PREFACE

This report has been written as part of the SUTRANET project (Work Package 1: Transport Research and Development Network). SUTRANET (‘Sustainable Transport Research & Development Network in the North Sea Region’) is a project within the framework of the European Commission’s (EC’s) Interreg IIIB North Sea Programme.

The report presents some methodological guidelines and recommendations as regards environmental impact assessment of maritime traffic in the North Sea Region. It is complementary to the following SUTRANET publications:

- ‘North Sea Region Transport and Environment – Sustainability concepts, criteria and the use of indicators’.
- ‘Documentation of a Calculation Tool for Maritime Emissions’. 
- ‘Spatial and Environmental Impact of Port Development’.

The report has been prepared by the Swedish Environmental Research Institute (Gothenburg branch), with Åke Sjödin and Eje Flodström as the main authors. Aalborg University’s Department of Development and Planning has contributed with some comments to draft versions of the report and with a few editorial amendments to the final version.

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1 Introduction

As part of achieving the objective of Work Package 1 of the SUTRANET project - “to establish a sustainable research and development network and improve the decision-making basis” as regards transportation within the North Sea Region (NSR), the present report was synthesised within the task: 'Elaboration of a first step of a region-wide trade and transport information system'.

Sea transportation is an interesting mode of transport from an environmental and cost-benefit point-of-view, compared to the other transport modes (road, rail, air), mainly for three reasons:

- maritime freight transport is roughly between two and three times more energy efficient than road freight transport, thus emitting half to one third of CO₂ less per weight unit cargo and unit distance transported compared to road transport.

- congestion is not a major issue.

- apart from ports and terminals, the infrastructure is more or less “free” of cost (this is also true for air transport).

However, there are several other potential environmental problems associated with sea transportation, which involves that it presently is not on a sustainable path. In Europe, as well as in several other regions of the world, sea transportation is a major contributor to acid rain and acidification and eutrophication through high specific emissions of sulphur dioxide (SO₂) and nitrogen oxides (NOₓ). Furthermore, in ports and port surroundings, noise and poor air quality may constitute a health problem. Pollution of water and soil due to oil spill is another potential problem associated with transportation at sea.

To make full use of the positive aspects associated with sea transportation listed above, it is necessary to deal with its drawbacks. In many cases technical solutions exist. This was e.g. demonstrated in a separate study within Work Package 3 of the SUTRANET project, 'Transports and Logistics Centres', exploring in more detail the environmental impact of sea transportation with a focus on ports/logistics centres (Sjödin and Fridell, 2007).

The present report takes a wider perspective, in order to involve and disseminate more of the environmental problems related to transport that occurs in the NSR. It forms input to the part of Work Package 1 that aims at establishing sustainability concepts, criteria and indicators for transport in the NSR, to be used throughout the SUTRANET project (Hansen et al., 2006).

Also within Work Package 1 of the SUTRANET project, a ship air emission calculation model has been developed, in order to further help support establishing a sustainable research and development network and improve the decision-making basis as regards sea transportation within the North Sea Region (Sjödin et al., 2007).

The report gives a general background of environmental impact of sea transportation, structured and disseminated after the national environmental quality objectives applied in Sweden since 1999. The progress towards these objectives is assessed, and the environmental effects related to sea transportation are described in general terms. The present knowledge as regards environmental impact of sea transportation in the North Sea Region specifically is presented, ending in a number of conclusions and recommendations regarding need for more knowledge as well as policy actions.
2 Environmental Impact of Sea Transportation - General Issues

The general description of environmental effects related to sea transportation in this study are illustrated by and structured according to the so called Swedish national environmental quality. Although specific for Sweden, the description and motifs of these objectives are both comprehensive and generic, and thus can be transferred to other countries and regions.

2.1 Environmental Quality Objectives

In 1999, the Swedish Parliament adopted 15 national environmental quality objectives, to be attained within about one generation (Swedish Environmental Objectives Council, 2007). In 2005, a 16th objective was added. The environmental quality objectives create a transparent and stable framework for environmental programmes and initiatives, and serve to guide such efforts at various levels and sectors in society. The 16 environmental quality objectives are (see also Figure 1):

1. Reduced Climate Impact
2. Clean Air
3. Natural Acidification Only
4. A Non-Toxic Environment
5. A Protective Ozone Layer
6. A Safe Radiation Environment
7. Zero Eutrophication
8. Flourishing Lakes and Streams
9. Good-Quality Groundwater
10. A Balanced Marine Environment
11. Thriving Wetlands
12. Sustainable Forests
13. A Varied Agricultural Landscape
14. A Magnificent Mountain Landscape
15. A Good Built Environment
16. A Rich Diversity of Plant and Animal Life

Between 2001 and 2005, in a series of decisions, the Swedish Parliament laid down 72 interim targets. These targets flesh out the environmental quality objectives by describing the situation in a given year, usually 2010. Progress towards the objectives - criteria - is measured and indicated in a three-step scale:

- **Current conditions**, provided that they are maintained and the decisions taken are implemented in all essential respects, are sufficient to achieve the environmental quality objective/interim target within the defined time-frame.

