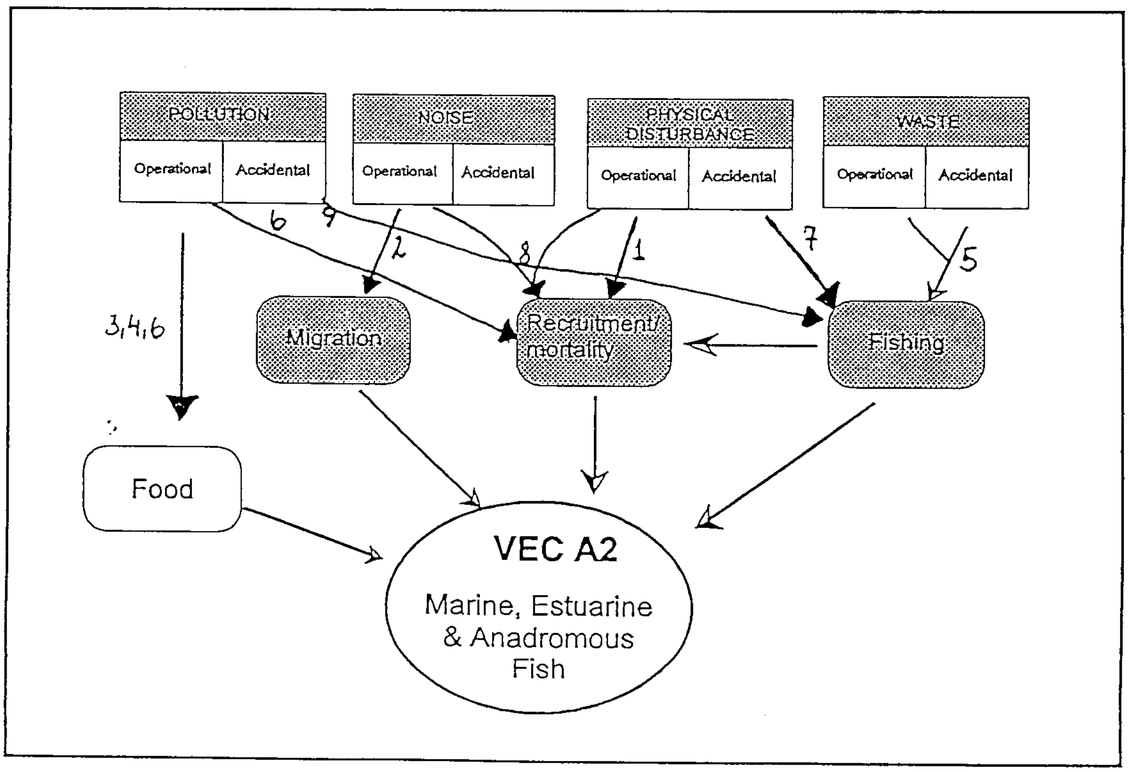

Figure 3 Schematic flow chart for the VEC Marine, Estuarine and Anadromous fish. The shaded boxes represents processes, while the white boxes represent system components.

4.3 Impact hypotheses (IH's)

A2-IH1: *Accidental pollution will cause reductions in certain fish stocks if it affects areas with high concentrations of fish, such as migration, nursing or feeding areas.*

A2-IH2 *Due to low diversity at each trophic level, effects on one single species will cause major impacts in the rest of the food chain.*

A2-IH3 *Discharges of oil or other pollutants in fresh water or along the coastal NSR area will cause increased mortality and reduced production in anadromous fish populations.*

4.4 Evaluated impact hypotheses (IH's)

VEC: **A2 Marine, Estuarine and Anadromous fish.**	**A2 - IH1**
HYPOTHESIS: *Accidental pollution will cause reductions in certain fish stocks if it affects areas with high concentrations of fish, such as migration, nursing or feeding areas.*	
EXPLANATION: Populations assembling in small areas are more vulnerable to local accidental events occurring in such areas as a large part of the population may be affected, than populations spread over large regions. Accidental impacts on essential habitats, such as spawning areas or migration routes, may lead to population decrease if the effects are permanent. See also A2-IH3.	
CATEGORY: C	
RATIONALE: Among the different areas occupied and used by fish during the year, the spawning areas are considered to be the most vulnerable to pollution from shipping accidents. Although eggs and juveniles are most vulnerable, these life stages suffer the highest natural mortality and most populations can recover from a loss of a large number of juveniles easier than from a large loss of mature adults. Therefore, migration areas where adults gather in small geographic areas during for example spawning migration, should be considered vulnerable to human activities. Spawning areas for anadromous fish often lie upstream of the NSR area, and the exposure to any discharges is thus reduced. However, the spawning areas of marine fish might be affected	
MANAGEMENT RECOMMENDATIONS: Reduce ship traffic in and close to major spawning and migration areas during sensitive periods.	
SURVEYS: Mapping of year-round distribution of the fish resources should be encouraged. As the marine parts of the NSR area are heavily influenced by freshwater, a vertical salinity gradient exists in large parts of the area. The vertical distribution of meroplanctic larvae is partly governed by the ambient salinity. Heavy stratification will reduce the exposure of larvae at intermediate depths to a surface oil-slick resting upon a layer of freshwater. Areas where shipping traffic will influence the stratification of the water mass could be indicated.	
MONITORING: Monitoring of importance of different areas.	
RESEARCH: Testing the effects of different chemical and radioactive pollutants on all life stages of fish eggs and larvae.	

VEC: **A2 Marine, Estuarine and Anadromous fish.**	**A2-IH2**

HYPOTHESIS:
Due to low diversity at each trophic level, effects on one single species will cause major impacts in the rest of the food chain.

EXPLANATION:
Low diversity and short food chains in the Arctic food-web renders each trophic level vulnerable to alterations. The possibilities for predators to switch to other food-items may be limited, and impacts on one species will be heavily manifested in its prey and predators. Impacts affecting only one species will always be related to periods and areas where this single species is congregated, e.g. during spawning or migration.

CATEGORY: B

RATIONALE:
River mouths or estuaries often act as "funnels," where anadromous fish, normally distributed over large sea areas, congregate during the upstream migration to the spawning areas. This aggregation occurs during a limited time period, and any accidental or intended actions might influence a large part of the population. Many marine fish also show periodical congregations during spawning or wintering, and any single species congregations make the actual species vulnerable. Due to low diversity, loss of one species, impacts on even one year-class of a species can be transferred to the entire food chain.

MANAGEMENT RECOMMENDATIONS:
Reduce shipping traffic in and close to major spawning, overwintering and migration areas during the sensitive period.

SURVEYS:
Some basic data on the use of the areas by different fish species is still lacking, and mapping is encouraged. The detailed composition of local food chains should also be investigated.

MONITORING:
Mapping of important migration routes in fish, and mapping of any changes after opening the NSR will reveal major changes in habitat use of fish. This also accounts for mapping of spawning areas and major feeding areas. Monitoring should be carried out regularly and particularly upon changes in sailing routes, number or types of ships.

RESEARCH:
Knowledge of predator - prey couplings and predators ability to switch to other organisms is essential in this context, and theses relationships should be studied.

