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στην

ΝΑΥΤΙΛΙΑΚΗ

ΔΙΟΙΚΗΤΙΚΗ

THE EFFECT OF BALLAST WATER ON MARINE AND COASTAL ECOLOGY OF THE MEDITERRANEAN SEA

Κωνσταντίνος Μαλισσόβας

Διπλωματική Εργασία

που υποβλήθηκε στο Τμήμα Ναυτιλιακών Σπουδών
του Πανεπιστημίου Πειραιώς ως μέρος των
απαιτήσεων για την απόκτηση του Μεταπτυχιακού
Διπλώματος Ειδίκευσης στην Ναυτιλιακή
Διοικητική

Πειραιάς

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Η παρούσα διπλωματική εργασία εκπονήθηκε στα πλαίσια του Μεταπτυχιακού Προγράμματος «Shipping Management» του Πανεπιστημίου Πειραιώς. Ξεκινώντας, η έρευνα αυτή πραγματεύεται τον Ερματισμό, την έννοια του και τη χρησιμοποίηση κυρίως θαλάσσιου νερού για την επίτευξη επαρκής ευστάθειας των πλοίων. Στη συνέχεια, αναφέρονται οι επιδράσεις του θαλασσέρματος από τα παλαιότερα χρόνια μέχρι και σήμερα στο περιβάλλον και τον άνθρωπο. Πιο συγκεκριμένα, υπογραμμίζονται προβλήματα από παρεμβατικά είδη (invasive species) που μεταφέρονται από τον θαλάσσιο ερματισμό στη Μεσόγειο Θάλασσα και την θαλάσσια οικολογία της. Επιπροσθέτως, οι διεθνής κανονισμοί που έχουν θεσπιστεί από τον Παγκόσμιο Οργανισμό της Ναυτιλίας (IMO) αναλύονται εκτενέστατα με αναφορές στα νέα συστήματα διαχείρισης έρματος. Τέλος, αποτελέσματα ερευνών, στρατηγικές και μέτρα δράσης από περιφερειακούς οργανισμούς και μηχανισμούς της Μεσογείου παρατηρούνται και αναγνωρίζονται.

Λέξεις κλειδιά : Ερματισμός, θαλάσσια οικολογία, θαλάσσια ρύπανση, παρεμβατικά είδη, Μεσόγειος Θάλασσα

ABSTRACT

This dissertation was conducted within the framework of the Master of Science Post – graduate program "Shipping Management" of the University of Piraeus. To begin with, this is a research that addresses ballasting and ballast water issues both internationally and in the Mediterranean sea in particular. The concept of ballast is being thoroughly analyzed and the effects of it to the environment through the years. An extensive reference of the ballast water invasive and alien species issues and their massive impact on the marine ecosystem and coastal ecology of the Mediterranean region is presented. Moreover, various problems that the invasive species have caused worldwide are also highlighted. In addition, all the applicable regulations and guidelines, such as the Ballast Water Management Convention, by the pillar of the shipping industry, the International Maritime Organization, are extensively analyzed. Finally, results of researches, strategic and action plans for addressing the ballast water issues at the Mediterranean Sea by the responsible regional organizations are outlined.

Key Words : Ballasting, Ballast Water, Invasive Species, Marine Ecosystem, Mediterranean Sea

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Introduction

Object and target of the Dissertation

The maritime industry is of crucial importance to the modern society. Shipping has for ever been the major form of transportation, delivering products and goods across the world, connecting continents, countries and coastal cities. The water transportation is financially and environmentally the most efficient way to transport goods and about 90% of the world's trade belongs to the maritime industry.

Even though shipping is "eco – friendlier" than road vehicles and aircrafts, when it comes to the environment and the marine ecosystem, damage can be done in various ways. Oil spills, emissions, sound pollution, wastewater and more importantly ballast water are harmful for the environment.

Ballast Water is the main object of the present dissertation, the better understanding of the concept and how it affects the marine ecosystem, the human and the Mediterranean Sea in particular. Vessels that dock their cargo at a port, must take on huge amounts of sea – water (on most of the occasions) in order to maintain their stability, which sea – water later will be discharged at the next destination. The transportation of non – native marine species through ballast water to foreign countries and the rapid growth of them to another marine ecosystem, poses a real threat towards the environment. That was the main concern that triggered and led to the writing of this research.

Structure

The task begins by simplifying the term Ballasting. The early effects that had to the environment, before ballast water really became an issue and the different types of vessels regarding the ballast tank. Afterwards, the concept of ballast water is being introduced, along with its effects to the marine ecosystem. There is a detailed analysis of various invasive and alien species that through the years damaged many oceans, seas and local marinas, causing huge problems to the biodiversity, the fauna, the flora,the local fisheries and the health of humans, with the highlight of it all being the Cholera outbreak in Peru, in 1992. The second unit, focuses on the region of the Mediterranean Sea, the importance of the Mediterranean Sea to the global industry, special examples of invasive species in the local area and the issues that were raised, not only by ballast water but from co – relating factors such as the oil spillage and the climate change. Consequently, after the first two units, since there is a better understanding of the ballast water issues and the seriousness of the threat, the International Maritime Organization (IMO), its importance and mission is being

emphasized. There is a chronological series of events that ultimately led to the IMO addressing the problem, creating guidelines and regulations for everyone involved in the Shipping industry to comply. The Ballast Water Management Convention and its regulations are being analyzed extensively, together with key dates and measures that vessels, ship owners, captains etc has to take into serious consideration and follow. Moreover, modern ways of technology that deal with ballast water issues, the Ballast Water Treatment plan, is highlighted. The final chapter refers again to the Mediterranean Sea and some regional mechanisms, strategies and actions that the country – members and sub – regional organizations agreed upon on the Barcelona Convention 2009, for the Mediterranean Strategy on Ships' Ballast Water Management. The research ends with the conclusions and the references that were used.

1 Ballasting and early effects of ballast

Ballasting is one of the most significant, if not the most significant, processes for the proper navigation of ships in general, which do not yet carry cargo or the proper amount of cargo required for the propeller to be underwater. The propeller needs to be sufficiently sunk in order to ensure safe navigation, flexibility, trim and stability of any vessel during voyages. The concept of ballasting is definitely not something 'new'. Since the old times, vessels used to be filled with all kinds of solid ballast such as rocks or bags of sand. Even ruins left from the big ports of World War II were used as ballast for vessels travelling the Atlantic Ocean. The 'early' effect of ballast in the world and the environment, started to show its colors and it can easily be understood with a small research and a few images. More specifically, rocks from the shores of Liverpool that served as ballast for vessels travelling from England to the United States, are the main characteristic of 'Cobblestone streets' in Georgia (U.S.A.).

Image 1 : Cobblestone street, Georgia, United States of America (photo by : Anthony Martin)

An entire island was created unintentionally in Sweden, called 'Little Norway', because of Norwegian Vessels releasing their ballast at the river while sailing through the river Angermanalven. Mounds and mounds of ballast grew and combined with sand flowing from the

river that caught up in the ballast, resulted in the creation of an island. It is well known that some special flowers grow in 'Little Norway', that can't be found elsewhere.

Image 2 : Little Norway (photo by : Lilian Vesterman)

However, in the modern times various difficulties came up during loading or discharging of solid ballast, adding the fact that it was time – consuming and therefore solid ballast was replaced by liquid ballast. The landscape changed and from there on only liquid ballast (salt or fresh water, brackish water) has been carried by vessels in their ballast tanks. As sea water could be found in vast amounts and easily available, it was mainly used for ballasting and de – ballasting processes. When there is not cargo carried by a vessel, she becomes lighter in weight and causes stability problems. To address this issue, ballast water is taken into the ballast tanks with the help of high capacity ballast pumps. This process is called Ballasting. On the other side of the coin, when the vessel carries cargo (fully or partially loaded), her stability is maintained by the weight of the cargo itself. So, ballast water is not anymore needed and the process of taking it out from the ballast tanks starts, in order to make them empty. This process is called de – ballasting.