- **The environmental quality objective/interim target can be achieved to a sufficient degree/on a sufficient scale within the defined time-frame, but further changes/measures will be required.**

- **The environmental quality objective/interim target will be very difficult to achieve to a sufficient degree/on a sufficient scale within the defined time-frame.**
Figure 1. National environmental quality objectives for Sweden (Swedish Environmental Objectives Council, 2007). The most important environmental objectives related to sea transportation are marked with red borders.

The progress was recently reported (Swedish Environmental Objectives Council, 2006). This is summarised below, along with a more detailed description of the most important environmental quality objectives related to sea transportation (nos. 1, 2, 3, 7, 10 and 15, marked with red borders in Figure 1—environmental objectives less related to sea transportation are nos. 4, 5, 8, and 16, whereas objectives more or less irrelevant as regards sea transportation are nos. 6, 9, 11-14 and 16).

1. Reduced Climate Impact

The UN Framework Convention on Climate Change (UNFCCC, 2007) provides for the stabilization of concentrations of greenhouse gases in the atmosphere at levels which ensure that human activities do not have a harmful impact on the climate system. This goal must be achieved in such a way and at such a pace that biological diversity is preserved, food production is assured and other goals of sustainable development are not jeopardized. All nations must assume responsibility for achieving this global objective. The outcome within a generation for this environmental quality objective should include the following:

- The measures focus on stabilizing greenhouse gas concentrations in the atmosphere at a level lower than 550 ppm (parts per million) and ensuring that there is no increase in the concentrations of other greenhouse gases in the atmosphere. The action taken by all countries is crucial to achievement of the objective.

Progress assessment:

Comment: Sweden’s climate objective includes a long-term target of reducing the country’s emissions to no more than 4.5 tonnes of carbon dioxide equivalents per capita per year by 2050, with further reductions to follow. This long-term target is based on the premise that, in the long run, emissions should be evenly distributed over the earth’s population. In 2004, Swedish emissions amounted to around 7.9 tonnes of carbon dioxide equivalents per capita.
2. **Clean Air**

The air must be clean enough not to represent a risk to human health or to animals, plants or cultural assets. The outcome within a generation for this environmental quality objective should include the following:

- Concentrations of air pollutants do not exceed low-risk concentrations for cancer or target values for protection against diseases or effects on plants, animals, materials and cultural objects. The target values are set with reference to persons who suffer from hypersensitivity and asthma.

*Progress assessment:●*

*Comment:* As regards nitrogen dioxide levels in urban areas the pace of remedial action is too slow, although there are still chances of meeting the interim target on time. Concerning air quality indicators particles and carcinogenic benzo(a)pyrene, the assessment is less optimistic. The targets for particulates are exceeded chiefly because of emissions from road surface abrasion and re-suspension of dust, while the main reason for the benzo(a)pyrene target being exceeded is probably wood-fired heating of individual houses.

3. **Natural Acidification Only**

The acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water. In addition, deposition of acidifying substances must not increase the rate of corrosion of technical materials or cultural artefacts and buildings. The outcome within a generation for this environmental quality objective should include the following:

- The deposition of acidifying substances does not exceed the critical loads for land and water areas.
- Measures to prevent anthropogenic soil acidification preserve natural production capacity, archaeological objects and biological diversity.
- Forestry is adapted to the sensitivity of each site to acidification, thus preventing the acidification of land and water areas due to land use.

*Progress assessment:●●*

*Comment:* Atmospheric emissions and deposition of acidifying pollutants are still falling, but not sufficiently rapidly. In addition, recovery of natural ecosystems from acidification will take a long time. To assess progress towards this objective, the concept of critical load exceedance is used. Critical loads are the maximum levels of deposition of acidifying sulphur and nitrogen which the environment can tolerate. Over the period 1990–2004, sulphur and nitrogen deposition in Sweden fell by around 60% and 30%, respectively. If no further action is taken beyond that already decided or agreed, the EU’s estimate is that, in 2020, critical loads for acidification will be exceeded for around 11% of the area of lakes and 15% of the forest area of Sweden. The new EU Thematic Strategy on Air Pollution, approved by the Council on 9 March 2006, will bring a slight improvement, of some 2%, but this will be far from enough.