VEC: **A2 Marine, Estuarine and Anadromous fish.**	**A2 - IH3**
HYPOTHESIS: *Discharges of oil or other pollutants in fresh water or along the coastal NSR area will cause increased mortality and reduced production in anadromous fish populations.*	
EXPLANATION: It is believed that anadromous fish recognise their native river by navigating after olfactory stimuli (Nordeng 1977). Discharges of oil or chemicals might interfere with this river-recognition, leading to reduced return rates and reduced production in affected rivers. Pollutants may also have toxic effects on eggs and larvae of anadromous fish from the NSR area, such as arctic char or omul.	
CATEGORY: C	
RATIONALE: Oil spills in the open sea generally have only a minor impact on anadromous fish. However, severe effect might arise if oil is spilled in a river estuary or further upstream the rivers.	
MANAGEMENT RECOMMENDATIONS: Strict regulations on periods, technology and performance when storing or reloading oil or other cargo in estuarine areas.	
SURVEYS: Mapping of size and distribution of important stocks of anadromous fish.	
MONITORING: Changes in numbers or distribution of anadromous fish species following the opening of NSR should be recorded.	
RESEARCH: Anadromous fish dependency of olfactory stimuli for orientation and recognition of the native river is still insufficiently studied, particularly for species other than Atlantic salmon and for populations in remote, undisturbed Arctic areas. Such research is strongly encouraged.	

5 VEC A3: Plant and animal life in Polynyas[3]

The VEC Polynya overlaps with the VEC's appointed in INSROP project II.4.2. and II.4.3, marine mammals and marine birds, as it is a habitat-VEC rather than a species-VEC. Some overlap between the impact hypotheses for these projects may therefore occur.

5.1 Background

Polynyas are regularly occurring areas of open water surrounded by ice. They vary in size and shape, and may be caused by a variety of factors, the most important of which are currents, tidal fluctuations, wind, upwelling, or a combination of these forces (Stirling & Cleator 1981). Knowledge concerning oceanographic and biological features of polynyas is still sparse, due to logistic difficulties related to the collection of such information.

Some polynyas occur at the same place each year, some of which are open throughout the winter, while others may be ice-covered through the coldest months. In addition to such recurring polynyas, there are extensive systems of shore-leads throughout the Arctic where variably sized areas of semi-permanent open water are maintained, largely by offshore winds, and to a lesser degree, by local currents (Stirling & Cleator 1981). For much of the year, large areas of the NSR are covered with ice. In these periods, maximal use will be made of polynyas and shore-leads to reduce shipping time, minimise the risk of damage and reduce the need for ice-breaker assistance.

This increased traffic through polynyas in the ice season is a major argument for selecting plant and animal life in polynyas as a VEC, even though it could be considered equally important to analyse information on the biota along the entire marginal ice-zone of the NSR area during the summer period.

It is widely accepted that polynyas are important to both seabirds and mammals, but less is known about the lower levels of the food web, upon which the seabirds and mammals feed. However, recent surveys have indicated that the primary production in polynyas may be as high as 65 g C/m^2/year (Keck & Wassmann 1993) which is several times the average primary production in ice-covered Arctic areas. There appears to be an exchange of energy along the ice edge between the sub-ice system, the open water, and, at least in shelf regions, the benthos. It is the ice edge rather than the open water of polynyas which appears to be the key to much of the biological significance of these areas, as ice edges are regions of high biological activity. Polynyas provide ice edge extensions in winter, and therefore offer what ice edges offer anywhere, such as an early spring bloom, and high biological activity. This so-called ice edge effect is probably due to wind driven upwelling at ice edges, combined with melting processes leading to stable stratified water masses (Dunbar 1985). In this way the true biological

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3 Rewiever comments that the marginal ice zone and shore-leads should be included in this VEC. However, due to heavy traffic through them, polynyas have been given priority as they are expected to be at higher risk than the marginal ice-zone. Shore-leads and artificial polynyas are ommitted as they are not expected to be of the same significance to marine life as polynyas.

importance of polynyas lie in such upwelling effects. In several parts of the year, the polynyas may be considered "oases" of open water in a "desert of ice," and thus the impacts of NSR traffic are generally expected to be greater in the polynyas.

Artificial traffic-leads and sailing routes created by ships will lack the natural mechanisms responsible for keeping polynyas open. It is thus expected that artificial openings in the ice will gain less biological significance compared to natural polynyas. Artificial polynyas will not be dealt with any further in this paper.

Ice provides a solid substrate for certain mammals, while the open waters in polynyas provides refuges for walruses, certain seals and whales in winter and for migrant seabirds in spring and fall (Dunbar 1981; Dunbar 1985). Polynyas are considered vulnerable to human activities, such as ship traffic due to the following natural factors:

- low temperatures (several processes proceed at a slow rate)
- high densities of algae and zooplankton
- high densities of marine mammals and seabirds
- ship traffic will be concentrated in polynyas, in order to reduce shipping times and the risk of damage.

5.2 Linkages

Possible effects of increased NSR traffic on the VEC "Plant and animal life in polynyas" are here described through a set of impact causing linkages. A scematic presentation of the linkages is given in figure 4.

1. Discharges from regular ship traffic and from accidents can influence mortality and reproduction in animals at all trophic levels inhabiting a polynya.
2. Noise from traffic can disturb fish, marine mammals and birds that feed and reproduce in, or close to, polynyas, thus affecting survival and recruitment in all groups.
3. Operational and accidental pollution can affect primary production in polynyas.

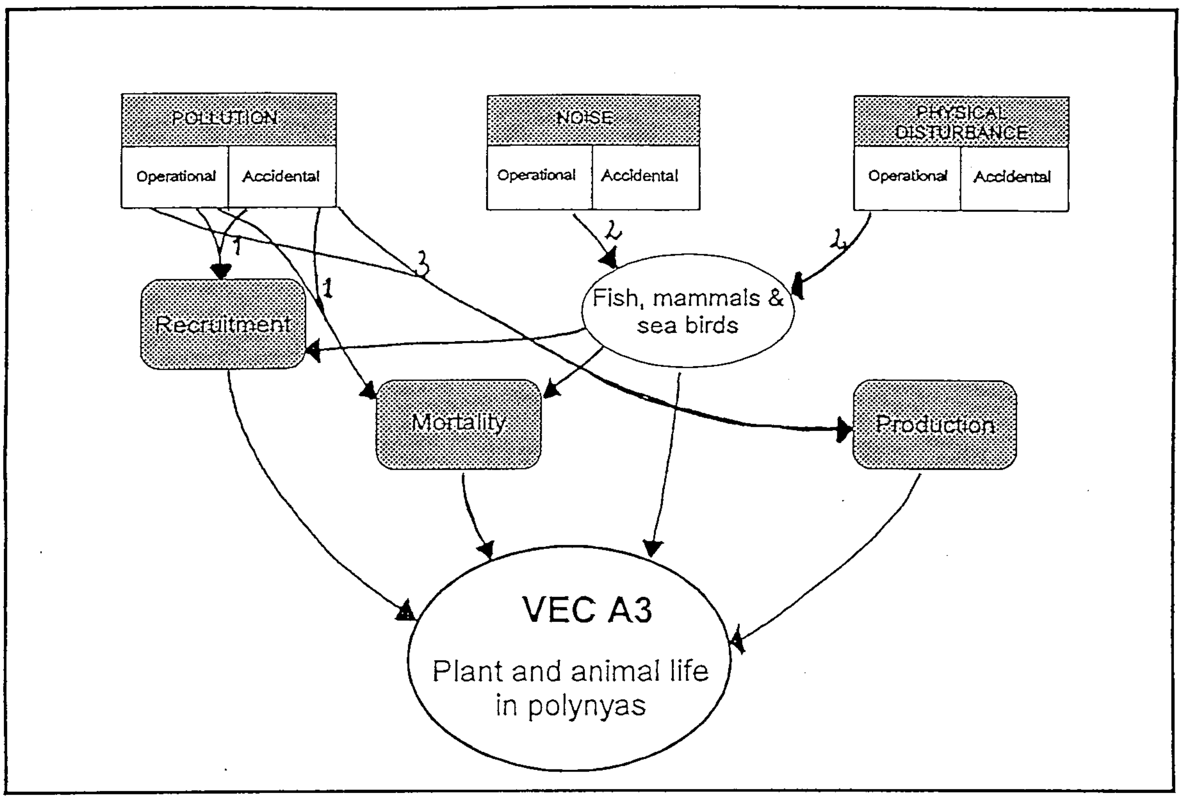

Figure 4 Schematic flow-chart for the VEC Plant and animal life in polynyas. The shaded boxes represents processes, while the white boxes represent system components.