The non – existence of a ballast water system can cause various issues to a vessel. The engine of a vessel and its efficiency can be reduced if the propeller is not fully immersed into the sea. Longitudinal instability and problems of dynamic transversal may arise for the vessel. Also, there could be increased stresses on the structure of the vessel that can easily lead to slamming and bending. Therefore, ballasting is crucial because it provides transverse stability, reduces the stresses and last but not least aids the propursion plant to maintain its efficiency and allows the vessel and the captain to have the ability to 'manoeuvre' in any incident he feels like is needed to.

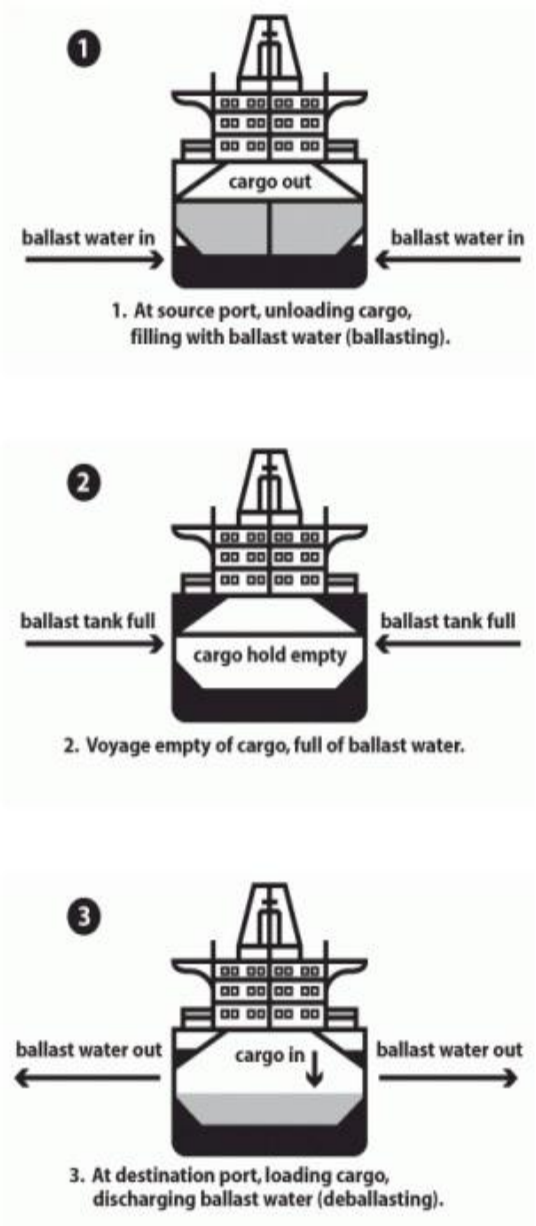


Diagram 1 : Ballast water, during loading/ discharging operations and voyage (courtesy of GloBallast)

Moreover, there are different kinds of vessel types and their ballast tanks, therefore, adding or removing water depends on the vessel's stability condition. Specifically there are three different types :

(1) " Light Ballast**:** When the vessel is heavily loaded, and it does not require an additional ballast, the water ballast tanks are kept empty. This condition is known as a light ballast.

(2) Heavy Ballast**:** During the seagoing state, if the ship is not fully loaded, ship ballast tanks are filled to its capacity. This condition is known as a heavy ballast.

(3) Port Ballast**:** Many ports around the world have a restriction for usage of ballast water. Dedicated port ballast tanks are provided to correct the trim and list of the ship during loading or discharging operation, and this is called port ballast. " (Anish Wankhede, 2019)

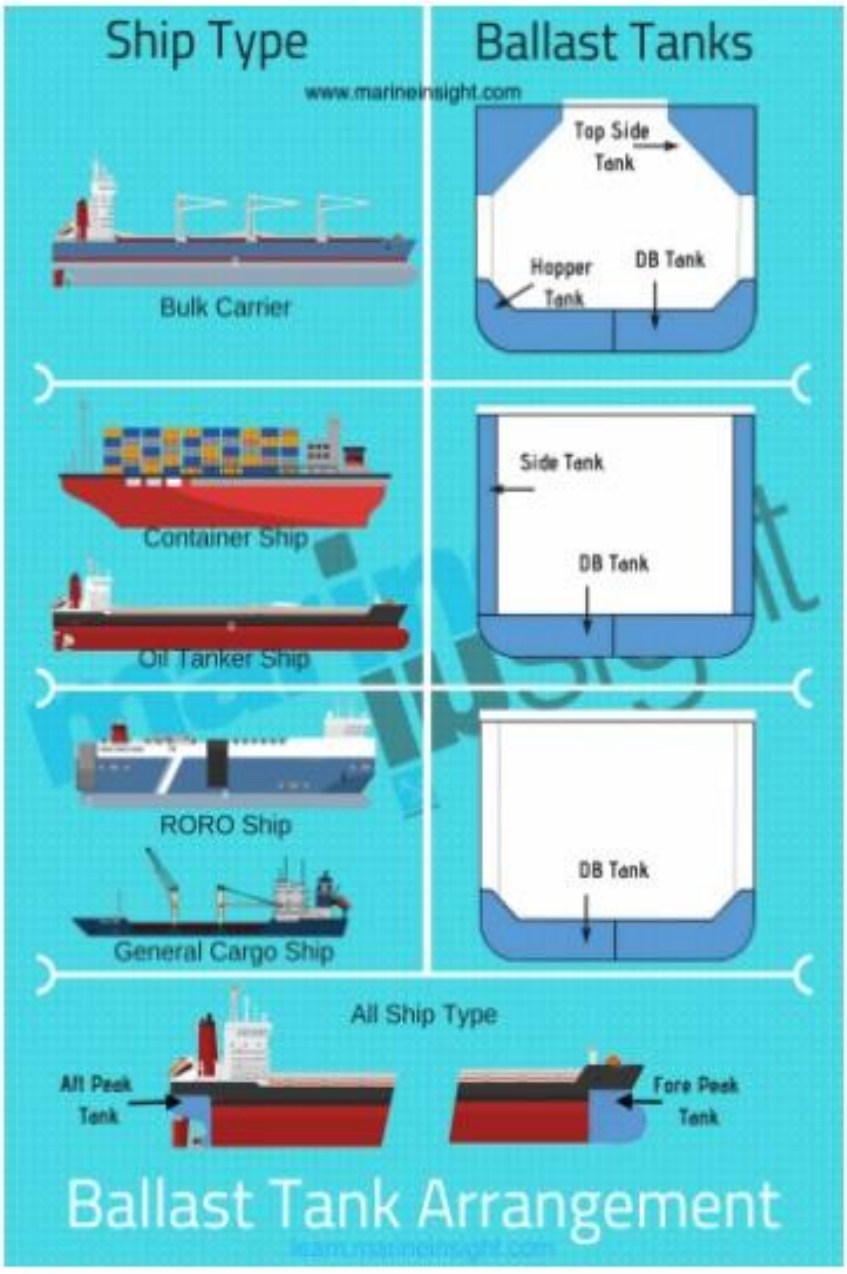


Diagram 2 : Vessel, Ballast tank types (by Wankhede)

The “diagram 2 ” above sums up the different kinds of ballast tanks and their location depending the type of the vessel. There are :

- The Topside tanks, which are more common in bulk carriers, where, the tank or the tanks, are located on the topside of the vessel. They are connected directly to vessel’s main ballast pipelines and during the loading or discharging operations of the cargo, the volume of the ballast water in the topside tanks is kept in equilibrium with the weigh of the cargo. This special design of the topside tanks, assists in avoiding possible shift of the cargo in inaccessible spaces for the grab.
- The Lower hopper tanks, which are of similar construction with the topside tanks, are located on the bottom side way of each cargo hold of the vessel and they are kept in continuation to the double bottom tanks, that passes through the middle of the ship.
- The Double bottom tanks, which are a crucial safety measure for the vessel in a case of a collision or running aground in order to avoid ingression of sea water. These tanks are used for storage of ballast water. These tanks are usually divided in two sections, between forward part and aft peak, dividing the engine room, or in three sections in ships like containers and bulk carriers.

