2011

The introduction of alien aquatic species by ships in the Arctic : the role of the Polar code and other international legal instruments

Anne Bouyssou
World Maritime University

WORLD MARITIME UNIVERSITY
Malmö, Sweden

THE INTRODUCTION OF ALIEN AQUATIC SPECIES BY SHIPS IN THE ARCTIC

The role of the Polar Code and other international legal instruments

By

ANNE BOUYSSOU
France

A dissertation submitted to the World Maritime University in partial
Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2011

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature : Anne Bouyssou

Date : 22 October 2011

Supervised by : Neil Bellefontaine
World Maritime University

Assessor : Olof Lindén
World Maritime University

Co-assessor : Carl Gustaf Lundin
International Union for Conservation of Nature (IUCN)
Global Marine Program (GMP)

ABSTRACT

Maritime transport plays, and will continue to play in the future, an important role in trade patterns as a result of globalization. Ships carry seawater in ballast tanks when they are not fully loaded in order to ensure transverse and longitudinal stability, and limit stresses on the hull. The water pumped contains aquatic organisms which can sink to the sediments in the bottom of tanks. Organisms can also attach to the outside of ships, on the hulls and appendages, through the process of biofouling.

By transferring species from one biogeographic region to another, shipping breaks through natural barriers. The introduction of non-indigenous organisms into a new biogeographic region may have environmental, economic and health impacts.

To remedy this situation, the International Maritime Organization (IMO) developed the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) and the Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (biofouling guidelines).

Global warming gives better access to the Arctic. Located in a median position between Eurasia and America, abundantly supplied with natural resources, the Arctic has considerable assets arousing greed. The expansion of human activities generates a greater need for maritime transport. Because existing instruments do not cover thoroughly polar specifics, the IMO has undertaken the development of a mandatory code for ships operating in polar waters (Polar Code). The draft Code includes an environmental protection chapter addressing the translocation of alien species through ballast water and biofouling.

This paper analyses, from the operational and environmental perspectives, the appropriateness and feasibility of the measures intended to limit the transfer of non-indigenous species by ships in the Arctic provided by the BWM Convention, the biofouling guidelines and the draft Polar Code.

Keywords : *Arctic, Alien species, Shipping, Ballast water, Biofouling, Polar Code.*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AEPS	Arctic Environmental Protection Strategy
AFS	Anti-fouling System
BWE	Ballast Water Exchange
BWM	Ballast Water Management
BWMS	Ballast Water Management System
BWT	Ballast Water Treatment
CAFF	Conservation of Arctic Flora and Fauna
CBD	Convention on Biological Diversity
CFCs	Chlorofluorocarbons
DE	Ship Design and Equipment Sub-Committee
EEZ	Exclusive Economic Zone
EP	European Parliament
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GHG	Greenhouse gas
IFREMER	French research institute for the exploitation of the sea
IMO	International Maritime Organization
IUU	Illegal, Unreported and Unregulated fishing
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MIC	Microbiologically Influenced Corrosion
MSC	Maritime Safety Committee
NGOs	Nongovernmental organizations
NSR	Northern Sea Route
ODSs	Ozone Depleting Substances
OIE	World Organization for Animal Health
OSPAR	Convention for the Protection of the marine Environment of the North-East Atlantic
PAHs	Polycyclic Aromatic Hydrocarbons
PSSA	Particularly Sensitive Sea Area
PCBs	Polychlorinated biphenyls
POPs	Persistent organic pollutants
SAR	International Convention on Maritime Search and Rescue
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TBT	Tributyltin
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCHE	United Nations Conference on the Human Environment
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme

1. Introduction

1.1. General remarks

The last twenty years have witnessed the development of worldwide awareness, research and action to protect and make a sustainable use of biodiversity. Collective consciousness arose during the 1992 United Nations Conference on Environment and Development (UNCED) and resulted in the adoption of the Convention on Biological Diversity (CBD), which defines biological diversity as “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part” (UN, 1992a). It is a three-level concept encompassing genetic variation within a species, variation between species and variation between different biotopes (UN, 1992a). State parties are committed to preserve biodiversity and make sustainable and equitable use of the Earth’s biological resources.

The marine environment is the richest one in terms of biodiversity, with nearly 250,000 known marine species (Census of Marine Life, 2010). Maintaining marine biodiversity is also preserving the possibility for humans to feed, to cure, to earn their living and to undertake scientific research.

Maritime transport plays an essential role in international trade patterns and is expected to expand as a result of globalization. Economies of scale have brought about bigger ships to convey more cargo. When they do not carry a full cargo load, ships pump seawater into ballast tanks to maintain proper stability, trim and draught, to adjust list and limit stresses on the hull. This practice is necessary to ensure safety, maneuverability (suitable propeller immersion) and resistance (to withstand rough seas). The water pumped contains aquatic organisms (including pathogens, fish eggs and larvae) which settle in tank bottoms as sediments. Organisms also attach to the outside of ships through the process of biofouling on e.g. the hull, anchor, chains, and propellers. These can be transferred between ports along the ship’s voyage. The spread of alien species threatens the integrity of ecosystem biodiversity. If they succeed in setting up into the new biogeographic region, they can alter habitats, compete with indigenous species, cause material damage and even endanger human health.

Non-indigenous species are regarded as biological pollution by some marine ecologists (Wallentinus & Werner, 2008). It seems so if substituting “substances” by “alien species” in the GESAMP definition of marine pollution (1991) :

> Pollution means the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities.

However, the introduction of alien organisms does not always result in the occurrence of adverse effects, which is a required condition to use appropriately the term “pollution” (GESAMP, 1991).

The Arctic is a pristine area undergoing significant change due to global warming. This phenomenon has direct and indirect consequences for the marine environment. On the one hand, it is a threat to biodiversity because some native species will not be able to adapt to changes in their environment (ecosystem stress) or, conversely, will become invasive. Meanwhile some non-native species may find more favorable conditions for establishment. On the other hand, it gives better access to the Arctic due to greater ice-free areas and paves the way for more human activities, namely ship transit, mining, offshore drilling, tourism, scientific research and fishing. These activities are attractive not only to countries which have an Arctic coastline, but also to countries worldwide.

The IMO has undertaken the development of a mandatory Polar Code. This instrument is intended to remedy the gaps or weaknesses of existing conventions as far as shipping in polar waters is concerned. However, some of the provisions set in the draft Polar Code are directly derived from existing instruments, without further adaptation.

Is the geographical scope of the Polar Code wide enough to protect thoroughly the Arctic marine environment ? Are its requirements achievable in Arctic waters and ports from an operational perspective ? Are the standards to which it refers appropriate for a vulnerable environment ?

1.2. Key international actors

Since environmental management requires scientific knowledge, assessment, regulation and planning, three international actors seem to have a major role to play with regard to the translocation of species by ships in the Arctic : the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), the IMO and the Arctic Council.

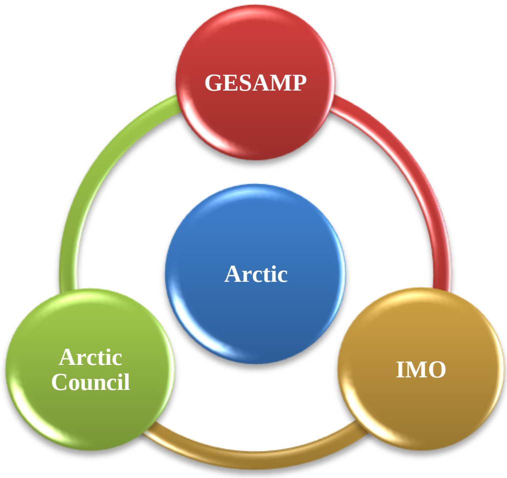

Figure 1 Key international actors.

<u>GESAMP</u>

The GESAMP is an advisory body, composed of 25-30 permanent specialized scientists, whose mission is "to provide authoritative, independent, interdisciplinary scientific advice to organizations and Governments to support the protection and sustainable use of the marine environment" (GESAMP, 2005).

It was created in 1969 to support the United Nations (UN) and the following seven organizations :

- IMO (which shelters the GESAMP Secretariat)
- Food and Agriculture Organization (FAO)
- Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO-IOC)
- World Meteorological Organization (WMO)
- World Health Organization (WHO)
- International Atomic Energy Agency (IAEA)
- United Nations Environment Programme (UNEP)

Although GESAMP experts are nominated by these institutions, their reports are independent and based on the latest scientific improvements in the field of marine and coastal area protection and management (GESAMP, 1991). Surveys are conducted within the framework of specialized working groups, such as the GESAMP ballast water working group (GESAMP-BWWG). This entity played a consultative role to the MEPC in the development of the approval procedure for ballast water management systems (BWMSs) making use of active substances. Today, it is involved in the scientific approval process of BWMSs (IMO, 2008b).

<u>IMO</u>

The IMO is a specialized agency of the UN whose purpose is to regulate maritime safety, maritime security and to protect the marine environment. The Organization was created by an International Conference held in Geneva, in 1948, and is based in London. Originally designated as the Intergovernmental Maritime Consultative Organization (IMCO), the institution changed its name in 1982 to become the International Maritime Organization. Like most of the UN institutions, the IMO is composed of a sovereign body, the Assembly, in which sit all member States, and an executive body, the Council, in which sit only a limited number of States (forty). These are elected by the Assembly when it meets once every two years. Administrative work is executed by a Secretariat, directed by a Secretary-General. This official is nominated by the Council upon the Assembly's approbation.

Technical work is carried out by five committees, among which are the Marine Environment Protection Committee (MEPC) and the Maritime Safety Committee (MSC). They are assisted by nine sub-committees, such as the Sub-Committee on Bulk Liquids and Gases (BLG), which addresses biofouling and ballast water issues, and the Sub-Committee on Ship Design and Equipment (DE), which is developing the Polar Code. Within this framework, nongovernmental organizations (NGOs) have consultative status.

Arctic Council

Intergovernmental cooperation among the eight Arctic States - the five coastal States, i.e. Canada, Denmark, Norway, Russia and the United States, plus Iceland, Sweden and Finland - began in 1989, on the initiative of Finland, with the Rovaniemi meeting. Government representatives joined efforts for the common purpose to protect the Arctic environment and developed the Arctic Environmental Protection Strategy (AEPS). This action plan was adopted in 1991, in Rovaniemi (Arctic Council, 1991). Five years later, on 19 September 1996, the eight States reaffirmed their engagement and signed the Declaration on the Establishment of the Arctic Council in Ottawa (Arctic Council, 1996).

Within this institution, indigenous peoples have permanent representatives who are involved in decision making (Koivurova, 2009) :

- Aleut International Association (Aleutian Islands in the Bering Sea)
- Arctic Athabaskan Council (United States and Canada)
- Gwich'in Council International (United States and Canada)
- Inuit Circumpolar Conference (United States, Canada, Greenland and Russia)
- Saami Council (Norway, Sweden, Finland and Russia)
- Russian Association of Indigenous Peoples of the North (Russia)

In addition, observers (non-Arctic States, inter-governmental organizations and NGOs) take part in senior meetings and working groups.

The Arctic Council is chaired by one of its members for two years (Sweden performs the current chairmanship until 2013). Strategic programmes are followed up by five working groups :

- Arctic Monitoring and Assessment Programme (AMAP)
- Conservation of Arctic Flora and Fauna (CAFF)
- Emergency Prevention, Preparedness and Response (EPPR)
- Sustainable Development Working Group (SDWG)
- Protection of the Arctic Marine Environment (PAME)

Member States are committed to achieve the sustainable development of economic, social and cultural activities in the region and to protect the Arctic environment, including its biodiversity and natural resources.

1.3. Aim

The purpose of this dissertation is to look into the feasibility and appropriateness of the measures set in the BWM Convention, the biofouling guidelines and the draft Polar Code, to minimize or ultimately prevent the introduction of alien aquatic species by ships in the Arctic.

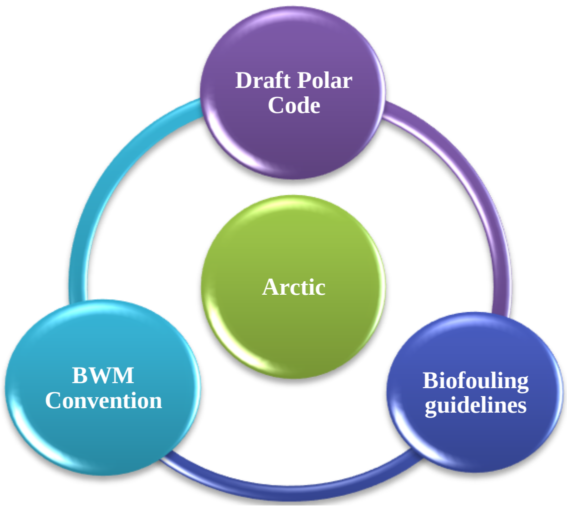

Figure 2 International instruments considered.

1.4. Methodology

The chosen approach to discuss the appropriateness and feasibility of the regulations applicable to the Arctic is illustrated in Figure 3.

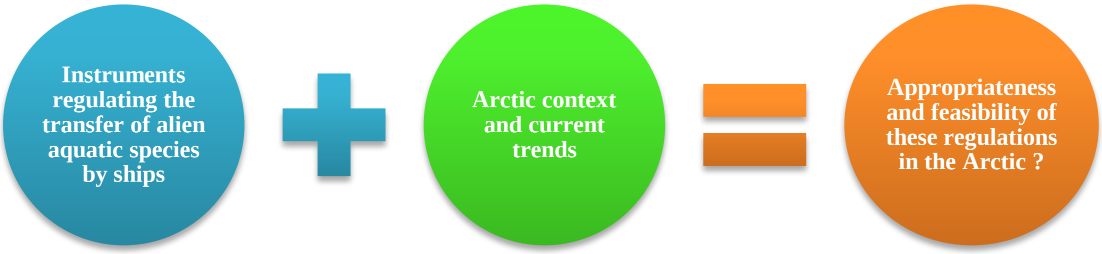

Figure 3 Schematic of the chosen approach.

Transfer of alien aquatic species by ships

The first two chapters define what the transfer of alien aquatic species by ships is, identify the challenges associated with this issue and provide an insight into its biological, regulatory and practical aspects.

Arctic context and current trends

Chapters three and four elaborate upon the situation in the Arctic, identify challenges and associated concerns. Geographical, political, ecological and socioeconomic dimensions are assessed and prevailing trends are identified.

Appropriateness and feasibility of the measures intended to limit the transfer of alien aquatic species by ships in the Arctic

In view of the provisions set in the draft Polar Code to reduce the transfer of alien aquatic species by ships in the Arctic, attention is given in the last two chapters to their feasibility and appropriateness. This includes assessing maritime safety aspects, reception facility availability and discharge impacts.

2. The transfer of alien aquatic species by ships

2.1. Basic physiology principles

The following items are a reminder of the basic physiology principles which help to understand the functions and activities of aquatic organisms, the extreme variety of their properties and also the difficulty in developing universal management technologies.

Organisms need a source of energy and a source of carbon to live. They can be divided in groups according to the way they use these sources.

Figure 4 distinguishes chemotrophic organisms, oxidizing chemical compounds, from phototrophic organisms, gaining energy from sunlight.

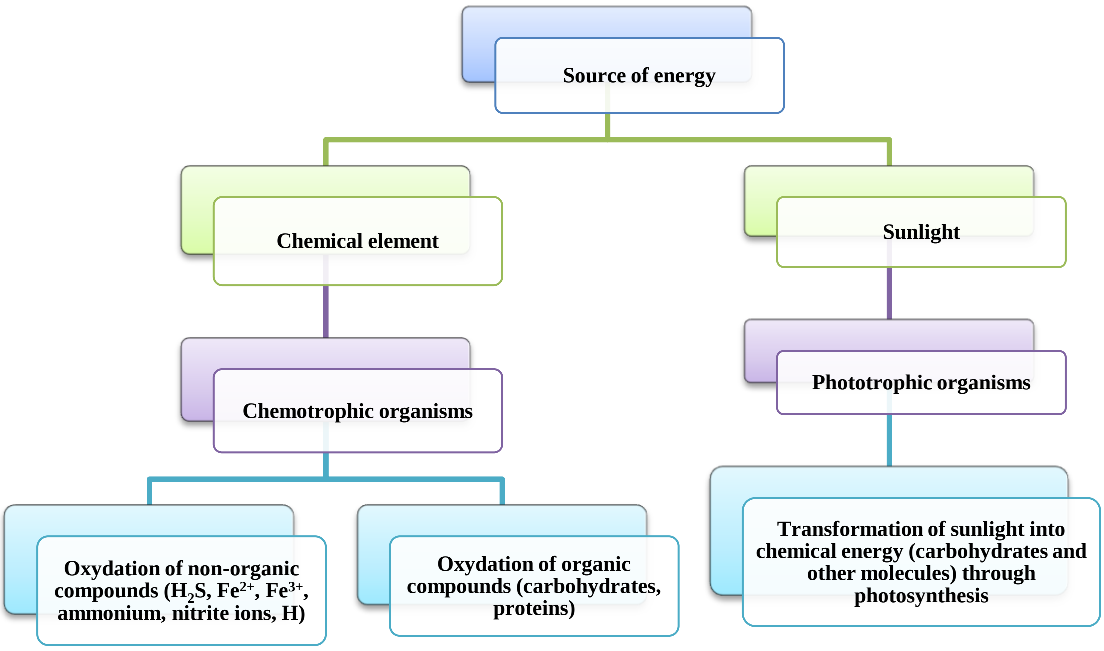

Figure 4 Energy use as a means of classifying organisms.
(Source : Ekenstierna, 2003)

Figure 5 sets apart autotrophic (producers, self-feeding from carbon dioxide) organisms, from heterotrophic/organotrophic (consumers of organic compounds) organisms.