5.3 Impact Hypotheses (IH's)

A3-IH1 *Any effect of NSR traffic will be manifested to a greater extent in polynyas than in other areas.*

A3-IH2 *Noise from ship traffic will scare fish, mammals and seabirds away from important feeding, resting and breeding areas in and near polynyas.*

A3-IH3 *Oil spills in polynyas will reduce primary production, and thus affect the whole feeding network.*

A3-IH4 *Even minor oil spills in polynyas, from regular NSR traffic, will cause suffering and death to vertebrates.*

A3-IH5 *Chronic pollution of polynyas affects reproduction and survival of individuals at all trophic levels.*

5.4 Evaluated Impact Hypotheses (IH's)

VEC: **A3 Plant and animal life in polynyas**	**A3 - IH1**
HYPOTHESIS: *Any effect of NSR traffic will be manifested to a greater extent in polynyas than in other areas.*	
EXPLANATION: Polynyas often form biological "oases" in which species diversity is higher, the fish and invertebrate fauna is richer (biomass) and the production is larger than in areas entirely covered by ice. Polynyas are also known to support high numbers of marine mammals and birds. Due to enhanced abundance at all trophic levels, the system is more vulnerable to pollution.	
CATEGORY: C	
RATIONALE: Any concentration of organisms (plants and animals) are more vulnerable to human impacts, as a larger part of the population will be affected if anything should happen.	
MANAGEMENT RECOMMENDATIONS: The polynyas are expected to be advantageous to shipping, and the ice free conditions might improve the overall safety of navigation. Thus, restrictions in general use of polynyas for traffic can hardly be enforced. However, detailed knowledge of particular vulnerable periods or areas might allow for a part time ban on navigation through polynyas.	
SURVEYS: Mapping of importance of different polynyas to different animal groups.	
MONITORING: Trends in species composition and abundance's in and near polynyas after the opening of the NSR should be monitored.	
RESEARCH: Detailed knowledge of the biological couplings in arctic polynyas is very sparse. General investigations of production and energy transfer in polynyas are needed.	

VEC: **A3 Plant and animal life in polynyas.**	**A3 - IH2**
HYPOTHESIS: *Noise from ship traffic will scare fish, mammals and seabirds away from important feeding, resting and breeding areas in and near polynyas.*	
EXPLANATION: Noise and physical disturbance from ship traffic may scare marine mammals and sea-birds away from favourable resting/feeding sites in productive polynya-areas, to areas with less favourable conditions. In this way, survival and reproductive success will be affected.	
CATEGORY: C	
RATIONALE: Increased abundance of species and individuals in limited areas will generally lead to such areas being sensitive to disturbances. Much of the discussion applied under the fish VEC is also valid for plants and animals in polynyas.	
MANAGEMENT RECOMMENDATIONS: See VEC A3-IH1.	
SURVEYS: See VECA3-IH1.	
MONITORING: See VECA3-IH1	
RESEARCH: See VEC A3-IH1.	

VEC: **A3 Plant and animal life in polynyas.**	**A3 - IH3**

HYPOTHESIS: *Oil spills in polynyas will reduce primary production, and thus affect the whole feeding network.*
EXPLANATION: A large feeding network in and around the polynyas relay on the primary producers in the polynya, as the production in these open waters is significantly higher than under the ice. The production under ice will probably be to low to support the large biomass of higher organisms that occur in and around polynyas. Any disruption to the primary producers may thus affect the whole feeding network.
CATEGORY: C
RATIONALE: Due to low temperatures, oil that is spilled in arctic areas will be very viscous. In polynyas the ice will probably act as a barrier, keeping the oil in the polynya, where the viscous mass may cover the surface in fairly thick layers. In experiments where the primary production has been measured under an oil slick, it has been shown that the production has been reduced, probably due to reduced light penetration.
MANAGEMENT RECOMMENDATIONS: See VEC A3-IH1.
SURVEYS: None
MONITORING: Measure the baseline primary production in polynyas and under ice. Follow up with such measurements if oil is spilled in a polynya.
RESEARCH: Effects of oil on arctic phytoplankton should be investigated through lab-experiments.

VEC: A3 **Plant and animal life in polynyas.**	**A3 - IH4**
HYPOTHESIS: *Even minor oil spills in polynyas, from regular NSR traffic, will cause suffering and death to vertebrates.*	
EXPLANATION: It is well documented that oil-polluted seabirds suffer high mortality. If a polynya is affected by oil, the damage is expected to be severe, due to larger concentrations of birds, and the fact that the ice edge will act as a barrier keeping the oil in the polynya. Similarly, seal pups and polar bears are expected to be vulnerable to any oil released in a polynya. In case of heavy oil spill, the photosynthesis might become hampered due to reduced light penetration.	
CATEGORY: B	
RATIONALE: More or less operational discharges of oil have proven to be a source of chronic pollution in traffic areas in other parts of the world.	
MANAGEMENT RECOMMENDATIONS: To avoid discharges of oil, facilities for collection of chemical waste and oil should be provided in major NSR harbours. To encourage the use, this service should be free of any charges.	
SURVEYS: None.	
MONITORING: General monitoring of the NSR traffic by planes or satellites will reveal any pollutionary discharges.	
RESEARCH: None.	

VEC: **A3 Plant and animal life in polynyas.**	**A3 - IH5**
HYPOTHESIS: *Chronic pollution of polynyas may affect reproduction and survival of individuals at all trophic levels.*	
EXPLANATION: The release of small amounts of chemical substances from regular shipping traffic will have the largest effects in areas with the highest density of traffic and in areas with high densities of biological resources. Polynyas are areas fitting into both categories, and with its high biological activity, the ecosystem in polynyas is most vulnerable.	
CATEGORY: C	
RATIONALE: A large range of pollutants have been shown to affect reproduction and survival in different animals. As the polynyas are of a relatively limited size, and serve as "oases" in the arctic ice, it is likely that chronic pollution will affect the whole polynya.	
MANAGEMENT RECOMMENDATIONS: Restrictions on when and where ship traffic is allowed should be enforced. To avoid discharges of oil, facilities for collection of chemical waste and oil should be provided in major NSR harbours. To encourage the use, this service should be free of any charges.	
SURVEYS: None.	
MONITORING: Continuos monitoring of pollutant levels in organisms living in NSR areas. Research on effects of components of bunker oil and major cargo types like ore, chemicals or crude oil on reproduction in all organisms will highlight risk areas and periods.	
RESEARCH: As previously stressed, the knowledge of the effects of different pollutants on reproduction in Arctic animals, all trophic levels, is very limited.	

6 VEC D1: Human settlements

Human settlements are designated as a VEC in the present context to focus on the impacts that the NSR traffic can have on provision of goods and needs to indigenous and non-indigenous people in the area. Subproject IV.4.1. will address questions concerning social and cultural impacts on indigenous people. Both people of indigenous and non-indigenous origin, living in the area, depend heavily on natural resources. The dependency is reduced only in the vicinity of larger cities, with regular connections to other parts of Russia.

The present economic crisis in the Russian community makes living conditions particularly difficult in remote areas of the NSR, and a larger use of, and an even larger dependency on local, natural resources is to be expected. In many villages and cities of Siberia, the population of non-indigenous origin is moving away, and the population is steadily decreasing. On the other hand, the indigenous settlements seem to have a more stable population size (V. Khlebovich, pers. com.).

