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GLOBAL APPROACH AND REGIONAL COOPERATION OF BLACK SEA COUNTRIES ON THE PROBLEM OF INVASIVE SPECIES

By

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Ukraine

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

MASTER OF SCIENCE
In
MARITIME AFFAIRS (MSEA)
2012
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.

(Signature): ...........................................
(Date): ........................................

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

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This thesis is dedicated to my father, Vladimir G. Rabotnov, who devoted a great part of his life to the development of the Maritime Industry of Ukraine in general and to the problem of aquatic invasive species in particular. Thank you for the inspiration and personal example.
Abstract

The productivity of water ecosystems plays a significant role in the development of human society. People delimitate oceans and the seas, however, ocean creatures are not familiar with those boundaries exist for them. They freely “travel” all over the world in and on ships, invade new ecosystems and harm them.

Invasive alien species are now globally recognized as one of the biggest problems in shipping, which impacts environment, social economics and human health. Due to the international nature of shipping, it is positively to eliminate the problem of invasive species, but only to find the most efficient ways of controlling the situation. Efficient control is impossible at the national level only, that is why the co-operation at the international level is so important here. Therefore, the International Convention for the Control and Management of Ships’ Ballast Water and Sediments (Ballast Water Management Convention) was adopted in 2004 and is expected to enter into force in the nearest future. It still causes a lot of discussions from the stakeholders.

The Black Sea is a very vulnerable water ecosystem due to its nature, and it suffered big losses a lot by the invasive alien species, especially last in two decades.

The purpose of this dissertation is to study the current state of the problem of Aquatic Invasive Species in the Black Sea Region, and to assess the effectiveness of cooperation in the region. During the research, some major challenges were identified, and some recommendations were given as per more effective actions towards the solution of the problem.

**Keywords:** Shipping, Alien species, Black Sea, Ballast water, Bio-fouling, Ballast Water Management Convention.
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LIST OF ABBREVIATIONS

AFS Anti-fouling System
AIS Aquatic Invasive Species
BS SAP Black Sea Strategic Action Plan
BS TDA Black Sea Transboundary Diagnostic Analysis
BSC Commission on the Protection of the Black Sea against Pollution
BSEC Black Sea Economic Cooperation organization
BWE Ballast Water Exchange
BWM Ballast Water Management
BWMS Ballast Water Management System
BWT Ballast Water Treatment
CBD Convention on Biological Diversity
EU European Union
GEF Global Environmental Facility
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
IMO International Maritime Organization
IOS Internal Oversight Service
LME Large Marine Ecosystem
MARPOL International Convention for the Prevention of Pollution from Ships
MEPC Marine Environment Protection Committee
MSC Maritime Safety Committee
NGOs Nongovernmental organizations
NIS Non-indigenous Species
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
UNEP  United Nations Environment Programme
UNESCO  United Nations Organization for Education, Science and Culture
UV  Ultraviolet
WSSD  World Summit on Sustainable Development
1. Introduction

1.1. General remarks

About two thirds of the surface of the Earth is covered with water such as oceans, seas, rivers and estuaries, which involve many kinds of ecosystems. The productivity of these ecosystems plays a significant role in the development of human society, especially those settled along coastal areas. Currently, about a half of the world’s population live within 200 kilometres of a coast line (Creel, 2003). However, not only human beings, but billions of species of the water creatures – animals, plants and algae – are dependent on water ecosystems, as it is the only option for their living, feeding, and reproduction.

People delimitate oceans and the seas in accordance with their political agreements and each country knows and protects its boundaries; however, ocean creatures are not familiar with those agreements and no boundaries exist for them. They “travel” freely, without documents and stay in new ecosystems without residence permits. Definitely most of the species do not want to leave voluntarily their regular habitats, where they are being a part of a toolled food chain, with perfect temperature, salinity and other conditions. Unfortunately, in most cases species are transported by people, either intentionally or not.

Over 90% of the world trade is done by means of the maritime transport (IMO, 2008a) as it is the cheapest way of transporting goods in big amounts on long distances. Year after year, speeds are increasing and the shipping industry is growing rapidly in size. Since times when shipping became international, so-called unwanted stowaways started the history of their voyaging all over the world on ships’ hulls and in ballast waters. Shipping is now agreed to be the predominant vector of transporting alien species around the world. Even though this problem has existed for centuries already,
the public awareness was raised only in the 1970s, when the scientific community started reviewing this issue in details.

Invasive alien species are now recognized as one of four major problems in shipping. Impacts have different levels and aspects, such as environmental aspect, including losses of indigenous biodiversity in ecosystems, and decreased habitat availability for indigenous species, socio-economic aspect, including huge material losses and threat to human health due to parasites and disease.

As far as international shipping exists, it is positively impossible to eliminate the problem of invasive species; the only aim today is to find the most efficient ways of controlling the situation. However, efficient control is definitely impossible at the national level only, as most water bodies are surrounded by at least few countries and “aliens” are not aware about the borders. The co-operation at the international and even global level is absolutely important here.

The International Maritime Organization took the responsibility to build an efficient international legal framework and help member states to develop regional and national policies. During last 40 years a significant progress has been achieved in this matter; however, the problem still exists and remains one of the biggest threats to global oceans.

Shipping is probably the most international industry in the world and the approach to the problem should be international and should involve more actors.

1.2. Key actors

There are three major international actors, involved in co-operation on solving the problem of invasive alien species, as shown in Figure 1:
The International Maritime Organization (IMO) – is the United Nations specialized agency, established in 1948 in Geneva as a permanent international body for more effective promotion of maritime safety and security of shipping and the prevention of marine pollution by ships. The IMO Convention entered into force in 1958 and the first Organization meeting was held following year. The purpose of the IMO, according to the Convention, is "to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships".

The Global Ballast Water Management Programme (GloBallast) was established in 2000 by joined forces of Global Environmental Facility (GEF), the United Nations Development Programme (UNDP) and International Maritime Organization (IMO) to assist developing countries to:

- reduce the transfer of harmful aquatic organisms and pathogens in ships' ballast water,
- implement the IMO ballast water Guidelines,
- prepare for the new IMO ballast water Convention.

The Commission on the Protection of the Black Sea against Pollution (the Black Sea Commission or BSC) was established by Black Sea countries with the purpose of implementing the provisions of the Convention on the Protection of the Black Sea against Pollution and Protocol and the Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (latest version adopted in 2009). Main challenges of the Commission are stated as:

- Combating Pollution from land-based sources and maritime transport,
- Achieving sustainable management of marine living resources,
- Pursuing sustainable human development.

1.3. Aim and methodology

The purpose of this dissertation is to study the current state of the problem of Aquatic Invasive Species in the Black Sea and to assess the effectiveness of the cooperation of Black Sea states regarding this problem, analyse the mechanism in which regional cooperation and national response are driven by international regulations, as shown in Figure 2.
This aim will be achieved by studying basic methods of controlling the problem of invasive species in the Black Sea together with effectiveness of the international and regional regulations in solving the problem, as shown in Figure 3.

Figure 3 Schematic of the chosen methodology
2. Basic understanding of the problem of invasive alien species

2.1. Vectors of the invasive species transfer

As long as the international shipping exists, it has been a predominant vector of transporting marine and terrestrial nonindigenous species around the globe. Commencing at least by the fifteenth century, nonindigenous species were unintentionally transferred all over the world in holes of wooden vessels, by hull fouling, with solid ballast, such as rocks and sand, with cargo, deck and bilge debris. However already archaeological records show that Vikings, probably for food, brought home with them species of the large North American clam. (Poorter, 2010) Many of these invaders, as well as a wide range of their commensal and parasitic associates, were only discovered in the twentieth century. For example, one likely solid-ballast introduction, the Southern Hemisphere littoral amphipod *Transorchestia engimatica*, was discovered in San Francisco Bay in 1962. However it was possibly introduced there in the nineteenth century. (Ruiz, 2003)

It is hard to say, when exactly the transition from solid to liquid ballast happened as at the ballast water was used experimentally as early as the mid-nineteenth century and some cargo ships using dry ballast, persisted into the twentieth century. Although since the time when steel hulled vessels were introduced, long-range ships started using ballast water, instead of ballast rocks for stability.

For each species associated with shipping, one or more sub-vectors are considered as possible mechanisms for transfer as follows:

**Hull fouling - for species with:**

(a) sessile or sedentary life stages

(b) eggs, spores and cysts attached to hard substrates
Dry ballast - for species that:
(a) likely colonized before 1900
(b) occur in the intertidal or super-littoral zone (i.e., relatively high on shore)
(c) can tolerate prolonged periods in damp environments out of water.

Ballast water - for species that colonized after 1900 and met one of the following criteria:
(a) occur commonly in the water column as post-larval stages
(b) occur in the water column as larval stages with relatively long duration (more than 5 days)
(c) small surface-dwelling organisms that may be re-suspended and entrained during ship operations.

Cargo or packing materials - for species:
(a) associated with particular commodities (or packing materials)
(b) tolerant of long periods of air exposure.

Ballast water has received much attention as a vector since the late 1980s, in contrast to hull fouling, which became a less important vector of invasive species transferring, mostly because of the following reasons: (Ruiz, 2003)

1) Extremely effective antifouling paints are being widely used over the twenty century;
2) The average time of each voyage have been decreased rapidly and thus there is less time for organisms to colonize ships;
3) The average speed of each vessel has considerably increased, which made sheer forces increase proportionally so fewer organisms remain on hull during the voyage.
On the other hand, it is fallacious to exclude bio-fouling as an important vector of transferring nonindigenous species. As this problem have not been paid much attention to recent years and the amount of fouling communities on most oceangoing vessels has not been well characterized, some species keep appearing in certain regions and the hull fouling is the most likely vector for them.

2.2. Basic physiology of marine organisms

As all marine organisms need sources of energy, they are linked by the feeding relationship. The basis of the marine food chain is phytoplankton; its livelihood is supported by the photosynthesis:

\[ \text{CO}_2 + \text{water} + \text{sunlight} \rightarrow \text{plant tissue} + \text{oxygen} \]

Because of the need for sunlight, the phytoplankton could exist only on the water surface. Marine organisms need energy and carbon for their vital activity. By the type of metabolism, organisms could be classified as it described in Figure 4:
Photoautotroph is an organism, typically a plant, that obtains energy from the sunlight to convert inorganic materials into organic materials for biosynthesis and respiration. For example, algae (kelp), protists (euglena), bacteria (cyanobacteria). (Campbell, 2008)

Chemoautotroph is an organism that uses oxidation of inorganic compounds to generate energy. For example, oxidation of reduced sulfur compounds to sulfuric acid in Thiobacillus.

Photoheterotroph is an organism that is capable of synthesizing its own food from inorganic compounds using light as an energy source. Green plants and photosynthetic bacteria are photoautotrophs.

Chemoheterotroph is an organism that obtains its energy from the oxidation of organic compounds, for example, fungi. (Abedon, 1997)

Marine organisms could also be divided by their size in macro-organisms, which can be
seen with the naked eye, and micro-organisms, which could be seen only using the microscope.

Macro-algae, molluscs, crustaceans are all examples of macro-organisms.

Micro-organisms could be divided into eukaryotes and prokaryotes. Prokaryotes are organisms without a cell nucleus (karyon), such as bacteria and viruses. Eukaryotes are the organism whose cells contain complex structures enclosed within membranes, such as micro-fungi, micro-algae and protozoa. (Nelson, 2005)

In accordance to their migratory needs, some marine species could be diadromous, which is a general category for species that spent some portions of their lifetime partially in fresh water and partially in salt water. Diadromous species are either anadromous or catadromous. Anadromous (salmon, smelt) spend most of their life cycles in the sea water and migrate to fresh water to breed. Catadromous species (most eels) spend most of their lives in fresh water and migrate to the sea to spawn. (Myers, 1949)

Also some organisms - eurytopic species - are capable of living under extremely varying conditions, such as salinities, varying from close to 0 to very high figures (euryhaline species) and temperature, ranging from freezing to well above normal ambient (eurythermal species). (Prokhorov, 1973)

Despite dramatically variable environmental conditions, a number of species can survive and travel long distances in ballast water tanks and as fouling on the surface of ships hulls and to go through the whole transferring and establishment process, which is described in Figure 5.
2.3. Classification of invasive alien species

Depending on the life history, different conditions tolerance and reproduction strategy we can classify species according to their potential for surviving in ballast water tanks of ships or on hulls of ships and become invasive in new environments.