7. **Zero Eutrophication**

Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water. The outcome within a generation for this environmental quality objective should, as regards coastal areas, include the following:

- Nutrient concentrations in coastal waters and seas are essentially the same as in the 1940s, and nutrient inputs into the sea do not cause eutrophication.
- The ecological status of coastal waters, as defined by the EU Water Framework Directive (European Commission, 2000), is good.
Progress assessment: ❋

Comment: Nutrient emissions to air and water continue to fall. Owing to large-scale natural fluxes of nitrogen and phosphorus and the long timescale of recovery, however, reductions in the effects of eutrophication in the environment are not as clear. The objective will therefore be difficult to achieve. The biggest sources of nutrients in Sweden are agriculture, single-household sewage systems and municipal sewage treatment plants. Emissions in neighbouring countries are also a major factor. Atmospheric emissions of nitrogen oxides from international shipping on the Baltic Sea, Kattegat and Skagerrak, for instance, exceed aggregate Swedish emissions of these gases.

10. A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos

The North Sea and the Baltic Sea must have a sustainable productive capacity, and biological diversity must be preserved. Coasts and archipelagos must be characterized by a high degree of biological diversity and a wealth of recreational, natural and cultural assets. Industry, recreation and other utilization of the seas, coasts and archipelagos must be compatible with the promotion of sustainable development. Particularly valuable areas must be protected against encroachment and other disturbance. The outcome within a generation for this environmental quality objective should include the following:

- Endangered species and stocks can spread to new habitats in their natural areas of distribution, thus ensuring viable populations.
- A good conservation status is maintained for habitats for endangered, rare and care-demanding species and for natural biotopes that are worth preserving.
- The natural beauty and natural and cultural assets of coastal and archipelago landscapes, biological diversity and variation are maintained by continuing prudent use.
- Consideration is given, in connection with fishing, shipping and other uses of seas and water areas, as well as construction and other development in coastal and archipelago areas, to the productive capacity, biological diversity, natural and cultural assets and outdoor recreation assets of the water areas.
- Measures are taken to maintain low noise levels.
- Buildings and built environments in coastal and archipelago landscapes that are particularly valuable are preserved and improved.
- All coastal waters have a good surface water status in terms of the composition of species and physical and chemical characteristics, as defined by the Water Framework Directive.

Progress assessment: ❋

Comment: In 2005 the Swedish government presented a national marine environment strategy, one aim of which is to ensure more effective coordination of user and conservation interests with impacts on the sea. A concerted plan of action for the Swedish marine environment is also being developed. Furthermore, in the autumn of 2005 the European Commission adopted a Marine Strategy, which is designed to create a better basis for integrating environmental concerns into relevant areas of EU policy.

15. A Good Built Environment

Cities, towns and other built-up areas must provide a good, healthy living environment and contribute to a good regional and global environment. Natural and cultural assets must be protected and developed. Buildings and amenities must be located and designed in accordance with sound environmental principles and in such a way as to promote sustainable management of land, water and other resources. The outcome within a generation for this environmental quality objective should include the following:

- The built environment provides aesthetic experiences and wellbeing and offers a wide range of housing, workplaces, services and culture that give everybody the opportunity to live a full and stimulating life, while reducing everyday transport needs.
• The cultural, historical and architectural heritage in the form of buildings and built environments, including places and landscapes with special assets, are protected and enhanced.

• A sustainable urban structure is developed, both in connection with the location of new buildings, structures and industries and with the use, management and conversion of existing buildings.

• The living and leisure environment, and wherever possible the work environment, meets society's requirements in terms of design, freedom from noise and access to sunlight, clean water and clean air.

• Areas of unspoiled nature and green spaces close to built-up areas, which are easily accessible, are protected in order to meet the need of play, recreation, local farming and a healthy local climate.

• Biological diversity is preserved and enhanced.

• Transports and transport facilities are located and designed in such a way as to limit interference with the urban or natural environment and so as not to pose health or security risks or be otherwise detrimental to the environment.

• Environmentally sound, good-quality public transport systems are available, and there are plenty of facilities for safe pedestrian and cycle traffic.

• People are not exposed to harmful air pollutants, noise nuisances, harmful radon levels or other unacceptable risks to health or safety.

• Land and water areas are free of toxic and dangerous substances and other pollutants.

• The use of energy, water and other natural resources is efficient, resource-saving and environmentally sound; the preferred energy sources are renewable.

• Natural gas is only used where it is not possible to use substitutes in specific applications.