6.1 Background

The coastal zone along the NSR is sparsely populated, and infrastructure is fundamentally lacking. Most settlements are located along the large rivers, and the few larger cities in the region are also located there. In the sparsely populated areas shipping traffic to and from settlements is sporadic, and in some areas there are only connections to other parts of the country once or twice a year. Thus, human settlements have to be self-sustaining, and are strongly dependent on fishing, hunting and in some areas (mostly west of the Jamal peninsula) reindeer herding as well as the collection of plant material like mushrooms and berries. Settlements of non-indigenous origin are often placed close to some natural resource, e.g. a mine, oil-extraction activities or exporting-harbours for fur, timber or ore. Traffic to and from these settlements is often fairly regular and the availability of goods and provisions from other parts of Russia is better.

An association exists between settlements and polynyas, probably due to the local abundance of animal resources that occur in these areas (Schledermann 1980). Increased NSR traffic through polynyas might disturb the animals, and thus affect hunting and fishing activities.

In certain inland areas, almost all land is used as grazing land for reindeer, and any factors that influence these areas may have great effects on the livestock (Bjørklund pers. comm.). In the NSR context, such effects can arise from the stranding of oil in flooded areas during the spring rise in the rivers. Also precipitation of evaporated oil after an accident can affect grazing areas. Human settlements along the coast are vulnerable to pollution as they depend on natural resources that may be affected by, for instance, pollution from ships travelling through the NSR. Any disturbances that may affect traditional grazing areas (islands, river banks, inland etc.) may have important consequences for domestic reindeer.

Reindeer livestock are mainly kept in inland areas during winter, but might become affected by ice-breaking in the rivers, caused by boats transporting goods to or from NSR ships further downstream.

6.2 Linkages

Possible effects of increased NSR traffic on the VEC "Human settlements" are here described through a set of impact causing linkages. A scematic presentation of the linkages is given in figure 5.

1. Accidental discharges can directly affect the health and survival of humans.
2. Accidental discharges can accumulate in organisms (including plants) that are used for humans consumption. This indirect exposure can affect the health, reproduction and finally the survival of humans.
3. If pollution has affected/influenced the resource base for human settlements, the people may be forced to move to other areas.
4. Noise from regular ship traffic can scare domestic animals away from traditional grazing areas, and wildlife-prey might be scared away from hunting areas.
5. Physical disturbance or breaking up of ice can render grazing areas on island or river banks inaccessible to reindeer.
6. Breaking up of ice can render existing hunting and fishing areas inaccessible by introducing impassable areas of open water. However, new potential hunting/fishing areas may be opened in the traffic leads.
7. Dumping of waste can render areas unsuitable for certain types of fishing gear.

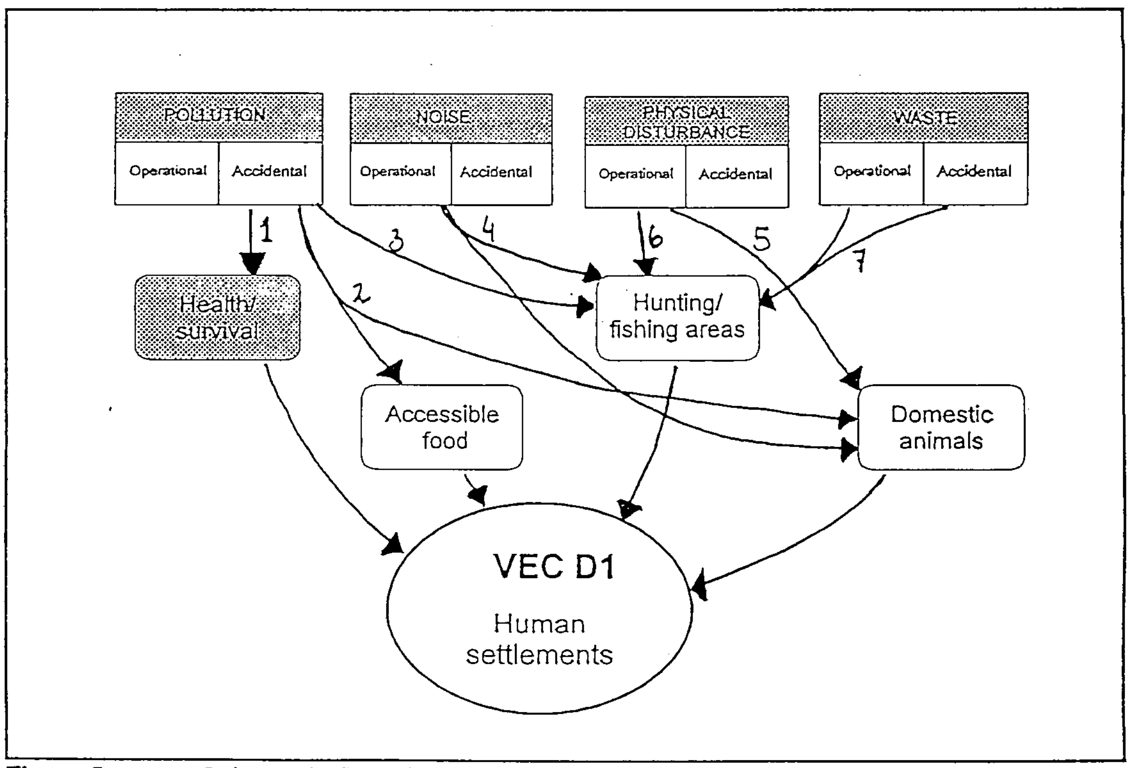

Figure 5 Schematic flow-chart for the VEC Human settlements. The shaded boxes represents processes, while the white boxes represent system components.

6.3 Impact Hypotheses (IH's)

D1-IH1 *Pollution (especially accidental) will affect the resources base for local people.*

D1-IH2 *Breaks in the ice render traditional routes for livestock and fishermen/hunters inaccessible*

D1-IH3 *Disturbance of fish, mammals or birds in polynyas and other major congregation areas affect indigenous hunting and fishing activities.*

6.4 Evaluated Impact Hypotheses (IH's)

VEC: **D1 Human settlements**	**D1 - IH1**
HYPOTHESIS: *Pollution (especially accidental) will affect the resources base for local people.*	
EXPLANATION: Several societies of especially indigenous people living in remote areas of the Russian Arctic depend heavily on natural resources for food and materials. It is known that pollution may render natural resources inedible or potentially dangerous for humans.	
CATEGORY: B	
RATIONALE: The hypothesis is verified through experience from accidents and pollution incidents world-wide (Fall 1993).	
MANAGEMENT RECOMMENDATIONS: Increased traffic will increase the risk of accidents. In case of engine breakdown onboard a ship, it will drift helpless in the sea. A rescue service should be established along the sailing route. To secure a minimum of time being available for rescue or repair, before the ship runs ashore, a minimum sailing distance off the coast could be enforced. The presence of anchors and sufficient length of anchor chain onboard the NSR ships should be mandatory. The equipment should be kept in working order, and the sailors have to have some practise in using it.	
SURVEYS: Mapping and evaluation of areas important to local people.	
MONITORING: Regular testing of contaminant levels in organisms serving as food for indigenous people can reveal any effects of the increased traffic.	
RESEARCH: None	

VEC: **D1 Human settlements**	**D1 - IH2**

HYPOTHESIS:
Breaks in the ice may render traditional routes for livestock and fishermen/hunters inaccessible

EXPLANATION: If the indigenous people use the ice to travel to hunting and fishing areas located in polynyas or at the ice edge, breaking of ice may complicate their travel, or even prevent them from reaching specific areas.