1.1 Effect of Ballast Water

To simplify what has been mentioned above, when a vessel dock her cargo in a specific port where the voyage will commence, she has to take on huge amounts of sea water to maintain her stability, that is then unloaded at the destined port (diagrams 3 & 4) . Historically, as have been already written, vessels used to take on ballast in the form of sand or rocks and this is likely to have transported many non-native plants everywhere. The likelihood of sea water ballast to carry no – native organisms from countries of the opposite side of the world, is real and a very serious threat to everyone, including people, oceans, ports, and last but not least the environment in general.

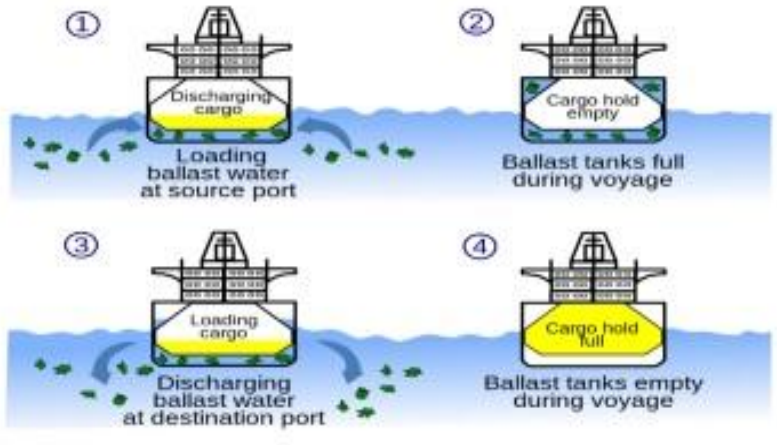


Diagram 3 : Ballast water, pollution of the sea (by Hartmann)

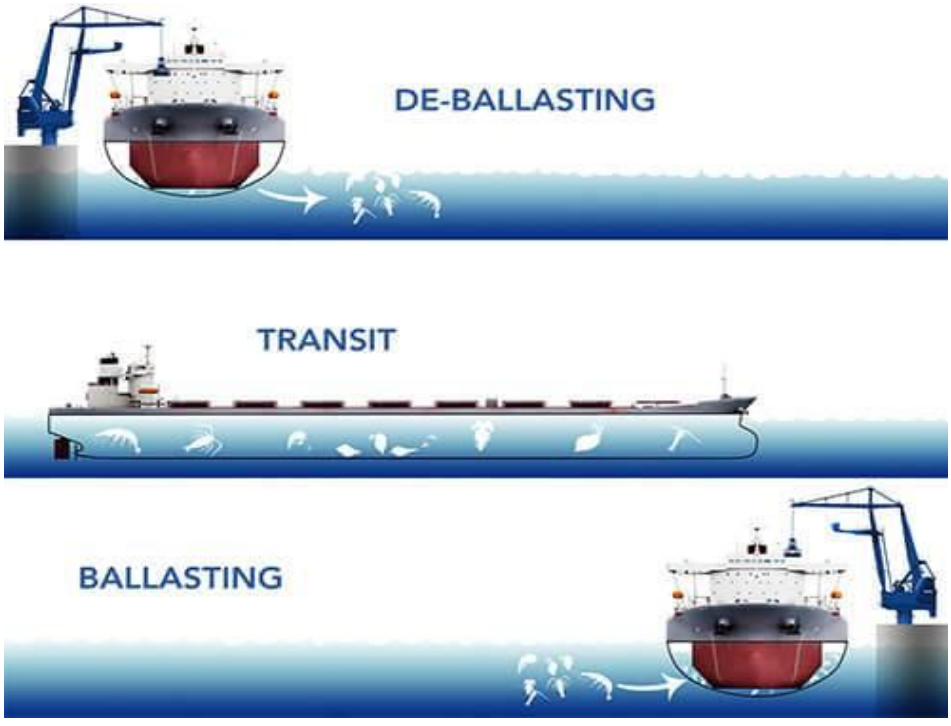


Diagram 4 : Ballasting and de – ballasting invasive species (by damengreen.com)

The effect to the marine environment that is caused by marine species in vessel's ballast water has been named as one of the four serious threats to the world's seas by Global Environment Facility. Through, the world shipping trade, maritime moves about 85% of the world's products and goods and transfers almost 10 billion tones of ballast water across the world. Thousands and thousands of different marine species can be carried to a vessel's ballast water; almost everything that is small enough to pass through a vessel's ballast water intake ports and pumps. These marine species can include bacteria and other microbes, small invertebrates and the eggs, cysts and larvae of various species. The main problem is a combination of the fact that all these species have life cycles that contain one or even more plank tonic stages. The majority of these species that are inside the ballast water cannot 'survive' the voyage and the loading / discharging operations because of the enclosed environment and the nature (no light, oxygen etc) inside the ballast tanks. That has a serious effect on the so called Biodiversity (the ecosystem, the fauna and flora) . To get a better understanding of the term Biodiversity and its importance lets refer to this article of "What Is Biodiversity?" :

"The term biodiversity (from "biological diversity") refers to the variety of life on Earth at all its levels, from genes to ecosystems, and can encompass the evolutionary, ecological, and cultural processes that sustain life. Biodiversity includes not only species we consider rare, threatened, or endangered but also every living thing—from humans to organisms we know little about, such as microbes, fungi, and invertebrates. At the Center for Biodiversity and Conservation, we include humans and human cultural diversity as a part of biodiversity." (What Is Biodiversity? By CENTER FOR BIODIVERSITY & CONSERVATION https://www.amnh.org/research/center-for-biodiversity-conservation/about-the-cbc/what-is-biodiversity)

The impact though, is not limited only to the environment. There is a huge impact to the world's global economy because of the biodiversity issues that comes along with the invasive aquatic species' corrective and preventive measures.

" In 2009, the cost of invasive species was estimated at USD 50 billion, corresponding to Bulgaria's current GDP. WWF's latest Living Planet Report shows that invasive species are one of the main reasons that large populations of marine life have disappeared from our global waters." (The end to alien species invasion in our waters starts today, Ottilia Thoreson (2017) https://wwf.panda.org/?310653/The-end-to-alien-species-invasion-in-our-waters-starts-today

"Based on the most recent OECD (Organisation for Economic Co – operation and Development) statistics, earnings by the world shipping industry in 2009 were $380 billion. So, if $12 billion in fleet – wide annual

Ballast Water compliance costs were absorbed fully by the shipping industry, it would reduce annual shipping industry earnings by 3.2 %." (The economic impact of the US ballast water regulations,Dennis King, (2013) https://www.bunkerworld.com/news/insight/124957/Dennis-King/The-economic-impacts-of-US-ballast-water-regulations)

Below, there will be an extensive analysis of the key elements and marine species that through the years caused numerous and serious issues to not only the environment but in several occasions, to humans.

1.2 Alien Species

With the term alien species, that are also known as invasive or exotic species, we perceive the species that have been most of the times unintentionally introduced and put inside a different and new ecosystem where they managed to dominate it and establish population in it. In such an ecosystem where the species originate, there are several of physical interactions that control most of the populations like for example, predators, parasitism and various diseases that prevent their growth. Though, in most of the occasions these species are considered as 'intruders' to these new different ecosystems because they are not always compatible with the above mentioned interactions. So, intruders – species are the those species that are installed into a new ecosystem (natural or semi natural) or environment and they are the main reason of alteration to the nature of each ecosystem, as they constantly establish new populations and further distribute and threaten each particular native biodiversity. These really harmful and dangerous micro – organisms are a real threat, either pathogenic or not and are the main and basic cause of marine pollution. The 'success' of their colonization to new ecosystems is owed to some specific elements and characteristics that allows them to be 'out of control'. Such elements, are the special ability of them to prosper inside difficult environments and to thrive through extreme and unusual environmental conditions, the lack of predators and the high – amount of growth rates they exhibit.