Adult characteristics influence the aptitude for different types of oceangoing transport. They could be classified by the following categories: (Ruiz, 2003)

1. **Sessile species** are attached to hard surfaces, with little or no adult movement and are mostly associated with hulls of ships. Examples of sessile species are sponges, anemones, serpulid and spirorbid tubeworms, hydroids, and mussels.

2. **Sedentary species** are dwelling in tubes or burrows in wood, but also capable of occasional movement outside of tubes or burrows. Examples include *spionid polychaetes* wood-boring and tube-dwelling crustaceans, and their protozoan and crustacean associates.
3. *Mobile species* are capable of actively moving or staying in suspension in water, or actively moving in or on sediment. Mobile species could be subcategorized as following:

- **Holoplanktonic organisms** occur predominantly in the water column and are readily transported in ballast water. There is a low probability for them to be carried by other shipping sub-vectors. Examples: planktonic diatoms, planktonic copepods, cladocerance, and mysids.

- **Epibenthic organisms** live on the surface of hard or soft substrates and occasionally in the water column. Some of them, such as prosobranch gastropods, most opisthobranch gastropods, gobiid fishes, attach eggs or egg masses to hard substrates. Others, like free-living epibenthic polychaetes, free-living amphipods, isopods, decapods, and some fishes, do not attach eggs to hard substrates.

- **Infauna** organisms burrow in soft sediments. Examples include many foraminiferans, annelids, bivalves, and crustaceans.

- **Intertidal** organisms have some tolerance to air exposure and desiccation, which means they could be carried by the dry ballast. Examples include littoral snails (*Littorina littorea*, *Myosotella myositis*), upper intertidal amphipods and isopods (*Transorchesteria engimatica* and *Ligia exotica*, respectively), and crabs (*Carcinus maenas*, *Hemigrapsus sanguineus*).

- **Intertidal-supratidal** organisms have some life stages that are essentially terrestrial. They have a great tolerance to air exposure and desiccation and also could be easily transferred by the dry ballast. Examples include terrestrial insects with aquatic larvae, and a semi-terrestrial crab (*Platchirograpsus spectabilis*).

The whole life history of the species is supposed to be considered regarding possible modes of transportation, as they might be transferred both in their larval and adult forms. The duration of planktonic larval stages of different organisms vary. Organisms in their plankton stage categories could be classified as in the following (Ruiz, 2003):
- **None.** Species that have direct development and little or no active swimming;
- **Short larval duration (0–5 days).** Species that have short-duration larval periods are primarily lecithotrophic larvae;
- **Long larval duration (more than 5 days).** Species that have long-duration larval periods are primarily planktonic larvae;
- **Sporadic (occasional swimming).** These species, mostly peracarid crustaceans (amphipods and isopods), have direct development, but may swim and even swarm. Many of these species swarm in the plankton at night or during reproductive periods;
- **Holoplanktonic.** Organisms that occur predominantly or frequently in the water column, as larval and adult forms (some of the categories above are included here as well);
- **Unknown.** Species or taxonomic groups for which insufficient information existed to characterize planktonic life stages.

In addition, there are some other characteristics that could possibly affect the potential for transfer by the different shipping sub-vectors. Those, which are directly related to the organisms, are (Ruiz, 2003):

- **Mobility and size.** Nektonic species and large, mobile epibenthic species (benthic fishes, shrimps, swimming crabs) are most likely transferred in ballast tanks of ships. Small species that live at or near the sediment surface (oligochaetes, certain molluscs, foraminifera) could be held in the water column (“tychoplankton”) by turbulence, caused by a ship’s propellers or by wave force, and taken up in ballast water. These species may also be transferred by solid ballast, oysters or aquatic plant shipment.
- **Salinity tolerance.** Most epibiotic species found at low salinities of fresh water cannot be transported across oceans on hulls of ships as they cannot survive long exposure to seawater in a ship’s fouling community. Such species are more likely transported either in ballast water, solid ballast or cargo.
Tolerance to air exposure. Species found in the upper intertidal zone, in or on sediment and stones, are potentially transported in solid ballast. Nonindigenous invertebrates such as snails, and insects, have been found in discarded packing material.

2.4. Ecological and socio-economic impacts

One way or another, human activities, aimed at increasing the economic productivity and profit, have caused the introduction of invasive species. Aliens are actually affecting a number of industries such as fisheries, human health, drinking water, tourism, to name a few. The relationship between ecosystems and economics is significant and it is necessary to realize it in sake of both the safeguard of ecosystems and economies. (Ciruna, 2004)

Ecological impact

The ecological impact of nonindigenous alien species includes loss of native biodiversity due to competing with local organisms through, for example, decreasing habitat availability, predation, hybridization, parasitism, competition for resources and causing genetic dilution (Tamander, 2010). The ecological impact of invasive nonindigenous species on ecosystems vary significantly depending on the type of organisms, the degree of the invasion and the vulnerability of the ecosystem that have incurred the invasion.

Generally, effects of invasive alien species could overall be classified into the following categories:

1. Alteration of hydrologic regime
2. Alteration of water chemistry regime
3. Alteration of physical habitat and habitat connectivity
4. Biological community impacts
5. Species population impacts
6. Genetic impacts
7. Alteration of ecosystem structure and processes (e.g. energy flow or food web structure)

Invasive alien species can cause the degradation or loss of biodiversity through all levels of biological organization, from genetic and population levels to the species, community and ecosystem levels. They may change the community structure and natural processes occurring in ecosystem such as nutrients cycling, energy flow, and hydrodynamic properties of a particular ecosystem, such as water quality and oxygen level. In turn, it impacts the fishing and the shipping industries.

The impact can vary in terms of the time passed between initial introductions and following spread of organisms, the seriousness of the impact, the probability of interactions with other threatening processes such as water and surrounding land use, fisheries management, which may reduce the resistance of the ecosystem to invasion, and the potential impulse for new effects spanning the whole ecosystem. It may also involve significant changes to water quality, physical habitat, essential resources and ecological processes. (McNeely, 2001)

Besides the ecology, invasive alien species also impact human health and wellbeing through the spreading of parasites and viruses, \textit{(vibrio cholerae)}, toxic phytoplankton and harmful algal blooms. All that in turn jeopardizes human health causes epidemics and affects the recreational opportunities.

\textit{Socio-economic impact}

The definition of invasive alien species under the Convention on Biological Diversity is based on their impact upon biodiversity, not economics. However, the cost of impact on biodiversity itself is being assessed quite rarely. Occasionally, considerable economic benefits also arise from the use of non-native species, which means that they could even make their contribution in getting economical profit from the utilization of the
ecosystem. Because of such a variety of ecological and socio-economic impacts of invasive organisms on every ecosystem, the assessment of the cost of their impact in the context of the Convention on Biodiversity is a complex task. It should consider the vulnerability of the particular ecosystem; interests of all the stakeholders and all possible risks and benefits should be taken into account and properly weighted. The main challenge is to understand clearly which non-native organisms should be considered as invasive to minimize their harmful impact on the sustainable use of the particular ecosystem. It makes the analysis even more challenging if the consideration of the impact of particular species indicates both socio-economic benefits and threat to the biodiversity of the ecosystem.

In fact, the socio-economic impacts of invasive alien species fall into two broad categories: market impact and non-markets impact. (Ciruna, 2004)

**Market impact** implies changes in productivity of commodities sold within the marketplace. For instance, these changes could lead to losses in fisheries and aquaculture production, decreases in the availability and accessibility of water for industries, changes in the navigability of inland waters and declines in property values. One of the most significant indicators of the **market impact** of alien species invasion is a change of market prices. (Halstead, 2003)

**Non-market impact** due to invasive alien species includes potential due to (Ciruna, 2004):

- Illness and premature deaths
- Declines in social capital due to the loss of ecosystem. Mostly impacts countries that are already weak in social capital.
- Increased transaction costs incurred in the process of caring out an activity, such as lawyers’ fees, personnel time, costs for meetings, etc.

Inasmuch as non-market impact has no clear market price, the potential impact requires careful study and surveying that may require more resources, such as time and money,
which are not always feasible. However, the potential impact of introducing invasive species should be considered even in those cases where they are not quantifiable.

Obviously, when the State is able to manage its ecosystems properly with regard to nonindigenous species, it also contributes to sustaining its biodiversity, and human health, so it is easier to support the production and trading on overseas markets. The economic cost of solving the impact of invasive hazardous organisms provides substantial justification for improving the management, which would also have benefits in reducing impacts upon biodiversity, where they occur. All humans depend on the ecosystems they live in for their livelihood, but they all affected differently depending on where they live, the sources of their food, range of control and eradication strategies available. Both positive and negative impacts due to alien species invasions in ecosystems can be inequitable. Some ecosystems are more vulnerable to invasions than others depending on how much the existence of habitats of the ecosystem is disturbed and how much losses could occur as a result. The impact varies for different sectors of society. For instance, lower income brackets may suffer more than those at higher income level (Shogren, 2000). Moreover, the control or eradication of nonindigenous species does not always benefit all stakeholders; equally in some cases it serves only small sectors of society. Therefore, governments should research the impact of AIS on different social groups, and their ability to adapt to, mitigate or benefit from it. The most efficient allocation of resources for its management should also be considered.

Finally, both the long-term and the short-term impacts should be considered, as if a strategy benefits to the current society but imposes large losses on future generations, it could not be implemented in terms of sustainable development.
3. Global approach to the problem of aquatic invasive alien species

6.1. International response

According to the International Chamber of Shipping Secretary-General, Peter Hinchliffe, “a global industry requires global rules.” The growing understanding of the harmful impact of invasive species has got a wide international response in form of legal instruments, international programmes and technical solutions.

Relevant instruments

The United Nations Law of the Sea Convention (UNCLOS) was adopted in 1982 and entered into force in 1994. Many of UNCLOS provisions regarding the protection of the marine environment and cooperation are generally regarded as customary international law on the matter. It contains a number of provisions relevant to both State rights and obligations to prevent the spread of harmful organisms and pathogens through ballast water.

State Obligations under UNCLOS to take action to protect the marine environment (Part XII)

States have a duty to protect and preserve the marine environment (Art. 192). This includes the duty to prevent, reduce and control pollution of the marine environment and to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life from all sources of pollution (Art. 194(1) to (5)). This obligation extends further to include the protection of the environment of other States. Furthermore, Article 194 adds more to the State obligations to prevent reduce and control pollution of the marine environment.

In addition to the obligations above, UNCLOS obligates States for the responsibility of the consequences of using technologies or introducing of alien or new species. In this
States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or 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.” This obligation is not limited to identified pests or harmful organisms but also includes the broader issue of the introduction of non-indigenous or alien species that may cause significant changes in a marine ecosystem.

While the above provisions highlight the States’ obligations to promptly adopt the preventive measures, UNCLOS goes further to impose liability on the States for polluting the environment. In this respect, Article 235 stipulates, that States “… are responsible for the fulfilment of their international obligations concerning the protection and preservation of the marine environment. They shall be liable in accordance with international law.”, “… shall ensure that recourse is available in accordance with their legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the marine environment by natural or juridical persons under their jurisdiction” and “… shall cooperate in the implementation of existing international law and the further development of international law relating to responsibility and liability for the assessment of and compensation for damage and the settlement of related disputes.”