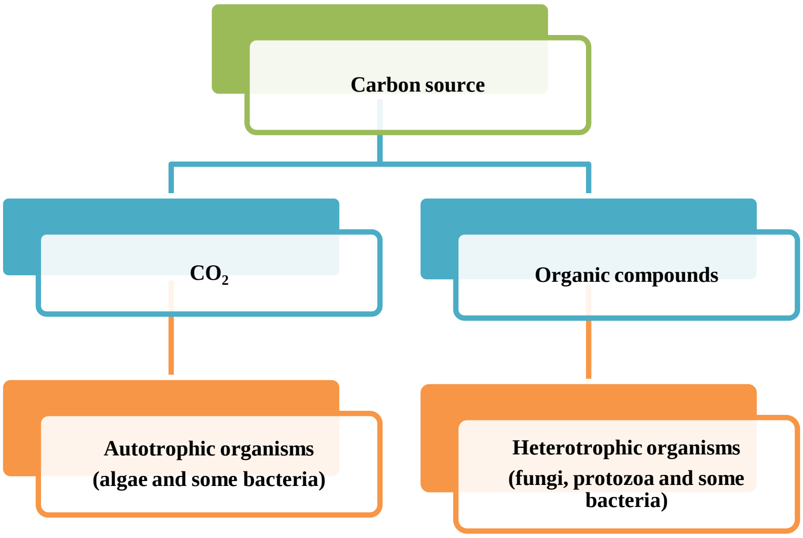

Figure 5 Carbon use as a means of classifying organisms.
(Source : Ekenstierna, 2003)

For each chemical (pH, salinity, oxygen concentration) and physical (temperature, sunlight) parameter, a given species has an optimum value.

Some species are sensitive to small changes in these parameters and may become "stressed". Coliform bacteria (enterobacteria), such as *Escherichia coli*, which end up in the marine environment are stressed by high salinity. The presence of organic matter in seawater - e.g. coming from raw sewage - helps them to overcome this stress because the organic effluent serves as a substrate for the growth of such heterotrophic bacteria (Dupont & Kevorkian, 1994 ; Perry, Staley & Lory, 2002 ; Monfort, 2006). Other species are able to endure considerable variations in their environments (eurytopic species), e.g. in salinity (euryhaline species) or in temperature (eurythermal species).

Some organisms switch between fresh and marine environments during their life cycle for reproduction. Catadromous species - e.g. eel - migrate from fresh to marine water to spawn in the oceans, while anadromous species migrate from marine to freshwater to spawn in rivers - e.g. salmon.

Organisms are classified as “macro” or “micro” according to their size. In the latter case, they cannot be seen with the unaided eye but only with a microscope.

Examples of macro-organisms are crustaceans - e.g. shrimps, molluscs - e.g. mussels - and macro-algae - e.g. the brown alga *Laminaria digitata*, with a size of 1 to 4 m.

Micro-organisms are divided into eukaryotes (micro-algae, protozoa and micro-fungi), which have a nucleus, and prokaryotes (bacteria and viruses), which do not. Of the two populations, prokaryotes are more numerous. They represent the simplest form of life.

The characteristics of micro-organisms can be summarized as follows :

- Micro-algae are photoautotrophic, drift in the water and constitute the phytoplankton, which is the basis of the food chain. They include diatoms (e.g. genera *Nitzschia* and *Thalassiosira*) and dinoflagellates (e.g. *Dinophysis* and *Alexandrium*). Diatoms are among the most important ship fouling algae (Callow, 2000). Some dinoflagellates that produce toxins can cause harmful algal blooms. These toxins may kill some animals directly (mass fish mortality) or accumulate in the filter-feeding bivalves. Humans eating these bivalves can become sick - e.g. paralytic shellfish poisoning (Heimdal, 1989 ; Hallegraeff, 1998).
- Protozoa are chemoheterotrophic and feed on bacteria, algae and other protozoa. Pathogenic protozoa are responsible for parasitic diseases (e.g. malaria, leishmania and amoebiasis). For instance, *Bonamia exitiosa* and *Perkinsus marinus* infect oysters (World Organization for Animal Health, 2009).
- Micro-fungi are chemoheterotrophic, include molds and yeasts, and produce spores. They are the most important cause of plant diseases, but also affect humans (skin and respiratory diseases) and animals (Perry *et al.*, 2002). For instance, *Batrachochytrium dendrobatidis* infects amphibians (OIE, 2009).

- Bacteria are characterized by their diversity and their adaptability. Some are photoautotrophic, others are photoheterotrophic. Their shape is spherical, cylindrical or helicoidal. Each bacterial species has an optimal temperature for growth, whether it is psychrophilic (between - 5°C and 30°C), mesophilic (between 10°C and 45°C) or thermophilic (between 25°C and 100°C). Psychrophilic bacteria inhabitat the polar sea ice (Perry *et al*., 2002). The largest group of bacteria, which includes all of the pathogenic forms, is the mesophiles (Volk, Gebhardt, Hammarskjöld & Kadner, 1996). In the same way, while their optimum surrounding pH is usually between 6.5 and 7.5, thermoacidophilic bacteria live in a pH of 1. *Vibrio cholerae,* which causes cholera, grows well above pH 8 (Volk *et al*., 1996). Some bacteria are able to live in extreme environments where other organisms cannot. For example, anaerobic bacteria live without oxygen (and use sulphur instead). They have also a great ability to adapt to their surrounding conditions. Enteric bacteria and *Staphylococcus* can grow in presence or absence of oxygen by changing their metabolic machinery in response (Volk *et al*., 1996). Examples of pathogenic bacteria include the genera *Salmonella*, *Listeria* (responsible for food poisoning) and *Vibrio*. They do not come from the marine environment but from humans. The bacterium *Escherichia coli* is often considered as a reference indicator for faecal contamination (Monfort, 2006).
- Viruses are infectious particles that can reproduce only when inside a living cell. Replication inside a host cell, either prokaryotic or eukaryotic, results in the release of virus particles. They infect animals, plants and humans - e.g. hepatitis A, paralytic poliomyelitis and gastroenteritis (Volk *et al*., 1996).

<u>Ballast water</u>

Ballast water is fresh, brackish or marine water pumped into ships' tanks either in ports or at sea. Ports are located in coastal areas, which tend to be the most abundant and diverse in phytoplankton and zooplankton. Meanwhile, port waters are often polluted by human activities and may contain fecal material (raw sewage). They may therefore be a vector of water-borne infectious diseases.

A settling process takes place in tanks when micro-organisms, as well as fish eggs and larvae, sand, mud and other organic material that are pumped into the tanks, sink and aggregate onto the bottom and transverse hull architecture elements - e.g. longitudinal framing. The direct consequence of sedimentation is organism concentration. It is estimated that sediments are 100 to 1000 times more contaminated than the surrounding waters (Monfort, 2006). Sediments must be periodically removed from ballast tanks to prevent microbiologically influenced corrosion. This metal/microbe interaction consists in electron transfer (Hamilton, 2000) and induces accelerated anodic dissolution of metals (Lewandowski, 2000).

<u>Biofouling</u>

Biofouling is the "accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. [It] can include microfouling and macrofouling" (IMO, 2011b). There are more than 4,000 marine fouling species (Arai, 2009).

Micro-organisms	**Macro-organisms**
Sessile bacteria (e.g. *Pseudomonas*, *Vibrio*, *Micrococcus*) Diatoms (e.g. *Nitschia*, *Navicula*) Micro-fungi Heterotrophic flagellates (e.g. *Monosiga*, *Pteridomonas*) Sarcodines Sessile ciliates	Sponges Hydroids Corals Sessile polychaetes Barnacles Mussels Bryozoans Sea cucumbers Ascidians Macro-algae : • green algae (e.g. *Ulva* and *Enteromorpha*) ; • red algae (e.g. *Ahnfeltia*) ; • brown algae (e.g. *Laminaria*).

Table 1 Examples of micro- and macro-fouling organisms.
(Source : Railkin, 2004)

The process can be decomposed in five stages (Zinn, Zimmerman & White, 2000 ; Callow, 2000 ; Quiniou & Compère, 2009) :

- Attachment of organic and nitrogen compounds as well as salts and silica on a surface (a few seconds to a minute).
- Attachment of primary colonizers (non-moving temporary adhesion) : bacteria, algal cells, spores and diatoms (a few minutes).
- Excretion of various compounds, among which are the extracellular polymeric substances (EPSs) (permanent attachment). EPSs consist mainly of proteins and polysaccharides. They are the construction material of biofilms (Flemming, Wingender, Griebe & Mayer, 2000).
- Production of a biofilm, i.e. a cell layer, as a result of cell division (few days to a month). This matrix is composed of micro-colonies of bacteria, diatoms, protozoa, larvae, algal cells and spores separated by interstitial voids filled with water (Lewandowski, 2000). It provides a substratum for attachment of macro-organisms. When structured in a biofilm, micro-organisms are more resistant against treatment with chemical biocides that would kill them in the planktonic form (Allison, Maira-Litran & Gilbert, 2000). Indeed, the EPS matrix acts as a physical barrier protecting embedded micro-organisms (Donlan, 2000).
- Macro-organisms, such as barnacles, mussels and algae, adhere to the biofilm. Algae are the major contributors. Limiting factors for their growth are light quantity and space availability (Holmström & Kjelleberg, 2000).

The development of biofouling depends on various environmental factors - e.g. temperature, pH, nutrient availability. At the beginning of the process, organisms are easy to remove. As time goes by, they stick fast, can make the ship heavier, induce greater hull frictional resistance and, in turn, increase consumption of bunker fuel and CO_2 emissions (Zinn *et al.*, 2000 ; IMO, 2010c). An increase of 100 µm in the average hull roughness augments approximately fuel consumption by 6 % (Arai, 2009). By hampering the operation of navigation instruments, they may compromise safety (Callow, 2000). Removal of biofouling can be expensive and is usually done with water jets, steam, ultrasound or acid and base baths. Some of these methods are not applicable to large ships or mobile drill rigs (Zinn *et al*., 2000). This is the reason why ships' hulls have to be coated regularly with anti-fouling systems (AFSs).

According to Alexander Railkin (2004), macro-fouling communities have low diversity because few macro-algal and invertebrate species can resist toxic paints and ship motion. Nevertheless, biofouling is deemed to be a greater conveyor of aquatic species than ballast water (Drake & Lodge, 2007).

Despite coatings, organisms are still found on underbodies. They accumulate in niche areas or on surfaces where the AFS is damaged, worn - e.g. ice abrasion - or improperly applied. Another source of concern is that non-toxic AFSs are less efficient in preventing biofouling :

> The type of anti-fouling coating (toxic versus non-toxic) was the most important influence on macro algal fouling assemblages. The ship carrying an unusually high number of species, including a large percentage of non-cosmopolitan species, was the only one with a non-toxic coating (Mineur, Johnson, Maggs & Stegenga, 2007).

Furthermore, research has shown that :

> Some common macro-algae, e.g. the green alga *Enteromorpha* and the brown alga *Ectocarpus*, can adopt a diminutive form when growing in hostile conditions, for example on anti-fouling paint on a ship's hull (…) mixed species diatom biofilms also adhere to non-toxic, foul-release silicone elastomers (…) the new generation of non-tin polishing anti-fouling paints frequently become fouled with biofilms dominated by diatoms and *Enteromorpha* (…) the ability of certain species to form biofilms on toxic coatings is due to the resistance of particular species to biocides (Callow, 2000).

Since the entry into force in 2008 of the International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001 (AFS Convention), the use of organotins in anti-fouling paints is prohibited. Two types of AFSs have been developed. First, paints that still make use of biocides, but other than tin - e.g. copper associated with booster biocides. Second, paints which are biocide-free, such as silicone-based products. These coatings may have a shorter service life than organotin paints and, consequently, may need to be applied more often (Champ, 2001 ; Readman, Van Hattum, Barcelo, Albanis, Riemann, Blanck, Gustavson, Tronczynski & Jacobson, 2002). Moreover, silicone elastomeric coatings may not be sufficiently robust for many deep-sea ships (Callow, 2000).

<u>The movement of species through ballast water and biofouling</u>

Through ballast water and biofouling, ships carry species from one biogeographic region to another over natural barriers (continents, differences in salinity or temperature). The species diversity conveyed by a ship is in proportion with the geographical variety of its trade areas. Provided species are able to survive the voyage - e.g. lack of light or nutrients in ballast tanks - and reach the new environment, the presence of alien organisms in an ecosystem creates a hazard. If biotic (other living organisms) and abiotic (sunlight, temperature, salinity and pH) factors are suitable, they can establish themselves and proliferate.

Figure 6 depicts the successive steps of alien species' establishment in a new ecosystem.

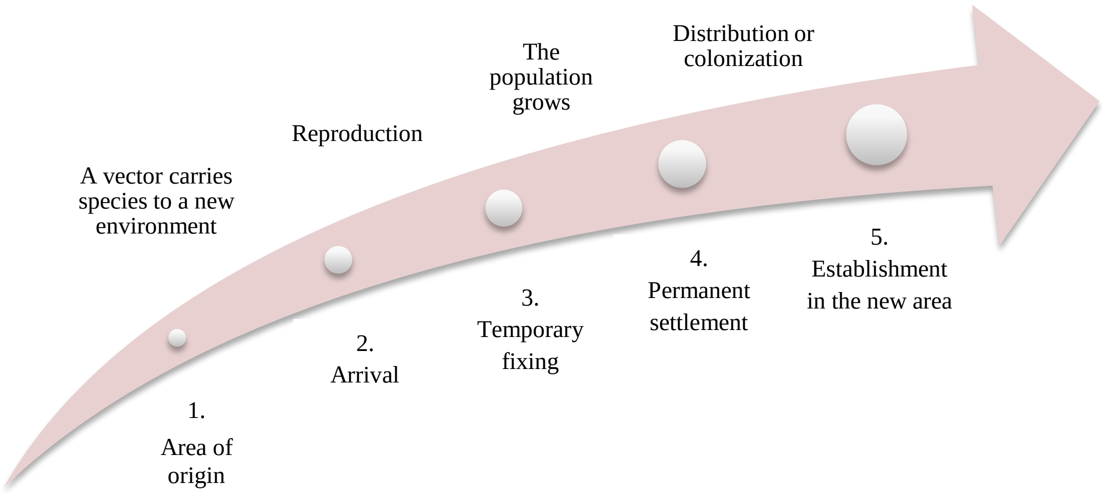

Figure 6 Alien species' establishment process in a new environment.
(Source : Wallentinus & Werner, 2008)

The first step is the movement of an organism to a new area by a vector (ship). Some micro-organisms have special dispersal and survival stages - e.g. endospores and cysts - which allow them to survive for many days, weeks or even years (Perry *et al*, 2002). This enables them to resist adverse environmental conditions, such as lack of food or moisture, temperature changes and even contact with toxic chemicals (Volk *et al*., 1996 ; Alekseev, Makrushin & Hwang, 2010). Ballast tank sediments provide a perfect shelter to dormant organisms such as toxic dinoflagellate cysts (Hallegraeff, 1998).

The two following steps, temporary and permanent settling, require favorable conditions - e.g. absence of predators, available food - for organisms to survive and fix. The last step is establishment in the new environment and sometimes colonization. Local species may disappear if the species become invasive.

Ensuing environmental, economic, social and health impacts are not immediately apparent. They are particularly significant in regions where seafood is the main source of nutrition and when commercial (fisheries and aquaculture) species are infected or disappear.

For example :

- *Escherichia coli* causes diarrheal diseases and dysentery.
- *Vibrio cholerae* is responsible for cholera ; people acquire the infection by the ingestion of fecally contaminated water and food (Volk *et al*., 1996).
- *Myxobolus cerebralis* affects salmon ; this parasite is responsible for deformed (curved) backbones which affect mobility in young fish (they swim in circles) ; the result is a higher mortality rate (Wallentinus & Werner, 2008).
- *Salmonella typhimurium* is responsible for salmonellosis ; cattle have recently been infected by this bacterium in the vicinity of a gas terminal in western Norway ; the outbreak was attributed to ballast water discharges (IMO, 2010b).

It is noteworthy that remoteness and harsh climate do not necessarily hamper the establishment of alien species and the development of pests and diseases. “All taxonomic groups have produced invasive alien species and all ecosystems are at risk. Distance and high latitude is not necessarily a barrier or impediment to invasive species” (De Poorter, 2006).

2.2. Global environment protection principles

States have an overall duty to protect, preserve and enhance the environment. The United Nations Conference on the Human Environment (UNCHE) held in 1972 in Stockholm was the starting point of the development of environmental consciousness at an international level. In particular, it led to the creation of the United Nations Environment Programme (UNEP), the introduction of the “common heritage of mankind” concept in the Charter of Economic Rights and Duties of States (UN, 1974) and the adoption of the World Charter for Nature. The latter provides that “ecosystems and organisms, as well as the land, marine and atmospheric resources that are utilized by man, shall be managed to achieve and maintain optimum sustainable productivity, but not in such a way as to endanger the integrity of those other ecosystems or species with which they coexist” (UN, 1982a).

As far as the marine environment is concerned, the 1982 United Nations Convention on the Law of the Sea (UNCLOS) includes a whole part (XII) dedicated to the protection and preservation of the marine environment. This treaty is considered as a framework, providing general guidance for more technical legal instruments. It is worth mentioning that the transfer of aquatic species is addressed among the general provisions : “States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from (…) the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto” (UN, 1982b).

The UNCLOS defines the concepts of flag, port and coastal State and specifies the scope of their prescriptive - i.e. their power to adopt legislation - and enforcement -

i.e. their power to give effect to this legislation - jurisdiction with regard to environment protection.

Another important momentum is the UNCED, which resulted in the adoption of the Rio Declaration on Environment and Development, the Agenda 21 Action Plan and the CBD. The objectives of the latter are “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources” (UN, 1992a). Its provisions are implemented through other instruments developed by international organizations.

Environmental protection should be conducted through a precautionary approach, i.e. “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (UN, 1992b).

The precautionary principle is applied by the IMO and is enshrined in the preamble of conventions dealing with marine environment protection. The BWM Convention is one of these. The precautionary approach governs the approval process of BWMSs making use of active substances.

States are obliged to cooperate to protect the environment, at international and regional levels. Regional cooperative agreements emerged after the UNCHE, which encouraged States to “join together regionally to concert their policies and adopt measures in common to prevent the pollution of the areas which, for geographical or ecological reasons, form a natural entity and an integrated whole” (UN, 1972).

This process has been fostered by the UNEP’s Regional Seas Programme, created in 1974. It currently has thirteen cooperative agreements throughout the world. Local cooperation also takes place outside of the UNEP framework.