CATEGORY: C

RATIONALE: The significance of this hypothesis is questionable, as breaking of the ice also may have some advantages for human beings. Ice fishing often occurs in areas where ice-breaking vessels have passed through, as the ice in such areas is thinner and easier to penetrate.

MANAGEMENT RECOMMENDATIONS: Mapping of potential conflict areas could create the basis for selection of the actual sailing route to be used at specific times of the year. Alternative routes could be selected, where these are available, e.g. in estuarine areas.

SURVEYS: Mapping of potential conflict areas.

MONITORING: None.

RESEARCH: None.

VEC: **D1 Human settlements**	**D1 - IH3**

HYPOTHESIS:
Disturbance of fish, mammals or birds in polynyas or other major congregation areas can affect indigenous hunting and fishing activities.

EXPLANATION: Hunting and fishing is normally carried out in areas with major or easy exploitable concentrations of the actual prey. Disturbances from NSR traffic might cause changes in migration routes, congregation areas, feeding areas, etc. and affect the accessibility of the resources to humans.

CATEGORY: D

RATIONALE: Indigenous peoples' use of natural resources is mostly based on undocumented traditions. As the use of hunting and fishing areas is influenced by natural variations in stock sizes, migrations etc., it will be difficult to documentate that any changes are directly related to NSR activities. However, influences are expected to be of minor importance to indigenous people.

MANAGEMENT RECOMMENDATIONS: In order to minimise local conflicts, knowledge of indigenous use of areas that will be affected by new NSR facilities, should be taken into consideration during the planning of such constructions.

SURVEYS: An inventory of the local peoples use of areas that may be affected by increased NSR traffic should be made.

MONITORING: None.

RESEARCH: None.

7 VEC D2: Water/land border zone (sensitive areas)

7.1 Background

Much of the littoral zone along the coast of the NSR is exposed to heavy ice scouring, freezing-erosion and summertime reduction in surface salinity. These factors render many areas "inhospitable to colonisation" (Menzies *et al.* 1973), and consequently, most of the coastal zone is only sparsely populated. The water-land border zone is most vulnerable to those forms of pollution that float on the sea surface (e.g. crude oil, refined oil products, chemicals etc.) and end up affecting the inhabitants of the coastal zone. Pollution may affect man made installations, such as harbours, water intake to the fishing industry and processing plants, fishing equipment etc.

If the exposed coastal zone along the NSR is affected by for example oil, wind and waveaction will rapidly wash it away, and only a few organisms will be damaged. On a world-wide scale, the exposed littoral zone has been shown to be highly "self-cleaning," with any oil being washed away to more sheltered areas within months to years. Normally a Norwegian exposed seashore will recover from an oilspill within 3 years (Lein *et al.* 1992).

In sheltered littoral areas, and especially in estuarine areas, accumulation of fine sediments occurs. In such areas, biological productivity is high, and the invertebrate fauna is an important foodsource for wading birds. Oil reaching areas with fine sediments may penetrate into the sediments, where it will stay for years (Laubier 1980; Vandermeulen 1982). Due to low temperatures the breakdown of oil proceeds extremely slowly in arctic areas, and especially in fine grained sediments, where oxygen supply often is limited. The rate of dacay of other polluting substances from ships traffic will vary. Radioactive isotopes will, however, decay at known rates (depending on the isotope) independent of temperature.

In case of an accident, the release of cargo-types like timber, ore, crude oil or fertiliser, which all are highly probable cargoes of the NSR, might lead to adverse effects on animal and plant life in the littoral zone, and via evaporation also on the neighbouring tundra. Also the release of bunker oil, fuel or cooling water from nuclear powered vessels might cause environmental stress in the coastal zone.

There is an enormous increase in river flow during the ice melting season. As a consequence, large inland areas surrounding the rivers become inundated and may be affected, should an accidental oilspill happen in the rivers in this period.

Above the littoral zone there is often a so-called "layda" zone (partly supra littoral), which is similar to a salt-marsh. Here permafrost renders vertical water-movement impossible, but horizontally this zone is influenced by the tide. In summer, many small lakes occur, and as they are influenced by the sea, pollutants in the sea water can affect for instance survival of mosquito larvae in such pools.

During periods with extreme weather conditions, wind and surf may spread oil and other pollution up to the supralittoral zone, thus affecting areas that may be used as grazing land. This effect was observed on Shetland after the "Braer" accident in January 1993 (Wills & Warner 1993).

7.2 Linkages

Possible effects of increased NSR traffic on the VEC "Water land border zone (sensitive areas)" are here described through a set of impact causing linkages. A scematic presentation of the linkages is given in figure 6.

1. Increased NSR traffic can increase the demands for harbour facilities and maintenance of lighthouses etc. in the coastal zone, causing major local changes.
2. Drifting waste from ships can eventually end up in the coastal zone.
3. Pollution from shipping accidents can affect mortality of permanent and temporary users of the coastal zone and alter its function as a habitat for such organisms.
4. Oil pollution reaching the large rivers during the ice melting season may be spread over extensive areas of tundra.
5. Pollution reaching land can damage man-made installations in the water/land border zone.
6. The substrate (sediment) composition in the littoral zone will influence the fate of an oil-spill.

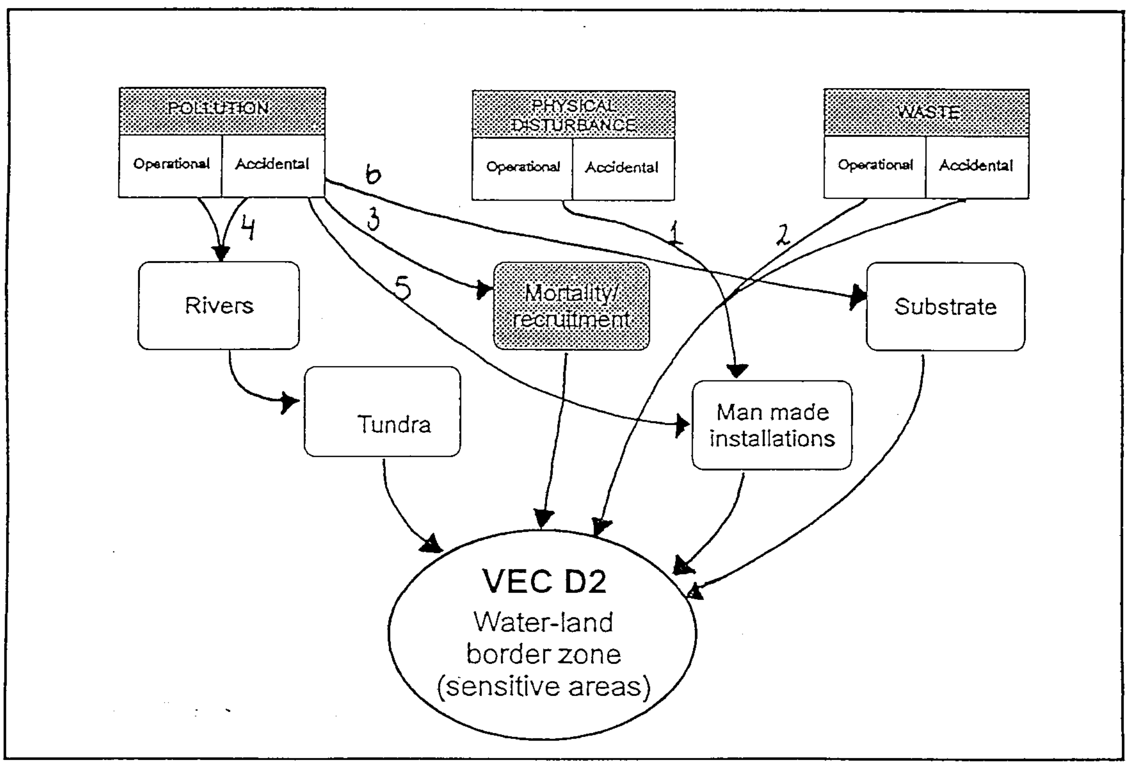

Figure 6 Schematic flow chart for the VEC Water-land border zone (sensitive areas). The shaded boxes represents processes, while the white boxes represent system components.