1.3 Invasive Species

The Marine ecosystem is the largest aquatic ecosystem of the whole Earth and marine waters cover almost 70% of the surface of the planet and account for more than 97% of the supply of water to earth's population. It is undoubtedly the richest source of life as it houses about 250 thousands of discovered species and many more that are yet to be found and recognized. More specifically, Europe has a large amount of marine biodiversity of higher organisms that are new non – endemic species of organisms (zoobenthoos), pathogens, plants (phytobenthos) to name a few. An instance of one of those living organisms, the freshwater zebra – mussels (Dreissena polymorpha) is native to several of the European seas (Black, Azov, Caspia). These specific zebra – mussels it is believed

to have been transported to the region among North America (Great lakes of basin) , Canada (Ontario) and the North Atlantic ocean that is called the Great Lakes region or Saint Lawrence Seaway through ballast water from transoceanic voyages. Almost 400 billion worth in cargo such as iron ore, coal, cement, stone and grain) has been transported to or from the Great Lakes ports to the rest of the world since 1959. That special region that is full of locks and canals that connects the Great Lakes to the Atlantic Ocean through Canada created a pathway for at least 80 invasive plants and fish. That caused serious damages to the local agriculture and fisheries and even affected stocks of drinking water. In addition, it also damaged many docks, small boats, clog pipes and some machinery. The zebra – mussels are one of the 187 no – native species that are now established in the great lakes region. They first have been spotted in 1988 in a North America lake called Saint Clair. These zebra – mussels managed to spread to every other lake within only 2 years. The problem in the area was enormous and extreme measures had to been taken in order to minimize it and prevent it. According to some researches especially to a (Matej, 2015) research, about 500 millions of dollars (US) had been spent yearly over a 10 – year span, for reparations and damage checks and also for the coverage and replace of native mussel species that ultimately led to their extinction. Many scientists, researches and industry groups from both the United States of America and Canada tried to study the phenomenon. That incident played a big role in the strict regulations the U.S. and Canadian governments have establish for ballast water.

Image 3 : Zebra – mussels , Great Lakes of USA (JIM MALEWITZ AND SARAH WHITES-KODITSCHEK, 2019)

Likewise, a plant species called water primrose (Ludwigia grandif lora) found in seabed and the wetlands, appears to be highly invasive especially in the Baltic seas and to several European aquifers. It is considered one of the most damaging plants in each particular country. That species are responsible for the destruction and killing of numerous fishes because it prevents them from absorbing enough oxygen.

Furthermore, species called green crabs (Carcinus maeanas) that can be found to Australian, South African and both Atlantic and Pacific ocean Coasts, are the main reason for highly increased amounts of cancer incidents to human population. It is considered to be one of the world's worst and 'deadliest' invasive species. In addition, through vessels that travel around the globe and load and unload ballast water, species named toxic dinoflagellates have been spread across the world. This particular invasive species can multiply rapidly and form the so called 'red tides'. Under specific conditions they will get absorbed by many shellfishes or even scallops and clams. They release toxins that in most of the occasions cause paralysis to humans. There is a possibility though, that these toxins can cause death to people that will consume that particular shellfish. Other dangerous invasive species are the sea squirt (Styela clava). They are immobile marine invertebrates that are able to extract food and some important organic material from the sea – water pumped by a branchial saque in its body cavity. Sea squirt can be found in the Eastern countries of Asia (China, Korea, Japan) and it has also invade the coast of Australia and USA. It is mainly responsible for the negative impact it has to the local food chain and for biofouling on ship hulls.

The non – native aquatic species of Phytoplankton are possibly the most 'succesful' micro – organisms that are transported through ballast water. The nature of Phytoplankton (small, ubiquitous, capable of surviving without light) allows it to colonize vastly. There have been found at least 150 species in the San Francisco Bay since 1973 and approximately 80 species in Coos Bay, Oregon in the Chesapeake Bay. There are about 350 Phytoplankton species (Cyanophyta, Dinoflagellata, Bacillariophyta etc) . These species through their high – development rate, are capable of single handedly destroy and massively decline the Zooplankton and pelagic fishes. In addition, some specific phytoplankton organisms produce toxins that can further transmit to humans through fishes. The WHO (World Health Organization) highlights the fact that these people can suffer from amnesia, diarrea, food poisoning and even death.

Another important aspect of marine invasive species and marine bio – invasions is the transfer of non – indigenous organisms. The extension and the importance of such organisms had not always been well – known and is possible that for many years the voyages and ballast water movement throughout the world had create a mechanism for them to grow and cause various waterborne

diseases that affect humans, plants and animals. The first concern about the transmission of pathogenic Bacteria from ballast water started in 1992. United States of America organizations such as FDA (Food and Drug Administration) and the CDC (Center for Disease Control and Prevention) found Vibrio Cholerae in shellfish that have been collected from vessel's ballast water. Originated from South America, these samples indicated that this particular organism, survives and thrives in marine waters. In January 1991, the bacterium of Vibrio Cholerae infected 3 major Peruvian ports and eventually spread throughout the whole continent of South America. From January of 1991 until June 1995 there were a total of over 1 million cases and 10 thousands deaths in South America. During the year 1994, all of the countries that the transmission of Vibrio Cholerae had been detected, continuously registered new cases. All the cases that reported in the United States of America were classified as 'imported'. More specifically, studies by (MacCarthy and Kambathy, 1994) in various ballast water samples in several ports of United States (Alabama, Mississipi) found Vibrio Cholerae in a 30% rate, with the most recent stop of these vessels voyage to be either Brazil, Colombia or Puerto Rico (South America Ports). After the end of the investigation by (MacCarthy and Kambathy, 1994) the United States of America and the Committee of Protection of the Sea Atmosphere produced the "International Guidelines for the Prevention of Introduction of Undesirable Pathogens for the Discharge of Water of Ballast and Sediments of the Ships". Immediately, the United States Coast Guard requested from all captains and agents to accept and follow the recommendations of those guidelines in order to reduce the possibility of pollution to the coastal waters. A global effort that started from the FDA, the United States Coast Guard and the CDC officials, showed that 6 out of 109 ballast water samples obtained from more than 90 vessels that travelled from South America to the United States of America were contaminated with Vibrio Cholerae 01 serogroup. The concentration of serogroup 01 was significantly high in plankton samples. Moreover, the disease had a seasonal distribution pattern and showed explosive outbreaks in some particular places. It was a catastrophic outbreak that really put the world on notice regarding ballast water issues and the serious effect it has. Afterwards, a study by (DELILLE D., DELILLE E. ,2000) mentioned that a cholera outbreak had begun way before the one of Peru, in Indonesia in 1961 and is possible that it completed the global cycle in 1991 when the infection found in South America. Through the history, the fact that was mentioned above (the seasonality of the cholera outbreak), has been confirmed due to special coastal areas outbreaks that happened during Spring and Autumn. Also, the study by (DELILLE D., DELILLE E. ,2000) showcased that enteric bacteria have been found in Antarctic Ice, of all places!

Cholera in Peru

Fred M. Reiff

Peru is making determined efforts to disinfect community water systems and thus control this ancient pestilence.

Since 7 March 1992 Peru has suffered more than 400 000 cases of cholera and over 3100 deaths in the epidemic which broke out in this country in late January 1991. Cholera is usually spread from one location to another by people, and can also be propagated by contaminated water. Travel is relatively inexpensive in Peru and the people use the well-developed national transport system extensively. This mobility to a large extent helped to ensure cholera's rapid introduction into all parts of the country, and as long as there is even one focus of infection it can spread in this way.