• Deposits of gravel that are valuable for the drinking water supply and the natural and cultural landscape are preserved.

• The quantity and dangerousness of waste are decreasing.

• Waste and residues are separated by categories and recycled on a cooperative basis by urban areas and the surrounding rural areas.

Progress assessment: 😐

Comment: It is uncertain whether this objective can be attained. The interim targets and intended outcomes within a generation in areas such as built environments of cultural heritage value, noise, waste generation and the indoor environment are expected to be difficult to achieve, as effective policy instruments are either not available or are not being used. Where the latter is the case, the reason may be a lack of resources, but also conflicting goals or interests, for example when new homes are to be built in central but noisy locations.
2.2 Environmental Effects Related to Sea Transport

The main environmental effects related to shipping may be divided into the following categories:

1) Emissions to air
   - Exhaust emissions (relevant mainly for environmental quality objective Nos. 1, 2, 3 and 7)
   - Emissions from ship building and maintenance (relevant mainly for objective No. 2 and 15)
   - Fire extinguishers & Refrigerants (relevant mainly for objective No. 1)
2) Emissions to water (relevant mainly for objective No. 10)
   - Oil spill and leakage
   - Antifouling paints
   - Ballast water
3) Waste/litter (relevant mainly for objective Nos. 10 and 15)
4) Noise (relevant mainly for objective No. 15)
5) Swell (relevant mainly for objective No. 10)

2.2.1 Emissions to air

*Exhaust emissions*

All ships activities are responsible of air pollutants emissions and particularly: ships movement in port, ships activities in hotelling phase (lighting, heating, refrigeration, ventilation, etc.), tanker loading and unloading.

Exhaust emissions are caused by burning of fuel onboard the vessel. From the engines, nitrogen oxides, hydrocarbons, carbon monoxide, particulates and carbon dioxide is the most dominant. The distribution among them is, however, dependant of the type of engine.

Typical for the diesel engines is the relatively high concentration of nitrogen oxides. This is an effect of the high combustion temperature and pressure in the diesel combustion process, the same features that enables the high fuel-efficiency relative to other engine types.

Emission of carbon dioxide, which is a green house gas, is directly connected to the fuel consumption. Low fuel consumption or energy consumption is therefore essential not only from an economical point of view, but also from an environmental aspect.

Sulphur oxides are also an important emission that is entirely dependent on the sulphur content in the fuel. The easiest way to cut sulphur emissions is consequently to use fuel with low sulphur content.

Hydrocarbons, particulates and carbon monoxides are all results of incomplete combustion in the engine. Under normal operations these emissions should be very low from diesel engines. Disturbances in combustion, for example due to excessive piston ring wear, bad injectors or unsuitable fuel, might however lead to substantial increases. Fast load changes may result in short smoke puffs with high concentrations of the mentioned emissions. Cold starting of engines might also lead to temporary high emissions of hydrocarbons.

Ships exhaust emissions stem from several sources with different functions. Normally, ships are equipped with main engines for propulsion, auxiliary engines for energy production on board and boilers for heat production. A separate emergency generator is compulsory. A few ships are also fitted with incinerators for the burning of waste.
Ships are generally powered with diesel engines that operate under fairly constant conditions with few transients. This means that the pollutant quantities from incomplete combustion, VOC, CO and particulates, are very small. In addition the vast majority of emissions are emitted away from population centres.

Ship transportation, with some exceptions, is not yet subject to limitations in fuel sulphur content. This means that the emissions of sulphur oxides are more significant than from the land transportation. The acidification effect of sulphur oxide emissions is on the regional to global scale and the contributions from semi-distant sea areas are of importance.

Emissions from ship building and ship maintenance

Volatile organic compounds, VOC, are emitted from metal degreasing and painting during ship building and maintenance. Occasionally also particles (aerosols) are emitted during these processes.

Fire extinguishing systems

Up until 2000, Halon has been the dominating media used for fire extinguishing in closed spaces. All halon based fire extinguishers are now supposed to have been replaced by more environmentally acceptable methods.

Refrigerating systems

Cooling and freezing systems are used onboard all ships. The systems are normally used for storage of provisions and air condition for the accommodation. The big consumers however, are found on freezer ships and big passenger ships with large air condition facilities. The environmental influence from these systems is connected with the use of cooling media. Normally, the cooling media is contained in a closed system and should not be released to the air.

Since the mid fifties the cooling media has been a chlorofluorocarbon (CFC) gas. Some CFC gases have a negative influence on the ozone layer and they are also considered as green house gases.