The UNCLOS reinforced the concept of a regional approach : “States shall cooperate on a global basis and, as appropriate, on a regional basis, (…) in formulating and elaborating international rules, standards and recommended practices and procedures

(…) for the protection and preservation of the marine environment, taking into account characteristic regional features" (UN, 1982b).

The BWM Convention incorporates this principle and poses an obligation of technical assistance and cooperation on States parties. This consists of training personnel, transferring expertise, regional agreements or research partnerships (IMO, 2004b).

2.3. International regulations

Canada was the first country to report to the IMO, in 1988, on the threat posed by the transfer of harmful organisms in ballast water. At that time, invasive species were proliferating in the Great Lakes (IMO, 2004a). The MEPC developed the first international guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges, which were adopted in 1991 (IMO, 1991). The following year, the UNCED assigned the issue of the transfer of alien species by ships' ballast water to the IMO. As the 1991 voluntary guidelines were not applied, the Organization decided to submit this point to the Assembly, which adopted the preceding guidelines in 1993, but this time in the form of an Assembly resolution (IMO, 1993). Thereafter, amendments were made to provide ships with thorough guidance (IMO, 1997a) on safe ballast water exchange at sea. Consequently, the Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens were adopted by the Assembly in 1997 (IMO, 1997b). Afterward, the Organization decided to develop a legally-binding instrument.

2.3.1. BWM Convention

The BWM Convention was adopted on 13 February 2004 by a Conference held in London. It requires ratification from thirty States, whose fleets represent 35 % of the world merchant fleet tonnage, to enter into force (IMO, 2004b). There are presently thirty Contracting States to the Convention, representing approximately 26.44 % of the gross tonnage of the world's merchant shipping (IMO, 2011c).

This instrument applies to all ships carrying ballast water, without tonnage condition, as well as to floating platforms. Its purpose is "to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments" (IMO, 2004b).

Ballast water management is achieved through, either ballast water exchange (BWE), ballast water treatment (BWT) or ballast water discharge to a reception facility.

This last option is often not practicable considering the large ballast water volumes carried, for instance, in bulk carriers. Moreover, after being collected, these volumes have to be stored and then treated. The required capacity for such treatment plants would be quite high and a new logistic service would have to be created in ports (Veldhuis, Hallers, Brutel de La Rivière, Fuhr, Finke, Steehouwer, Van de Star & Van Sloote, 2010). Another hindrance is that only tankers are fitted with standardized connections to piers. On other ships, additional equipment would have to be installed to enable them to discharge ballast water (Gollasch, David, Voigt, Dragsund, Hewitt & Fukuyo, 2007). Conversely it can be argued that, in certain countries experiencing a shortage of freshwater sources, there may be a need for treated water reuse (Donlan, 2000) ; that a land-based ballast water reception and treatment facility would offer economies of scale (Donner, 2010) ; and that shore personnel would be better skilled than ship crews to handle chemical agents and operate water treatment plants (Donner, 2010). Parties are not required to provide ballast water reception facilities.

According to the BWE standard (regulation D-1), exchange is achieved if, at least, 95 % of the volume of ballast water is replaced (IMO, 2004b). This can be done by way of three approved exchange methods (IMO, 2005) :

- sequential method : ballast tanks are first emptied and then refilled.
- flow-through method : pumped water passes through tanks and comes out through the overflow onto the deck.

- dilution method : ballast tanks are filled with a certain volume of water and simultaneously discharged of the same volume through the bottom.

The last two techniques are called “pump-through” methods. They are accepted provided pumped water is three times the volume of each ballast water tank or, if less than three times, provided it can be demonstrated that 95 % of ballast water has been exchanged (IMO, 2004b). Their advantage is that they do not impair ship stability since equivalent volumes of water are simultaneously pumped in and discharged.

BWE should be conducted in areas located at, at least, 200 nautical miles from the shore and with a water depth of, at least, 200 meters. The replacement of coastal water by open-ocean water aims at removing coastal organisms. It is assumed that deep sea water contains fewer organisms and that species taken on during the operation are less likely to invade coastal zones (IMO, 2003b ; Minton, Verling, Miller & Ruiz, 2005). A ship should not be compelled to deviate from its route to perform BWE (IMO, 2004b).

Interim regional strategies have been developed as far as BWE is concerned. It is noteworthy that in the Arctic waters covered by the Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 (OSPAR Convention), ships are encouraged to renew ballast waters before entering the area, keep records of BWE operations and have a BWM plan on board (IMO, 2008).

The Convention provides a time schedule for gradual implementation of BWT, which will completely replace BWE in 2016. After that date, ships will be required to comply with the ballast water performance standard (regulation D-2) (IMO, 2004b). The introduction of enforcement dates - as early as 2009 for new ships - in the text of the Convention, without knowing when the instrument would enter into force, was an adventurous undertaking. Indeed, in 2004, the availability of treatment technologies at the scheduled dates was unknown (Minton *et al.*, 2005). It may be deemed that these deadlines were purposely introduced in the Convention to prompt industries to develop innovative technologies (Greensmith, 2010).

The ballast water performance standard (regulation D-2) provides maximum levels of organism size categories and indicator microbe concentrations in discharged ballast waters (IMO, 2004b) :

> Ships conducting ballast water management in accordance with this regulation shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension ; and discharge of the indicator microbes shall not exceed the specified concentrations described in [the following] paragraph.
>
> Indicator microbes, as a human health standard, shall include:
>
> - Toxicogenic *Vibrio cholerae* (O1 and O139) with less than 1 colony forming unit (cfu) per 100 millilitres or less than 1 cfu per 1 gram (wet weight) zooplankton samples.
> - *Escherichia coli* less than 250 cfu per 100 millilitres.
> - Intestinal Enterococci less than 100 cfu per 100 milliliters.

Treatment can be executed through mechanical, physical, chemical or biological processes. In fact, most of the BWMSs use a combination of them because no single process can alone be efficient against the great diversity of organisms. For example, filtration is a mechanical method associated with ultraviolet light and chemical treatment (Veldhuis *et al.*, 2010). By removing organic particles from water, the action of disinfectants (chlorine, chlorine dioxide, hydrogen peroxide, bromine and ozone) and ultraviolet light is enhanced (Taube, 2010). Other techniques include cyclonic separation, energetic shock (electric current and wave effect of cavitation), heating, deoxygenation and magnetic field (Suban, Vidmar & Perkovic, 2010). The toxicity of the substances used is of special concern, so the MEPC has developed guidelines for basic and final approval procedures of BWMSs. Proposals submitted by member States are carefully analyzed by the IMO and the GESAMP-BWWG (IMO, 2008b). Biocides, intended to kill organisms, are highly toxic for the marine environment and human health. When storing and handling these chemicals on board, the crew is exposed (inhalation, contact, ingestion) to substances which have the potential to cause cancer. Disinfection processes produce toxic fumes and an exhaust system has to be installed to remove them (OIE, 2009). Therefore, it is essential that seafarers are properly trained to operate and monitor BWT plants as well as to keep records. In this respect, the development of BWM standardized training courses and appropriate amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention) and STCW Code has been an early objective of the IMO (IMO, 2003a).

In addition, within the framework of a partnership with the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP), the Organization created in 2000 the Global Ballast Water Management (Globallast) Programme. Its objective is to help developing countries in preparing the implementation of the BWM Convention.

Sediment management is achieved when ships discharge them either ashore, to a reception facility, or at sea. In the former case, port State parties are obliged to arrange such equipment in ports and terminals where ballast tanks are cleaned and repaired (IMO, 2004b). In the latter, disposal has to take place in areas located 200 nautical miles from land and with a water depth of 200 meters (IMO, 2005).

A ship is obliged to carry on board and implement a regularly updated BWM plan, describing ballast water and sediment management methods used on board. It must be ship-specific and approved by the flag State. Ships must undergo surveys performed by the Administration and are provided with an International BWM Certificate (IMO, 2004b).

In waters under their jurisdiction, port and coastal States must monitor the effects of BWM (this ecological monitoring allows early detection of ecosystem disturbance) and may grant, after having carried out an environmental risk assessment, exemptions to ships operating exclusively between specified ports or locations.

Port States must inspect ships while in ports and terminals. Such inspections include verification of the BWM Certificate, the Ballast Water record book and/or sampling of ballast waters. Besides, flag States must determine equivalent compliance requirements for pleasure craft and search and rescue boats (IMO, 2004b).

2.3.2. Biofouling guidelines

General perception of biofouling as a vector of alien species came onto the scene in IMO work in the wake of the adoption of the AFS Convention. Australia informed the MEPC of a study conducted on biofouling accumulated in hulls' niche areas, where AFSs were inoperative (IMO, 2006). Later on, New Zealand also reported the findings of a research programme assessing biofouling risk on ships arriving in the country. The MEPC assigned this issue to the BLG Sub-Committee for deeper analysis (IMO, 2007b) and adopted the Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species in July 2011. The intended goal is to reduce the accumulation of micro- and macro-fouling on the hull by choosing the appropriate AFS, by conducting in-water inspection and effective cleaning and maintenance, either in the water or at dry dock. The guidelines provide recommendations to avoid niche areas at the design and construction stages, to manage biofouling waste in land-based facilities and to train crews. Ships are encouraged to develop and follow a biofouling management plan and to keep a biofouling record book which mentions, in particular, periods of time spent in Arctic waters (IMO, 2011b).

2.4. Conclusion

Regarding alien species as a whole, it should not be forgotten that this designation hides in reality various forms of life, with dissimilar physiological tolerances and growth ranges. A ship is a vector inasmuch as it carries aquatic organisms in ballast water or as biofouling. The presence of alien species in an ecosystem is a hazard. States have an obligation to consider the consequent risk and take appropriate preventive measures. The IMO has developed dedicated legal instruments and guidelines to this purpose.

3. The Arctic : synopsis of the region

3.1. Boundaries

Unlike the Antarctic, which is a continent surrounded by an ocean, the Arctic is an ocean surrounded by continents. It is enclosed by ten marginal seas, namely the Barents, Kara, Laptev, East Siberian, Chukchi, Bering, Beaufort, Lincoln, Greenland and Norwegian Seas, with shallow waters.

Considering the Arctic, land areas are generally included to an extent which is often not clearly determined. As a matter of fact, Annika E. Nilsson (2011) stresses the multiplicity of definitions referring to the Arctic : geographers designate the area located beyond the Arctic Circle ; climatologists designate the area located beyond the isotherm line corresponding to an average temperature in July of less than 10 °C ; ecologists consider either the vegetation limit or the ecosystem ; ethnologists consider indigenous populations settlements.

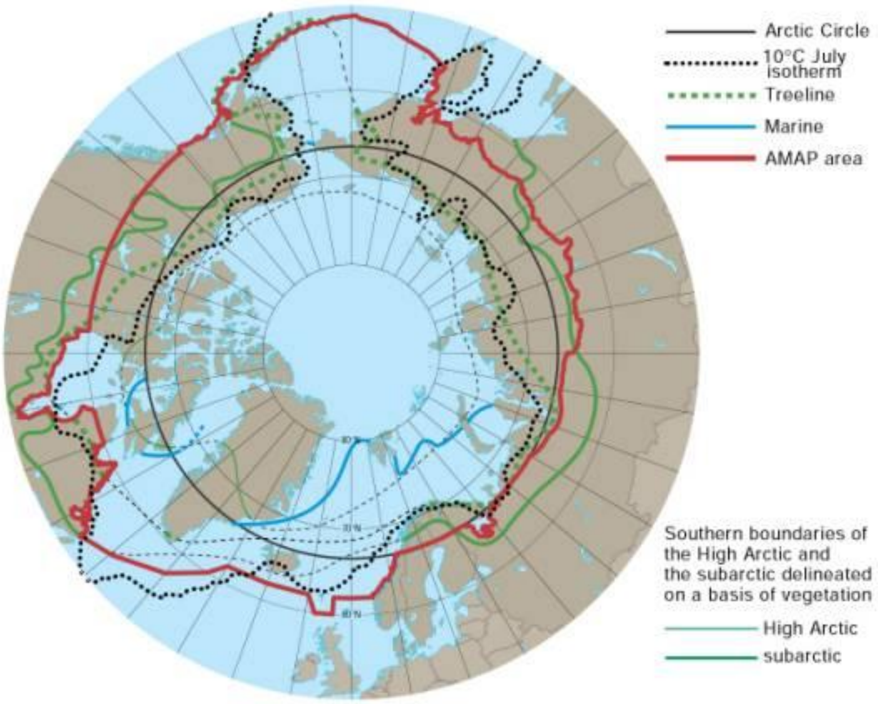

Figure 7 Multiple definitions of the Arctic.
(Source : http://www.amap.no/, 2011)

Julian Dowdeswell and Michael Hambrey (2002) reached the conclusion that "the Arctic [has] a group of attributes that are concerned with climate, the presence of ice and snow, a unique fauna and flora adapted to harsh conditions, sparseness of population and remoteness and [does not have] precise boundaries".

Timo Koivurova (2009) recognizes the absence of consensus about the definition of the southernmost boundary of the Arctic, but points out that "in Arctic-wide cooperation, the Arctic Circle (…) has been used as a criterion for membership, with only those States that possess areas of territorial sovereignty above the Arctic Circle being invited to participate in the cooperation".

The definition of Arctic waters provided by the draft Polar Code is similar to the one included in the Guidelines for ships operating in polar waters (IMO, 2009e), but a little wider in scope than the one given by the Guidelines for ships operating in Arctic ice-covered waters (IMO, 2002).

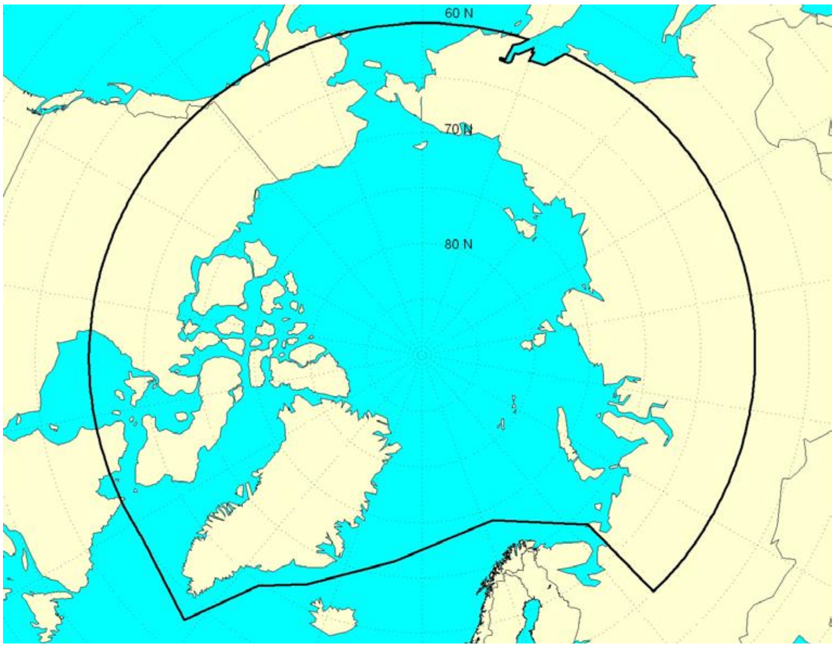

Figure 8 Definition of Arctic waters provided by the draft Polar Code.
(Source : IMO, 2009c)

It is noteworthy that this definition does not correspond to any of the preceding delimitations (cf. Figure 7). The southwest part of the Barents Sea, including the

White Sea, is excluded. Indeed, this area remains permanently ice-free during winter due to the influx of warm Atlantic water masses (Heimdal, 1989 ; Matishov, Golubeva, Titova, Sydnes & Voegele, 2004). As a result, the environmental requirements of the Polar Code would not apply there.

For this reason, NGOs claim a broader geographical scope (IMO, 2009d).

The area is nevertheless covered by the OSPAR Convention (region I – Northern OSPAR region).

Figure 9 Arctic waters protected by the OSPAR Convention.
(Source : http://www.ospar.org, 2011)

Seven scientific criteria are used to identify ecologically or biologically significant marine areas (EBSMAs) in need of protection in open-ocean waters (Conference of the Parties to the Convention on Biological Diversity, 2008). The Arctic owns thirteen "super" EBSMAs, i.e. areas that "meet most or all of the criteria, or meet one or more of them at a global level of significance". The White Sea/Barents Sea Coast area is one of them :

> This region is characterized by highly productive coastal waters (…) supports diverse and productive benthic communities (…) provides important nursery habitat for several species of pelagic fishes, and supports Atlantic salmon as well as seabird colonies with diverse species composition (…) [it] also supports local populations of White Sea beluga whales and provides pupping

and molting areas for the entire East Ice harp seal population (Speer & Laughlin, 2011).

Meanwhile, the region undergoes several environmental stresses from anthropogenic sources (Doskoch, 2004).

First, although aquaculture (farmed salmon, Rainbow trout) and fisheries (Northeast Arctic cod, haddock, shrimp, capelin and saithe) represent a major economic sector on the Barents Sea coast, fish stocks have been depleting since the mid-1960s as a result of both overfishing and illegal, unreported and unregulated (IUU) fishing (Matishov *et al*., 2004 ; Burnett, Dronova, Esmark, Nelson, Rønning & Spiridonov, 2008).

Second, several navigation routes cross the Barents Sea (not in the least, the Northeast Passage) with vessels transiting throughout the year. This traffic will intensify in view of the development of large-scale offshore drilling operations (Matishov *et al*., 2004 ; Burnett *et al*., 2008). As a matter of fact, the Barents Sea shelf holds the Shtokmanovskoe gas condensate field (three trillion cubic meters of gas and more than twenty million tonnes of gas condensate) and the Prirazlomnoe oil field (more than two hundred million tonnes) (Patin, 1999). The estimated oil transport volume goes up to forty million tonnes by the year 2020. Plans for Prirazlomnoe alone are to extract seven million tonnes of oil each year. According to these projections, the corresponding fleet would be composed of eighteen ice-resistant platforms, ten to twelve ice-breakers, about sixty supply ships, and tankers with a total deadweight of four million tonnes. The corollary is higher risks for oil spill and alien species transfer (Matishov *et al*., 2004). Figure 10 shows export ports and trade routes for Russian oil traffic in the Barents Sea. Four of these ports fall outside of the scope of the Polar Code. Among them, Murmansk and Arkhangelsk, which handle 73 % of the traffic (Kystverket, 2004). Murmansk is Russia’s fourth port and can berth ships up to 250,000 tonnes deadweight (Matishov *et al*., 2004).