The appearance of cholera, however, does not necessarily result in epidemic propagation, which occurs only where environmental health conditions and hygienic practices are deficient. This was confirmed in Latin America, where the overwhelming majority of cholera cases have been in economically disadvantaged areas with no basic infrastructure of public services (water supply, sanitation and solid waste disposal).

Prompt treatment with rehydration therapy and antibiotics can reduce the severity of the disease and save lives, but this has a limited effect on the spread of cholera. Mass immunization is generally not prescribed as a public health measure because of the short-lived and uncertain immunity it provides. Environmental health measures to protect water and food from contamination (or to decontaminate them) and to promote good personal hygiene practices remain the most effective barriers to the spread of cholera.

Water and food contamination

In the absence of safe water, adequate sanitation and food safety, water and food can be vehicles for the spread of cholera. Indeed, contaminated water is frequently the cause of contaminated food, and it follows that the sanitary disposal of excreta should play a key role in the prevention of this disease. Direct contamination of food with a cholera victim's excreta is a rarity but indirect contamination with polluted water during handling and processing is commonplace. Even when the level of contamination of water is below the infective dose, once it comes in contact with foods which support the growth of *Vibrio cholerae* such as rice, fish, crab, shrimp and so forth, the subsequent proliferation of this organism on the food can result in an infective dose in a matter of hours or even minutes.

Various studies in Peru have demonstrated the poor water quality in many of the areas now affected with cholera. Between 1984 and 1985, 100 water supply systems were examined, including wells, springs and surface water supplies both with and without filtration. Most of them produced contaminated water. Only two of the 40 systems claiming to practise chlorination were satisfactory (with adequate chlorine residuals) and, among the simple gravity systems, none of the 20 claiming to practise disinfection showed chlorine residuals.

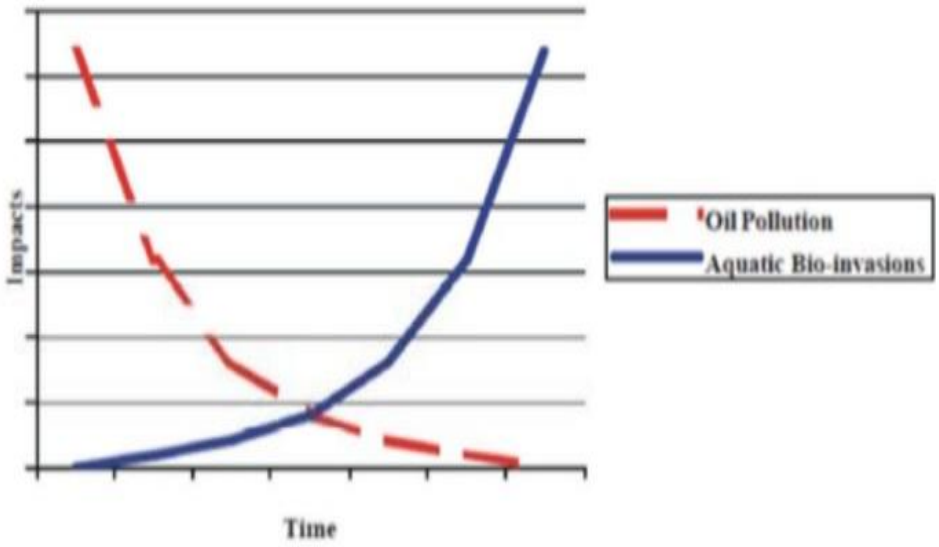
In many localities, ice is prepared from water which receives little or no treatment, a situation perpetuated by the myth that freezing destroys the pathogen. This simply is not true. Ice proved to be a common source of food and beverage contamination. Washing-up water used many times by street vendors for glasses, plates

When latrines contaminate drinking-water, cholera danger lurks

Image 4 : Cholera Outbreak News , Peru (Fred M, Reiff, World Health Organization, 1992)

1.4 Ballast Water Issues and Oil pollution

The vessel's ballast water can be separated into two main categories, 1) Is the ballast from the usual holds of a vessel and 2) the oil tank ballast water. A lot of crude oil tankers do not have clean ballast tanks, so they use the so called oil tanks that a Crude Oil Washing (COW) has happened in order for them to carry ballast water. Therefore, oil residuals that are still left inside the oil tanks, when necessary, will be loaded or unloaded, depending the loading / discharging operations. This whole incident causes oil pollution to the environment and in the sea – water especially. Someone, who may not pay the proper attention, might think that the ballast water issues with the invasive species and oil pollution are two concepts that are not closely relatable. Which in essence is correct, but, the huge importance of marine biodiversity through ballast water invasive organisms can be highlighted by just comparing it with a major oil spillage that is possible to happen in a sea environment. People's perception is that if an oil spillage happens at any time during a voyage from a tanker vessel, it is conceived as natural disaster. The international Community, Governments, Insurance companies, Classification Societies, Ship Owners, Captains etc, must immediately take actions to address the issue. Billions of dollars will be spent in the attempt of repairing such a major disaster. On the other side of the coin, an invisible enemy called alien species or invasive species, when a microorganism invades to an ecosystem and creates an environment in which he can prosper and establish itself, then is nearly impossible to 'repair' such an incident. It takes some serious thoughts and actions for people to understand the effect and the impact that invasive species through ballast water has to humanity and the environment short or long – term. Even though, an oil spillage is a huge destruction to marine ecosystems, with concentrated efforts, like decontamination practices it can be reduced steadily and in cases that it happens in the middle of an Ocean is not as harmful to the environment. But, once the invasion of aquatic species happens, the effect is irreversible and similar practices cannot be applied to reduce or minimize the problems. There have never been a successful eradication of marine invasive micro – organisms, till this day. Only in some special circumstances, in which invasive species have been found at close in – land waters of a bay, their actions, growth and effect have been controlled and been limited, with the use of some special biocidal products. Below, it will be presented a really useful graph, regarding the impact and the time of oil pollution and aquatic bio – invasions.



Graph 1 : ‘Relationship’ of effects between Oil Pollution and Aquatic Bio – Invasions (Alaa, M.I. & Manal, M.A. 2012)

2 Mediterranean Sea and Ballast Water

The Mediterranean Sea, one of the most complex marine ecosystems in the world, is inhabited by diverse species and rich biota which affects the quality of the waters of the sea and the environment. Today, marine invasive species are considered to be one of the most crucial threats to biodiversity all over the world. Due to its position, the Mediterranean Sea is affected by a number of reasons, such as on – going vessels, degraded habitats and different marine species that come from canals and other marine roads, pollution of humans, traffic and blast of ships, as well as the high occurrence of aquaculture. For example, it is estimated that more than 4,000 marine species have been transferred around via commercial vessels around the world and it's also very important to state that 30% of these species may have entered the Mediterranean Sea. Even though the Mediterranean Sea represents just a small part of the oceans worldwide, it is inhabited by an unusually rich and diverse biota. For instance, it is estimated that is home to more than 17,000 species, representing 4–18% of the world's marine biodiversity. Moreover, it includes temperate, cosmopolitan, subtropical, Atlantic and indo- pacific, temperate taxa. As a result, the Mediterranean Sea is considered as a "hotspot" of biodiversity from all over the world. It's also important to state that a lot of species have entered Mediterranean through the Strait of Gibraltar when it re – opened, allowing species of the Atlantic Ocean to enter the Mediterranean. Also, various other marine species entered in the Mediterranean through the Suez Gulf. All these new species have caused a great impact on biodiversity, human health, marine far, fishing activities and more. Ballast water have been a source of both chemical and biological pollution. Actually, it is estimated that more than 10 billion tons of ballast water is released in the water of foreign places. From oil tankers to smaller vessels, seawater is polluted by ballast water.