7.3 Impact Hypotheses (IH's)

D2-IH1 *Construction of necessary harbour-facilities will cause major local changes in the coastal zone.*

D2-IH2 *Floating wastes will accumulate in protected areas of the coastal zone, causing aesthetic disturbance and providing substrates that will be colonised by invertebrates.*

D2-IH3 *Oil and other pollution will cause major disturbances in the coastal zone, and at certain times also in inland areas.*

7.4 Evaluated Impact Hypotheses (IH's)

VEC: **D2 Water land border zone (sensitive areas)**	**D2 - IH1**
HYPOTHESIS: *Construction of necessary harbour-facilities will cause major local changes in the coastal zone.*	
EXPLANATION: Harbour construction, including dredging and construction of piers and breakwaters will cause local changes in the substrate composition and may lead to changes in current conditions.	
CATEGORY: B	
RATIONALE: Experiences from harbour construction world-wide has shown that changes will occur, but also that a new steady state flora and fauna will develop after some time.	
MANAGEMENT RECOMMENDATIONS: Building of harbours in vulnerable, important or species-rich areas should be avoided.	
SURVEYS: Description and geographic extent of sensitive areas.	
MONITORING: According to type of cargo, shipping frequency and number of people in the harbour area, the pollution status should be monitored regularly.	
RESEARCH: None	

VEC: **D2 Water land border zone (sensitive areas)**	**D2 - IH2**

HYPOTHESIS:
Floating wastes will accumulate in sheltered areas of the coastal zone, causing aesthetic disturbance and providing substrates that will be colonised by invertebrates.

EXPLANATION:
Debris and waste thrown overboard from ships will be carried by currents and ice-movement to sheltered parts of the littoral zone. Plastic debris is non-degradable, and will not be broken down. Experience from Norwegian waters have shown that local currents can create large piles of stranded waste even in remote areas.

CATEGORY: B

RATIONALE: In many harbours a charge is collected for unloading rubbish. This tempts ship operators to dispose waste at sea. On-board incineration is also usual, followed by the dumping of the residue. Regulations forbidding such activities are enforced by some coastal states, but control is almost impossible..

MANAGEMENT RECOMMENDATIONS: Russia has suggested that the Arctic should be a special area under MARPOL 73/78, thus enforcing the use of waste facilities in harbours. The waste facilities should be able to treat any type of waste, including chemicals. A deposit system, in addition to strong penalties for dumping of waste at sea, could be introduced to secure the "Polluter Pays Principle." Regular collection and registration of stranded debris along standard sections of shoreline can document the problem, but little can be done about it without the above described actions.

SURVEYS: None.

MONITORING: Mapping of coastal areas where waste is accumulating, in order to minimise the area that has to be cleared of waste.

RESEARCH: None.

VEC: **D2 Water land border zone (sensitive areas)**	**D2 - IH3**

HYPOTHESIS:
Oil and other pollution will cause major disturbances in the coastal zone, and at certain times also in inland areas.

EXPLANATION:
The NSR follows the coast-line at varying distances. However, an oil spill can reach the shore within a relatively short time, no matter where along the route the spill might occur. In Norwegian waters, most large oil spills that reached the shore originated from grounded ships (Lein *et al.* 1992). There is also a correlation between the quantity of oil drifting ashore and the number and standard of ships passing the coast. During the spring tides, oil spills from harbours (storage tanks, re-loading facilities etc.) in the large Siberian rivers can be transported to terrestrial or fresh-water environments by the rivers. Entrapment and accumulation of pollutants in these areas can affect crops, fishing or hunting. Evaporated oil or other chemicals may precipitate on the tundra and cause negative effects on vegetation and animal life.

CATEGORY: B

RATIONALE:
Oil pollution is documented to have long-lasting and profound effects in the coastal zone world-wide. After stranding of oil, finally only the asphalt-like components will remain onshore, while the lighter components will gradually be transported to the subtidal sediments (Owens *et al.* 1987). Incorporation of oil in ice by freezing and transport of oil contaminated ice-floes might contribute to distribution of the oil over larger areas than in areas at lower latitudes. Due to the low ambient temperatures, evaporation and solubility of oil is expected to be lower in Arctic areas.

MANAGEMENT RECOMMENDATIONS: Oil contingency equipment must be available.

SURVEYS: Mapping of the coastal zone sediment composition is in progress in the NSR-project "The Coastal zone." This will be used to indicate where oil and other pollution are most likely to accumulate.

MONITORING: To be established following an accident. Chronic effects of minor discharges in harbours or areas of transfer of oil from barges to larger ships should be monitored.

RESEARCH: Studies of the breakdown of oil in Arctic areas are sparse, and general research on such topics should be encouraged. Mapping of biological resources in areas of the coastal zone which are identified as potentially vulnerable is recommended. Bird feeding areas and breeding areas of marine mammals in the coastal zone are discussed by the INSROP projects on these groups.

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APPENDIX

Appendix 1 The major comments from reviewer

Appendix 2 General outline of INSROP Subprogramme II.

Appendix 1

Dr. Eike Rachor (Biologie I)
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10.03.1995

Review of INSROP Disc. Paper, part II.4 (Larsen, Evenset, Sirenko)

Dear colleagues,

the document seems to be well prepared; nevertheless, I have some comments and proposals, most of which will be found directly in the manuscript.

One main difficulty arises from the "mixture" of categories (organisms - habitats/systems), by which problems have to be tackled several times (e.g. birds/polynyas/coastleads/coastal zone). The reviewer cannot control whether this is sufficiently done in the other (sub-)projects and how cross-references will be made.

Another point is that the evaluation system seems to be in a exploratory state; thus, other possible systems should not be forgotten and given at least in an overall description of the whole project. In Germany we have, for instance, a register ("kataster") of differentially sensitive areas at the North Sea coast, describing properties, fauna/flora etc. and making proposals how to manage/treat the area (esp. including cases of oil spills). For instance: Where are Nature Reserves along the Russian coast ? Moreover, there should be accepted European guidelines for environmental compatibility studies of larger projects, which may be useful for the INSROP work.

Another important point is to come to strong regulations for any future shipping along the NSR, considering the "precaution principle", which means (safety) measures are to be taken if there is any suspicion that a human activity may be harmful on a longer term and not locally restricted. Accordingly, the declaration of the route area a "special area" according to MARPOL would be very important. To achieve this, arguments have to be very strong (not: "should be ...", but: "have/are to be ...").

Some of the graphs seem to be insufficiently carefully thought out in some points and relations; they may be amended.

Sincerely yours,

International Northern Sea Route Programme (INSROP)

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship & Ocean Foundation, Japan

Sub-programme II: Environmental factors

CONCEPTUAL DESIGN & CURRENT STATUS

INTRODUCTION

The INSROP Sub-programme II Environmental Factors is a large scale assessment of the potential environmental impacts of shipping, navigation and related activities on the Northern Sea Route (NSR). The Sub-programme is designed to produce the foundation for political and commercial decision making regarding environmental conditions in the NSR both within and outside the areas of Russian jurisdiction - to reflect national and international concerns for the Arctic environment and for Northern Indigenous peoples. Based on an integrated, multi-disciplinary approach, the main elements beeing as follows:

The Sub-programme is broken down into 29 separate projects (see Table 1), organized for implementation in three conceptual phases. Each project is designed as independent, but inter-related parts of the Sub-programme, in order to ensure the successive integration of the results. In all phases, work is carried out in close cooperation within the Sub-programme and between the other INSROP sub-programmes, advancing information of mutual interest to the participants. Tasks and obligations are evaluated continuously.