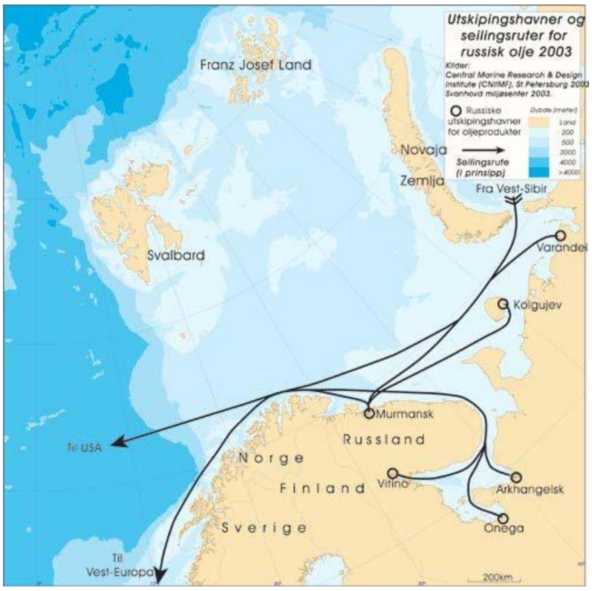

Figure 10 Export ports and trade routes for Russian oil traffic in the Barents Sea. (Source : Kystverket, 2004)

The third stress is atmospheric, hydrologic and sediment radioactive pollution. It stems from the testing of heavy nuclear devices in the 1950s - 1960s (especially on the Novaya Zemlya Island), the aftermath of the Chernobyl accident, dumped nuclear submarine and ice-breaker reactors as well as solid and liquid radioactive wastes. The focal point is the Kola Peninsula where the port of Murmansk lies (Anderson & Dyrssen, 1989 ; Giltsov, Mormoul & Ossipenko, 1992 ; Dowdeswell & Hambrey, 2002 ; Matishov *et al*., 2004 ; Vasilyev, Dubasov, Safronov, Tkachenko, Filippovsky & Chugunov, 2004 ; Ramirez-Llodra, Tyler, Baker, Bergstad, Clark, Escobar, Levin, Menot, Rowden, Smith & Van Dover, 2011).

Fourth, the ecosystem has already been modified by biological invasions resulting from experiences of new commercial species introduction - e.g. the Red king crab - and ballast water discharges - e.g. Snow crab. A risk evaluation regarding further invasions suggests a need for control measures :

> The expected changes in the future caused by intentional and unintentional introduction of alien species cause a great potential risk for the region (…) alien species (…) pose a serious threat to the economy of northern Norway as well as for coastal communities in Russia. Due to the ecological and socio-

> economic value of the living marine resources in the Barents Sea and their sensitivity to the threats associated with human development, a potential risk from the introduction of alien species has to be taken very seriously (Matishov et al., 2004).

Consequently, the Barents Sea ecosystem appears vulnerable and should benefit fully from the environmental protection of the Polar Code. As far as the prevention of non-indigenous species transfer is concerned, the current geographical scope of the draft Polar Code is insufficient.

3.2. Political dimension

A political analysis is important insofar as it determines the cooperation potential to remedy environmental issues. Political decision is a key factor, for instance, in the settlement of national and regional strategies (Tamelander, Riddering, Haag & Matheickal, 2010).

Intergovernmental cooperation among Arctic States relies on soft law - i.e. voluntary measures without legally-binding power - and does not have any enforcement mechanisms (Koivurova, 2009). Conversely, the Antarctic regime relies on the 1959 Antarctic Treaty signed in Washington and, as far as environment protection is concerned, on the 1991 Protocol signed in Madrid. When comparing the two, Davor Vidas (2000) notes that :

> While the Antarctic Treaty System is a true form of international administration, the Arctic Council is still largely confined to international consultation (…) the Arctic still lacks any counterpart to the Antarctic Treaty System, governing the whole spectrum of human activities in the Antarctic with an increasing reliance on hard law (…) even the Arctic Council has been established, not by an international treaty, but by a declaration.

This assertion is confirmed by the principle enshrined in the Arctic States' first formal common decision : "the implementation of the Strategy will be carried out through national legislation and in accordance with international law, including customary international law as reflected in the 1982 United Nations Convention on the Law of the Sea" (AEPS, 1991).

Four out of five coastal States are parties to the UNCLOS (the United States has not ratified it). The Convention addresses the protection of the marine environment in ice-covered areas (article 234). Coastal States are given the right to adopt and enforce specific regulations within the limits of their exclusive economic zone (EEZ). However, global warming challenges the application of this provision since its two requirements, severe climatic conditions and the presence of ice for most of the year, will no longer be met (Mare, 2009).

The Arctic marine environment is not as well protected as the Antarctic despite of its vulnerability. It is neither a special area in the International Convention for the Prevention of Pollution from Ships (MARPOL) nor a Particularly Sensitive Sea Area (PSSA). Norway contemplates a PSSA application for the Lofoten Archipelago/Barents Sea marine area (Kystverket, 2004), but it has not been submitted to the IMO yet. The Arctic Council (2009), Norway (IMO, 2010a) and NGOs (IMO, 2010d), have stressed the lack of mandatory environmental standards to protect the Arctic marine environment. Whereas almost 20 % of the Arctic land has protected area status, little of the Arctic marine environment has been designated as marine protected area (Koivurova, 2009).

In the legal study commissioned by the World Wide Fund for Nature, Timo Koivurova and Erik J. Molenaar (2009) concluded that a new multilateral agreement was necessary to protect the Arctic marine environment :

> Given the pace of change in the Arctic, it is difficult to see how the Arctic and its ocean could be sustainably and coherently managed without an institution with the legal and political mandate to carry out the necessary changes to ensure the Arctic ecosystem is protected. Rules alone - especially non-legally binding ones - are hardly enough to govern the new sea emerging from the sea ice.

The European Parliament (EP) has also underlined the need to open international negotiations in order to adopt an international treaty for the protection of the Arctic environment (EP, 2008).

There are some geopolitical disputes and competition among Arctic States. Two of the contentious issues are maritime claims regarding the extension of sovereign rights over the continental shelf beyond 200 nautical miles, and the conditions of navigation in territorial waters (Dodds, 2010).

According to the UNCLOS (article 76.8), Coastal States must submit their claims to the Commission on the Limits of the Continental Shelf. Russia did it in 2001 (UN, 2001), Norway in 2006 (UN, 2006), Iceland in 2009 (UN, 2009) and Denmark in 2010 (UN, 2010). The exclusive sovereign rights exercised over the continental shelf consist in the exploration and exploitation of natural resources, except fishing migratory species (article 77).

The right of innocent passage in territorial seas, laid down in the UNCLOS (article 17), is also controversial. Canada, the United States and the European Union disagree about the legal status of the Northwest Passage (waterway in internal and territorial waters *vs*. strait used for international navigation) (Kraska, 2007). The same goes between Russia and the United States (Brass, 2002) about the Northeast Passage or Northern Sea Route (NSR) - strictly speaking and according to Russian Law, the NSR is the segment of the Northeast Passage extending between the Kara Gate (south of the Novaya Zemlya Island) and the Bering Strait (Arctic Council, 2009a).

At the time when the UNCLOS was written, lawyers did not suspect the far-reaching effects of global warming on sovereignty delimitation.

3.3. Ecological dimension

Jean-François Hamel and Annie Mercier (2005) distinguish five marine ecosystems in the Arctic : the High Arctic oceanic region (deep sea), the High Arctic coastal region, the High Arctic brackish water subregion (along the coasts of Russia, Canada and the United States), the Boreal littoral region of Norway (influenced by the Gulf

Stream) and the Low Arctic shallow region (transitional area between the boreal Norwegian fauna and the High Arctic fauna).

The United States National Oceanic and Atmospheric Administration (NOAA) and the Arctic Council have identified seventeen Large Marine Ecosystems (LMEs) in the Arctic (Arctic Council, 2009b).

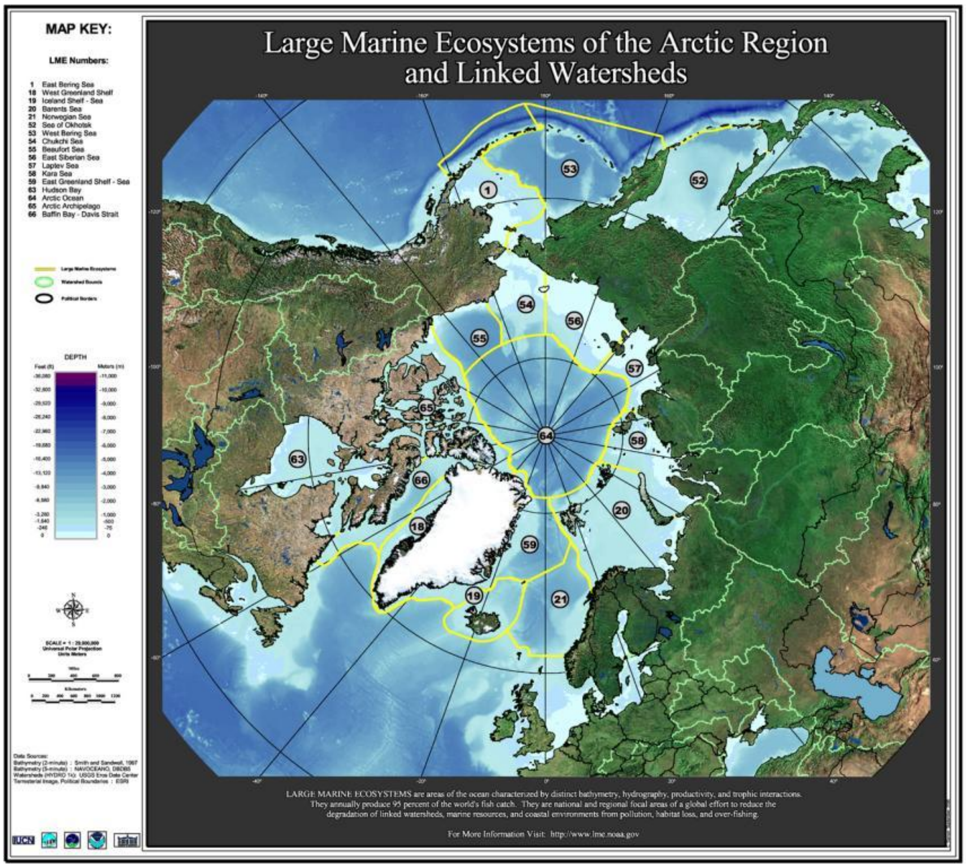

Figure 11 The seventeen Arctic Large Marine Ecosystems.
(Source : http://www.pame.is/, 2011)

Polar regions are harsh living environments in winter. Individuals can survive only if their metabolism withstands very low temperatures (between - 20 °C on coastal areas and - 50 °C in the interior of Greenland), the lack of sunlight (22 weeks without sun), the presence of sea ice and the lack of available liquid water (Dowdeswell & Hambrey, 2002 ; Elander & Windstrand, 2008). Flora and fauna have adapted to these conditions. Marine mammals such as polar bears, seals and cetaceans reduce their heat loss thanks to a thick layer of fat. Polar fishes have a specific protein-carbohydrate compound in their blood acting as an antifreeze (Dowdeswell & Hambrey 2002 ; Shirihai, 2007). Physiological processes such as growth, reproduction, respiration, absorption and assimilation of nutrients are influenced by surrounding conditions. In the history of evolution, the way species have succeeded in adapting to the cold temperatures is a continuous matter of interest for scientific research. Ice algae are also studied as indicators of past environmental conditions (Horner, 1989).

Aquatic organisms must adjust to temperature and salinity variations in the upper water layer. These are induced by the alternate succession of ice melting and freezing, as well as the inflow of precipitation water drained by streams and rivers (Hamel & Mercier, 2005). During the freezing period, brine is released from sea ice (seawater loses about two-thirds of its salinity through this process) and salt is carried downward. The melting of ice in May brings large amounts of relatively fresh water. During summer, air temperatures may rise above 20 °C (Anderson & Dyrssen, 1989 ; Dowdeswell & Hambrey, 2002 ; Matishov *et al*., 2004).

The sea ice microbial community develops during the early spring and includes algae (mostly diatoms), bacteria and protozoa. It grows in the lower 10 to 20 cm of the ice layer, just above the seawater, at a temperature of - 1.8 °C, and accounts for approximately one-third of the primary productivity (Perry *et al*., 2002). More than 300 species of micro-algae (e.g. *Nitzschia* spp.) have been found in sea ice. Some of them are distributed over a wide geographic area while others have been reported from only one or a few small areas. Ice algae support an extensive food web (copepods, amphipods and fish) (Horner, 1989).

Inbreeding populations have few connections with species from other oceanic masses because the Arctic Ocean is a semi-enclosed area. The connection with the Pacific Ocean is very narrow and its influx is of minor importance. The main exchange of water is therefore with the Atlantic Ocean (Heimdal, 1989), when warm waters enter the Norwegian Sea with the Gulf Stream. The Arctic Ocean's outflow takes place when pack ice goes out with the Eastern Greenland Stream (Elander & Widstrand, 2008).

In spring and summer, Arctic waters provide shelter for highly migratory species, among which are the cetaceans. Whales migrate northwardly in order to feed and reproduce. By late August, they move southwards and congregate in warmer waters during winter. They use four main migratory paths, namely the Norwegian Sea, Bering Sea/Bering Strait/Chukchi Sea, Baffin Bay/Davis Strait, and Denmark Strait/Greenland Sea/Fram Strait (Arctic Council, 2009a & 2010).

The Arctic Ocean has a low species diversity and biological productivity (Hamel & Mercier, 2005). The main limiting factor for phytoplankton growth is sea ice, which affects salinity, temperature and light penetration (Heimdal, 1989). However, recent research has shown that it shelters abundant eukaryotic organism populations (Stoeck, Kasper, Bunge, Leslin, Ilyin & Epstein, 2007).

Throughout the year, the production of phytoplankton undergoes significant variations according to sunlight duration and ice coverage ; it is low in winter and reaches a peak in spring (Dowdeswell & Hambrey, 2002). This phenomenon has repercussions on the whole food chain since zooplankton fluctuates proportionally, and so does the quantity of food for fish, birds and marine mammals.

Over the shelves, marginal seas have a rich productivity and biodiversity (Anderson & Dyrssen, 1989). Two examples are the Barents Sea (Patin, 1999 ; Matishov *et al.*, 2004) and the Bering Sea (Anderson & Dyrssen, 1989). The latter receives nutrients from volcanoes and is therefore very productive with 450 species of fish, crustaceans, and mollusks, 50 species of seabirds and 25 species of marine mammals (United States National Research Council, 1996).

The six pollution issues against which Arctic States join efforts are persistent organic pollutants (POPs), oil, heavy metals, noise, radioactivity and acidification (AEPS, 1991). The Arctic is the terminus for contaminated air and water streams. Polluted air masses, from other regions of the world, cool when they reach the Arctic and release harmful substances in its ecosystems. Ozone-depleting substances (ODSs), such as chlorofluorocarbons (CFCs) and halons, used respectively in refrigerating and fire-extinguishing systems, end up and accumulate in the Arctic. The 1987 Montreal Protocol has imposed control and elimination of production of most CFCs and halons (Intergovernmental Panel on Climate Change, 2005).

POPs, such as polychlorinated biphenyls (PCBs), have long-term impacts on human health and the environment because they degrade relatively slowly and bioaccumulate in fatty tissues, due to their lipophilicity (Safe, 1994). This explains why they can still be found today in spite of the fact that they have been banned. Since they are persistent and lipophilic, these pollutants concentrate along food webs (Skaare, Larsen, Lie, Bernhoft, Derocher, Norstrom, Ropstad, Lunn & Wiig, 2002), especially in higher trophic levels, i.e. top predators such as polar bears, cetaceans and seals.

PCBs impair reproductive ability, nervous and immune responses (Safe, 1994 ; Lahvis, Wells, Kuehl, Stewart, Rhinehart & Via, 1995). A direct consequence is that marine mammals produce fewer antibodies against infectious diseases caused by virus and bacteria. High levels of PCBs in fish can cause immunosuppression in marine mammals (Lahvis *et al*., 1995), particularly in polar bears :

> Significantly lower lymphocyte responses to lipopolysaccharide from *Escherichia coli* and Mycobacteria with high PCB exposure levels and significantly negative correlation between PCBs and IgG (the major immunoglobulin class in blood) were also registered. From the present preliminary results on effects of PCBs on the immune system of polar bears, it is reasonable to assume that PCBs are associated with decreased resistance to infections (Skaare et al., 2002).

POPs levels in the Arctic are so high that they even pose a risk for human health (UNEP, 2001), particularly because indigenous Arctic communities eat “country” food, i.e. lipid-rich higher trophic organisms (GESAMP, 2001).

Other sources of concern for the marine environment and human health are the reported high quantities of heavy metals (lead and mercury), resulting from extracting and metallurgic activities (GESAMP, 2001), polycyclic aromatic hydrocarbons (PAHs) in seawater and marine sediments (GESAMP, 2001), and tributyltin (TBT). The latter has been found in mussels collected in northern Norway, especially near harbors (Kannan & Tanabe, 2009). TBT has immunotoxic effects on fish and increases its susceptibility to pathogen infections (Nakayama, Segner & Kawai, 2009). The resuspension of sediments during oil exploration and exploitation may remobilize these contaminants and result in higher levels of exposure for marine life (GESAMP, 2001 ; Langston, Harino & Pope, 2009).

3.4. Socioeconomic dimension

Almost four million people live in the Arctic and half of them are settled in Russia (Arctic Council, 2004). The largest native populations include the Aleuts, the Inuit of the Canadian Eastern Arctic, the Cree of the Canadian Sub-Arctic, the Inuit of Northwest Greenland, the Saami of the Norwegian, Swedish and Finnish Arctic, the Karelians, the Nenets of Siberia and the Samoyed people (Caratini, 1990 ; Alexander, 1996). But there are also smaller communities. In Russia alone, for example, forty ethnic groups are conferred the "Indigenous Numerically Small Peoples of the North, Siberia and Far East of the Russian Federation" official status (Aslaksen, Dallmann, Holen, Høydahl, Kruse, Poppel, Stapleton & Turi, 2009).