According to the Montreal protocol, some CFC gases are to be exchanged to other cooling media not harmful to the ozone layer. The coolant media in question is the R12 that is used on most small systems. R12 is now forbidden. The most used coolant media on ships is the R22. This is not included in the Montreal protocol and has a lower (factor of 20) influence on the ozone layer.

2.2.2 Emissions to water

Ship emissions to water can take place in many ways (Trozzi, 2000; Trozzi & Vaccaro, 2003):
- Oil of bilge and motor fuel leakage from ships and gasoline and diesel oil;
- Accidental leakage of oil and chemical substances in loading and unloading of products;
- Pollution from slop (residual of chemical products contained in the tanks and of the product used in the washing operations), either in the case in which it is treated and in the case in which it is unauthorized discharged (tanks washing close to the coast);
- Leaching of antifouling paints;
- Discharge of ballast water;
- Dumping of black (sewage) and grey (shower, sink and galley) water.

Statistics and data on emissions to water are generally much more limited than for air.
Oil spill and leakage

Normally there should not be any spill during bunker operations, but it can be difficult to avoid during special conditions or when accidents occur. Even though the environmental influence of such spill is of limited significance, it is important to have appropriate routines and devices to avoid spill or to take care of spill when it has occurred.

Leakage of hydraulic and similar oils is mostly dependant on accidents and in some cases due to wear and is consequently unwanted from a strict commercial point of view. There are also some leakages that are so common that they might be taken as normal, such as leakages from the propeller shaft. For both hydraulic oils and shaft oils it might be an alternative to use biologically degradable oils.

To prevent from oil spill when grounding, the ship must be designed with protected bunker tanks. This can be done by positioning the tanks inside a double skin. Ships trading in Swedish fresh waters must have double skin from July 1996. If trading in inland waters used for consumption, it may be wise to carry emergency equipment to be able to take care of oil from the own ship.

Antifouling paints

Leaching of antifouling paints (particularly containing organotin tributyltin) used to coat the bottoms of ships to prevent sea-life such as algae and mollusks attaching themselves to the hull - thereby slowing down the ship and increasing fuel consumption.

Ballast water

Transfer of harmful aquatic organisms (including dormant stages of microscopic toxic aquatic organisms such as dinoflagellates, pathogens such as the bacterium vibrio cholerae) with ballast water, used to stabilize vessels at sea (globally, IMO estimates that about 10 billion tons of ballast water is transferred each year). As ships travel faster and faster, the survival rates of species carried in ballast tanks have increased; as a result, many introductions of non-indigenous organisms in new locations have occurred, often with severe consequences for the local ecosystem - which may include important fish stocks or rare species.

2.2.3 Waste/litter

During ships operation a number of waste products are generated onboard ships. Ecological awareness from the crew and more strict legislation has lead to a decrease in the dumping of waste directly to the sea. Depending on trade and area the ship is operating in, the ship must collect the waste to be discharged ashore at ships call. The IMO regulations, Annexes I - V, give guidance for most of the main products that are to be discharged and not dumped at sea (IMO, 2006). It is still a big problem however, which can easily be seen e.g. around the Swedish coast, and it is therefore necessary to take more action. On many ships it is a handling problem. It is not easy and healthy to accommodate waste from a typical crew during a week or two, if the ship is not equipped with appropriate storage and handling facilities. The space is limited and it can be troublesome to get rid of the waste in some ports. To have easy available reception facilities requires co-operation with shore representatives.

A ship produces many kinds of waste that makes it necessary to have some sort of sorting. From the engine department it is common with waste contaminated with oil of different types. This waste needs to be segregated from other garbage, thus it is necessary to have adequate storing facilities.

Ship generation of waste can not easily be measured in ports. Due to the rules, regulations and cost of discharging waste in the port, some information will not be correct by collecting information from ports only as the ship try to save the waste and discharge it where it gives the lowest cost. Results from a research project under the European Commission 4th Framework Programme yielded suitable waste
production factors for oily waste, sewage and garbage for different ship types (European Commission, 1998).

On some ships it is common to burn waste in an incinerator. The emissions are very small compared to the emissions from the engine, even though the composition is more difficult to determine. In some waters it is prohibited to use incinerators.

### 2.2.4 Noise

Noise is a serious issue - levels over 40 dB(A) affect our well-being, while there is evidence that levels over 60 dB(A) can affect our physical and psychological health. While the last two decades have seen significant reductions in the noise produced by all sorts of vehicles, the rapid growth in transport – particularly air and road – has resulted in well over 120 million people in the EU being exposed to noise levels above 55 Ldn dB(A) on the front facade of their houses (EEA, 2007).