Under UNCLOS, States also have correlative rights to take action to protect the marine environment in all waters where the State either has sovereignty or exercises some level of jurisdiction. The regime governing enforcement rights is primarily under Part XII of the UNCLOS. These rights are very complex and depend on a range of factors including the restrictions, placed upon the right to inspect and detain ships to institute proceedings and impose penalties (Arts. 220, 226-232).
The Rio Declaration on Environment and Development is a Programme of Action for Sustainable Development, which was endorsed by the international community at the 1992 United Nations Conference on Environment and Development. It includes 27 key principles supported by all States attending the Conference as a providing guidance for the future development of national and international law, decision making and actions in order to achieve both socio-economic development and environmental protection—two goals that were seen as, ultimately, inseparable. Among the better known of the 27 principles are:

- The precautionary approach to decisions that may affect the environment;

- The polluter pays principle (internalization of costs and use of economic instruments);

and,

- The need for environmental impact assessment.

Agenda 21 is a comprehensive global management plan to achieve sustainable development in the 21st Century. Accordingly, it is not binding per se as a legal instrument of international law; however its influence on subsequent legal and institutional development at all levels and in all sectors has been substantial. The document covers almost all sectors of human activity and environmental interaction. It identifies fragmented or sectorized governmental decision making as one of the main problems impeding the ability of countries to achieve sustainable development.

Chapter 17 of Agenda 21 deals with the protection, rational use and development of oceans and their living resources. According to this Chapter, Coastal States should protect marine biodiversity and habitats and conduct surveys, gather and disseminate data, identify fragile areas or areas in need of special protection and carry out environmental impact assessments.
It also contains a provision directly related to States’ international, regional and national commitments to develop international rules governing ballast water discharge to prevent the spread of non-indigenous organisms.

*The 1992 Convention on Biological Diversity (CBD) was adopted along with Agenda 21* and came into force several years later. By September 2001, 191 States have declared themselves bound by its provisions. The CBD sets out States’ obligations to protect biological diversity, which includes marine biodiversity. Article 8 of the CBD states that each Party should “… Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species”.

The Convention obliges States to prevent both the export and the import of alien species and pathogens in ships’ ballast water. Through its decision IV/1 C, entitled "Alien species that threaten ecosystems, habitats or species", the Conference of the Parties requested the Subsidiary Body on Scientific, Technical and Technological Advice to develop guiding principles for the prevention, introduction and mitigation of impacts of alien species. Pursuant to that request, the Subsidiary Body, at its fourth meeting, held in Montreal in June 1999, adopted recommendation IV/4, in which it requested the Executive Secretary, inter alia, to develop, in cooperation with the Global Invasive Species Programme (GISP), principles for the prevention, introduction and mitigation of impacts of alien species and the draft IUCN Guidelines for the Prevention of Biological Diversity Loss Due to Biological Invasions. The draft principles have been classified into four categories: a general category, which constitutes an introductory chapeau to more specific principles; and three categories reflecting the aspects of the alien species such as prevention, introduction and mitigation of impacts (UNEP, 1999).

*World Summit on Sustainable Development (WSSD) was held in Johannesburg, South Africa in August-September 2002 and is also known as Rio +10. The Johannesburg Action Plan was presented there and the Political Declaration was adopted. The section*
of the Declaration on protection and management of the natural resources based on economic and social development stated: “Enhance maritime safety and protection of the marine environment from pollution by actions at all levels to ... accelerate the development of measures to address invasive alien species in ballast water. Urge the International Maritime Organization to finalize its draft International Convention on the Control and Management of Ships Ballast Water and Sediments.”

United Nations Conference on Sustainable Development also known as “Rio+20” took place in Rio de Janeiro, Brazil in June 2012 – twenty years after the landmark 1992 Earth Summit in Rio. At the Rio+20 Conference, world leaders, along with thousands of participants from the private sector, NGOs and other groups, came together to find the solution on how to reduce poverty, advance social equity and ensure environmental protection on an ever more crowded planet (UN, 2012). Two major issues were discussed there:

1) How to build a green economy to achieve sustainable development and lift people out of poverty;

2) How to improve international coordination for sustainable development.

As a result of the Rio + 20 Conference parties agreed to pledge more than $513 billion for building a sustainable future.

The proposal of Strengthen the legal Framework to Effectively Address Aquatic Invasive Species, stated at the Conference, has its primary objective as follows: Actions to reduce stressors and maintain or restore the structure and function of marine ecosystem for equitable and sustainable use of marine resources and ecosystems (Objective 1) and secondary objectives: Actions that support the Blue-Green Economy (Objective 2), Actions leading to Policy, Legal and Institutional Reforms for effective Ocean Governance (Objective 3) and Actions supporting marine research, monitoring and evaluation, technology and capacity transfer as a
mean for improving knowledge, addressing emerging issues, developing capacities in support of sustainable use of the ocean (Objective 4).

It was stated that 80% of the world’s 232 marine eco-regions reported the presence of invasive species, which is the second worst cause of biodiversity loss after coral reefs and mangroves loss and degradation.

The main objectives to the proposal in reference to Objective 1 are to:

1. Accelerate global efforts to bring the Ballast Water and Sediments Management Convention into force;
2. Continue the efforts to implement the voluntary guidelines on hull fouling and, based on lessons learned, invite the IMO to explore the possibility of progressing towards a more effective instrument to address the issue;
3. Identify on-going threats including species and pathways and prevent movement and utilization of potentially invasive species into specific areas of ecological importance without proper risk assessment and management;
4. Work with the industry to facilitate the development of mechanisms for compliance with regulatory measures;
5. Develop and promote the use of market instruments to control and manage invasive species transfer;
6. Increase scientific knowledge of aquatic invasive species, and improve its availability and dissemination;

As the result of the Conference, it is expected to decline the introduction of new invasive species and reduce the adverse impacts from existing species through technology innovation, coordinated global monitoring and enforcement and effective
international, regional and national responses (IOS/UNESCO, 2011).

3.2. IMO and international regulations

**Ballast Water Management Convention**

As a result of UN Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, IMO, as the United Nations specialized agency was called to solve the problem by means of considering the possibilities of developing an internationally binding instrument to address the transfer of harmful aquatic organisms and pathogens in ballast water. Following this negotiations, the Ballast Water Working Group, established by MEPC in 1994, has focused its efforts on the preparation of a free-standing Convention on control and management of ballast waters and sediments.

The introduction of harmful aquatic organisms and pathogens to new environments had been identified as one of the four greatest threats to the oceans together with land sourced marine pollution, over exploration of living marine recourses and destruction of habitat.

In 2002 the World Summit on Sustainable Development held in Johannesburg, called all levels of marine related structures for actions towards the development of measures to protect the oceans from harmful aquatic invasive species in ballast water.

In February 2004 the International Conference on Ballast Water Management for Ships, held in London and member states, agreed on the text of the International Convention for the Control and Management of Ships’ Ballast Water and Sediments (Ballast Water Management Convention), which was adopted together with four conference resolutions. Basically the BWM Convention is the guidelines on how clean ballast water should be with the clear instruction on deep sea ballast water exchange methods. It also stated the need for a ballast water management plan and a record book.
According to the Convention, ballast water management could be achieved through three basic methods:

- ballast water exchange (BWE)
- ballast water treatment (BWT)
- ballast water discharge to a reception facility

**Ballast Water Exchange.** According to the Regulation B-4, the vessel that is applying ballast water exchange, should “…whenever possible, conduct such Ballast Water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth…” or, when it is not possible, should conduct it “…as far from the nearest land as possible, … at least 50 nautical miles from the nearest land and in water at least 200 metres in depth.”

Ballast water exchange can be done by way of three approved exchange methods (IMO, 2005):

- Sequential method: when ballast tanks are first emptied and then refilled.
- Flow-through method: when pumped water passes through tanks and comes out through the overflow onto the deck.
- Dilution method: when ballast tanks are filled with a certain volume of water and simultaneously discharged of the same volume through the bottom.

The Regulation D-1 requires exchanging at least 95% of the ballast water or, in case of pumping-through method application, to pump through the volume of water at least three times or less if 95% efficiency is achieved.

**Ballast Water Treatment.** According to the Regulation B-3, eventually all ships will be required to use an approved ballast water “treatment system”. This regulation was included into the Convention with the purpose to set a goal for manufacturers and to
intensify the investments. Since the time of publication of the Convention, the number of viable treatment systems has rapidly grown: in addition to 28 already approved, 3 more BWMS granted final approval, and 5 more BWMS granted basic approval on 64th session of MEPC, held in London 1-5 October 2012 (ABS, 2012). This has been achieved by the commitment of the manufactures and researchers (Greensmith, 2010).

Regulation D-4 states the Standards for Prototype Ballast Water Treatment Technologies. (IMO, 2005)

According to the Guidelines for ballast water reception facilities (G5), Ballast water reception facilities “should provide pipelines, manifolds, reducers, equipment and other resources to enable … all ships wishing to discharge ballast water in a port to use the facility” and “… should be capable of receiving ballast water from ships so as not to create a risk to the environment, human health, property and resources arising from the release to the environment of Harmful Aquatic Organisms and Pathogens.” (IMO, 2006)

To date the BWM Convention has not yet entered into force. To enter into force, the Convention is supposed to be ratified by 30 member States representing 35% of the world merchant fleet (Article 18). There has been much speculation that the 35% target will be reached in 2012, but despite the predictions, by the date 36 member States representing 29.07% of the world fleet have ratified it (ABS, 2012).

What takes the Convention so long to be ratified even in terms when the whole world takes a sustainable course of going forward and the problem of invasive alien species is agreed to be one of the worst ocean threats?

First of all, it needs the required systems to be created and approved, not only for the sake of shipowners’ confidence, but also to allow some member States to ratify the Convention. As it stated in Article 4 paragraph 1 of the Convention (IMO, 2004), “… Each Party shall require that ships to which this Convention applies and which are entitled to fly its flag or operating under its authority comply with the requirements set forth in this Convention, including the applicable standards and requirements in the
Annex, and shall take effective measures to ensure that those ships comply with those requirements.” Nevertheless, some States in their turn insist on impossibility of bringing the instrument into force without an available system that could allow the owners to obey it.

Another stumbling block is that tests, approved by IMO, do not reflect operations in fresh or very cold water; however, shipowners will still be responsible if the system they have selected fails to meet the standards of the Convention when a ballast water sample is inspected for compliance (Eason, 2012).

At the time when the Convention will come in force, thousands of ships will need to install a ballast water treatment system the ship has to certify, and also many systems will require dry-docking. However, some shipowners fear the installation according to the IMO schedule.

On MEPC 64th session 1 – 5 October 2012, the issue of harmful invasive aquatic organisms was one of the most discussed topics. During the session, following were outlined as major challenges affecting ratification and implementation of BWM Convention (“BWM discussed on MEPC 64”, 2012):

1) Need for revision the Guidelines for approval of ballast water management system (G8) with the purpose of improving the transparency and ensure appropriate robustness of ballast water management systems;

As shipowners are required to invest big amounts of money in new treatment systems (between one and five million dollars per ship (“BWC: ICS welcomes”, 2012), which are still considered as seriously flawed, a number of suggestions regarding water testing, assessing the temperatures effect on the treatment process and other points of the G8 were made on the session (“IMO MEPC 64 concluded”, 2012). Many states accept shipowners’ arguments about a difficulty of such a modification within two or three years after the Convention enters into force. MEPC refused to open the existing type approval guidelines (G8) for revision, which, in

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opinion of ICS, will make it harder for governments that have not yet ratified the Convention to do so or for shipowners to invest in such an equipment.