Indigenous communities' traditional occupations are fishing (e.g. Arctic char), collection of wild plants, trapping (e.g. beavers) and hunting (e.g. polar bears, seals, moose, caribou, otters and wild geese). Fatty meat and seafood, mostly eaten raw, are important sources of nutrition (Alexander, 1996).

Global warming and the extension of human activities alter Arctic native peoples' traditional lifestyle, based on values such as the transmission of inherited practices, sharing and close relationship to nature (Aslaksen *et al*., 2009 ; IMO, 2011b) :

> Among indigenous people in Alaska, approximately 50 % of the calories consumed come from country foods. The seal, walrus, whale and fish components of the subsistence harvest will change as the climate changes (…) these changes may be accompanied by the growth of commercial harvesting in

the region by fishing vessels from farther south. In the Russian Arctic, subsistence hunting and fishing at sea may well expand due to the retreat of the European population and the consequent reduction in the supply both of food staples and of the cash economy necessary for the purchase of imported food (Brass, 2002).

The extracting industry development has several negative impacts on Arctic communities' land. For example, reduction of pasturelands for reindeer grazing (compulsory purchase orders), disturbance of wildlife migratory paths and pollution of rivers, lakes and ground water by petroleum and chemical contaminants (Aslaksen *et al.*, 2009).

However, these productive activities also create economic opportunities for Arctic inhabitants. In Russian Arctic, the gross regional product per capita is three times higher than in the rest of the country. The Canadian Northwest Territories and the State of Alaska derive as well substantial revenues from their local natural resources. Meanwhile, Arctic regions also import consumer goods. Because of a low population density and high transport costs, they face higher costs of living than non-Arctic regions (Glomsrød, Mäenpää, Lindholt, McDonald & Goldsmith, 2009 ; Lindholt & Glomsrød, 2009 ; Mäenpää, 2009).

3.5. Conclusion

The geographical scope of the draft Polar Code should integrate the whole Barents Sea because this ecosystem experiences various anthropogenic stresses, resulting in increased environmental risks.

The Arctic marine environment suffers from a lack of international legal protection and enforcement institution, compared with the Antarctic. Yet it shelters rare species, undergoes various sorts of pollution and sustains native peoples.

4. The Arctic : a region in change

4.1. Global warming

Global warming is particularly acute in the Arctic. As a matter of fact, in its Fourth Assessment Report (2007), the Intergovernmental Panel on Climate Change (IPCC) noted that "average Arctic temperatures have increased at almost twice the global average rate in the past 100 years (…) in some projections Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century".

American researchers (Stroeve, Holland, Meier, Scambos & Serreze, 2007) have shown that sea ice is shrinking even faster than predicted by the IPCC's models :

> Observations indicate a downward trend in September Arctic sea ice extent from 1953–2006 that is larger than any of the IPCC AR4 simulations, and current summer minima are approximately 30 years ahead of the ensemble mean model forecast (…) the Arctic has often been viewed as a region where the effects of GHG loading will be manifested early on, especially through loss of sea ice. The sensitivity of this region may well be greater than the models suggest.

Warmer temperatures, particularly in summer, lead to the shrinkage of ice pack, snow and permafrost extent. This modifies living conditions for local flora and fauna, changes their distribution and hierarchies in ecosystems. It can also threaten their survival when, for example, habitats disappear - e.g. polar bear (Arctic Council, 2004 ; Masters & Norgrove, 2010). In a sense, climate warming can be compared to a "powerful natural selection filter" (Stoeck *et al*., 2007). The climate-induced stress creates more favorable conditions for exotic species to survive, settle and spread (Rosentrater & Ogden, 2003 ; IPCC, 2007 ; Hall, James & Wilson, 2010). That is why some ecologists (Masters & Norgrove, 2010) advise to regard biological invasions as a component of climate change.

In its "Scenario for Arctic Ocean Sea Ice in the Year 2050", the United States Arctic Research Commission made the following projection :

> During winter, the central Arctic and all peripheral seas including the Greenland Sea, Bering Sea, and Gulf of St. Lawrence will continue to have significant ice cover. Extent and, in most areas, ice thickness will be reduced. The Sea of Okhotsk and Sea of Japan will be ice-free for the entire year. In late summer, the entire Russian coast will be ice free, allowing navigation through the Barents, Kara, Laptev and East Siberian Seas along the entire Northern Sea Route. The Northwest Passage through the Canadian Archipelago and along the coast of Alaska will be ice free and navigable every summer by non-icebreaking ships. Ice will be present all year along the eastern and northern coasts of Greenland. Ice will also remain throughout the summer within and adjacent to the northern Canadian Archipelago. Significant ice will remain in the central Arctic Ocean, though the mean thickness will be about 1.5 m, and it will be less compact (Brass, 2002).

4.2. Exploitation of natural resources

Both developed and developing countries are longing for Arctic natural resources, mainly oil, gas and minerals. On the other hand, Arctic States are determined to develop economic activities in their northern regions. For instance, Sweden’s strategy for economic development in the Arctic includes oil, ores and forest exploitation as well as land transport infrastructure upgrading (Sweden’s Department of Foreign Affairs, 2011). The reduction of ice coverage and the thaw of permafrost create better material conditions to exploit natural resources.

An estimation of undiscovered oil and gas north of the Arctic Circle executed within the framework of the United States Geological Survey (2008) revealed that “90 billion barrels of oil, 1,669 trillion cubic feet of natural gas and 44 billion barrels of natural gas liquids may remain to be found in the Arctic”.

The Arctic is said to shelter almost 13 % of the Earth’s oil resources and 30 % of the Earth’s natural gas resources (Granholm, Haldén, Larsson, Lindvall, Ljung, Neretnicks & Oldberg, 2008).

Russia owns a vast continental shelf in the Arctic, with great potential for future exploitation :

> Unique reserves of oil and gas on the Arctic shelf of Russia may constitute the basis for an increased development of Russia in the 21st century. At present, 62.5 trillion m^3 of natural gas and 9 billion tons of oil have been discovered in the seas of the Arctic Ocean and 3.5 billion tons of oil have been discovered on the coast (Matishov et al., 2004).

Russian and American interests have allied in the energy sector and oil companies concluded an agreement for exploratory offshore drilling in the Kara Sea (Parker, 2011).

Nevertheless, competition for Arctic resources may also be a potential cause of conflict, not only between Arctic States but among all countries which intend to benefit from the Arctic's rich deposits (European Parliament, 2008 ; Arctic Council, 2009a). One example is China (Dodds, 2010).

In a situation of fossil fuel shortage, owning huge reserves of natural resources gives geopolitical power.

Navies are patrolling, first to assert sovereignty over national maritime territories and, second, because NGOs protest against exploitation plans. For instance, Greenpeace activists boarded an oil rig in Greenland's waters. This action aimed at preventing a Scottish oil company from deep sea drilling (Carrell & Van Der Zee, 2010).

The life cycle of offshore installations is composed of four stages (Patin, 1999), namely geological and geophysical survey (test drilling), exploration (rig emplacement, exploratory drilling, well plugging), development and production (platform emplacement, pipe laying, well and pipeline maintenance), and decommissioning (disassembling, structure removal). All have environmental impacts - e.g. turbidity, disturbance of fish migrations - and require support vessels.

Arctic living marine resources provide indigenous peoples with subsistence but also have a global economic significance (Murray, Anderson, Cherkashov, Cuyler, Forbes, Gascard, Haas, Schlosser, Shaver, Shimada, Tjernström, Walsh, Wandell & Zhao, 2010). For instance, 70 % of the world's total white fish supply comes from Arctic waters (Burnett *et al*., 2008). Because of global warming, some fish species migrate northwards in order to find the cold waters they need to feed and reproduce. Such northward ecosystem migration has been observed in the Bering Sea and in the Northeast Atlantic (Murray *et al*., 2010). This phenomenon brings new species in the Arctic and some major marine fisheries, such as those for herring and cod, will become more productive (Murray *et al*., 2010 ; Arctic Council, 2004). Therefore, commercial fishing also moves northwardly. Besides IUU fishing (Burnett *et al*., 2008), it will reinforce overfishing in marginal seas. In 2005, the total catch of cod in the Barents and Norwegian Seas was estimated to be in excess of at least 100,000 tonnes compared with the quota (Kosmo, Stub, Høegh, Hansen & Frøiland, 2007). This threatens the sustainability of fisheries with a global interest. It also hinders the capacity of Arctic fish stocks to adapt to climate change (Burnett *et al*., 2008).

The enlargement of natural resources exploration and exploitation will bring a greater need for maritime transport in the Arctic, thereby increasing maritime safety and environmental risks.

4.3. Increasing cargo ship traffic

The Arctic has a strategic median location between the Eurasian and American continents. From the shipping company's viewpoint, Arctic waterways reduce distances between Asian, European and North-American markets. Three enviable advantages come forth. First, a gain in time thanks to shorter voyages. Second, a gain in voyage costs through reduced fuel costs - which would nevertheless be mitigated by the higher fuel consumption of Polar Class ship engines - and by avoiding the spending of canal charges - the Northwest Passage avoids transiting the Panama Canal and the Northeast Passage avoids transiting the Suez Canal. The third gain relates to maritime security, since Arctic routes will enable ships to steer clear of regions where pirate attacks rage (Baldursson, 2007).

Reduced sea-ice cover, both in extent and in thickness, will lengthen the navigation window and widen the range of ships able to transit Arctic waters (Arctic Council, 2004). Transit routes will be accessible for ships via the Northwest Passage, along the coasts of Canada and the United States, via the Northeast Passage, along the coasts of Russia, and in a farther future across the North Pole itself (Future Central Arctic Shipping route). In the latter case, navigation would take place beyond coastal State jurisdiction (Brigham, Santos-Pedro, McDonald, Juurmaa & Gudmundsdottir, 2006 ; Arctic Council, 2009a).

On the other hand, voyage costs must integrate escort costs charged by ice-breakers. As far as Russia is concerned, the international shipping community disapproves of the lack of transparency from the Northern Sea Route Administration :

> The Russian authorities have yet to declare their 2011 fee structure, and if and when they do, owners will look at how these compare in terms of freight rates to determine if there are benefits in sending cargoes east, or, depending on the cargo, selling into Europe, or sailing round the Cape or through the Suez Canal (Eason, 2011).

The shipping industry is eager to take advantage of these new opportunities. China, for instance, intends to use the Northeast Passage for both importing and exporting. Dry bulk cargoes, such as ores and fertilizers, would be shipped from Europe to Asia - e.g. iron ore from Narvik to Qingdao and fertilizers from Porsgrunn to Shekou - with ice-breaking bulk carriers. In return, steel products and structures used in building construction would be sent to Europe (Murphy & Eason, 2011 ; Parker, 2011). During the Northern Sea Route User Conference, held in Oslo in 1999, Ronald Bergman expressed the following point of view :

> The NSR is indeed potentially very interesting to many shipowners. Each of us would welcome the opportunity to drastically cut our freight rates if the distance from, for example, Hamburg to Japan can be decreased by thousands

> of miles. Owners would save huge amounts on daily running costs and bunker use, savings that would immediately be reflected in the freight rates. Additionally, a shortening of travelling time of this magnitude would allow us to take on more business, thereby improving the status of international commerce.

In the more northerly options, Panamax and Suezmax ships can transit the NSR (Eason, 2011). This means dry bulk carriers and tankers with a deadweight tonnage between and 60,000 and 200,000 tonnes. Several successful voyages, from Russian ports in the White and Barents Seas to Thailand and China, lead shipping analysts (Parker, 2011) to consider that "the northern sea route moves from its present experimental status towards true commerciality".

4.4. Increasing non-cargo ship traffic

Non-cargo ship traffic relates to ice-breakers, tugs, fishing boats, floating platforms, barges, pipe carriers, pipe layers, and offshore supply, research and passenger vessels.

Even though scientific research has been conducted in the Arctic for a long time, greater accessibility and remote countries' growing interest in natural resources will reinforce scientific activities in polar bases and hence research vessel movements.

A particular source of concern for the Arctic environment is the development of cruise shipping (UNEP, 2007 ; Hall *et al*., 2010). Tourists sail about in Arctic waters either on ice-breakers and reconverted research vessels or, mainly, on cruise ships which are not Polar Class (Elander & Widstrand, 2008 ; Arctic Council, 2009a). In 2007, 1.5 million tourists visited the Arctic region - including Iceland and North Scandinavia. More than 70,000 tourists come to Svalbard each year and Greenland welcomes annually 50 cruise ships, i.e. more than 15,000 passengers. Among the vessels which transited the Northwest Passage in 2005, more than a half were cruise ships. These figures are expected to increase. Furthermore, with regard to its length, the Russian coastline owns a great potential for tourism development. The

“Socioeconomic strategy for the Murmansk region till the year 2025” includes tourism development in the following directions : ski, forestry ecotourism, sport fishing, fishery tourism, ethno-cultural tourism, cruise, educational and business city tourism in Murmansk (Ministry of Economic Development of the Murmansk region, 2010).

While tour operators are organized within the International Association of Antarctic Tour Operators (IAATO) in the Southern Ocean, there is no similar organization for cruises in the Arctic. This type of association would yet help to disseminate good practices to protect the environment.

4.5. Conclusion

Global warming in the Arctic results in the retreat of sea-ice and the thaw of permafrost. These changes facilitate or create anthropogenic activities, namely mining, offshore drilling, cargo transportation, fishing, scientific research and tourism. All of these have in common to generate a need for maritime transport. Therefore, the rising Arctic ship traffic is an indirect consequence of climate change.

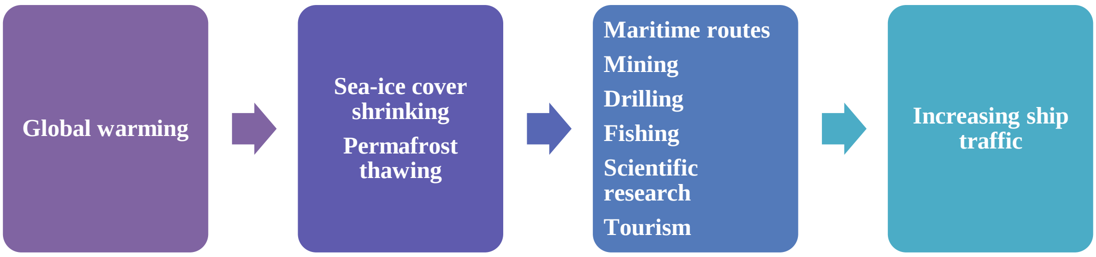

Figure 12 Increasing ship traffic : an indirect consequence of global warming.

5. Regulating the transfer of alien aquatic species by ships in the Arctic

5.1. Draft Polar Code

Most of the major IMO Conventions do not address the specific conditions and risks inherent to the operation of ships in polar waters. The reason for this is that at the time when they were adopted, ship traffic in polar areas was so scarce that even charts were insufficiently developed (Arctic Council, 2009a). Few countries conducted hydrographic surveys and, in the same way, few legislative bodies cared about those remote areas. Today, the situation is different and there is therefore a need, on the one hand, to adapt the provisions of existing IMO instruments to polar conditions and, on the other hand, to add extra requirements which will guarantee an equivalent level of life and environment protection as everywhere else. A practical outfit for those specific regulations would be a single document, entitled Polar Code, compounding technical and operational provisions with regard to ship design, life saving appliances, training of crew and prevention of pollution.

The DE Sub-Committee has been entrusted by the MSC with the development of a mandatory code for ships operating in polar waters. The scheduled deadline of this "high-priority item" is 2012 (IMO, 2009a).

In the wake of the adoption of the Guidelines for Ships Operating in Arctic Ice-covered Waters (IMO, 2002) and the Guidelines for Ships Operating in Polar Waters (IMO, 2009e), both being recommendatory measures, the IMO was requested by the Antarctic Treaty Parties to issue mandatory requirements for ships operating in Antarctic waters (IMO, 2009b). In addition, the Arctic Council issued a report (2009) with recommendations directed to the IMO to enhance the regulations governing Arctic shipping. These steps reinitiated the development of an IMO instrument wholly dedicated to polar waters.

The present draft is the second draft of a Polar Code. The first one was submitted to the IMO by Canada, on behalf of an Outside Working Group, in 1998 (Brigham, 2000). The reason for which it never came to an end was that "it failed to distinguish between the conditions and nature of shipping in the Arctic and those in Antarctica, which is unique in its geography and governance (…) there were conflicts between the draft Code and the Antarctic Treaty and UN Law of the Sea Convention" (IMO, 1999).

It was decided that "Antarctic waters [were] to be excluded from the application of the guidelines, unless Antarctic Treaty members decide otherwise" (IMO, 1999).

The second draft Polar Code submitted by Canada (IMO, 2009c) applies in Arctic and Antarctic waters. It is structured as other IMO codes, i.e. part A contains mandatory requirements and part B recommendatory measures, and arranges for construction, equipment, operation and environmental protection. The intention is to make it applicable to all ships, existing and new ones.

The environmental protection chapter addresses both ballast water management and biofouling issues. In the first case, the requirements are those of the BWM Convention, i.e. exchange, treatment, discharge to a reception facility or retention (paragraph 16.5.2). Ships would have to manage ballast water before and after entering polar waters (paragraph 16.5.1).

As for biofouling management, "vessels and offshore installations that have been stationary in polar waters for a period of months shall have hull and sea-chests cleaned *in situ* before moving to a new location" (paragraph 16.6).

It is noteworthy that this provision applies to the Arctic as a donor region, but not as a potential receiver. Therefore, the issue is not completely addressed.

A recent proposal, submitted by Norway (IMO, 2010g), amends the initial environmental protection chapter to prohibit any discharge of ballast water in polar waters, unless treated or delivered to a reception facility.

As far as the adoption of the Code is concerned, three options are considered by the IMO (IMO, 2011a). The first option would be to add a new chapter to the International Convention for the Safety of Life at Sea (SOLAS Convention) through the tacit acceptance procedure. It would be dedicated to ships operating in polar waters and would include the entire Polar Code. The second option would be to split the Code by amending both the SOLAS and MARPOL Conventions. In that case, it would also be necessary to amend the AFS and BWM Conventions. Finally, the third option would be to adopt a new convention on ships operating in polar waters. The major drawback being that the Polar Code would come into force later in time, since a certain number of ratifications would be required.