The major noise sources in a ship are the main propulsion machinery, the auxiliary engines, the propeller and transverse propulsion unit, and the heating, ventilation and air conditioning system. The majority of main and auxiliary machinery is driven either by diesel engines or steam turbines. The latter generate less noise than diesel engines with equal output power. Machinery generates noise into the surrounding air and also induces vibration into any structure to which it is connected. Noise transmission can either be waterborne, airborne or structure borne (Trozzi & Vaccaro, 2000).

One of the most significant changes that has occurred in the world’s oceans in the last century has been the introduction of propeller driven ships. As a result of this change, shipping noise now dominates the background noise over the frequency ranges 20Hz – 300Hz throughout much of the oceans (underwater noise). These frequencies are also used by many species of whale, particularly the large baleen whales. Calls from whales can be detected from hundreds of kilometres away because sound travels much further underwater than in air. Unfortunately, underwater man-made noise of similar frequencies, such as the noise generated by commercial shipping, travels far as well. The concern is that shipping noise may have long-term, population-level impacts on these species, which, given what is known of their sound production and ecology, are thought by some specialists to rely on low-frequency sound for communication over large distances (IFAW/NRDC, 2004). The leading noise producers are oil tankers and bulk dry ships (OMI, 2004).

Noise disturbances from a ship are not only related to the sound from the engine. It also depends to a great extent on location of terminals and the type of operation that is going on. Most dominantly during port stay is slamming sounds when trucks or trailers pass the ramp, but also fans from ventilation and various hydraulic systems can cause noise.

### 2.2.5 Swell (wave/wash generation)

Increased demand for fast maritime transport has resulted in rapid evolution of high-speed crafts. These vessels sometimes have adverse environmental impacts in shallow water due to wake and wash effects. Additionally the flow induced by the passage of high-speed crafts generates erosive forces that may damage harbour basins, navigable channels, beaches and seaside properties. Wake and wash effects from e.g. high-speed vessels have been studied within a research project under the European Commission 5th Framework Programme (European Commission, 2002).
3 Environmental Impact of Sea Transportation in the North Sea Region

3.1 Air Emissions

The most recent studies conducted to quantify total air emissions from sea transportation in the North Sea Region were carried out by MariTerm (2002) and by ENTEC (2004). Both studies use ship movement data supplied by Lloyd’s Fairplay (formerly Lloyd’s Information Services), but utilise different models to quantify ship emissions.

The MariTerm study was primarily concerned with emissions from the sea areas surrounding Sweden, but also includes the additional impact from the North Sea, cf. Figure 2 and Table 1.

Figure 2. Geographical demarcation of the North Sea and Baltic regions in the study conducted by MariTerm (2002).

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<td>2001</td>
<td>320</td>
<td>140</td>
<td>15</td>
<td>36</td>
<td>12</td>
<td>5,8</td>
</tr>
<tr>
<td>2002</td>
<td>350</td>
<td>160</td>
<td>17</td>
<td>39</td>
<td>13</td>
<td>6,6</td>
</tr>
</tbody>
</table>

Table 1. Emissions from ships in the North Sea Region and the Baltic Region (MariTerm, 2002).
The ENTEC study used a GIS-system together with estimated sea routes for assigning the emissions geographically, cf. Figure 3 and Table 2.

Figure 3. Geographical demarcations for estimating ship emissions in Europe in the study conducted by ENTEC (2004).

<table>
<thead>
<tr>
<th>Area</th>
<th>NOx</th>
<th>SO2</th>
<th>CO2</th>
<th>HC</th>
<th>PM (in port)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Sea + Baltic</td>
<td>1074</td>
<td>763</td>
<td>40849</td>
<td>39</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 2. Emissions from ships in the North Sea plus the Baltic Region (ENTEC, 2004).

Of interest are the large differences in estimates despite roughly similar geographical boundaries and traffic data source. One significant difference is the estimate of sulphur content in the fuel in the two investigations.

North Sea shipping accounted for only about 0.5% of the overall CO2-emissions in the North Sea countries in 2003 (EEA, 2005). Yet small, this fraction is increasing since base year 1990.

As for the acidifying and eutrophying compounds SO2 and NOX, North Sea shipping accounted for 3% of the overall SO2-emissions and 5% of the overall NOX-emissions within EU-15. These fractions have increased substantially since 1990, and may be even higher in cities hosting major ports, thus contributing to exceedances of air quality standards for SO2, NO2 and also particulate matter (PM).
3.2 Emissions to Water

3.2.1 Oil spill

One of the biggest threats from shipping to the environment of the North Sea, in particular the Kattegat and Skagerrak (and subsequently the Baltic), is the rapidly growing volume of oil carried by large tankers from ports in Russia and the Baltic states. Currently, 160 million tonnes of oil are transported by sea every year, and the figure is expected to rise by at least 40% by 2015 (Swedish Environmental Objectives Council, 2006). A significant number of oil spills is observed in the North Sea each year (cf Figure 4).