Some of the most significant new enters of species cause various problems are considered to be among other the zebra mussel, the comb jelly (from Black Sea), the Asian clam Potamocorbula amurensis (in the US), the Asteria amurenisis (northern Pacific seastar) and the toxi dinoflagellate. (Shunshkina et al., 1990). All these taxa that are introduced by means of ballast water include molluscs, marine plants, decapo crustaceans, bryozoans, ascidians and fishes. It is estimated that 30% of the invasive species are plants, 38% of molluscs and more than 55% crustaceans that have introduced in these waters that came from cold-water regions.

Mediterranean is one of the most usable routes for ships and that is why it has a log of non-native habitats in its waters. European Mediterranean ports receive a huge number of ships compared to other ports in the world every year. In fact they get at least 75% of ship calls. Is extremely

important to be noted that, that the most significant traffic hotspots in the Mediterranean Sea are generally some canals and straits, the Straits of Gibraltar, the Suez Canal, the Black Sea (through the Turkish Straits) and the route of North Africa. Today there is a lot of traffic in these seas from ships from Asia and in general vessels from all over the world often discharge their ballast water and as a result they cause pollution to the sea. Over the last years many vessels cross the Mediterranean Sea in order to reach their destinations. According to estimations, around 77% of the ships from all over the world used the Mediterranean ports in order to load or reload their cargo.

Though, it's needless to state that the use of ballast water for ship stability it's not something new, it actually exists since the 19th century, when many vessels at that time carried a number of heavy materials, such as rocks. In fact, vessels always used water to ballast in order to be able to travel safely in different seas around the world. (Carlton, 1985).

2.1 Pollution of Mediterranean Sea and Coasts

Even though it has already been mentioned, ballast water and oil pollution are two "worries" that can be co – related. When a large ship is being loaded, it discharges seawater, in order to stabilize its balance. But these ballasts that are discharged from ships are to an extent responsible for tar ball in the seas and oceans around the world. It's important to state though that oil pollution from these type of vessels can be present because of accidents or because of deliberate actions (including oil tankers or smaller vessels). Either way the environment of the sea is polluted or that can have other effects for biodiversity and for humans. More specifically, many ships that travel around the world today produce wastes of oil in their everyday operations around the seas. Some examples are the oil – contaminated ballast water, that is generally used to vessels in order to help them to be stable, the bilge water, that vessels produce in order to clean different parts of their ship, such as the engine and other spaces, while traveling, and tank washing residue, which is in fact produced when big vessels, like for example oil tankers are cleaned by using crude oil or similar substances.

Generally there are a number of very strict regulations about this matter (ex. 50 nm of land as well as well as in some –so-called- "Special Areas", such as the Mediterranean Sea, among others in the world, according to MARPOL, Annex 1). Even though the managers of ships are very responsible, we need to state that there are some instances and some pollute the sea deliberate for a number of reasons. For example, instead of collecting and storing the dump waste at the ship, it's actually easier and quicker to dump it at the sea. Concerning these actions, it's important to state that some people believe that they won't get caught and they continue to pollute the sea. the emissions of ships can be felt more in cities that have ports or extensive coastlines. These emissions (ex. Sulphur aerosols) cause a great deal of health problems to the people that reside around these areas. (EEB et

al., 2004). These types of aerosols contribute to different formations of clouds that generally can be found above the oceans in various parts of the world. A number of studies that have made by the IMO have actually shown that a percentage around 75% of the ships occur within 400 km of the coasts (IMO, 2000)

Even though accidents do not take place in a regular basis in the sea, they are still a big problem for the pollution of the waters. In certain instances, oil from ships may be spilt into the sea. These actions are caused by accidents of ships in the environment and they are believed to make up to 36% of the oil entering the environment of the sea.

One incident like this, concerns the "Prestige" tanker, when in November 2002 one of its tanks burst during a severe storm, near Spain, of the coast of Galicia. The tanker burst and it split around 63,000 tons of oil in the sea. The tanker subsequently sank and the spill polluted tens of thousands of kilometers of coastline and thousands of beaches on Spain, France and Portugal. It is the largest environmental disaster in the history of these Mediterranean Countries, that caused a great harm and was a huge blow for the Mediterranean Sea in general and the local fishing industries. There are various other similar examples in the world that have caused a significant pollution to the sea. This is mainly why a number of organizations around the world have taken important steps and adjusted certain regulations, in order these kinds of cases to be avoided in the future.

Image 5 : Prestige Accident and Sinking, (Duygu Ulker, researchgate.net 2016)

2.2 Invasive Species on the Mediterranean Sea

Commercial and other vessels of all types, pollute the sea environment by also carrying, among others, a number of non – indigenous organisms. Vessels do not only discharge ballast water in the seas, but they also transport various organisms in their ballast water that are harmful for the environment. It has been estimated that their ballast often contains different species, such as various types of algae, like the zebra mussel, comb jellyfish, the killer algae and more, that enter a new environment and disrupt the environment of the native species. It's important also to state that there are a number of micro-organisms that enter coastal ecosystems through ballast water.

There are a number of examples around the world of different kind of micro-organisms that cause various problems when invaded a new environment. Like a particular species of comb jellyfish, like the Memphiosis leidyi (introduced for the first time in 1982), that inhabits estuaries from the USA to Argentina (ex. to the Valdes Peninsula) along the Atlantic coast, has caused damage in the Black Sea. More specifically, as it was thought it transported jellyfish and it cause a very significant problem upon the fishing industry in these areas. The increase on the population of Memphiosis leidyi was a result of a decreased number of plankton – consuming species and the breakdown of the local fisheries. The so – called Black sea Anchovy extinction due to this invasive marine species, is a representative sample of fauna annoyance. Many of these type of organisms, such as worms, mollusks, protozoa, as well as some other type of species usually settle inside the tanks of the vessels and they can actually live in the muds and they can remain there for several months. Therefore, all these biota are considered to be crucial components of ballast water uptake, adding to the diversity of carried organisms released in various different regions and they can also carried away by the strong wings.

It's important also to state that various invasive species, such as jellyfish can take over the new environment they are found in and they may cause various problems to local seas and the people living around these areas. For example, they may alter the geomorphology of different landscapes, spread various new diseases, introduce new genetic material and they even cause problems to the native species, such as they may jeopardize their ability to look for their everyday food. More specifically, invasive herbivore species as the silver – cheek toadfish, Lagocephalus scaleratus, alters the landscape of rocky coasts with algae. Likewise, the micro – organism of clam Ruditapes Philippinarum, causes great deal of harm in local fisheries as it displaces the native species in the area and it benefits from the harvesting process of these fishermen because the loads of suspended materials are getting increased. Moreover, an ecosystem like the Mediterranean Sea is extremely vulnerable to invasive species and to intrusions because of the state of the environment. Areas that

are polluted and degraded tent to accept invasion of marine species rather than places that are environmental friendly. For example, the sea worm Hydroides elegans, can be found very often in marinas of Mediterranean Coasts and destroy the local aquatic fauna that has contaminated water, but on the other side of the coin the same organism cannot be found in marinas that contain clean waters.

2.3 Alien Species on the Mediterranean Sea

Even though the impact of alien species and subspecies has not been explored widely, they are considered to be one of the biggest threats of the biodiversity and the ecosystem of the seas. According to estimations, more than 5% of the marine species are non – native ones in the Mediterranean Sea. Due to the increasing number of new introductions of these species in a regular basis, Mediterranean Sea is one of the main hotspots of marine bio – invasions.

One of the top reasons why these species are been attracted in the Sea is because of the warmer waters and the weather conditions that exist in the area. They all manage to find their way, through canals and other pathways, to enter this region. For example, it is estimated that more than 800 new species have been introduced in this region after 1950. (Zenetos et al., 2012). The vast majority of alien species come from different parts of the world, such as the Indo-Pacific area (41%), the Indian Ocean (16%) and 12% from Red Sea. The majority of these marine species are been found mainly in the Eastern sub – region. We need to highlight though, that many plants and species are put into a marine environment deliberately in order to support aquaria and other fisheries and ventures of a certain area. On the other hand, various exotic species have been traveled to new seas through the ballast water of the ships. As a result they enter through canals and other "gates" new waters.