5.2. Difficulties with regard to ships

Performing BWE operations at sea may jeopardize ship safety, especially when using the sequential method. Potential effects include impaired stability, longitudinal and torsional stresses, sloshing action in partially-filled tanks, hull vibrations, impaired bridge visibility as a result of increased blind sectors or reduced horizontal fields of vision (IMO, 2004c), tank over-pressurization and additional hazards to crew (IMO, 1997a & 2005). Most current ships have not been designed to execute this operation. This also explains why ballast tanks cannot be fully emptied (Gollasch, David, Voigt, Dragsund, Hewitt & Fukuyo, 2007). The bigger the ship, the longer is the time necessary to perform the operation in unsafe conditions. Some large vessels need one to three days to execute BWE (Gollasch *et al.*, 2007). A provision of the BWM Convention allows a master to renounce BWE if he deems it dangerous for passengers, crew and ship safety (IMO, 2004b).

Versatile, poor weather conditions and the presence of constantly drifting sea ice characterize Arctic waters (Dowdeswell & Hambrey, 2002). Another difficulty for Arctic navigation will be the increase in wave amplitude due to the gradual reduction of the ice cover. Insufficient reliable marine weather information and hydrographic data worsen the situation (Arctic Council, 2009a).

On board the ship, equipment functioning is altered by the freezing conditions. The ballast water overflow on the deck may turn into ice and accumulate, jeopardizing stability. Water flux through valves and pipes may be disrupted. The hull bears additional stresses caused by ice. This is precisely the reason why the IMO recommends avoiding BWE operations in freezing weather conditions (IMO, 2005).

Specific guidelines for BWE in the Antarctic Treaty area have been adopted (IMO, 2007b), but nothing equivalent has been developed with regard to the Arctic.

A ship already experienced severe list while exchanging ballast water in the Pacific Ocean (IMO, 2007a). Considering the lack of assistance and rescue facilities (e.g. tugs) in the Arctic, the BWE operation does not seem to be safe.

Is the retention of ballast water on board a realistic option ? Intake and discharge operations are not limited to ports, they are also necessary at sea to maintain ship safety (Veldhuis *et al*., 2010).

Another hindrance is that navigation through the Northwest and Northeast Passages is performed close to shore, in shallow waters. The BWE conditions of distance from land and depth are seldom achievable. For instance, along the NSR the average depths of the Chukchi, East Siberian and Kara Seas are 88 m, 58 m and 90 m respectively (Arctic Council, 2009a).

5.3. Difficulties with regard to port facilities

For the same reason as charts were insufficiently developed, so is infrastructure equipment in Arctic ports. In the Guidelines for ships operating in Arctic ice-covered waters, the IMO recognized the lack of waste reception and repair facilities in the region (IMO, 2002).

The Arctic Council (2009) also acknowledged this infrastructure deficit and recognized necessary improvements as a matter of urgency.

The Norwegian Maritime Directorate contracted (2006) Det Norske Veritas (DNV) to conduct a study on Arctic port reception facilities. A questionnaire was sent to the coastal States. The results remain incomplete since :

> No Russian ports have answered the electronic questionnaire (…) no specific comments have been received from Russian authorities regarding what regulations and incentives the country has implemented (…) for Russia the only available information is the information from the IMO-database on port

reception facilities which indicates that all the listed ports can receive some kind of oily waste.

Presently, only two of the coastal Arctic States are parties to the BWM Convention, namely Canada and Norway - Denmark, Russia and the United States have not ratified it. When the Convention enters into force, these countries will have to provide, at least sediment reception facilities, at most sediment and ballast water reception facilities.

What will be provided in other coastal States ? What about the Barents Sea, where shipping is expected to increase by a factor of 6 (Matishov *et al*., 2004) ?

If, as required by the provisions regarding biofouling, ships/rigs that have been stationary in Arctic waters for a period of months want to have their underbody cleaned *in situ* before moving to a new location, will they find facilities to do so ?

5.4. Adjustment to pristine environmental conditions

One of the reasons put forward to explain the success of biological invasions was environment susceptibility resulting from a combination between ecosystem disturbance and low biological diversity (GESAMP, 2007). These two conditions can be found in some areas of the Arctic and its marginal seas. For example, variations in climate and perhaps overfishing led to lower abundance levels in certain fish - e.g. walleye pollock - stocks in the Bering Sea. This had repercussions on the whole food web, i.e. fishes, marine mammals and seabirds (United States National Research Council, 1996 ; Walther, Post, Convey, Menzel, Parmesank, Beebee, Fromentin, Hoegh-Guldberg & Bairlein, 2002 ; Nilsson, 2011).

As far as BWE is concerned, this management option is not fully reliable (IMO, 2003b). First, the effectiveness of the exchange depends on the water depth and seasonal organism concentration of the area where water is pumped (Gollasch *et al*., 2007). Second, ballast tanks can never be totally emptied and “a 95 % volumetric exchange of water may not always be equivalent to a 95 % organism removal as the organisms are not homogeneously distributed in a tank” (Gollasch *et al*., 2007).

In remaining ballast waters and sediments, organisms can still proliferate (Hallegraeff, 1998). They use the organic material accumulated in the sediment layer. Moreover, in cold temperature micro-organisms have a longer life span because their metabolism is slowed down (Monfort, 2006).

A study was conducted on the life span of the enteric bacteria *Listeria* and *Salmonella* in the marine environment (Monfort, Piclet & Plusquellec, 2000). Experiments were made in estuarine and sea water at two temperatures, 18°C and 5°C.

The results (Figures 13 and 14) indicated that :

> The survival profiles were independent of the bacteria (*Salmonella* or *Listeria*) or the origin of the water (estuarine water or seawater) but differed markedly with the temperature (…) this incidence of the water temperature is sanitarily relevant and the higher persistence noted at a low temperature may be related to the higher prevalence observed *in situ* (…) in the winter period.

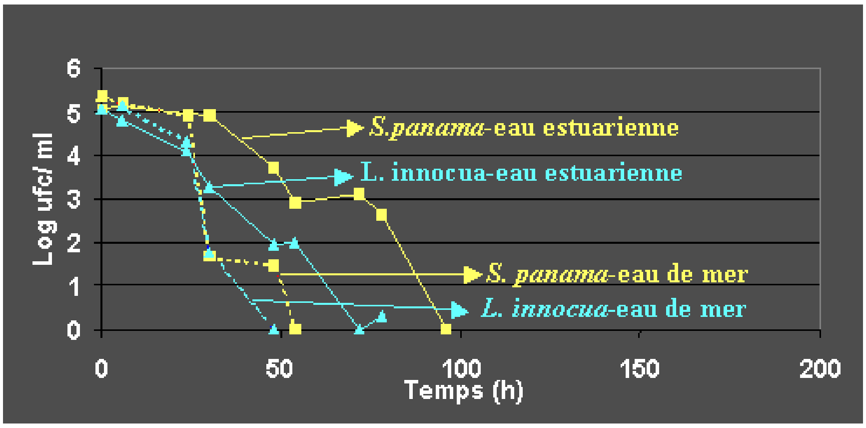

Figure 13 Life span of *Listeria* and *Salmonella* at 18°C.
(Source : IFREMER, 2000)

Continuous lines are data collected in estuarine water, dotted lines those collected in seawater. Data concerning *Listeria* are in blue, those concerning *Salmonella* in yellow.

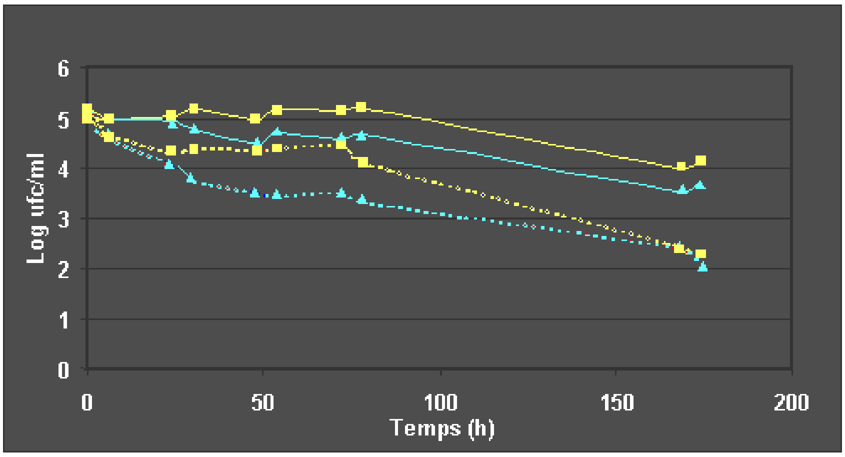

Figure 14 Life span of *Listeria* and *Salmonella* at 5°C.
(Source : IFREMER, 2000)

Organisms which have a life cycle including a stage of resilient cysts - e.g. the apicomplexans, affecting mammals, or which produce cysts during periods of environmental stress - e.g. dinoflagellates, will demonstrate a greater ability to survive (Horner, 1989 ; Stoeck *et al*., 2007).

When BWE cannot be executed in the prescribed conditions of depth and distance from the shore, port States have to indicate the BWE areas they have previously identified (IMO, 2004b). On which basis, national or regional approach, would these areas be determined in the Arctic ? Is it practicably feasible and safe ?

As far as BWT is concerned, treated ballast water discharges still contain viable organisms because no BWT can remove or kill 100 % of these. Disinfection for instance, even with chlorine, does not kill all of the bacteria and protozoa - e.g. *Cryptosporidium* cysts (Perry *et al*., 2002). Are the maximum organism concentrations provided by the performance standard (IMO, 2004b) suitable for the Arctic marine environment ?

Although the ballast water performance standard is stringent - nearly as strict as drinking water standards (Veldhuis *et al*., 2010), it remains to be pointed out that, in many regions of the world, humans and animals have developed defenses against targeted micro-organisms. Immune protection is passively acquired at an early age when maternal antibodies pass to the fetus across the placenta or to the newborn in the colostrums of the mother's milk (Perry *et al*., 2002). Nevertheless, is it the case in a remote place ? In addition, as seen in previous analysis, some pollutants found in the Arctic can impair human and animal immune responses.

Another source of concern is that treated ballast water discharges may contain residual oxidants, for example in case of treatment plant malfunctioning or manipulation error. What would be the consequences of chlorine or bromine discharges into the marine environment ?

Ships have the option to dispose of sediments at sea, provided they respect two conditions, i.e. distance of 200 nautical miles from land and water depth of 200 meters. Is this provision acceptable in the Arctic ?

As for biofouling removal, when executed in open waters, it poses a hazard to the environment since coating waste may be toxic. Underbody cleaning should be done in contained spaces and wastes should be collected. This operation generates risks, both chemical - biocides used - and biological - removed organisms, and therefore requires adequate facilities.

The precautionary approach should prevail when considering these interrogations and favor the adoption of stricter environmental requirements. NGOs have called for more stringent measures than those set in the draft Polar Code (IMO, 2009d & 2010e), arguing the vulnerability of polar regions.

The Arctic's vulnerability is due to a relatively short growing season and a smaller biodiversity - concentrated in key areas - compared with temperate areas, as well as harsh climatic conditions (Arctic Council, 2004). "Arctic ecosystems are highly sensitive to changes in species or community composition and population dynamics and are highly vulnerable to ecological or artificially imposed stresses such as pollution, waste and physical disturbances, all of which often have more widespread environmental effects than in other regions" (CAFF, 1996).

The specific vulnerability to biological invasions can be explained by considering two sources of ecosystem imbalance and their interrelation. On the one hand, there is the climate-induced stress which creates higher risks for alien species invasions. On the other hand, a higher risk for biological invasion, for example due to greater ship traffic, means that some local species are likely to reduce in abundance or disappear. This alters communities' structure and functions. It results in a more critical sensitivity to climatic perturbation. The combined actions of alien species invasions and climate change seem to be synergistic (Masters & Norgrove, 2010).

Conversely, a survey conducted by DNV (IMO, 2010f) led to the following conclusion :

> This study has found no evidence for considering the threats from spread of alien species under the IMO Ballast Water Convention any differently in polar waters than in any other areas. In polar areas, as in other areas, the Convention is considered sufficient for controlling the spread of species via ballast water ; however it does not control the spread of organisms via fouling on ship's hull and rudder.

Yet the BWM Convention entitles coastal Arctic States parties to take additional measures within a regional approach (IMO, 2004b). Such an initiative would be in line with the Arctic States' commitment to promote the adoption of measures to protect areas of heightened ecological and cultural significance from the impacts of shipping (Arctic Council, 2009a).

5.5. Conclusion

The Polar Code is an instrument being developed by the IMO to strengthen or remedy the lack of specific provisions regarding navigation in polar waters. However, as far as the transfer of alien organisms is concerned, it does not prescribe extra measures but rather refers to existing standards. As a result, ships may face practical difficulties in implementing safely the prescribed operations, ports may not be able to play the role they are assigned and the vulnerability of the Arctic marine environment is not sufficiently taken into consideration.

6. Overall conclusion

Too often, unfortunately, humans realize the value of natural resources only when they begin to disappear. Most of the time consciousness arises too late to take action (Mora & Sale, 2011). The development of the Polar Code is a unique opportunity to anticipate the multiple changes affecting the Arctic and take preventive measures before the expansion of maritime transport. This instrument aims at complementing the major IMO conventions as far as shipping in polar waters is concerned. The brisk pace of climate change in the North Pole region urges the outcome of the Polar Code.

In the environmental domain, especially in the prevention of alien species transfer by ships, the standards are directly derived from existing instruments without further adaptation. Navigational constraints in the area, the lack of port reception facilities and the ecological vulnerability of the Arctic have not been sufficiently taken into consideration.

The presence of non-indigenous organisms in an ecosystem is a hazard. The associated risk is biological invasion, leading to biodiversity loss. Global warming in itself has the potential to trigger a chain of events resulting in environmental imbalance. As it opens new opportunities for human activities, there is an increase in ship traffic. Thereby, there is a higher biological invasion risk.

The Arctic suffers from a lack of international legal protection and enforcement institution, compared with the Antarctic. Yet it shelters rare species, undergoes various sorts of pollution and sustains native peoples. The Barents Sea, which is subjected to several anthropogenic stresses and experiences a significant growth in ship traffic, should benefit fully from the environmental protection of the Polar Code.

Arctic States have a duty to preserve the biodiversity of their marine environment, particularly because it is pristine and because native peoples depend on it.

Since the UNCHE, the concept of a regional approach to protect the marine environment has been supported by authoritative fora, such as the UNEP and the Third United Nations Conference on the Law of the Sea. IMO instruments also emphasize the need for regional cooperation to efficiently address environmental issues. From the beginning, Arctic States have founded their association on a strategy to protect the Arctic environment. The control of the transfer of alien species by ships should come within this regional strategy.

In view of the global insatiable thirst for fossil fuels and the ensuing race to find new supply sources, potentially divergent national interests regarding resources exploitation and subsequent reevaluation of political priorities, the Arctic States' determination to protect and preserve their marine environment will undoubtedly be challenged in a near future.

APPENDIX A

GLOSSARY

“Active Substance” means a substance or organism, including a virus or a fungus that has a general or specific action on or against harmful aquatic organisms and pathogens (IMO, 2008a).

“Anadromous” species are organisms that spawn/reproduce in freshwater environments, but spend at least part of their adult life in a marine environment (IMO, 2007b).

“Apicomplexans” are parasites of animals. Most species live in or on cells lining the intestine and are transmitted by resistant spores passed out with feces. They are united by features of the life cycle and ultra structural details rather by readily visible gross morphological features (Perry *et al*., 2002).

“Arctic waters” means those waters which are located north of a line from the latitude 58º00´0 N and longitude 042º00´0 W to latitude 64°37´0 N, longitude 035°27´0 W and thence by a rhumb line to latitude 67º03´9 N, longitude 026º33´4 W and thence by a rhumb line to Sørkapp, Jan Mayen and by the southern shore of Jan Mayen to the Island of Bjørnøya, and thence by a great circle line from the Island of Bjørnøya to Cap Kanin Nos and thence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º N as far as Il’pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60º N and thence eastward along parallel of latitude 60º N, to longitude 56º37´1 W and thence to the latitude 58º00´0 N, longitude 042º00´0 W (IMO, 2009c & 2009e).

“Ballast Water Management System” means any system which processes ballast water such that it meets or exceeds the ballast water performance standard. This system includes ballast water treatment equipment, all associated control equipment, monitoring equipment and sampling facilities (IMO, 2008c).

“Biofilms” are heterogeneous, complex matrices composed of micro-colonies interspersed with channels allowing the movement of fluids (Lewandowski, 2000).

“Biogeographic region” is a large natural region defined by physiographic and biologic characteristics within which the animal and plant species show a high degree of similarity. There are no sharp and absolute boundaries but rather more or less clearly expressed transition zones (IMO, 2007b).

"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part ; this includes diversity within species, between species and of ecosystems (UN, 1992).

“Catadromous” species are organisms that spawn/reproduce in marine environments, but spend at least part of their adult life in a freshwater environment (IMO, 2007b).

“Euryhaline” species are organisms able to tolerate a wide range of salinities (IMO, 2007b).

“Eurythermal” species are organisms able to tolerate a wide range of temperatures (IMO, 2007b).

“Greenhouse Gases” are the gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation within the spectrum of the thermal infrared radiation that is emitted by the Earth’s surface, by the atmosphere and by clouds. This property causes the greenhouse effect. The primary greenhouse gases in the Earth’s atmosphere are water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3). Moreover, there are a number of entirely anthropogenic greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances that are covered by the Montreal Protocol. Some other trace gases, such as sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), are also greenhouse gases (IPCC, 2005).

“Ice-covered waters” means polar waters where local ice conditions present a structural risk to a ship where ice covers more than one-tenth of the water’s surface (IMO, 2009c).

“Non-indigenous species” is any species outside its native range, whether transported intentionally or accidentally by humans or transported through natural processes (IMO, 2007b).