A range of protective measures have been introduced by HELCOM, OSPAR and IMO. The risk of collisions and groundings is being reduced by improved traffic management systems, hydrographical surveys, modern navigation instruments and greater use of pilotage. In parallel with a stepping up of aerial surveillance and growth in shipping movements, the welcome downward trend in numbers of discharges is continuing, showing that the agreed measures are having an impact (cf Figure 5). Aerial surveillance, in particular, has proved to have a deterrent effect, significantly reducing illegal discharges. There has also been an increase in the quantities of waste oil delivered to port reception facilities, showing that more and more vessels are now opting to leave such oil in port rather than discharging it at sea (Swedish Environmental Objectives Council, 2006).

Figure 4. Oil spills detected in the North Sea and in the Baltic Sea, in 2002 (left, HELCOM, 2002) and 2005 (right, Swedish Environmental Objectives Council, 2006).
3.2.2 Antifouling agents

The impact of tributyltin (TBT) from shipping in the North Sea Region is greatest in harbours, marinas and shipyards, and close to shipping routes (OSPAR, 2000). The Ecotoxicological Assessment Criteria (EACs) for sediments are exceeded by up to 30 million times in some harbours, necessitating special attention in some cases with regard to the removal and disposal of sediments to avoid dispersing the contamination. Away from the sources, concentrations in water and sediments are often below detection limits, which are close to or even above the EACs, although accumulation of TBT in aquatic organisms and seabirds is encountered, even in remote areas. The most prominent ecological effect of this substance is changes in sexual organs, leading to impaired reproduction in several species of marine snails. In addition, shell thickening has been observed in oysters. The grazing capacity of zooplankton is also affected by low TBT concentrations, with problems similar to those mentioned for pesticides. Imposex affected female common whelk, dog whelk and red whelk (Neptunea antiqua) are now extremely common in the North Sea (and the Baltic) Region in contrast to the situation before 1978, when no imposex was found in samples from the same areas. Offshore occurrence of imposex in prosobranch gastropods is correlated with shipping traffic intensity. Marina areas still show evidence of historical contamination of TBT. Recovery times may well be in the order of decades. Information on other antifouling substances is limited.

3.2.3 Ballast water

Likely introductions of non-indigenous species via ballast water in the North Sea Region are the North American razor clam (Ensis directus, Syn: E. americanus) and polychaetes of the Marenzelleria species group (cf. Figure 6). In the 1980s, the North American razor clam spread along the eastern shores of the North Sea, and is now present from the Kattegat to the river Seine and the south-east coast of England. There are as yet no indications that any indigenous species have been out-competed by this newcomer (OSPAR, 2000).

3.2.4 Waste/litter

Despite pertinent laws and regulations, waste/litter is still a considerable problem for the marine environment and the coastal communities in the North Sea Region (OSPAR, 2000). Potential sources of litter are mainly related to waste generated by shipping (fishing, commercial) on the North Sea and touristic and recreational activities (cf. Table 3). Some waste may be deposited illegally and some by accident. Litter may also be transported into the sea by winds, currents and rivers. It has been estimated that the North Sea has to cope with about 70 000 m$^3$ of litter per year, and some 6.6 million pieces (or 8 600 t) were estimated to be present in the Dutch sector alone. Non-degradable plastics may constitute up to 95% of the total amount of litter in many areas of the North Sea Region. Litter, including drifting fishing nets and ropes, may entangle and drown mammals and seabirds. It has also been found to carry a variety of epiphytic organisms to sea areas that these organisms would not normally reach. Economically, the recreation sector is likely to be most affected by litter. Remains of plastic nets can easily get caught in ship’s propellers. The North Sea (1991) as well as the Baltic Sea (1988) have both been designated as MARPOL Special Areas (Annex V) where the dumping of garbage and litter from ships (e.g. household waste, cargo waste, wire straps, covering material, fishing equipment) is prohibited. Dumping of waste is also prohibited under the OSPAR Convention. So far, however, there is no indication of any improvement with regard to litter.
Table 3. Waste (m³) generated yearly in the North Sea region by different sectors, whereof a part may end up as litter (OSPAR, 2000).