* *Geographical Information System*; -developing a tool to store, retrieve, integrate and analyse environmental information

* *Dynamic Environmental Atlas*; -identification, recording and mapping of valuable ecological components and their properties in the NSR area

* *Environmental Safety of Ship and Navigation*; -contribution to the EIA and implementation of efficient pollution control measures in the NSR area

* *Environmental Impact Assessment*; -assessing the environmental impact of relevant NSR activities on the valued ecological resources

* *Environmental Pilot*; -developing the framework for an operational, environmentally friendly navigation system for NSR activities.

The three main components of the Sub-programme, the Geographical Information System (GIS), the Environmental Atlas (EA) and the Environmental Safety of Ship and Navigation (ESSN), will all provide information to be analysed in the fourth component, the Environmental Impact Assessment (EIA). (See Figure 1).

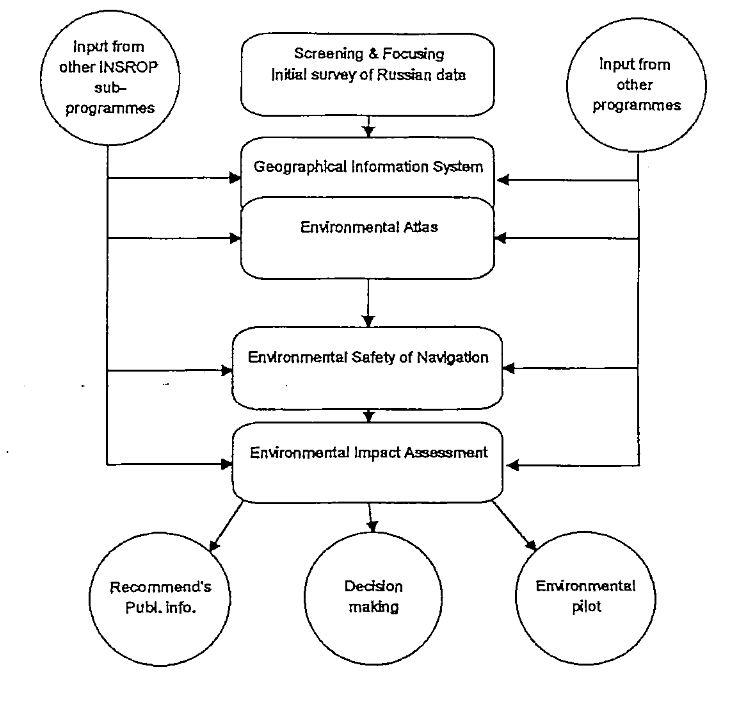

Figure 1. The conceptual design of INSROP Sub-programme II Environmental Factors; - main components and interactions.

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RELATIONSHIP TO OTHER PROGRAMMES AND DATA SOURCES

Issues such as baseline contamination studies, surveys and analyses, long term pollution studies, pollution fate and effect studies, as well as long term environmental monitoring, are generally beyond the scope of the Sub-programme. Selected information and results will be imported from programmes and activities other than INSROP.

In this context, the Sub-programme will cooperate closely with the environmental authority bodies in the countries involved, and operate in liason with and exchange information and results with relevant international and national organizations and institutions. These are the working groups under the Arctic Environmental Protection Strategy (AEPS), including the Arctic Monitoring and Assessment Programme (AMAP) and the Conservation of Arctic Flora and Fauna (CAFF), as well as the Joint Russian-Norwegian Commission on Environment, the International Arctic Science Committee (IASC), the Ministry of Industry and Energy Programme of Impact Assessments (AKUP), and others.

Expanded cooperation with the AMAP secretariat, both regarding information system design / data strategy and analytical approach, has been initiated. Relevant data from the AMAP status reports produced in the course of INSROP will be included in the EA / GIS and the EIA.

THE NSR AREA

A core area to which the Sub-programme will apply is the summer ice-free zone between the north coast of Russia and the ice edge from the Kara Gate to the Bering Strait. Depending on the sailing routes, the temporal and spatial distribution of ecological resources, and other factors that may turn out to be important in course of the INSROP, substantial drift ice areas (- i.e. marginal ice zone), polynias north of the ice edge, as well as river estuaries and deltas, may be included.

Information brought forward by other sub-programmes will support the selection of focal geographical areas, particularly in the context of defining most realistic scenarios for the NSR activity to the EIA.

CURRENT STATUS

The Sub-programme is concentrated on a limited number of priority issues; -Valued Ecosystem Components (VECs), which have been carefully selected from a large and complex biogeographical region and a large number of potential activities and impacts during the *initial phase* (1993-1994).

This kind of screening and focusing, included preliminary data inventory on existing Russian and other relevant baseline data. In parallel, the design of the INSROP GIS was developed in collaboration with Sub-programme I. The GIS will serve as a tool to store, retrieve, integrate and analyse information produced by all INSROP sub-programmes. The preparation of summary reports on the screening and focusing process and GIS design, concluded the initial phase.

The baseline data inventory of the EA makes up the gradual transition to the *second phase* (1994-1996), where the main effort of the Sub-programme will be devoted to mapping of the selected VECs. The data inventory is assumed to reach a maximum in 1995, and then subsequently decrease and gradually change towards validation and analyzation of the data in the GIS.

The ESSN includes a group of projects which is established to review the current status and contribute towards implementation of relevant pollution control measures in the NSR area. Pollution emergency plans and guidelines for environmentally safe ship operations and associated activities on the NSR, are prepared to improve the environmental safety of ongoing NSR operations. Implementation however, still remains.

The EIA is the *third phase* of the Sub-programme (1995-1997), and will conclude the results from the EA and ESSN. Relevant information from the other INSROP sub-programmes integrated in the GIS, e.g. selected scenarios based on ice and physical conditions, trade and commercial aspects, and political and legal aspects, will serve as multidisciplinary approaches to assessments of potential environmental impact.

Ultimo 1994, more than 50 experts distributed amongst 30 different institutions in 8 countries, have been participating in the execution of the Sub-programme projects since the start in 1993. So far, one INSROP Working Paper (- prepared in collaboration with Sub-programme I), 13 INSROP Discussion Papers, and 5 reports/papers published in other, international fora, have been prepared (see below).

PUBLISHED PAPERS

Published papers prepared by the INSROP Sub-programme II Environmental Factors (per. 1st. of January 1995), are listed below.

WORKING PAPERS (1)

Løvås, S.M., Smith, C. & Moe, K.A., 1994. Design and Development of Information System. INSROP Working Paper I.3.1/II.3.1. No. 4 - 1994. (Prepared in collaboration with Sub-programme I)

DISCUSSION PAPERS (13)

Bakken, V., 1994. Project II.4: Mapping of Valued Ecosystem Components. 3. Marine Birds. INSROP Discussion Paper, October 1994.

Hansson, R., Moe, K.A. & Løset, S., 1994. Project II.2: Screening and Focusing Workshop. INSROP Discussion Paper, February 1994.

Korotkevich, E. & Novozhilov, A., 1994. Project II.1. Initial Survey of Russian Data Sources. INSROP Discussion Paper, May 1994.

Larsen, L.H., Evenset, A. & Sirenko, B., 1994. Project II.4: Mapping of Valued Ecosystem Components. 1. Marine and Anadromous Fish and Invertebrates; 4. The Coastal Zone; 5. Large River Estuaries and Deltas. INSROP Discussion Paper, December 1994.