2) Availability of ballast water management systems and sufficient installing facilities;

Regarding this matter, it was agreed to make the process of implementation smoother by providing greater transparency and expand on the information that would be supplied with the type approval documentation, including detailed provision of actual limitation of the BWMS. With this purpose the assembly agreed to develop an IMO Resolution for adopting in 2013 (“BWM discussed”, 2012).

3) Survey and certification requirements for ships constructed prior to entry into force of the BWM Convention;

It was agreed to issue a circular with challenges outlined by the class societies to bring them to the attention of flag- and port state authorities to make sure ship operators who comply with this solution are not being inappropriately penalized (“BWM discussed”, 2012). It was also proposed by ICS that all ships constructed prior to entry into force of the Convention should be determined as ‘existing ships’ and that the implementation schedule should be at the next ‘special’ rather than ‘intermediate’ survey, as it currently specified in Regulation B-3. This proposal was supported by some and opposed by other delegations, as sufficient Type Approved systems are currently available and being installed (“IMO MEPC 64 concluded”, 2012).

4) Sampling and analysis procedures for port state control purposes.

Regarding this matter, MEPC has instructed BLG (Bulk Liquids and Gases) and FSI (Flag State Implementation) Sub-committees to draft sampling and analysis guidelines for port state control no more stringent than the type approval process (“BWM discussed”, 2012).
**Bio-fouling guidelines**

*Bio-fouling* is an unwanted growth of animals and plants, such as barnacles or algae, on a hull surface immersed in the water. Unprotected vessel hulls could collect some 150 kg of bio-fouling material per square meter in about six month of sailing at sea. A simple calculation shows that it is about 6,000 tonnes of fouling on one Large Crude Carrier with 40,000 square meter underwater area. Bio-fouling could be classified to *micro-fouling* and *macro-fouling* as shown in Figure 6:

![Classification of bio-fouling](image)

**Figure 6 - Classification of bio-fouling**


*Bio-fouling* is not just a dangerous invasive alien species transporting vector, it also leads to significant financial losses by increasing the fuel consumption up to 50% since the resistance to movement will be increased (“Antifouling systems”, 2002), as shown in Figure 7.
Moreover, it takes extra time and money to clean a ship’s hull in a dry-dock. That is why during the 1960s the chemicals industry developed effective anti-fouling paints using metallic compounds, in particular the organotin compound tributyltin (TBT) and by the 1970s, most seagoing vessels had TBT containing paints covering their hulls. These compounds slowly "leach" into the sea water and kills biomaterials that have attached to the hull. But after some studies it became clear that these compounds persist in the water, affecting non-target organisms, harming the environment and jeopardizing human life by entering the food chain. Therefore, in 2009 European Union banned use of TBT-based paints.

This issue was first considered by IMO I 1988, when the Paris Commission requested MEPC to consider measures to restrict the use of TBT compounds in Anti-fouling systems on ships.

The International Convention on the Control of Harmful Anti-fouling systems on Ships (AFS Convention) was adopted 5th of October 2001 and entered into force on 17th of September 2008. On 30th of June 2012, it had been ratified by 60 Parties, representing about 79.11% of the world’s merchant fleets.
The Convention defines “anti-fouling systems” as “a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms”. Under the terms of the Convention, Parties to the Convention are required to prohibit or restrict the use of harmful anti-fouling systems on ships flying their flag or those which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party.

Annex I to the Convention states that all ships shall not apply or re-apply organotins compounds which act as biocides in anti-fouling systems, and ships either:

(a) Shall not bear such compounds on their hulls or external parts or surfaces; or

(b) Shall bear a coating that forms a barrier to such compounds leaching from the underlying non-compliant anti-fouling systems.

Prohibited or controlled anti-fouling systems are listed in an Annex 1 to the Convention, which is updated as and when necessary (IMO, 2001).

**GloBallast initiative**

The Global Ballast Water Management Programme for the Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries (the GloBallast Programme) was introduced in 2000 by the IMO, Global Environmental Facility (GEF) and UN Development Program (UNDP) (Figure 8). It was recognized as one of the most successful GEF International Waters projects.
Figure 8 – IMO, GEF and UNDP cooperation on GloBallast Programme
Source: http://globallast.imo.org/

It was initiated with a purpose to assist developing countries to:

- reduce the transfer of harmful organisms from ships’ ballast water;
- implement the IMO Ballast Water Guidelines; and
- prepare for implementation of the IMO Ballast Water Convention (still under negotiation at that stage). (Appendix A)

The First Phase of the programme was implemented between 2000 and 2004 and focused on six developing regions. Six demonstrational sites were organized respectively in Dalian (China, Asia/Pacific), Khark Is. (I.R Iran, Middle East), Mumbai (India, South Asia), Odessa (Ukraine, Eastern Europe), Saldanha (South Africa, Africa) and Sepetiba (Brazil, South America). They were focused on:

- communication, education and awareness-raising
- risk assessment and port surveys for each of the demonstration ports
- review of existing ballast water management legislation
- compliance, enforcement and monitoring
- regional cooperation and replication
The Second Phase of the Programme, called GloBallast Partnership, was initially planned as a five-year project, from October 2007 to October 2012 and if has been implemented in 5 high priority sub-regions: the Caribbean, the Mediterranean, the Red Sea and the Gulf of Aden, the South East Pacific, and the West Coast of Africa, through 15 Lead Partnering Countries and more than 70 Partner Countries. It was initiated to build on the progress achieved in the original project and focused more on national policy, legal and institutional reforms in targeted developing countries with an emphasis on integrated management. (Appendix B)

It includes:

- building on the achievements and momentum, and utilising the capacity and skills generated by the pilot phase;
- replication of best-practices and technical activities in the beneficiary countries with a view to stimulating policy reforms at national level;
- supporting especially vulnerable and/or environmentally highly sensitive countries in their efforts to effect legal reforms to implement the Ballast Water Management Convention;
- working towards advanced integration through other interested structures, mechanisms and programs, including where optimal, GEF-IW LME projects and UNEP Regional Seas; and
- promoting collaboration with industry to facilitate the successful transfer of new technologies from developed to developing countries.

3.3. Methods of controlling the problem

Because organisms transferred by ships both in ballast water and by bio-fouling vary in size (from viruses to fish) and physical properties so much, there is obviously no
technique that is suitable in every case. There is not one single method that is able to remove all types of organisms, only a combination of different techniques is more efficient.

The evaluation of optional treatment methods must include the consideration of the following basic criteria (Chase, n.d.):

- Safety of the crew and passengers
- Effectiveness at removing target organisms
- Ease of operating treatment equipment
- Amount of interference with normal ship operations and travel times
- Amount of fuel being consumed during the treatment process
- Structural integrity of the ship
- Size and expense of treatment equipment
- Amount of potential damage to the environment
- **Ease for port authorities to monitor for compliance with regulations**

Treatment options for ballast water, both tanker-based and shore-based, are shown in a Figure 9.
**Ballast Water Exchange**

*Ballast water exchange* is an operational method used to remove nonindigenous species (NIS) from ballast tanks by replacing seawater taken on in port and near-shore areas with deep, open-ocean seawater. As the matter of fact, organisms from coastal waters pose little contamination risk to the deeper ocean water as in most cases these organisms are not able to survive in the open ocean. In turn, the ballast water, loaded in the deep ocean areas does not pose a big risk for a coastal area after being discharged there. That is why the mid-ocean Ballast Water Exchange is usually recommended for reducing the risk of introduction of unwanted stowaways by transferring them in ballast water. Ballast water exchange costs relatively little and involves ballast water management plans and increased pumping and fuel cost.
There are three main types of ballast water exchange:

1) **Sequential ballast water exchange** involves completely emptying segregated ballast tanks (individually or in sequence) and then refilling them with open ocean water, as shown in Figure 10. Because of the complete emptying of the ballast tanks and refilling them with clean ocean water, this method is considered as the most effective one.

![Sequential Ballast Water Exchange Schematic](image)

**Figure 10 - Sequential Ballast Water Exchange Schematic**


However the process of sequential exchange changes ships stability, trim and drafts, which makes impossible using this method for some types of ships, especially in heavy weather. Moreover, this method does not effectively remove sediments that may contain unwanted organisms from the bottom of the tank. The approximate efficiency of the sequential method is 95–99 %, however it is impossible to remove 100% of the
organisms because it is impossible to pump the whole amount of the water and sediments out of the tank, especially from the bottom, below the pump threshold and corners, which are considered as areas of the most concentration of aquatic species.

2) Flow-through ballast water exchange method involves pumping open ocean water into a full ballast tank for a length of time sufficient to flush the ballast water tank, as shown in Figure 11.

![Flow Through Water Exchange Schematic](image)

**Figure 11 - Flow-through Water Exchange Schematic**


Tanks are typically flushed with a quantity of water equivalent to three times the tank volume. Assuming perfect mixing, a three-tank volume flush will theoretically achieve 95% replacement of the original ballast water volume. The goal of the flow-through method is to dilute the original in-port and near-shore ballast water with high volumes of deep, open-ocean ballast water, leaving a very small percentage of NIS remaining in the tank. Although the flow-through method is not as effective in NIS removal as sequential exchange, this method is safer since it is completed with full ballast tanks. Flow-through
ballast water exchange does not alter the stability, stress, and ship attitude, and can be accomplished in a wider range of weather conditions (PWSRCAC, 2005c).

1. **Dilution method** is a process by which replacement ballast water is filled through the top of the ballast tank intended for the carriage of water ballast with simultaneous discharge from the bottom at the same flow rate and maintaining a constant level in the tank throughout the ballast exchange operation. As with the flow-through method, ballast equal to approximately three times the tank capacity must be pumped through the tank to achieve 95% effectiveness in eliminating aquatic organisms (ABS, 2010).

The dilution method has the advantages of the flow-through method with regard to maintaining the stability and strength and other similar benefits. By discharging water from the bottom of the ballast tanks, sediments are more easily removed. This method avoids the use of air vent pipes and the removal of manhole covers to discharge water over the deck.

The flow-through method and the dilution method are often referred to as “pump-through” methods.

The Regulation B-4 of the BWM Convention states that the exchange should be conducted “…at least 200 nautical miles from the nearest land and in water at least 200 metres in depth;” or, in cases when it is impossible, “…as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth.”

However, as everything has its pros and cons, this method is not perfect. The downsides of this method are the following:

1) **It is almost impossible to remove 100% of sediments and residual water from the bottom of ballast tanks**

2) Organisms stuck to the sides of the tank or structural supports within the tank will not be readily removed

3) During stormy or rough seas it is unsafe for a ship’s stability
**Ballast Water Treatment**

*Chemical treatment* of ballast water is done by means of adding a particular amount of chemicals to the tank, mixing it with ballast water and maintaining a residual chemical level with the aim of the nonindigenous species. The effective chemical treatment kills a wide range of organisms, have a quick decay rate, and degrade into non-toxic compounds prior to discharge (PWSRCAC, 2005d).

Chemicals used in this method are called **biocides**. There are several biocide options, evaluated for the chemical ballast water treatment:

- **Oxidizing agent**: Chemicals that destroy cell membrane through oxidization. A molecule that is electron deficient removes an electron from another molecule in this reaction. The process of rusting is an oxidation reaction.

- **Non-oxidizing biocide**: Biocides can also be lethal through various other chemical means.

- **Ozone**: This molecule, O₃, is very important in the upper atmosphere, where it shields us from harmful ultraviolet rays. In the lower atmosphere, however, it is the major component of smog and is a harmful pollutant. It is also often used as a biocide in water. Ozone is inherently unstable and dangerous to produce, but it is a very powerful oxidizing agent.

Biocides must be chosen very carefully to avoid hazardous impacts to humans and the environment. Biocides are usually shipped and stored in the form of a concentrated solid or liquid, so they can easily be stored on-board a ship. Except from ozone, all the biocides are recognized as unfeasible for large vessels because of their corrosive nature and potential risk to human health. However, some of them could be used effectively in a shore-based application.