<table>
<thead>
<tr>
<th>Sector</th>
<th>Waste (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferry traffic</td>
<td>290,000</td>
</tr>
<tr>
<td>Fishing vessels</td>
<td>100,000</td>
</tr>
<tr>
<td>Offshore installations †</td>
<td>90,000</td>
</tr>
<tr>
<td>Merchant shipping</td>
<td>60,000</td>
</tr>
<tr>
<td>Pleasure crafts</td>
<td>40,000</td>
</tr>
<tr>
<td>Recreation, tourism</td>
<td>20,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>600,000</td>
</tr>
</tbody>
</table>

† Waste collection, return to land and disposal onshore is strictly controlled in this sector. Consequently there is a low risk that waste from offshore installations contributes to marine litter.

Very little information is available on the effects of litter. Recent estimates suggest that at least 600,000 m³ of litter could presently be resting on the North Sea floor. Entanglement and drowning of birds (especially gannets (Sula bassana) and fulmars (Fulmarus glacialis)), and marine mammals in lost fishing gear does occur, but the impacts at the population level are not known. A study in Helgoland found that around 3% of all living fulmars were tangled to some extent and 29% of fulmars found dead had been killed by entanglement in plastic. Birds can also be affected when they ingest small plastic particles, which has frequently been observed. In particular, the feeding behaviour of fulmars may be affected, since plastics are known to accumulate in the gizzard of this species. This phenomenon may have increased rapidly over the last two decades. Seabird chicks may also ingest small plastic items together with normal food when they are fed by regurgitation by their parents, and the items may be retained for long periods, owing to limited regurgitation by the chicks. Many birds use plastics to make their nests which chicks may ingest. In particular gannets build coloured nests. A study from The Netherlands found that the stomachs of beached fulmars contained on average 12 plastic objects and up to a maximum of 96. Floating and drifting litter may also be a vector for transoceanic or trans-regional movements of non-indigenous species (OSPAR, 2000).

3.3 Noise

There is no information available regarding noise exposure for the approximately 184 million people who live within the catchment area of the North Sea, and thus neither from noise related to shipping. Compared to the other transport modes - road, rail, air - the lack of information indicates that noise related to shipping and shipping activities is not a major health issue. For EU as a whole about 120 million people (more than 30% of the total population) are exposed to road traffic noise levels above 55 dB, and more than 50 million people are exposed to levels above 65 dB. It is estimated that 10% of the EU population are exposed to rail noise above 55 dB. The data on noise nuisance by aircraft are the most uncertain, but studies indicate that 10% of the total EU population may be highly annoyed by air transport noise (EEA, 2001).
As regards levels and impact of underwater noise in the North Sea, available information is equally poor. However, the Agreement on the Conservation of Small Cetaceans (whales, dolphins and porpoises) of the Baltic and North Seas (ASCOBANS) has recognized the dangers of underwater noise pollution in its Conservation Management Plan (ASCOBANS, 2007).

### 3.4 Swell (wave/wash generation)

No relevant information has yet been found available for the North Sea Region.
4 Conclusions and Recommendations

- The share of emissions of greenhouse gases (mainly CO₂) from sea transportation to the overall emissions of greenhouse gases in the North Sea Region is marginal (about 0.5%). Although slowly increasing, the increase is small compared to the increase of CO₂ emissions from road transport since e.g. 1990. This means that there is room for further modal shift from road to waterborne transport, that would be beneficial for the climate change issue.

- Simultaneously, however, the shares of emissions of the acidifying and eutrophying compounds SO₂ and NOₓ from North Sea transport to the overall SO₂ and NOₓ emissions, are very significant (3% and 5% of the overall EU 15 emissions, respectively), and a further increase in waterborne transport in the North Sea Region need to be accompanied with the use of low-sulphur fuels and further enforcement of the introduction of NOₓ emission reduction equipment onboard ships, in order to be on a sustainable path.

- The situation as regards oil spill in the North Sea Region appears to have been improved during the last ten years, but further action is needed.

- The situation as regards waste and litter being dumped into the North Sea is unsatisfactory, and no improvements are observed, which is a threat mainly to seabird life in the North Sea Region.

- Although the use being increasingly prohibited, the impact of antifouling agents, mainly tributyltin (TBT), is still a major environmental problem in the North Sea, preferably in harbours, marinas and shipyards, and close to shipping routes. Recovery times for TBT may well be in the order of decades. Information on other antifouling substances is limited.

- Compared to noise from the other transport modes - road, rail and air - noise related to shipping does not occur to be a major health issue in the North Sea Region, although of course locally such noise problems may occur. However, underwater noise affecting ocean mammals may be a rising problem in the North Sea Region and deserves further attention along with the growing traffic.

- There is evidence for non-indigenous species having been introduced in the North Sea area due to ballast water releases, however, yet without any evidence for that indigenous species have been out competed.
5 References

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