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INSROP NEWSLETTER CONTRIBUTIONS (2)

Moe, K. A. & Hansson, R., 1994. Project II.2: Screening and Focusing Workshop. INSROP Newsletter 2(1): 8.

Thomassen, J., 1994. Project II.5: Environmental Impact Assessment. INSROP Newsletter 2(2): 9-10.

OTHERS (5)

Brekke, B. & Fjeld, P.E., 1991. The Northern Sea Route Programme Environmental Factors. Introductory notes on available literature. Norw. Polar Inst. Report No. 70.

Hansson, R., 1992. An Environmental Challenge to Half the Arctic. International Challenges 12 (1): 90-96.

Hansson, R. 1993. The NSR - A Route to Destruction or Protection. Pp. 133-140 in Simonsen, H. (ed.): Proceedings from The Northern Sea Route Expert Meeting, Tromsø, 13-14 October 1992.

Hansson, R., 1994. The Northern Sea Route: Plain Sailing or Environmental Disaster? WWF Arctic Bull. no.3.94: 10-12.

Moe, K.A., Thomassen, J., Løvås, S.M. & Hansson, R., *in press*. The Northern Sea Route - Environmental Assessments as an Integrated Part of the International Northern Sea Route Programme (INSROP). Paper presented at the International Conference organised by the Advisory Committee on Protection of the Sea (ACOPS), Moscow, 19th-22nd Sept. 1994. *In Press*: ACOPS Conf. Proc.

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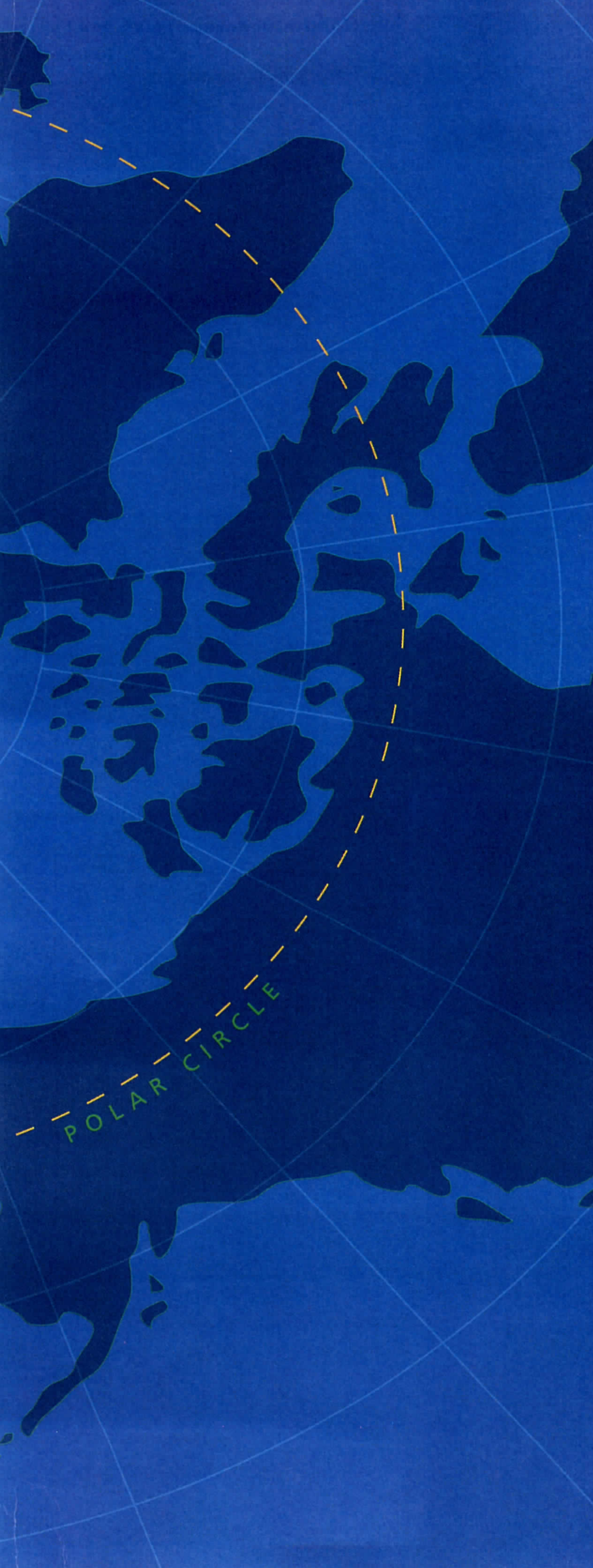
Table 1. Projects within INSROP Sub-programme II Environmental Factor (per. 1st of January 1995). 1) Projects carried out in other INSROP sub-programmes; 2) Projects carried out in other programmes; 3) Projects will be started later.

Projects	Duration	Responsible
II.1 Initial survey of Russian data sources	1993	AARI
II.2 Screening and focusing workshop	1993	NP
II.3 GIS		
II.3.1 GIS design	1993-1994	GRID/DNVI
II.3.2 Implementation of data base	1994-1996	NP
II.4 Environmental Atlas (EA)		
II.4.1 Invertebrates and Fish	1993-1997	Akvaplan-niva
II.4.2 Marine Birds	1993-1997	NP
II.4.3 Marine Mammals	1993-1997	NP
II.4.4 The Coastal Zone	1993-1997	Akvaplan-niva
II.4.5 River, Estuaries and Deltas	1993-1994	Akvaplan-niva
II.4.6 Physical and Chemical Factors	-	1/2
II.4.7 Indigenous Peoples	-	1/2
II.5 Environmental Impact Assessment		
II.5.1 Assessment design	1993-1994	NINA-NIKU
II.5.2 Sensitivity modelling	1994	NINA-NIKU
II.5.3 Pollution levels	-	2
II.5.4 Oil drift modelling	-	1
II.5.5 Scenarios for NSR activities	1994	NINA-NIKU
II.5.6 Environmental impact assessment	1994-1997	NINA-NIKU
II.6 Environmental Safety; Ship and Navigation		
II.6.0 Navigation in ice covered waters	1994	Kvaerner M-Y
II.6.1 Control of pollution from ships	1993-1994	CNIIMF
II.6.2 Environmental safety of ships	1993-1995	CNIIMF
II.6.3 Shore reception facilities	1993-1994	CNIIMF
II.6.4 Ship pollution emergency plan	1993-1994	CNIIMF
II.6.5 Coastal pollution emergency plan	1995-1996	CNIIMF
II.6.6 Oil spill combatting techniques in ice	-	2
II.6.7 Environmental safety of nuclear icebreakers	1994-1996	CNIIMF
II.7-10. Coordination, activation of results		
II.7 Recommendation, public info.	3	-
II.8 Environmental pilot	3	-
II.9 Coordination Norway	1993-1997	NP
II.10 Coordination Russia	1993-1997	CNIIMF



The three main cooperating institutions of INSROP

Ship & Ocean Foundation (SOF), Tokyo, Japan.
SOF was established in 1975 as a non-profit organization to advance modernization and rationalization of Japan's shipbuilding and related industries, and to give assistance to non-profit organizations associated with these industries. SOF is provided with operation funds by the Sasakawa Foundation, the world's largest foundation operated with revenue from motorboat racing. An integral part of SOF, the Tsukuba Institute, carries out experimental research into ocean environment protection and ocean development.

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.
CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stockholding company.

The Fridtjof Nansen Institute (FNI), Lysaker, Norway.
FNI was founded in 1958 and is based at Polhøgda, the home of Fridtjof Nansen, famous Norwegian polar explorer, scientist, humanist and statesman. The institute spesializes in applied social science research, with special focus on international resource and environmental management. In addition to INSROP, the research is organized in six integrated programmes. Typical of FNI research is a multidisciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.