Biocides under investigation include (PWSRCAC, 2005d):
- Bromine is a disinfectant effectively used in land-based application.
- Chlorine is a well-established and proven disinfectant, particularly for fresh water. Chlorine is effective against most viruses and bacteria; however, its behavior in seawater, especially the potential reaction with bromides is not well understood.
- Chlorine Dioxide (ClO₂) is an oxidizer similar to chlorine and is effective against cysts, bacteria, and viruses.
- ClO₂ is more costly than chlorine and has potential to be an effective addition to a comprehensive water treatment program; however, no specific testing on ballast water has been completed.
- Glutaraldehyde is an organic acid biocide that is widely used as a disinfectant. It is highly corrosive in concentrated form creating a potential health and safety risk. Research indicates use of glutaraldehyde may be the most effective for one-time disinfection of small vessels. Large scale use aboard a tanker is expected to be cost prohibitive.
- Hydrogen Peroxide is a strong oxidant capable of destroying 100% of cyst stage NIS at high doses (10,000 parts per million). Hydrogen peroxide degrades to oxygen and water, making its residual impact very low.
- Hydrogen peroxide is extremely corrosive, creating a potential safety risk.

Some other chemicals, like chloramines, iodine, copper and silver could also be used, but do not perform a high effectiveness.

The chemical method of water treatment is easy in application and highly effective in killing a wide range of organisms, particularly at the microbial and cyst stage and is a proven technique in land-based, industrial and municipal fresh water systems. However, most of the chemical treatment options have been rejected for reasons of safety, cost and unacceptable level of toxins in water that is being discharged during de-ballasting. There
is also a risk to the ship and crew from the storage and handling of organic biocides because of their corrosive and toxic nature.

**Thermal treatment.** Another effective on-board ballast water treatment option is using high temperatures to sterilize water and kill nonindigenous organisms before de-ballasting, as shown in Figure 12. Both heat produced by ship’s engines or created by auxiliary boiler systems installed aboard could be options for thermal ballast water treatment.

![Figure 12 – Thermal Ballast Water Treatment](image)


Using the waste of heat produced by ship engines, as shown in Figure 13, may be a cost-effective technical solution for on-board ballast water treatment while in transit. This option could increase the ballast water temperature to 37-38°C (98-100°F), which is effective in killing a majority of nonindigenous organisms.
Figure 13 - Using heat waste of ship engines for on-board ballast water treatment


To kill all microorganisms including cysts, more expensive auxiliary systems that can produce higher temperatures are required. These systems involve installation of additional boiler systems including pre-treatment filtration systems, plumbing modifications, construction of deck shelter to a house system if no below-deck location is available, plumbing for a bypass system in the event of a failure, routing of fuel lines and potential installation of an additional fuel tank, and routing of the boiler exhaust to main stack or other exhaust systems (PWSRCAC, 2005e).

In both cases, the longer time the water is exposed to target temperatures, the higher kill rate is. Current research shows typical exposure time to range from a minute to four hours; however, the optimal time of exposure depends on physical characteristics of particular species and must be researched and tested.

The strong advantage of application of the thermal ballast water treatment method in terms of a current way of blue-green economy is that waste heat from ship’s engine is being recycled instead being simply pumped overboard as a waste product. It is also an advantage that in both cases, the ballast water is treated directly on-board during the transit. Another benefit of this method, in contrast to ballast water exchange, the thermal treatment method is relatively effective to organisms accumulated in sediments.
at the bottom of the ballast tank. Moreover, no chemical byproducts are used during this method.

However, the thermal treatment of ballast water in transit is a challenge for large volume vessels because of the big amount of time needed for the effective treatment. The voyage must be long enough, like for instance oil tankers’, to allow water to reach particular temperatures for the necessary amount of time. Also, the amount of heat provided by engines is limited, so the amount of ballast water to be treated must be proportional if no auxiliary equipment is being used.

Another important aspect is human health. The temperature that is adequate for killing nonindigenous organisms is not enough to eradicate most human pathogens, viruses or cysts, so the installation of auxiliary boilers to supply the adequate amount of heat will be required. Moreover, the heating water in ballast tanks of older ships may create safety problems due to its effect of corrosion, but because heating occurs only for a short period of time, corrosion may not actually be a major concern. The method is not very useful in colder waters due to higher energy consumption for the heating process.

**Physical treatment.** Basically there are two types of physical ballast water treatment methods: Filtration and Hydrocylone (centrifugal). Both of them involve the physical separation and removal of organisms above a certain size from ballast water. Physical separation systems could be installed both on-board the vessel and at onshore treatment facilities to treat ballast water prior to discharge into the receiving port. Physical separation combined with biocide auxiliary, thermal or UV treatment is considered as an effective technology for the removal of a wide range of nonindigenous species, which currently is used on crude oil tankers, for example.

Ballast water filtrationsystems design is based on the original filtration system concept but equipped with more sophisticated selective screens (such as sea chest grates, perforated metal plates, rapid sand or multimedia filters, and stainless mesh), which
filter out much smaller organisms. The selection of a specific filter system depends on organisms that are supposed to be filtered, as various species need to be filtered by various filter sizes.

The large volume filtration systems in large, high flow rate, high nonindigenous species volume application, like those used on crude oil tankers, have to be supported by self-cleaning systems. These systems remove and store filtered organisms and should be installed to maximize filtration efficiency by minimizing filter fouling and plugging (PWSRCAC, 2005f). As the water can be filtered before entering the ballast tank, the advantage of this system is that organisms may be retained in their native habitat.

Hydrocyclone treatment, also known as centrifugal separation, is based on density. It operates by pushing sediments and other heavier particles (including NIS) to the outer portion of an intake pipe, and then they are collected and removed. Centrifuges can be used both aboard and onshore, and operate at high water flow rates and there is a little water pressure decrease in the system. In combination with additional chemical or UV treatment, hydrocyclones could be even more effective in fighting a broad range of organisms.

Both filtration and centrifugal separation are commonly used in a variety of municipal and industrial water treatment applications and are well established as a water treatment system.

Filter sizes in the 10-50µm range are capable of capturing and removing zooplankton and large organisms, while smaller filters (less than 10µm) are capable of removing cysts of toxin-producing harmful marine dinoflagellates. Both operations have been used for years already and demonstrated to be relatively safe for the ship and crew.

Technology challenges facing physical separation systems involve both the system effectiveness and the length of treatment time. Unacceptable pressure drops across filter media and long back-wash cycles are a continued problem for filtration technologies. Other challenges include storage and removal of captured organisms and additional responsibilities for the crew (filter maintenance and operation). While hydrocyclones are
relatively simple to operate, they are less effective at removing smaller organisms than membrane filter systems.

**Discharge to Reception Facilities** is a good solution for small harbours without tense traffic of big vessels, but not very practicable in terms of large ballast water volumes. After being collected, ballast water should be stored and properly treated in treatment plants, and this kind of plants requires big capacities. Another point is that no vessels, excepting tankers, are equipped with the standard connection to berths. However, the water that has been treated could be reused and as the matter of fact, the treatment facility could offer economies of scale. Moreover, the treatment operation needs some additional skills and training, and it is probably better to leave for shore-based personnel rather than a ship’s crew (Donner, 2010). However, according to the Ballast Water Management Convention, Parties are not required to provide such facilities.

**Other methods** of ballast water treatment are currently being investigated and developed. These methods need much more research and development before they will be applied to ballast water treatment. Ultraviolet (UV) light is currently used in hospitals, homeless shelters, and prisons to kill microorganisms and prevent the spread of disease. This method is most effective on microorganisms, so it would need to be combined with other methods to effectively remove all potential bio-invaders from ballast water. One of the main drawbacks is that UV light is ineffective in water containing suspended matter, so ballast water may need to be filtered before treatment. Although many methods are being investigated, no treatment has been found that cost effectively prevents all living organisms from being transported through ballast water. Or, for example, specific acoustic frequencies kill specific organisms, so acoustic treatment may be effective at removing target organisms but not the wide range of organisms found in ballast water. Magnetic forces have been shown to kill certain invertebrates, such as zebra mussels, in laboratory tests. This method has not been tested
on a wide variety of organisms in sea water, so its effectiveness for treating ballast water is yet to be determined. Electric pulses may be sent through ballast water killing most organisms. The risk to the crew and the expense and size of the equipment needed to generate these pulses are the major drawbacks to this method of ballast water treatment.

Some treatments may need to be accompanied by another treatment that covers another category of organism. For instance, UV treatment may be accompanied by filtration. Filters of different sizes are also needed in order to cope with the volume of water exchanged. Larger material must be filtered out, in other words, before the water can be filtered by a finer mesh.

4. The Black Sea Region

4.1. History, geography, ecology and socio-economy of the region

The political dimensions of the Black Sea Region were vague and changing from time to time during the whole historical process. In a wide political sense, it extends from Balkans to the Caucasus Mountains and from the Ukrainian steppe land to central Anatolia. Almost all countries in this wide area are members of the Black Sea Economic Cooperation organization (BSEC), which was established in 1992 as an international forum with the objective of strengthening commercial, political and cultural ties in southeastern Europe. In a narrow geographical sense there are only six countries that adjoin the Black Sea: Bulgaria, Romania, Ukraine, Russia, Georgia and Turkey. This States delimitate and control Black Sea waters and major port facilities (King, 2005).

The Black Sea is a body of water with the total area of over 423,000 km³, average depth of 1,300 m reaching maximum 2,245 m and with volume of 547,000 km³ (Kubijovich, 1984). The Sea expands on 1,174 kilometres from the Bulgarian port Burgas on the west to the Georgian port of Batumi in the east, and stretches on a maximum of 611 km from South to North and only 260 km from the tip of Crimean peninsula to the Turkish port of
Inebolu (Encarta Encyclopaedia, 2003). The strait of Kerch (also known as the “Cimmerian Bosporus”), connects the Black Sea to the shallow semi-fresh Sea of Azov. Even though the Black Sea is directly bordered by only six countries, it is being influenced by another 10 States through the major rivers meeting it, among which Danube, Dnieper and Dniester are the biggest ones. On the north and north-west, where rivers meet the Sea, there are limans—estuaries and brackish wetlands. The western tip of the Black Sea lies at the Bosporus in Turkey and the eastern tip lies on the mouth of the river Rioni which flows from Caucasian mountains through the country of Georgia.

The Black Sea is considered to be a residual basin of the Central European Tethys Sea (Kubijovich, 1984). Possibly because of its unpredictable and peculiar behaviour, in ancient Greek and Romanian sailors called it Axeinos meaning “dark” or “gloomy” from Iranian and later Axenos Pontos (“unwelcoming sea”). They claimed that storms were appearing from nowhere and heavy fogs were making the navigation impossible (King, 2005). At the early fifth century b.c. the name was replaced with Euxinos Pontos (“hospitable sea”) which was meant to ward off the wrath of the gods (Gibbon, 1910).

The Black Sea as is known today is a relatively young body of water. Through the times it used to be connected with the ocean, isolated as a small semi-saline lake, linked with what is now known as the Caspian Sea. In fact some 18,000 – 20,000 ago it used to be a shallow lake, or Neoeuxine lake, two third of its current size.

At some point (7,500 years ago—c. 5500 bc—in the middle of the Neolithic period), when melting ice water swelled the oceans, the higher Mediterranean Sea started spilling over into the low-lying lake, creating Dardanelles and Bosporus straits and the intermediary Sea of Marmara. The water level was rapidly raising (presumably about 15 cm per day) destroying islands and human settlements on its way. In fact, the former shoreline is now lying approximately 150 meters below the surface. Another interesting fact is that because of the difference in salinities, this torrent was divided into two flows: the upper level with less salinity was floating toward the Mediterranean Sea, while the
lower level with the salty water was moving to the Black Sea and there was practically no intermediate zone between those two layers.