“Ozone-depleting substances” are controlled substances which can significantly deplete or modify the ozone layer in a manner that is likely to result in adverse effects on human health and the environment. These are, for instance, CFCs and halons (UNEP, 1987).

“Polychlorinated biphenyls” are aromatic compounds formed in such a manner that the hydrogen atoms on the biphenyl molecule (two benzene rings bonded together by a single carbon-carbon bond) may be replaced by up to ten chlorine atoms (UNEP, 2001).

APPENDIX B

STATES PARTIES TO THE BWM CONVENTION

ALBANIA
ANTIGUA & BARBUDA
BARBADOS
BRAZIL
CANADA
COOK ISLANDS
CROATIA
EGYPT
FRANCE
IRAN
KENYA
KIRIBATI
LIBERIA
MALAYSIA
MALDIVES
MARSHALL ISLANDS
MEXICO
MONGOLIA
NETHERLANDS
NIGERIA
NORWAY
PALAU
REPUBLIC OF KOREA
SAINT KITTS AND NEVIS
SIERRA LEONE
SOUTH AFRICA
SPAIN
SWEDEN
SYRIAN ARAB REPUBLIC
TUVALU

REFERENCES

Alekseev, V., Makrushin, A. & Hwang, J.-S. (2010). *Does the survivorship of activated resting stages in toxic environments provide cues for ballast water treatment ?* Marine Pollution Bulletin 61 (2010). Elsevier. http://www.sciencedirect.com/

Alexander, B. (1996). *The vanishing Arctic*. Blandford. London.

Allison, D.G., Maira-Litran, T. & Gilbert, P. (2000). Antimicrobial resistance of biofilms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Anderson, L. & Dyrssen, D. (1989). Chemical oceanography of the Arctic Ocean. In Y. Herman (Ed.), *The Arctic Seas : climatology, oceanography, geology and biology*. Van Nostrand Reinhold. New York.

Arai, T. (2009). Preface. In T. Arai, M. Ohji, H. Harino & W.J. Langston (Eds.), *Ecotoxicology of antifouling biocides*. Springer. Tokyo.

Arctic Council. (1991, June 14). *Arctic Environmental Protection Strategy (AEPS)*. http://arctic-council.org/filearchive/artic_environment.pdf

Arctic Council. (1996, September 19). *Declaration on the establishment of the Arctic Council*. http://arctic-council.org/filearchive/ottawa_decl_1996-3..pdf

Arctic Council. (2004). *Arctic Climate Impact Assessment (ACIA) : impacts of a warming Arctic*. Cambridge University Press. http://www.amap.no/acia/

Arctic Council. (2009a, April). *Arctic Marine Shipping Assessment 2009 Report*. http://www.pame.is/images/stories/PDF_Files/AMSA_2009_Report_2nd_print.pdf

Arctic Council. (2009b, April). *PAME Summary Report 2006-2009 Activities*. Sixth Arctic Council Ministerial Meeting. Tromsø, Norway. http://arctic-council.org/

Arctic Council. (2010, May). *Arctic Biodiversity Trends 2010 : selected indicators of change*. CAFF International Secretariat. Akureyri (Iceland). http://www.arcticbiodiversity.is/

Aslaksen, I., Dallmann, W., Holen, D.L., Høydahl, E., Kruse, J., Poppel, B., Stapleton, M. & E.I. Turi (2009, November). Interdependency of subsistence and market economies in the Arctic. In S. Glomsrød & I. Aslaksen (Eds.), *The Economy of the North 2008*. Statistics Norway. http://www.ssb.no/english/subjects/00/00/30/sa_economy_north/sa112_en/sa112_en.pdf

Baldursson, R. (2007, March 28). *Arctic development and maritime transportation : prospects of the Transarctic Route, impacts and opportunities*. Breaking the Ice Conference in Akureyri (Iceland). http://www.mfa.is/media/Utgafa/Breaking_The_Ice_Conference_Report.pdf

Bergman, R. (1999, November). *The Shipping industry and the Northern Sea Route*. Northern Sea Route User Conference held in Oslo in November 1999. BIMCO bulletin. Volume 94. No. 6. December 1999.

Brass, G.W. (2002). Arctic Ocean Climate Change. United States Arctic Research Commission. Special Publication No. 02-1. http://www.arctic.gov/publications/arctic_and_climate_change.pdf

Brigham, L.W. (2000). The emerging International Polar Navigation Code : bi-polar relevance ? In D. Vidas (Ed.), *Protecting the Polar Marine Environment : law and policy for pollution prevention*. Cambridge University Press.

Brigham, L.W., Santos-Pedro, V., McDonald, R., Juurmaa, K. & Gudmundsdottir, S. (2006). *Arctic marine shipping assessment of the Arctic Council : responding to changing marine access in the Arctic Ocean***.** Arctic Forum 2006. Arctic Research Consortium of the U.S. http://www.arcus.org/annual_meetings/arctic_forum_archive/2006/

Burnett,M., Dronova, N., Esmark, M., Nelson,S., Rønning, A. & Spiridonov, V. (2008, April). *Illegal fishing in Arctic waters : catch of today, gone tomorrow ?* WWF International Arctic Programme, Oslo (Norway). http://www.wwf.ru/data/Barents/arctic_fishing.pdf

Callow, M.E. (2000). Algal biofilms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Caratini, R. (1990). *Dictionnaire des nationalités et des minorités en URSS*. Larousse. Paris.

Carrell, S. & Van Der Zee, B. (2010, August 31). *Greenpeace "shuts down" Arctic oil rig : environmental campaigners slip through security boats to scale Cairn Energy oil rig in dawn raid*. The Guardian. http://www.guardian.co.uk/environment/2010/aug/31/greenpeace-oil-rig-arctic

Census of Marine Life (2010). *First Census of Marine Life 2010 : highlights of a decade of discovery*. http://www.coml.org/pressreleases/census2010/PDF/Highlights-2010-Report-Low-Res.pdf

Champ, M.A. (2001, November 8). *The status of the treaty to ban TBT in marine antifouling paints and alternatives*. Proceedings of the 24th UJNR (US/Japan) Marine Facilities Panel Meeting in Hawaii. National Maritime Research Institute of Japan. http://www.nmri.go.jp/main/cooperation/ujnr/24ujnr_paper_us/Ocean_Engineering_and_Resource/OERD_Champ.pdf

Conference of the Parties to the Convention on Biological Diversity. (2008, October 9). *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its ninth meeting IX/20 : Marine and coastal biodiversity*. Ninth meeting of the Conference of the Parties to the Convention on Biological Diversity, 19 - 30 May 2008. Bonn, Germany. http://www.cbd.int/doc/decisions/cop-09/cop-09-dec-20-en.pdf

Conservation of Arctic Flora and Fauna (CAFF). (1996). *Circumpolar Protected Areas Network : strategy and action plan.* CAFF Habitat Conservation Report No. 6. Directorate for Nature Management. Trondheim. Norway. http://arcticportal.org/

De Poorter, M. (2006, April). Non-native species issues challenges of international approach in the Antarctic context. In *Final report of the "Non-native Species in the Antarctic" Workshop*. Gateway Antarctica, University of Canterbury Christchurch, New Zealand. http://www.anta.canterbury.ac.nz/

Det Norske Veritas. (2006, September 19). *Port reception facilities in the PAME region*. Technical report No. 2006-1517. http://arcticportal.org/

Dodds, K. (2010). *Flag planting and finger pointing : the Law of the Sea, the Arctic and the political geographies of the outer continental shelf*. Political Geography 29 (2010) 63-73. Elsevier. http://www.sciencedirect.com

Donlan, R.M. (2000). Biofilm control in industrial water systems : approaching an old problem in new ways. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Donner, P. (2010). Ballast Water Treatment Ashore Brings More Benefits. In N. Bellefontaine, F. Haag, O. Lindén & J. Matheickal (Eds.), *Emerging Ballast Water Management Systems : Proceedings of the IMO-WMU Research and Development Forum, 26-29 January 2010.* Malmö (Sweden).

Doskoch, Y.Y. (2004, December). The North test site : aspects of environmental monitoring. In the International Atomic Energy Agency's publication, *Nuclear explosions in the USSR : the North test site*. Reference material (version 4). http://www-ns.iaea.org/downloads/rw/waste-safety/north-test-site-final.pdf

Dowdeswell, J. & Hambrey, M. (2002). *The islands of the Arctic*. Cambridge University Press. Cambridge.

Drake, J.M. & Lodge, D.M. (2007, May). *Aquatic Invasions : hull fouling is a risk factor for intercontinental species exchange in aquatic ecosystems* (2007). http://www.vliz.be/imis/imis.php?module=ref&refid=143380

Dupont, J. & Kevorkian, O. (1994). *Effet d'un effluent de station d'épuration sur la survie et l'état physiologique d'Escherichia coli et Salmonella manhattan en eau de mer*. Grand programme qualité et épuration des eaux. http://archimer.ifremer.fr/doc/00041/15208/12536.pdf

Eason, C. (2011, May 20). Arctic appeal. *Lloyd's List*. http://www.lloydslist.com/ll/sector/ship-operations/article370996.ece

Ekenstierna, L. (2003). *Mikrobiologi*. Studentlitteratur. Lund.

Elander, M. & Widstrand, S. (2008, August). *Vindar från Arktis*. Prisma. Stockholm.

European Parliament. (2008, October 9). *Resolution on Arctic governance*. P6_TA(2008)0474. http://www.europarl.europa.eu/

Flemming, H.-C., Wingender, J., Griebe, T. & Mayer, C. (2000). Physico-chemical properties of biofilms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Giltsov, L., Mormoul, N. & Ossipenko, L. (1992). *La dramatique histoire des sous-marins nucléaires soviétiques : des exploits, des échecs et des catastrophes cachées pendant trente ans*. Editions Robert Laffont. Paris.

Glomsrød, S., Mäenpää, I., Lindholt, L., McDonald, H. & Goldsmith, S. (2009, November). Arctic economies within the Arctic nations. In S. Glomsrød & I. Aslaksen (Eds.), *The Economy of the North 2008*. Statistics Norway. http://www.ssb.no/

Gollasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C. & Fukuyo, Y. (2007). *Critical review of the IMO International Convention on the management of ships' ballast water and sediments*. Harmful Algae. Elsevier. http://www.sciencedirect.com/

Granholm, N., Haldén, P., Larsson, R., Lindvall, F., Ljung, B., Neretnicks, K. & Oldberg, I. (2008, January). *Arktis : strategiska frågor i en region i förändring*. Underlagsrapport nr. FOI-R-2469-SE. Totalförsvarets Forskningsinstitut. Stockholm. http://www.foi.se/upload/pdf/Foi-R--2469--SEArktis.pdf

Greensmith, G.J. (2010). Ballast Water Technology Availability : An Update. In N. Bellefontaine, F. Haag, O. Lindén & J. Matheickal (Eds.), *Emerging Ballast Water Management Systems : Proceedings of the IMO-WMU Research and Development Forum, 26-29 January 2010*. Malmö (Sweden).

Hall, C.M., James M. & Wilson, S. (2010). *Biodiversity, biosecurity and cruising in the Arctic and sub-Arctic*. Journal of Heritage Tourism. http://canterbury-nz.academia.edu/CMichaelHall/Papers/249275/Biodiversity_biosecurity_and_cruising_in_the_Arctic_and_sub-Arctic

Hallegraeff, G. (1998, July 9). *Transport of toxic dinoflagellates via ships' ballast water : bioeconomic risk assessment and efficacy of possible ballast water management strategies*. Marine Ecology Progress Series. Volume 168. http://www.int-res.com/articles/meps/168/m168p297.pdf

Hamel, J.-F. & Mercier, A. (2005). Arctic, coastal ecology. In M. Schwartz (Ed.), *Encyclopedia of coastal science*. Springer. Dordrecht. The Netherlands.

Hamilton, W.A. (2000). Microbially influenced corrosion in the context of metal microbe interactions. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Heimdal, B.R. (1989). Arctic Ocean phytoplankton. In Y. Herman, *The Arctic Seas : climatology, oceanography, geology and biology*. Van Nostrand Reinhold. New York.

Holmström, C. & Kjelleberg, S. (2000). Bacterial interactions with marine fouling organisms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Horner, R.A. (1989). Arctic sea-ice biota. In Y. Herman (Ed.), *The Arctic Seas : climatology, oceanography, geology and biology*. Van Nostrand Reinhold. New York.

Intergovernmental Panel on Climate Change. (2005). *Safeguarding the ozone layer and the global climate system: issues related to hydrofluorocarbons and perfluorocarbons*. Summary for policymakers and technical summary. http://www.ipcc.ch/pdf/special-reports/sroc/sroc_full.pdf

Intergovernmental Panel on Climate Change. (2007, November). *Climate change 2007 : synthesis report*. Fourth Assessment Report. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

International Maritime Organization. (1991, July 4). *Resolution MEPC 50(31) : international guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges*. London.

International Maritime Organization. (1993, November 4). *Resolution A. 774(18) : international guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges*. London.

International Maritime Organization. (1997a, June 6). *Guidance on safety aspects of ballast water exchange at sea* (MSC/Circ.806). London.

International Maritime Organization. (1997b, November 27). *Resolution A. 868(20) : guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens*. London.

International Maritime Organization. (1999, June 2). *Report of the Maritime Safety Committee on its 71st session* (MSC 71/23). London. http://docs.imo.org/

International Maritime Organization. (2002, December 23). *Guidelines for ships operating in Arctic ice-covered waters*. (MSC/Circ.1056, MEPC/Circ.399). London. http://docs.imo.org/

International Maritime Organization. (2003a, April 29). *Work programme and budget for the twenty-third financial period 2004-2005, part 2 : proposals by the Secretary-General* (C 90/18). London. http://docs.imo.org/

International Maritime Organization. (2003b, May 23). *Harmful aquatic organisms in ballast water : ballast water background paper by the Intergovernmental Panel on Harmful Algal Blooms*. Edited by Dr. Gustaaf Hallegraeff. Submitted by the International Oceanographic Commission (IOC) of UNESCO (MEPC 49/INF.28). London. http://docs.imo.org/

International Maritime Organization. (2004a, February 12). *International Conference on Ballast Water Management for Ships : opening statement by the Secretary-General* (BWM/CONF/INF.8). London. http://docs.imo.org/

International Maritime Organization. (2004b, February 16). *Adoption of the final act and any instruments, recommendations and resolutions resulting from the work of the Conference : International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*. Text adopted by the Conference (BWM/CONF/36). London. http://docs.imo.org/

International Maritime Organization. (2004c, October 11). *Harmful aquatic organisms in ballast water : legal opinion on transitory non-compliance with SOLAS V/22 when conducting ballast water exchange*. Note by the Secretariat **(**MEPC 52/WP.3). London. http://docs.imo.org/

International Maritime Organization. (2005, July 22). *Report of the Marine Environment Protection Committee on its fifty-third session* (MEPC 53/24/Add.1). London. http://docs.imo.org/

International Maritime Organization. (2006, January 13). *Investigating biofouling risks and management options on commercial vessels.* Submitted by Australia (MEPC 54/INF.5). London. http://docs.imo.org/

International Maritime Organization. (2007a, June 18). *Report to the Maritime Safety Committee and the Marine Environment Protection Committee* (FSI 15/18). London. http://docs.imo.org/

International Maritime Organization. (2007b, July 30). *Report of the Marine Environment Protection Committee on its fifty-sixth session* (MEPC 56/23). London. http://docs.imo.org/

International Maritime Organization. (2008a, April 4). *Report of the Marine Environment Protection Committee on its fifty-seventh session* (MEPC 57/21). London. http://docs.imo.org/

International Maritime Organization. (2008b, June 10). *International Convention for the Control and Management of ships' ballast waters and sediments : methodology for information gathering and conduct of work of the GESAMP-BWWG* **(**BWM.2/Circ.13). London. http://docs.imo.org/

International Maritime Organization. (2008c, August 28). *International Convention for the control and management of ships' ballast water and sediments, 2004. Communication received from the Administration of the United Kingdom on behalf of the contracting parties of the OSPAR and Helsinki Conventions* (BWM.2/Circ.14). London. http://docs.imo.org/

International Maritime Organization. (2008d, October 16). *Report of the Marine Environment Protection Committee on its fifty-eighth session* (MEPC 58/23). London. http://docs.imo.org/

International Maritime Organization. (2009a, June 12). *Report of the Maritime Safety Committee on its eighty-sixth session* (MSC 86/26). London. http://docs.imo.org/

International Maritime Organization. (2009b, July 22). *Development of a mandatory code for ships operating in polar waters. Outcome of the 32nd Antarctic Treaty Consultative Meeting* (ATCM XXXII) (DE 53/18). London. http://docs.imo.org/

International Maritime Organization. (2009c, November 20). *Development of a mandatory code for ships operating in polar waters. Proposed framework for the code for ships operating in polar waters*. Submitted by Canada (DE 53/18/2). London. http://docs.imo.org/

International Maritime Organization. (2009d, November 20). *Proposed mandatory code for ships operating in polar waters. Shipping management issues to be addressed.* Submitted by FOEI, IUCN, Greenpeace, IFAW and WWF (DE 53/18/3). London. http://docs.imo.org/

International Maritime Organization. (2009e, December 2). *Guidelines for ships operating in polar waters* (A 26/Res.1024). London. http://docs.imo.org/

International Maritime Organization. (2010a, January 12). *Environmental aspects of polar shipping*. Submitted by Norway (MEPC 60/21/1). London. http://docs.imo.org/

International Maritime Organization. (2010b, January 15). *Harmful aquatic organisms in ballast water : outbreak of Salmonella in cattle probably due to infection from ballast water*. Submitted by Norway (MEPC 60/INF.15). London. http://docs.imo.org/

International Maritime Organization. (2010c, July 23). *Reduction of GHG emissions from ships : marginal abatement costs and cost-effectiveness of energy-efficiency measures*. Submitted by the Institute of Marine Engineering, Science and Technology (MEPC 61/INF.18). London. http://docs.imo.org/

International Maritime Organization. (2010d, August 20). *Development of a mandatory code for ships operating in polar waters : additional MARPOL provisions for the Polar Code*. Submitted by FOEI, IFAW, WWF, Pacific Environment and CSC (DE 54/13/8). London. http://docs.imo.org/

International Maritime Organization. (2010e, August 20). *Development of a mandatory code for ships operating in polar waters : wider environmental provisions for the polar code*. Submitted by FOEI, IFAW, WWF, Pacific Environment and CSC (DE 54/13/9). London. http://docs.imo.org/

International Maritime Organization. (2010f, August 20). *Development of a mandatory code for ships operating in polar waters. Environmental aspects of emissions and discharges from shipping during regular operation in polar areas.* Submitted by Norway (DE 54/INF.5). London. http://docs.imo.org/

International Maritime Organization. (2010g, December 17). *Development of a mandatory code for ships operating in polar waters. Draft proposal for an environmental protection chapter for inclusion in the Polar Code*. Submitted by Norway (DE 55/12/5). London. http://docs.imo.org/

International Maritime Organization. (2011a, May 6). *Outcome of DE 55 – Legal opinion on making the Polar Code mandatory*. Note by the Secretariat (MEPC 62/11/4/Add.1). London. http://docs.imo.org/

International Maritime Organization. (2011b, July 26). *Report of the Marine Environment Protection Committee on its sixty-second session* (MEPC 62/24/Add.1). London. http://docs.imo.org/

International Maritime Organization. (2011c, September 28). *International Convention for the Control and Management of Ships' Ballast Water and Sediments : accession by Mongolia and Palau* (BWM.1/Circ.20). London. http://docs.imo.org/

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). (1991). *Global strategies for marine environment protection*. Reports and studies No. 45. http://www.gesamp.org/

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). (1997, January). *Opportunistic settlers and the problem of the ctenophore Mnemiopsis leidyi invasion in the Black Sea*. Reports and studies No. 58. http://www.gesamp.org/

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). (2001, January 15). *Protecting the oceans from land-based activities : land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment.* Reports and studies No. 71. http://www.gesamp.org/

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). (2005). *The new GESAMP : science for sustainable oceans*. A strategic vision for the IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. IMO. London. http://www.gesamp.org/data/gesamp/files/media/Publications/GESAMP_The_New_GESAMP__Science_for_Sustainable_Oceans/gallery_1043/object_1043_large.pdf

Kannan, K. & Tanabe, S. (2009). Global contamination by organotin compounds. In T. Arai, H. Harino, M. Ohji & W.J. Langston (Eds.), *Ecotoxicology of antifouling biocides*. Springer. Tokyo.