At the beginning, the problem that was created in the sea and in the environment by these species has been underestimated and no one could actually understand and comprehend the huge problems they cause. (Guala et al., 2003). But today this phenomenon has been taken a lot into consideration and Europe has introduced a number of project to take care of this matter, such us the Algae Introduction to European Shores. Most of these alien species enter the Mediterranean Sea through ships or human activity and other transported stuff. One of the major paths of these marine organisms into the Mediterranean is the Suez Canal. According to estimations, approximately 53% of different types of exotic species enter the Mediterranean Region through this way.. These, non – endemic macroalgae can overtake their new environment by competing with native species for more space or food and sometimes these external type of species even manage to replace the existing floral and faunal species. The Mediterranean Sea holds the record for the highest number of alien plants in the entire world, as more than 65 Macroalgae have been introduced with the biggest

amount of them being serious and dangerous intruders. For example, certain species like Caulerpia taxifolia and caulerpia racemosa have been actually spread around this sea via vessels and other activities, like fishing. The former, constructs dense layers that disrupts various sectors like sea path – ways, displacing native plants, rapidly reducing the reproduction of local fishes and of course harms human life with difficulties in diving and parasitism. Also, Caulerpia taxifolia produces some toxins that turn their taste into a really unpleasant one. That affects certain fishes which cannot consume them, a fact that results into their rapid growth. The latter, Caulerpia racemosa, benefits greatly from the growth of the offshoots and overlap other algae. The sudden and rapid growth of Caulerpia racemosa into the bottom of the Mediterranean Sea, has caused huge problems to fishermen because their nets are getting blocked and filled with macroalgae.

Finally, it also needs to be noted, that the success of alien species in a different environment depends upon various other characteristics, like biological ones. Moreover, rich ecosystems are considered to be way more resistant to invasion of marine species and to "allowance" of alien species to increase their population, than poor ones.

Image 6 : Caulerpia Racemosa in the Seabed, image by Wikipedia.org

2.4 Aquaculture of the Mediterranean Sea

Aquaculture is not a recent phenomenon in the Mediterranean Sea. Actually it existed for many years and there is evidence of the existence of fish in various lagoons and ponds around the world since 2,000 years ago. It is important to state that there is also evidence of marine farms during Roman times. Back then, people used to captivate oysters and mullets among others, in order to have their everyday food. Since then, the Mediterranean aquaculture has evolved extremely and various species have been found in certain hotspots in the Mediterranean, such as the Venice lagoon, in Italy, and the Thau lagoon in France and in various other places.

The industry of aquaculture has evolved a great deal, especially the last twenty years. More specifically, aquaculture increased from approximately 487 tons in 1995 to 1,228 tons in 2007. This industry has been developed a lot in various countries around the world, such as France, Greece, Italy and Turkey among others. All the above countries had the perfect weather and the best conditions for these species to thrive. The warming weather has influenced a great deal the distribution of marine species in the seas and the oceans around the world. More specifically, various tropical species of Atlantic origin have found their way into the Mediterranean, such as the Lessepsian migrants, where they settled in the region. In addition, the warmer weather had some other effects; it led to the decrease of the number of some boreal species that lived in the cold waters and they didn't have the ability to migrate to other water. Moreover, these places also had various towns near the sea and the ports and people could sell fresh products. Another example of these types of invasions is the marine plants that have been traveled through various paths, through the ballast of the ships, to get to these warmer waters. Actually, the Mediterranean Sea has acquired a large number of plants and the last years this number has actually doubled. In our times, around 90 different plants exist in the Mediterranean Sea and most of them have come in these waters from the Indo – Pacific Ocean and they have settled in the Mediterranean Sea. (Ribera and Boudouresque, 1995).

Mediterranean Sea attracts all these non – native organisms for various reasons, such as its geographical position, the weather conditions and warmer waters. In fact during the course of history, the low temperatures contributed a lot in the invasion of external species, especially during the glacial periods, where several species found their way in warmer waters. (Grosholz, 2002).

2.5 Global Climate Change and Marine Species

Global climate change has been associated with a number of impacts in the sea – waters and oceans around the world, especially the last 30 years. For example, various things around seas changed drastically because of the weather around the globe that is getting warmer and warmer. There is also ocean acidification and the level of the seas is rising (about 1mm each year). This phenomenon has become a real threat for the whole world and it's going to be worse in the years to come if nothing changes. The climate change has a number of consequences on the environment, such as it affects human activities and health and it also affects marine ecosystems. For example, some marine species can be largely affected by these new conditions in the atmosphere, which eventually will lead to various problems, such as extinctions of certain other species.

Due to its geographic position, Mediterranean Sea is considered to be one of the most vulnerable regions around the world. The weather becomes warmer and it is expected to become even warmer and drier in the years to come. The first anomalies of the environment in this region were actually observed in 1999 and four years later, there were various catastrophic events for certain marine species, like gorgonians and molluscs. In addition, the warming of the sea and the sea – waters is the reason for the expansion of toxic plants, like dinobionts, which product palytoxins, that can cause a great deal of harm at the human health. Moreover, various pathogens are introduced which benefit from these new climate conditions, under which they can survive, prosper and harm the environment, human life, the marine fauna and flora even more the upcoming years.

3 Ballast Water Management Convention (International Convention for the Control and Management of Vessels' Ballast Water and Sediments)

3.1 About the International Maritime Organization (IMO)

The International Maritime Organization (IMO) is an agency specialized by the United Nations. It is responsible and takes actions in order to improve safety, security and nowadays cyber – security of shipping worldwide. Furthermore, preventing marine pollution from the travelling vessels is amongst its top priorities. The International Maritime Organization has its headquarters located in London, the so called 'Capital of the Maritime Industry', its main slogan is "safe, secure and efficient shipping on clean oceans" and is the only current United Nations Agency that is located in London. The IMO dedicates effort and time in setting the appropriate standards and regulations for every single vessel that commences a voyage. It makes sure and oversees everything to be in compliance with these standards and regulations by covering every aspect, including legal matters. The IMO was founded in 1959 and it was named as IMCO (Intergovernmental Maritime Consultative Organization, then at 1982 named after its current IMO status showcasing a strong commitment to a vigorous international organization and institution. Ultimately, IMO sets policies for international ships, discourages ship owners, captains, ship management companies etc from compromising on issues like safety and marine pollution, addresses and takes actions on various security and environmental issues. Finally, aims at maritime excellence, by promoting efficient, financial oriented and innovative techniques for vessels and companies involved into the maritime market.

3.2 Chronological 'Timeline' that led to the Ballast Water Management (BWM) Convention

1903 : Is the date of the first scientifically recognized finding of non – native marine species that being transported through ballast water from a sea – going vessel. It was the Asian Phytoplankton Odontella, that appeared in the North Sea.

1919 : Is the date that the Welland Canal was constructed. It was a bridge connecting Lake Erie and Lake Ontario that allowed ships of that time to travel from the North Atlantic Ocean to the region of the Great Lakes. Also, It was the first time that an invasive marine organism named sea lamprey first reached the Lakes for the first time.

1953 : The fisheries in the region and especially in the Great Lake of Michigan (Chicago, USA) were going from bad to worse and the local fishermen reported that a fishing catch in the Lake was less than four thousand pounds, whereas ten years ago (1943) was more than Seven Million Pounds!

1961 : A later study by (DELILLE D., DELILLE E. ,2000) highlighted that in Indonesia in 1961, a cholera outbreak had begun, as marine species of Vibrio Cholerae found in the local area.

1973 : Non – native aquatic species of Phytoplankton have been found in the San Francisco and in the Coos bay, Oregon in 1973.