Today two almost closed circular horizontal sea current systems dominate in the Black Sea (Kubijovich, 1984). The major surface current is caused by the cyclonic pattern of the winds counter clockwise along the coast and is fed by river Danube on the west and river Rioni on the east (Jones, 1827). The two circular currents are crossing the sea and are supported on the northeast by the river Don flowing in through the Sea of Azov and the strait of Kerch and on the southwest by the water running from the Bosphorus. Besides there are also vertical currents on the surface waters not deeper than 200 m. The Black Sea Ecosystem is strongly influenced by the limited exchange of water through the Bosporus as well as from a number of rivers flowing into it and contributing to a high phytoplankton production (Caddy, 1993). Sea grass and macro-algal communities, such as brown algae Cystoseira barbata and red algae Phyllophora sp, provide the bulk of primary productivity in shallow parts of the sea (Heileman, 2007). The nutrient supplies originating from drainage areas flow along coasts of the basin and then turns to the open sea providing the blooming of plankton algae (King, 2005). The Black Sea is considered a highly productive ecosystem. The ecology of the Black Sea is quite unique and influenced by salty dense water from the Mediterranean Sea which fills up the deeper areas and river water at the surface. The less salty and dense water stayed on the surface and the water exchange between the surface and the bottom is limited. In fact there are four layers of water gradually changing one another (Heileman, 2007):

1. The oxygenated upper level, about 80-90 m along the coast and about 40 m in the deep sea;
2. The oxycline (60 – 150 m under the upper level), where the concentration of oxygen decreases rapidly;
3. The suboxic zone, in which oxygen levels decline slowly to the anoxic layer;
4. The anoxic (sulphide-bearing) zone with no oxygen (close to 90% of Black Sea deep waters).
Due to the anoxia, there is no deep pelagic and benthic life in the Black Sea; most of the marine life is situated on the top layer excepting quite a few anaerobic bacteria in the hydrogen sulphide layer. There are some less sensitive species that have survived from the time of the Neoeuxine Lake, such as herring and sturgeon. Others, like the flounder, whiting, sprat, and Black Sea trout, have migrated to the rivers and adapted to semi-saline waters. Even though 80 per cent of the Black Sea species are historical invaders from the warm Mediterranean Sea (King, 2005), the number of such species is only on third of the number of species in the Mediterranean Sea: 350 species of protozoa, 650 species of crustaceans, over 200 species of molluscs, about 180 species of fish, and 4 species of mammals (the monk seal and 3 species of dolphin) (Kubijovich, 1984). The plant community consists of around 350 unicellular phytoplankton species, 280 bottom macrophytes, several grass species, and sea herbs. Nonetheless, the total productivity is higher in the Black Sea rather than in the Mediterranean Sea.

The ecological degradation of the Black sea has gone very far compared to other regional seas. Besides alien species, the main ecological threats to the biodiversity in the Black Sea are eutrophication, oil, litter and chemical pollution, inappropriate water management and regulation and overfishing (Heileman, 2007).

4.2. Alien species in Black Sea and their impact

The diversity of ecosystems provides a favourable environment for invasion of alien species to the Black Sea. Due to constant invasions, the composition and structure of the biodiversity in the Black Sea is constantly changing, the population of one species expand, and others decline (Heileman, 2007). Most “invaders” were introduced there by ballast water and hull fouling, but natural vectors such as a current flow from the Mediterranean Sea could not be excluded. According to W.Ryan’s and W.Pitman’s book “Noah’s Flood”, first “invaders” entered Black Sea waters in the bilge water of ancient Greek row galleys (Ryan, 2000).
Today there are many invasive species, introduced to the Black Sea one way or another. Different species have adapted to life in the Black Sea and expanded their ranges depending on salinity and temperature. Some of them have been introduced intentionally, for example the oriental mullet *Mugil soiuy*, also known as *kefali*. It was brought from the Sea of Japan, successfully adapted to the Black Sea and became extremely popular among industrial and local fisheries. *Kefali* is rather tolerant to various temperature conditions and salinities and can occupy both salty and fresh waters and dwells both in the sea and in estuaries. It subjects some food competition to native species; especially in freshwater estuaries and some reduction of population of some of them have been noted, but not significant. Even though it is important to remember that ill-conceived invention could bear the risk, at the time *kefali* does not constitute much menace to the ecosystem and is expected not to do so.

Other species were introduced unintentionally by numerous vectors and had various impacts. Such organisms as *Balanus improvisus* or *Mya arenaria*, described further, could be considered as examples of the good impact.

The presence of *Balanus improvisus* (also known as Sea acorn) in the Black Sea was first recorded in 1844 and most likely was brought there from the Atlantic coast of America by hull fouling; however, more recent introductions were possibly made by ballast water or with commercial shellfish (Gomoiu, 2002). It is a barnacle surrounded with 6 smooth shell palates with maximum size of 20 mm in diameter. It is usually attached to solid surfaces or other animals’ shelters with the calcareous base with radial pattern. This base remains on the surface even after the removal of the animal. It is a rather euthermal (survives with temperatures as low as -2° C and up to 35° C) (Southward, 1957) and euhaline (it could habitat both in salty sea water and in fresh water of estuaries) organism, tolerant to various depths, low oxygen, eutrophication and pollution (Leppäkosli, 1999). They are filtering water around themselves, actively purifying the sea water from the organic suspension of bacteria, unicellular algae and
zooplankton. *Bimprovisus* definitely plays a positive role in a maritime community as it provides feeding for numerous marine habitats, as millions of *Balanus*’ larvae constitute a significant part of the zooplankton that is a part of the daily ration of different marine species. Moreover, it is not engaged in a food conflict with other organisms, for example when attached to the shell of a lobster, it eats leftovers from its food.

Another good example is a bivalve *Mya arenaria* that was first found in bottom sands of the Black Sea in 1966 and probably was introduced by ships from North Europe or even North American coast. Same as *Bolanus improvisus*, obtains food by filtering sea water and purifying it without having any significant food conflict with indigenous organisms. As neighbours in a block, they are supposed to interact and have one or another kind of relationships among each other. Those interactions could be either mutually beneficial or dangerous for them. One of the brightest examples of the interesting interaction is the “battle” *Beroe vs Mnemiopsis*, which have already collected a grateful audience of scientists and environmentalists from all over the world.

Basically there is only one indigenous ctenophore species in the Black Sea, which is *Pleurobrachia pileus* however, during the last two decades three other ctenophores were unintentionally introduced to Black Sea waters - *Mnemiopsis leidyi* and *Beroe ovata* and *Bolinopsis vitrea* (Vinogradov et.al, 1989).

The ctenophore *Mnemiopsis leidui* (also known as American comb jelly, comb jellyfish, sea walnut, Venus' girdle) have become famous among European hydrobiologists and environmentalists recently. There was not much discussion of this beautiful jellyfish in terms of its invasive capabilities before it was first found in Sudak Bay in November 1982 (Pereladov, 1988), where it was accidentally transported in ballast water (Ghabooli et al., 2010). By the fall 1988 it has literally occupied the Black Sea and surrounding areas, disordered the ecosystem and collapsed fisheries (Oguz et al., 2008). It was recognized as one of the major ecological problems for the Black Sea LME (Kideys, 2002) with the impact cost of approximately $200 million per year.
Comb jellyfish is a hermaphrodite with high self-reproduction rate and capability of rapid colonization of new areas (Kremer, 1994). It is physiologically tolerant to temperatures (about 0°-32°), salinity and dissolved oxygen levels (Purcell et al., 2001). However, it is able to reproduce only in warm water, so cold winter seasons are unsuitable for the reproduction and in some regions lead to elimination (Costello et al., 2006), like it happened, for instance, in the cold Sea of Azov, where the jellyfish disappears for the cold period and then being brought back from warmer Black Sea in a spring time. In suitable food and temperature conditions, larvae are predisposed to grow into adult form within some 14 days (Reeve & Walter, 1978). *Mnemiopsis* is also rather flexible in terms of its diet; it consumes variable planktonic food sources, including microplankton, mesozooplankton and ichthyoplankton. However, the reproduction of *Mnemiopsis* is sensitive to food supply as the high reproductive growth nature demands high-prey availability.

The dramatic reduction in zooplankton, ichthyoplankton, and zooplanktivorous fish population has been recorded sharply after the comb jelly’s invasion. It caused the whole chain of effects such as an increase in phytoplankton, free from grazing pressure and increasing of bacterioplankton population, and led to the increase in zooflagellates and *infuzoria* population. It also caused the collapse of planktivorous fish and disappearance of dolphins in the Black Sea. Even though it does not represent direct danger to human life, it entails significant economic losses for coastal countries of the Black Sea region due to decline in pelagic fish catches, estimated in hundreds of millions of dollars.

Comb jelly’s invasion in suitable conditions is uncontrollable in areas where they have no natural predators, such the Black Sea used to be until 1997, when *Beroe ovata*, the old enemy of the jelly fish from the Atlantic Ocean reached it (Shiganova et al., 2003).

*Beroe ovata* (*B. cucumis*) originally inhabits the Atlantic Ocean coasts near the USA and Canada (Mills, 1996). It is a pelagic organism tolerant to low water salinity (4-7 %%). It swims freely in the water column at depths from just below the surface to more than
1,700 meters below it and inhabits estuaries as well as coasts (*Beroe ovata Bruguière 1789, 2011*). *Beroe ovate* development is much the same as most of the ctenophores; they are hermaphrodites e.g. capable for constant self-reproduction under favourable temperatures and feeding conditions. Similar to the *Mnemiopsis*, it produces several thousands of eggs daily. They do not change their general body types, but just increase in size. This species’ diet consists only of other jellyfish, like *Mnemiopsis* or *Pleurobrachia*. Interestingly, it is still not understood how exactly it senses its prey, but once being around one, it finds it easily and digests it in minutes.

**Beroe vs Mnemiopsis**

When it became clear that *Mnemiopsis* causes a real hazard to the Black Sea, it was considered to artificially introduce its original biological enemy to control the population of the jellyfish. However, this idea was recognized by biologists as a risky one. They assumed that even if *Beroe* would help to fight *Mnemiopsis*, this experiment could go unpredictably wrong. It could start eating other native Black Sea comb jellies or even other species and misbalance the ecosystem again, so nobody was willing to take such a responsibility. However, *Beroe ovata* has found its own way to the Black Sea without intervention by humans, most likely in ships’ ballast water again, as *Mnemiopsis* did before. It first appeared in the shallow water of the Black Sea in October 1997 (*Zaitsev, 1998*) and by September 1999 in Sevastopol bay and on the north-eastern coast (*Finenko, 2000*). While a lot of scientists all over the world were thinking how to deal with *Mnemiopsis* invasion, *Beroe* has caused a massive decline in the *Mnemiopsis* population and some species of plankton began to increase. However, the long-term effect still remained difficult to predict and scientists kept monitoring the dynamics and seasonal variations. This monitoring helped to make some really important conclusions, such as the population on *Mnemiopsis* in the joint habitat have been reduced by ten times comparing to the year with favourable conditions with absence of *Beroe* (*Shiganova et al.*, 1998).
al., 2000). They were also able to formulate some statements predetermining the effective scientific and industrial work with regard to the *Beroe ovata* controlling over development of *Mnemiopsis* population in the Black Sea, as follows (Volovik, n.d.):

- Sharp reduction of the Mnemiopsis population is possible when the population of the *Beroe* is numerous;
- The dynamics of populations of both species remains the same as in the natural habitat: first Mnemiopsis sharply increases its population, reaching maximum figures, and then outbursts of Beroe appear and cope with them during 3-4 weeks.

Scientists expect *Beroe ovata* to help to control the population of *Mnemiopsis* and solve the biggest alien invasion threat of last three decades. Unfortunately, it is impossible to predict the result and the issue remains hot and needs constant monitoring and control.