Koivurova, T. (2009, June). *Governance of protected areas in the Arctic*. Utrecht Law Review. Volume 5, Issue 1. http://www.utrechtlawreview.org/

Koivurova, T. & Molenaar, E.J. (2009, December). *International Governance and Regulation of the Marine Arctic*. WWF International Arctic Programme. Oslo. http://wwf.panda.org/what_we_do/where_we_work/arctic/publications/?193130/New-Arctic-needs-new-rules-WWF

Kosmo, J., Stub, J.L., Høegh, A., Hansen, G.-K. & Frøiland, R. (2007, November 6). *Riksrevisjonens undersøkelse av forvaltningen og kontrollen av fiskeressursene i Barentshavet og Norskehavet : en* *parallell revisjon mellom norsk og russisk riksrevisjon*. http://www.riksrevisjonen.no/SiteCollectionDocuments/Dokumentbasen/Dokument3/2007-2008/Dokument322007_2008s1195.pdf

Kraska, J. (2007). *The Law of the Sea Convention and the Northwest Passage*. The International Journal of Marine and Coastal Law. Vol. 22, No. 2. http://www.marad.dot.gov/documents/ARCTIC_Law_of_the_Sea_Convention_and_NorthWest_Passage.pdf

Kystverket (2004, May). *Utredning av konsekvenser av skipstrafikk i området Lofoten-Barentshavet*. http://www.kystverket.no/arch/_img/9120756.pdf

Lahvis, G.P., Wells, R.S., Kuehl, D.W., Stewart, J.L., Rhinehart, H.L. & Via, C.S. (1995, May). *Decreased lymphocyte responses in free-ranging bottlenose dolphins (Tursiops truncatus) are associated with increased concentrations of PCBs and DDT in peripheral blood*. Environmental Health Perspectives. 103 (Suppl. 4) : 67–72. http://ehp03.niehs.nih.gov/home.action

Langston, W.J., Harino, H. & Pope, N.D. (2009). Behaviour of organotins in the coastal environment. In T. Arai, H. Harino, M. Ohji & W.J. Langston (Eds.), *Ecotoxicology of antifouling biocides*. Springer. Tokyo.

Lewandowski, Z. (2000). Structure and function of biofilms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.

Lindholt, L. & Glomsrød, S. (2009, November). Future production of petroleum in the Arctic under alternative oil prices. In S. Glomsrød & I. Aslaksen (Eds.), *The Economy of the North 2008*. Statistics Norway. http://www.ssb.no/

Mare, C. (2009). *L'Arctique : eldorado polaire menacé cherche désespérément régime de protection juridique*. Annuaire Français de Relations Internationales. Vol. X. Centre Thucydide – Analyse et recherche en relations internationales. http://www.afri-ct.org/IMG/pdf/Article_Mare.pdf

Masters, G. & Norgrove, L. (2010, November). *Climate change and invasive alien species*. CABI. http://195.144.0.240/Uploads/File/CABi%20worldwide/Invasive%20alien%20species%20working%20paper.pdf

Matishov, G., Golubeva, N., Titova, G., Sydnes, A. & Voegele, B. (2004, August). *Global International Waters Assessment : the Barents Sea*. GIWA Regional assessment 11. University of Kalmar on behalf of the UNEP. http://www.unep.org/

Mineur, F., Johnson, M.P., Maggs, C.A. & Stegenga, H. (2007). *Hull-fouling on commercial ships as a vector of macro algal introduction*. Marine Biology. Volume 151. Springer-Verlag. http://fn3dn7gc5p.scholar.serialssolutions.com/

Ministry of Economic Development of the Murmansk region. (2010, August 26). *Socio-economic strategy for the Murmansk region till the year 2025*. The BarentsInfo.org portal. http://www.barentsinfo.org/loader.aspx?id=db2be5c2-8ef4-43da-9b92-3c7a1c08655a

Minton, M.S., Verling, E., Miller, A.W. & Ruiz, G.M. (2005). *Reducing propagule supply and coastal invasions via ships : effects of emerging strategies.* Frontiers in Ecology. The Ecological Society of America. http://www.serc.si.edu/labs/marine_invasions/publications/Minton%20et%20al%202005%20%28Frontiers%29.pdf

Monfort, P., Piclet, G. & Plusquellec, A. (2000). *Listeria innocua and Salmonella panama in estuarine water and seawater : a comparative study*. Water Research, Vol. 34, No. 3. Elsevier Science. http://www.sciencedirect.com/

Monfort, P. (2006). *Microbiologie et coquillages*. IFREMER Concarneau. http://www.ifremer.fr/delcc/pdf/coquillages_microbiologie.pdf

Mora, C. & Sale, P.F. (2011, July 28). *Ongoing global biodiversity loss and the need to move beyond protected areas : a review of the technical and practical shortcomings of protected areas on land and sea*. Marine Ecology Progress Series. Vol. 434. http://www.int-res.com/articles/theme/m434p251.pdf

Murphy, C. & Eason, C. (2011, May 12). China eyes more Arctic business. *Lloyd's List*. http://www.lloydslist.com/ll/sector/ship-operations/article370359.ece

Murray, M.S., Anderson, L., Cherkashov, G., Cuyler, C., Forbes, B., Gascard, J.-C., Haas, C., Schlosser, P., Shaver, G., Shimada, K., Tjernström, M., Walsh, J., Wandell, J. & Zhao, Z. (2010).

International Study of Arctic Change : Science Plan. ISAC International Program Office, Stockholm. http://www.arcticchange.org/
Mäenpää, I. (2009, November). Comparative analysis of Arctic economies at macro level. In S. Glomsrød & I. Aslaksen (Eds.), *The Economy of the North 2008*. Statistics Norway. http://www.ssb.no/english/subjects/00/00/30/sa_economy_north/sa112_en/sa112_en.pdf
Nakayama, A., Segner, H. & Kawai, S. (2009). Immunotoxic effects of organotin compounds in teleost fish. In T. Arai, H. Harino, M. Ohji & W.J. Langston (Eds.), *Ecotoxicology of antifouling biocides*. Springer. Tokyo.
Nilsson, A. E. (2011). *Varmare klimat skärper kampen om Arktis framtid*. Utrikespolitiska institutet. Stockholm.
Parker, B. (2011, September 9). *Northern promise : Russia's Arctic waters return to top of the agenda*. Lloyd's List.
Patin, S. (1999). *Environmental impact of the offshore oil and gas industry*. EcoMonitor Publishing. New York.
Perry, J.J., Staley, J.T. & Lory, S. (2002). *Microbial life*. Sinauer Associates. Sunderland (USA).
Quiniou, C. & Compère, C. (2009). *La chimie et la mer : ensemble au service de l'homme*. EDP Sciences. Les Ulis (France).
Railkin, A.I. (2004). *Marine biofouling : colonization processes and defenses*. CRC Press.
Ramirez-Llodra, E., Tyler, P.A., Baker, M.C., Bergstad, O.A., Clark, M.R., Escobar, E., Levin, L., Menot, L., Rowden, A.A., Smith, C.R. & Van Dover, C.L. (2011, August 1). *Man and the last great wilderness : human impact on the deep sea*. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0022588
Readman, J.W., Van Hattum, B., Barcelo, D., Albanis, T.A., Riemann, B., Blanck, H., Gustavson, K., Tronczynski, J. & Jacobson, A. (2002, 27 June). *Assessment of antifouling agents in coastal environments (ACE) : Final Scientific and Technical Report*. MAS3-CT98-0178. http://www.pml-ace.org.uk/
Rosentrater, L. & Ogden, A.E. (2003, August). Building resilience in Arctic ecosystems. *Buying time : a user's manual for building resistance and resilience to climate change in natural systems*. WWF Climate Change Programme. Berlin. http://assets.panda.org/downloads/buyingtime_unfe.pdf
Safe, S. (1994). *Polychlorinated biphenyls : environmental impact, biochemical and toxic responses, and implications for risk assessment*. Critical Reviews in Toxicology. http://informahealthcare.com/doi/abs/10.3109/10408449409049308
Shirihai, H. (2007). *A complete guide to Antarctic wildlife*. A&C Black Publishers. London.
Skaare, J.U., Larsen, H.J., Lie, E., Bernhoft, A., Derocher, A.E., Norstrom, R., Ropstad, E., Lunn, N.F. & Wiig, Ø. (2002, December 27). *Ecological risk assessment of persistent organic pollutants in the Arctic*. Toxicology. Volumes 181-182. Elsevier. http://www.sciencedirect.com/
Speer, L. & Laughlin, T.L. (2011, April 7). *IUCN/NRDC Workshop to Identify Areas of Ecological and Biological Significance or Vulnerability in the Arctic Marine Environment (La Jolla, California, November 2-4, 2010).* Workshop Report. http://cmsdata.iucn.org/downloads/arctic_workshop_report_2011_2.pdf
Stoeck, T., Kasper, J., Bunge, J., Leslin, C., Ilyin, V. & Epstein, S. (2007, August). *Protistan diversity in the Arctic : a case of paleoclimate shaping modern biodiversity ?* Paleoclimate and biodiversity. Issue 8 e728. http://www.plosone.org/
Stroeve, J., Holland, M. M., Meier, W., Scambos, T. & Serreze, M. (2007, May 1). *Arctic sea ice decline : faster than forecast*. Geophysical Research Letters, Vol. 34. http://www.ualberta.ca/~eec/Stroeve2007.pdf
Suban, V., Vidmar, P. & Perkovic, M. (2010). Ballast Water Replacement with Fresh Water : Why Not ? In N. Bellefontaine, F. Haag, O. Lindén & J. Matheickal (Eds.), *Emerging Ballast Water Management Systems : Proceedings of the IMO-WMU Research and Development Forum, 26-29 January 2010.* Malmö (Sweden).
Sweden's Department of Foreign Affairs. (2011, May 12). *Sveriges strategi för den arktiska regionen*. Utrikesdepartementet. http://www.sweden.gov.se/

Tamelander, J., Riddering, L., Haag, F. & Matheickal, J. (2010). *Guidelines for Development of National Ballast Water Management Strategies*. GEF-UNDP-IMO GloBallast Monographs No. 18. http://globallast.imo.org/Monograph_18_NBWMS_Guidelines_web.pdf

Taube, A. (2010). Microwaves + Ultraviolet + Ozone Ballast Water Treatment. In N. Bellefontaine, F. Haag, O. Lindén & J. Matheickal (Eds.), *Emerging Ballast Water Management Systems : Proceedings of the IMO-WMU Research and Development Forum, 26-29 January 2010*. Malmö (Sweden).

United Nations. (1972, June 16). *Report of the United Nations Conference on the Human Environment*. Stockholm. 5-16 June 1972. (A/CONF.48/14/Rev.1, Annex III). http://documents-dds-ny.un.org/doc/UNDOC/GEN/NL7/300/05/img/NL730005.pdf?OpenElement

United Nations. (1974, December 12). *Charter of Economic Rights and Duties of States*. General Assembly. (A/RES/29/3281). http://www.un-documents.net

United Nations. (1982a, October 28). *World Charter for Nature*. General Assembly. (A/RES/37/7). http://www.un-documents.net

United Nations. (1982b, December 10). *United Nations Convention on the Law of the Sea*. http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm

United Nations. (1992a, May 22). *Convention on Biological Diversity*. http://www.cbd.int/convention/text/

United Nations. (1992b, June 14). *The Rio Declaration on Environment and Development.* http://www.unescap.org/esd/environment/rio20/pages/Download/Rio_Declaration-E.pdf

United Nations. (2001, December 20). *Receipt of the submission made by the Russian Federation to the Commission on the Limits of the Continental Shelf*. CLCS. 01. 2001. http://www.un.org/depts/los/clcs_new/submissions_files/rus01/RUS_CLCS_01_2001_LOS_English.pdf

United Nations. (2006, December 21). *Receipt of the submission made by Norway to the Commission on the Limits of the Continental Shelf*. CLCS. 07. 2006. http://www.un.org/depts/los/clcs_new/submissions_files/nor06/clcs_07_2006_los_e.pdf

United Nations. (2009, April 30). *Receipt of the submission made by the Republic of Iceland to the Commission on the Limits of the Continental Shelf*. CLCS. 27. 2009. http://www.un.org/depts/los/clcs_new/submissions_files/isl27_09/isl_clcs27_2009e.pdf

United Nations. (2010, December 6). *Receipt of the submission made by the Kingdom of Denmark to the Commission on the Limits of the Continental Shelf*. CLCS. 54. 2010. http://www.un.org/depts/los/clcs_new/submissions_files/dnk54_10/clcs54e.pdf

United Nations Environment Programme. (1987). *The Montreal Protocol on Substances that Deplete the Ozone Layer*. http://ozone.unep.org/Ratification_status/montreal_protocol.shtml

United Nations Environment Programme. (2001, May 22). *The Stockholm Convention on Persistent Organic Pollutants.* http://chm.pops.int/Convention/ConventionText/tabid/2232/language/en-US/Default.aspx

United Nations Environment Programme. (2007). *Tourism in the polar regions : the sustainability challenge*. http://www.unep.fr/shared/publications/pdf/DTIx0938xPA-PolarTourismEN.pdf

United Nations Environment Programme. (2010, October). *Global synthesis : a report from the regional seas conventions and action plans for the marine biodiversity assessment and outlook series*. http://marinebiodiversityseries.org/reports/2-global-synthesis-report.html

United States Geological Survey. (2008, May). *Circum-Arctic resource appraisal : estimates of undiscovered oil and gas north of the Arctic Circle*. http://pubs.usgs.gov/fs/2008/3049/

United States National Research Council, Committee on the Bering Sea Ecosystem. (1996). *The Bering Sea Ecosystem*. National Academy Press. Washington.

Vasilyev, K.G., Dubasov, Y.V., Safronov, V.G., Tkachenko, A.F., Filippovsky, V.I. & Chugunov, V.V. (2004, December) Radioactivity of water in the Barents and Kara Seas. In the International Atomic Energy Agency's publication, *Nuclear explosions in the USSR : the North test site*. Reference material (version 4). http://www-ns.iaea.org/downloads/rw/waste-safety/north-test-site-final.pdf

Veldhuis, M., Hallers, C.T., Brutel de La Rivière, E., Fuhr, F., Finke, J., Steehouwer, P.P., Van de Star, I. & Van Sloote, C. (2010). Ballast Water Treatment Systems : "Old" and "New" Ones. In N.

Bellefontaine, F. Haag, O. Lindén & J. Matheickal (Eds.), *Emerging Ballast Water Management Systems : Proceedings of the IMO-WMU Research and Development Forum, 26-29 January 2010.* Malmö (Sweden).

Vidas, D. (2000). Protecting the polar marine environment : interplay of regulatory frameworks. In D. Vidas (Ed.), *Protecting the Polar Marine Environment : law and policy for pollution prevention*. Cambridge University Press.

Volk, W.A., Gebhardt, B.M., Hammarskjöld, M.-L. & Kadner, R. (1996). *Essentials of medical microbiology*. Fifth edition. Lippincott-Raven Publishers. Philadelphia.

Wallentinus, I. & Werner, M. (2008). *Främmande arter i svenska vatten : ska vi bry oss ?* Institutionen för Marin ekologi. Göteborgs universitet. Göteborg.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesank, C., Beebee, T.J.C., Fromentin, J.-M., Hoegh-Guldberg, O. & Bairlein, F. (2002, March 28). *Ecological responses to recent climate change*. Nature. Vol. 416. Macmillan Magazines Ltd. http://eebweb.arizona.edu/courses/Ecol206/Walther%20et%20al%20Nature%202002.pdf

World Organization for Animal Health. (2009). *Manual of Diagnostic Tests for Aquatic Animals.* http://www.oie.int/en/international-standard-setting/aquatic-manual/access-online/

Zinn, M., Zimmerman, R.C. & White, D.C. (2000). Environmentally acceptable control of microbial biofilms. In L.V. Evans (Ed.), *Biofilms : recent advances in their study and control*. Harwood Academic Publishers. Amsterdam.