The presence of the third ctenophore-invader, *Bolinopsis vitrea* (L. Agassiz, 1860) (*Ctenophora: Lobata*) was first reported in 2007, when it was found in Turkish waters and in 2010 in Bulgarian waters. Most possibly it was brought by currents from the Aegean Sea through the Sea of Marmara; however, the further distribution is believed to be done by ballast water (Öztürk, 2011). *B. vitrea* habitats preferably in shallow warm waters and its diet consist of zooplankton, eggs and fish larvae. It has not yet been considered as an established species, but in case does, it may have an impact on the biodiversity of the Black Sea. For example, it could become a natural competitor for *M. leidyi* and along with *B. ovata* would help to control its population; however, negative impacts cannot be excluded.

Another interesting interaction: *Mytilus galloprovincialis vs Rapana thomasiana*

*Mytilus galloprovincialis* (blue mussel, *Mediterranean mussel, Black Sea mussel*) is native to the Mediterranean coast and Adriatic and Black Seas (mostly around
Ukrainian, Romanian, Turkish and Bulgarian coasts). Basically, the mussel grows up to 140 mm in length, and has a smooth blue-violet, black of brown-shaded shell (Day, 1969). It could be found mostly attached to rocky surfaces and sometimes on the sandy bottom. This small animal plays a significant role in Black Sea ecology and aquaculture.

**First of all, because it is a perfect natural sea water cleaning filter or, as locals call it, “marine janitor”.** As it was mentioned before, the greatest human impact on the ecosystem of the Black Sea is shown in the bacterial pollution of its coastal waters, and this mussel is a highly important actor of the sanitary-bacteriological reclamation of the Black Sea. During the filtration, a mussel absorbs all the organic compounds, which in warm water facilitate the rapid developing of bacteria, including pathogens (Alekseev, 2011). The filtration process depends on the outer conditions, as temperature, salinity, oxygen and continues 12-16 hours per day. It is estimated that one 80-100 mm long mussel is capable of passing through itself 100 liters of sea water per day. The estimate speed of the filtration is 0,5 litres per hour for 1 gram of body mass, so it is fair to say that it can significantly influence the process of the coastal water purification.

*Rapana thomasianna (Rapana venosa).* The figured shell of this beautiful mollusc became a popular souvenir to remember the beastliness of the Black Sea. Not everybody knows however, that it is a dangerous invader from the western Pacific, native to the Sea of Japan, East China Sea and Bohai Sea (Richerson, 2008). It was introduced to the Black Sea region in the mid-1940s most likely by ship fouling and ballast water. It is a dioecious gastropod, mating during winter and spring. Upon hatching the larvae are planktotrophic with variable duration of the planktonic period which facilitate its dispersal and invasion. The adult form habitats on rocks and solid substances, sublittoral sediments and sandy bottoms. *Rapana* has large tolerance in temperatures (4-27°C), water pollution and low oxygen conditions (Gollasch, 2006). It is a predator carnivore, which prefers mainly molluscs, such as oysters (*crassostrea virginica*) and mussels (*Mytilus galloprovincialis, Geukensia*) (Savini, Occhipinti-
Ambrogi, 2006). The invasion of *Rapana* is believed to be the main reason for declining the population of *Mytilus galloprovincialis*, an important mollusc in commercial aquaculture, mostly in Bulgarian coastal waters and Crimea. As it does not have any natural enemies in the Black Sea (such as Sea stars), it is believed that the best way to control the population of *Rapana* is intensive catching and utilization in food; moreover, it is rich for protein and useful nutrients.

Bulgaria has managed to develop the exploitation of this invasive sea snail in a large scale and make it the main export sea catch product. *Rapana* alone accounts for 47.7% of total catches, with the total revenue of 4.200.000 euro only in 2005 and more than two thousand seasonal employees (Popescu, 2011). Moreover, everybody is invited to catch as many sea snails as they are willing with the non-industrial purpose.

In Ukraine however this problem has raised a lot of discussions and confusion. The State Fisheries Committee of Ukraine has decreed the limitation of unauthorized catch of *Rapana Thomasiana* for 10 sea snails per person per day and set the fine of around 1 euro for every extra one caught. Moreover, it is not allowed to catch *Rapana* with an aqualung or another self-contained breathing apparatus. Local divers and hydrobiologists are extremely outraged by such a sanction and have addressed the petition towards the Committee to “amend the legislation to remove restrictions on the catch of the gastropod and suspension catch mussels, ... sought permission to use breathing apparatus to catch *Rapana*, ... urge the authorities of the city of Odessa and the Ministry of Agrarian Policy of Ukraine, to investigate the matter and take steps to establish control over the situation.”

Many scientists think that the only way to preserve the Black Sea ecology is to increase the population of mussels, and this is possible only with the decrease in the population of the predatory *Rapa* welk. That is why they believe it is so important to cancel all the restrictions on catching *Rapana*, permit trade souvenirs of its shell and actively promote catching this predator (Alekseev, 2011).
5. Black Sea Regional cooperation on the problem of AIS

5.1. Regional cooperation and its objectives

Full and timely work on all the stages of the implementation of the Convention on the national level is quite a challenging task. It requires not only the explicit will of the governmental and legislative branches, but also a well-regulated interaction mechanism of the governmental agencies. The mechanism for implementing the provisions of certain international agreements, such as BWM Convention, in the shipping industry varies greatly depending on:
- The purpose of the agreement (vessels, shore facilities, waterways, staff);
- The adoption of the agreement (approaches and implementation mechanisms are changing and improving through the time);
- International Forum (organization) and framework of which the agreement is being developed;
- Urgency (topicality) of the implementation which depends on the original purpose of the agreement;

All that makes it necessary for the State to have a wide range of administrative tools and a flexible approach to the implementation on the national level. Further, it much depends on the success of the multilateral co-operation on the regional level.

Objectives of the regional cooperation

Major opportunities for mutually beneficial cooperation between the neighbouring states on the implementation of international agreements are:

- The co-operation of governmental delegations and groups of experts in discussing the draft agreements in international organizations such as IMO due to the similarity of the objectives, economic conditions, and industrial cooperation;
- Exchange of the experience, information, legislation and ideas in the early stages of implementation, before the agreement enters into force;
- Coordination of procedures for implementing the requirements of the agreement;
- Development of information procedures for more effective meeting the requirements of the agreement;

Because of the international character of the commercial shipping, the attempt to avoid the regional cooperation in the implementation of agreements leads to barriers and even conflict. Of course, this situation should be avoided.

**Features of the situation in the Black Sea region**

In order to harmonize and co-ordinate all these positions, there is one important condition: national legislation, political objectives and economic interests of the participating countries should be similar. Despite the fact that three out of six Black Sea region countries, Ukraine, Russia and Georgia, used to be parts of the USSR, and they are now participants of the Commonwealth of Independent States, and two others, Romania and Bulgaria, are now a part of the EU; therefore, legislation, managing system and economic interests of all six countries differ increasingly. In these conditions the development of the uniform strategy for all the countries is problematic or impossible.

The adoption of the strategy, the establishment of the regulatory framework and infrastructure for implementation of the agreement, and an analysis of the effectiveness of the measures taken should be done first, and then, on the basis of these results, a decision on ratification should be made. In this case, each government will come to a new international regime fully mobilized. This way the each State can implement its own strategy based on national interests.

*The Commission on the Protection of the Black Sea against Pollution with its Permanent Secretariat in Istanbul, Turkey was created as a result of acting on the mandate of the Convention on the Protection of the Black Sea Against Pollution and implements the provisions of the Convention and the Black Sea Strategic Action Plan, adopted in 1996 and amended in 2009.*
The Convention on the Protection of the Black Sea against Pollution (Bucharest Convention) was signed in Bucharest in April 1992, and ratified by all six legislative assemblies of the Black Sea countries in the beginning of 1994. Basic objectives of the Convention include prevention, reduction and control of the pollution of the marine environment from vessels, protection of the biodiversity and the marine living resources and provision of the framework for scientific and technical co-operation and monitoring activities.

The Convention states that actions needed for the prevention of introduction of exotic species include improvement of the national reporting on exotic species and supporting regional activities related to continuous studies of invasive species such as *Mnemiopsis leidyi* and *Rapana venosa*.

**Black Sea Strategic Action Plan** is a document representing an agreement between the six Black Sea Coastal states to act in concert to assist in the continued recovery of the Black Sea. This document provides a brief overview of the status of the Sea, based on information contained within the 2007 Black Sea Transboundary Diagnostic Analysis (BS TDA). For example, among other pieces of information, the state of the biodiversity is described in paragraph 2.4. as follows:

“Between 1996 and 2005 a total of 48 new alien species were recorded, which represents over 22% of all registered aliens. The majority belong to phytoplankton (16) and zoobenthos (15), followed by zooplankton (8), fish (5), macro-algae (3) and mammals (1). This increase in invasive aliens suggests a serious impact on the Black Sea native biological diversity, with negative consequences for human activities and economic interests.”

Also, BS SAP takes into account the progress achieving the aims of the original (1996) Black Sea Strategic Action Plan (BS SAP). This updated version of the BS SAP describes the policy actions required to meet the major environmental challenges now facing the Black Sea, and includes long-term Ecosystem Quality Objectives (EcoQOs) –
statements regarding the vision of how the state of the Black Sea is desired to be seen in a long term, with identification of the priorities based on BS TDA, as shown in Table 1.

*Table 1. Targets and priorities regarding AIS*

<table>
<thead>
<tr>
<th>Reference (Annex 3)</th>
<th>Overall target</th>
<th>Short-term target</th>
<th>Mid-term target</th>
<th>Long-term target</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>(26)</td>
<td>Promote cooperation in the Black Sea in line with principles and recommendations of the International Convention for the Control and Management of Ships' Ballast Water and Sediments.</td>
<td>✓</td>
<td></td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>(27)</td>
<td>Harmonise ballast water procedures using IMO guidelines.</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>(28)</td>
<td>Identify actions towards ratification of the BWM Convention in the BS region.</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

Source: BS SAP, 2008.

Among others, the EcoQO on the Conservation of Black Sea Biodiversity and Habitats is stated as follows (BSC, 2009a):

*EcoQO 2a: Reduce the risk of extinction of threatened species.*

*EcoQO 2b: Conserve coastal and marine habitats and landscapes.*

*EcoQO 2c: Reduce and manage human mediated species introductions*

A report by the Commission on the Protection of the Black Sea against Pollution (BSC, 2009b) regarding the implementation of the Strategic Action Plan for the Rehabilitation and Protection of the Black Sea states a significant movement noted in the last decade in
Black Sea rehabilitation and protection. In particular, a real progress in the development of regional/international cooperation, including co-operation on diversity, habitat and landscape protection and development of Black Sea information system and monitoring program. However, the challenges faced in the 1990s are noted to still be present and urgent. Further strengthening of safety aspects of any human activity in the region are mentioned as needed as the picture with the invasive species still looks threatening. According to the Report, between 1996 and 2005 a total of 48 new alien species were recorded, which represents over 22 % of all registered aliens in the Black Sea. The majority belong to phytoplankton (16) and zoobenthos (15), followed by zooplankton (8), fish (5), macroalgae (3) and mammals (1).

The majority (68 %) of the introductions are human-mediated and only 13 % are a result of the natural expansion of species. Ship ballast waters are clearly identified as the primary vector (30 %) of alien introductions in the Black Sea, followed by aquaculture (11 %).

During the process of implementation of the BS SAP, the following challenges regarding the cooperation on the Black Sea region countries on the problem of invasive alien species were stated (BSC, 2009b):

“4. ... the past introduction of exotic species, through the deballasting of vessels, has seriously damaged the Black Sea ecosystem and constitutes a threat to the adjacent Mediterranean and Caspian Seas.

The considerable number of records of new aliens between 1996 and 2005 show that the Black Sea is still a favourable region by those transported especially with ballast water. Therefore, the prediction and prevention of invasion by potentially harmful species continues to be a challenge for the Black Sea.

14. Pending the resolution of ocean boundary matters in the region, close cooperation among Black Sea coastal states, in adopting interim arrangements which facilitate the
rehabilitation of and protection of the Black Sea ecosystem and the sustainable management of its resources shall be pursued.

15. Cooperation among all Black Sea basin states, and, in particular, between the Black Sea coastal states and the states of the Danube river basin, shall be promoted.

41. Black Sea states will present a joint proposal to the IMO, in 2004, for conducting an in-depth study on measures to avoid any further introductions of exotic species into the Black Sea through the de-ballasting of vessels. Given the danger of such species migrating to other seas in the region, the coastal states of the Caspian and Mediterranean Seas will be consulted.

5.2. GloBallast in BS Region

Activities of the GloBallast programme around the Black Sea region is aimed to increase the competitiveness of its port and maritime industry, supporting the development of awareness of the problem and aid port state responsibilities in enforcement.

GloBallast Programme (Phase I)

As it was mentioned above, the Black Sea region was one of the focus points of the GloBallast Programme starting with the first Black Sea Conference on Ballast Water Control and Management Odessa, Ukraine 10-12 October 2001 and resulted in the signing of the Ballast Water Management Convention by all six countries in 2004.

During this time a lot of work was done by the governments of all six states namely, the Regional Action Plan to minimize the transfer of harmful aquatic organisms and pathogens in ships ballast water was drafted and its main recommendations were incorporated in the updated Strategic Action Plan in 2008.
Also, ballast water related Regional Task Force was implemented to minimize the transfer of harmful aquatic organisms and pathogens in ships’ ballast water. Moreover, the Strategic Action Plan of the Black Sea had been revised in a framework of this programme, where the present status of ballast water management requirements was summarized (Annex II.5). It was stated that the level of ballast water management was varying from country to country and a harmonized and agreed upon uniform approach had been lacking.

**BWM Convention implementation in the Black Sea region**

The purpose of the Convention is to prevent, minimize and finally eliminate the danger to the environment and human health due to the transfer of harmful organisms and pathogens through the control and management of ships’ ballast water and sediments, as well as to avoid undesirable side effects of this control and the promotion of development of related sciences and technologies.

The objectives of the Convention at the national level need the implementation of the following tasks:

- The creation of national standards of common law (regulatory) and legal institutions (institutional structures), to address the problem of ballast water;
- Ensure the effective coordination and support, including the functioning of the information analyses and spread;
- Development and implementation of a national plan of action aimed at minimizing of the movement of harmful aquatic organisms in ballast water of ships;
- **Assessment of levels and types of risks and the most vulnerable resources and wealth**, which can be subject to these risks;
- The maintenance of coordinated research aimed at the development of the new and more efficient processing of water ballast;
- On-going monitoring of the implementation of the Convention and adherence to its standards;
- Providing support in the implementation of notable improvements to the navigation aimed at solving the problem of ballast waters;
- **Increasing the national capacity to address the ballast water problem**;
- The development of a national strategy to prevent the invasion of aquatic organisms;
- Matching of ballast water management programs with existing marine and coastal management systems;
- Facilitation of the cooperation of countries with different levels of development at the regional level;
- Development of sustainable financial and organizational systems for the management and control of ballast water.

Due to the fact that its provisions apply equally to both vessels and on-shore monitoring systems, their implementation should involve central executive authorities responsible for the functions of the flag state and port state (transport, fisheries) and the coastal state (health and environment protection).

Due to the special status of the Black Sea as a land-locked sea basin, the agreement on coordination on the regional level would be appropriate. Therefore, all six countries appointed organizations responsible for the implementation of the Convention and coordination with administrations of other countries both on the regional and international levels. Moreover, the exchange of the information on biological status of the marine environment and identification of invasive organisms between all relevant countries, international organizations and research centres is extremely important for the **timely prevention of new introductions** (‘‘*IMO – BSC join hmds*’’, n.d.).
**GloBallast Partnership (Phase II)**

Within the framework of GloBallast Partnerships, on 8th of July 2010 the International Maritime Organization and Black Sea Commission signed a *Memorandum of Understanding* to increase mutual support on environmental aspects of shipping such as the oil pollution preparedness, ballast water management and dumping (*“IMO – BSC join hands”*, n.d.). The agreement for this co-operation was approved by IMO on its 26th session held on November - December 2009, and by the Black Sea Commission at the meeting held in January 2010 to increase the further contribution to achieving the common objectives of both organizations. Shortly after, as a first joint activity within the framework of the signed MoU, two organizations arranged a workshop to prepare the Black Sea littoral States to ratify the International Ballast Water Management Convention. Regarding the Convention, among all the Black Sea states, only Russia has ratified it since 2004.

Since 2004 the Russian port of Novorossiysk carries out tool control of replacement of ship ballast, monitoring of biological pollution of ballast water dumped in port areas, complex ecological research together with the Institute of Oceanology and Oceanography of the Russian Academy of Science.

A comprehensive project for the development of the management plan in Turkey has been nearly finalized. Regular monitoring of ballast water was planned in Romania and Bulgaria, but not in place so far. Unfortunately, this is a core gap for the management of transport related environmental damages in the region. Harmonization of ballast water rules is still under discussion in the frames of the Black Sea Commission work plan and upon availability of financial support.

Ukraine, as one of the first countries that implemented requirements for the ballast water exchange, developed several projects for ballast water treatment, developed proposals
and even made some corrections for Ballast Water Management Convention when it was already after consideration. Shortly after adoption, the text of Convention was translated and filed and that is where the process of ratification of the Convention by Ukraine has stopped. In spite of all the actions taken by the Ukrainian GloBallast team, after all this time the Convention is still under consideration, but in fact not going to be ratified at the nearest future. The fleet is ready for meeting the requirements of the Convention because the ballast water exchange is being done and the ballast record books and ballast plan are being kept. But obviously the concept of the ballast water management expands not only on fleet, but on a significant amount of shore-based services, which still remain not ready for the ratification. Even though ballast water from every vessel calling Ukrainian ports has to be compulsory to be analysed, it is being tested for the iron content but not for the presence of exotic species. The problem of the iron content could barely be more important for local ecosystem than a problem of non-indigenous species; however, in fact, local legislation has not changes since 1990s (Sagaydak, 2012). Thus shipowners have to meet the requirements of not only the Convention, but those established but the local legislation.

Another important feature of this problem is that the ballast water treatment equipment is quite difficult in exploitation, and often dangerous, especially equipment using active substance or ultrasound. Obviously it supposed to be operated by highly qualified and trained personal and as countries of the Black Sea Region are the key human resources suppliers in shipping, to keep this leading position they have to prepare their seafarers to the requirements of the Convention (Sagaydak, 2012).

How is it possible that the problem, which is considered as one of the biggest threats to world oceans is so much ignored in a region that suffers so much of it? Funds for meeting BMW requirements are not being allocated and obviously the problem of
ballast water management is not being paid enough attention. Why is it happening and how to deal with it?

In opinion of the author, there are three main challenges on the way of solving the problem of invasive alien species in the Black Sea Region:

1) Lack of public awareness, as public understanding of a scale of exotic species invasion problem is obviously insufficient and enlightening could possibly lead to more actions from not only government but residents of the region. According to the interview with one of former leaders of the Black Sea Regional GloBallast team, there are very few people in the region, including both scientists and officials, who understand actual scale of the problem and they are not enough to budge the whole system towards solving it. That also explains why the GloBallast programme became so inactive in the region lately. Therefore, some more actions including training programs, mass media coverage and conferences aimed on raising the public awareness are needed in the region.

One of the significant steps towards supporting awareness was the Black Sea water training organized by the European Bank for Reconstruction and Development together with the International Maritime Organization. The aim of the training “was to establish global awareness, particularly in developing regions, to uphold the ballast water convention and to make local authorities aware of what they can do.” Introductory training sessions have already been conducted in Russia and Ukraine in 2011 (Eason, 2011).

2) Incomprehension of the fact that even though actions towards solving the problem of aquatic invasions and implementation of the Ballast Water Management Convention require big investments and do not give any material profit excepting healthy ecosystem, it is still important to take care in sake of
sustainable future not only of the Black Sea, but also all the other water ecosystems. In fact, as during last decades the Black Sea is suffering from a decrease in fishing haul and other problems, described earlier in this paper, it entails even greater monetary losses. This fact should be considered in case the healthy environment itself is not a sufficient argument.

3) Lack of funds, as most of the Black Sea countries are “developing” and the mitigation of harmful impact of invasive species unfortunately is not the top priority for the national investments, especially in terms of an economic crisis. In fact, even those investments that are made, in most cases are not distributed properly and need to be highly controlled due to the fact that countries such as Ukraine or Russia hold top positions in the list of the most corrupted countries in the world (Transparency International, 2011). For instance, Ukraine gets a lot of complains from shipowners all over the world, about the imperfection of legal regulation such as serious offenses in Ukrainian ports in connection with the abuse of power when dealing with ballast water operations, which is already a favourite way for ecological inspectors to put pressure on Masters (Sagaydak, 2012).

Apparently, the lack of motivation is one of the major obstacles on the way to solving the problem of invasive alien species in the Black Sea Region. Therefore, some pressing from the global society and responsible international organizations such as IMO or NGO’s could be useful. However, it barely could be a way out of the problem unless there is a strong political will of the Black Sea region countries to solve it, as the environment of the region should basically be protected by them.
6. Conclusions

The problem of alien invasive species is one of the biggest threats to the ocean biodiversity. All over the world “invaders” stress ecosystems, ruin food chains, spread dangerous disease and cause significant material losses. As most of the alien species are transported unintentionally by humans through the international shipping, the responsibility is supposed to be taken by humans.

During last few decades this problem has been reviewed by many scientists and other international, regional and national actors. The progress is quite noticeable as the Ballast Water Management Convention was adopted and ratified by many countries and is about to enter into force in a short time. The GloBallast programme and GloBallast partnership were initiated with the aim to support developing countries with the problem; international, regional and national organizations all over the world support IMO’s and other organizations’ initiative regarding the problem and cooperate on all the levels for solving the problem; scientists from all over the world are looking for most effective mechanisms, methods and techniques for prevention, treatment and mitigation of consequences. However, this problem is impossible to solve, but only to control and even this aim seems to be unbelievably challenging. Once the invaders are in the sea, it is almost impossible to eliminate them or the harm they cause.

On the one hand, due to the international nature of the problem, it is impossible to solve it without strong, effective cooperation on the international level. On the other hand, due to the specific character of every ecosystem, it is impossible to make up one uniform solution for all ecosystems. However, it is reasonable to make decisions on the regional and in some cases national levels. That is why the solution is only in the interaction between international mechanisms with regional organizations and implementation of results of such cooperation on the national level.

The Black Sea region is one of the most vulnerable ecosystems because of its characteristics. The cooperation of Black Sea countries is pretty strong. However, the Convention has still not yet entered into force and not all possible actions have been
taken. During this research it became clear that there are two major challenges regarding the problem of invasive alien species:

1) Lack of public awareness;
2) Incomprehension of the importance of the problem;
3) Lack of funds in “developing” countries of the Black Sea region.

If not all necessary actions are taken rapidly, the result might be catastrophic. In fact, the situation is already distressful and only effective cooperation and willingness to make a difference could be a key to the successful solution of the problem of invasive alien species for the sake of the sustainable future of every single water body particularly and Global Ocean in general.
APPENDIX A

Global Shipping routes in 2007

Source: http://globallast.imo.org/
APPENDIX B

Strategy for GloBallast Project Implementation

Source: http://globallast.imo.org/
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