1988 : The zebra – mussels are spotted in 1988 in a North America lake called Saint Clair. These zebra – mussels managed to spread to every other lake within only 2 years.

1988 : As the issue of ballast water became more prevailing and earned more and more recognition, along with the enormous increase of the maritime industry in those years, it was first raised as an issue in 1998 at the International Maritime Organization.

1990 : The first legislation about controlling the discharge of Ballast Water and therefore preventing the invasive species from polluting foreign ecosystems came from the Non – indigenous Aquatic Nuisance and Prevention with the Control Act of 1990 (NANPCA)

1991: A huge cholerae epidemic starts in 1991, in Peru having huge fatalities for human life. More than one million cases through 1996 had been registered in South America. Invasive marine species of Vibrio Cholereae was the responsible for the sewage water.

1996 : NANPCA was later re – authorized and revised by the National Invasive Species Act of 1996 (NISA)

2004 : For decades and many many years, environmental organizations, local and national governments and the international community in general had address manyfaceted issues such as economic, health and environmental issues that had been raised from the transport of non – native, alien species through the vessels' ballast water, across the face of the earth. Even though the awareness was there, it took a lot of time and an unresolved problem that was constantly growing, for the International Maritime Organization, after years of development, to finally adopt, publish and enter into force the Ballast Water Management Convention (International Convention for the Control and Management of Vessels' Ballast Water and Sediments) or simply the Ballast Water Management Convention.

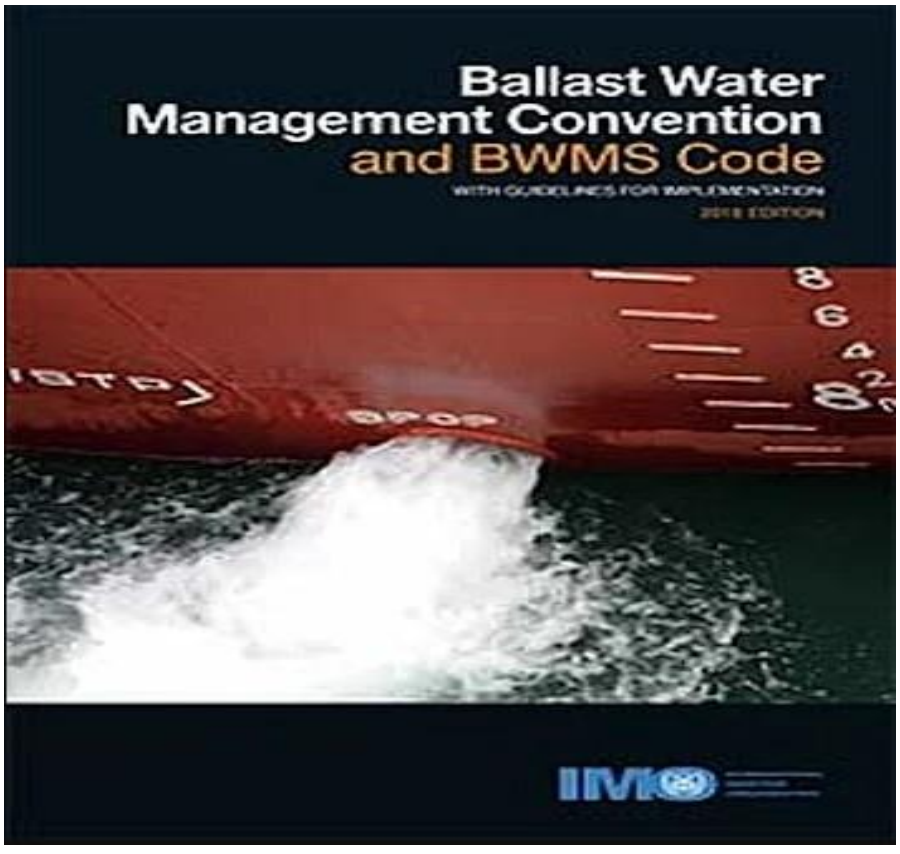


Image 7 : Ballast Water Managament convention Booklet by International Maritime Organization, (2004)

3.3 Detailed Analysis of the BWM Convention

The Convention is a 'treaty' that was adopted by the International Maritime Organization in order to minimize and ideally prevent the spread and further growth, of potentially harmful marine species, micro – organisms and pathogens in vessels' ballast waters. The full document is intended to provide guidance to ballast water sampling procedures, to identify the best practices based on various different standards and has set D – 1 and D – 2, which both will be analyzed thoroughly later, for ascertaining the compliance with the BWM Convention.

The Conventions applies to every Vessel or Ship that are entitled to "fly the flag of a Party" and to Vessels or Ships that are not entitled to "fly the flag of a Party" but that operate under the authority of a Party and of course use, load and empty their tanks with ballast water during international voyages. (BWM – Guidance, EMSA, 2019). Those sea – going vessels in order to be established and in compliance with the requirements of the Convention are obliged to carry proper and relevant documentation :

a) Ballast Water Management plan, that is specific for each vessel and includes a detailed description of actions that have to be taken in order for the vessel to implement the requirements of the ballast water management .
b) The International Certificate of Ballast Water Management (is a requirement on vessels of 400 gross tonnage and above), which is issued by or on behalf of the Flag State (Administration) . It certifies that a vessel that carries out ballast water management is in compliance with the Convention, also specifies the exact certain standards that each vessels complies with and also the date that the Certificate Expires.
c) A Ballast Water Record Book, that has extreme importance, as this book records when ballast water is taken on – board , passes through circulation or special treatment for ballast water management purposes and then is discharged into sea – waters .This particular record book also records circumstances when ballast water is discharged to reception facilities or other accidental discharges. (BWM – Guidance, EMSA 2019)

According to the Article 2 of the convention, there is an obligation by IMO send to all country – members, so as to each one individually, take measures against harmful marine invasive species and other pathogens by controlling and managing ballast and vessel sediments. The Article 5 of the Convention focuses on ports and terminals and how they can affect, 'do their part' and provide reception for the sediments, when a cleaning process of ballast tanks takes place. Then the Article 6,

again refers to country – members, in order to take action, either individually or in close co – operation with each other and conduct researches and studies centered on ballast water management plans and the impact of ballast water in their region and jurisdiction. Moreover, Article 7 obliges vessels to undergo inspection and certification and also to be inspected by port state control officers based on Article 9. In addition, the second part of the BWM convention, states that every ship has to possess a unique ballast water management plan that only applies on that specific ship. That management plan must be approved by a qualified authority, this is the B – 1 regulation. There are some specific demands of ballast management which are detailed inside the convention. Vessels that have been built before the year 2009 and have ballast capacity of 1500 – 5000 cubic meters, must use this ballast management system till its 'ballast water exchange levels or operate in efficient ways' until the year 2014. Vessels that have ballast capacity lower than 1500 or higher than 5000 cubic meters, should operate the exact same way as the above category but until the year 2016. Then, about vessels built the year 2009 or after and of course rior the year 2012, that have capacity higher than 5000 cubic meters have to comply with both the D – 1 and D – 2 regulations and still operate in an efficient manner till the year 2016.

3.4 The D – 1 , D – 2 Regulations

The Ballast Water Management Convention establishes some certain standards that every vessel is required to meet. The D1 regulation sets the standards for the water exchange of the vessel and the D2 regulation sets the standards for the performance of the BWM system.

First, the D – 1 regulation requires vessel to exchange ballast water in the deep ocean or open sea. When the ship does this, there will be less micro – organisms that will survive and therefore it will be less likely to produce invasive species when the ballast water will be released. That is going to happen because the temperature, chemical structure and the salinity of those waters is way different. Special instructions have been proposed by the convention for the exchange of the water :

" 1. Do it with an efficiency of at least 95 percent volumetric exchange of Ballast Water or, 2. If the ships exchange Ballast Water by the pumping-through method, pumping through three times the volume of each Ballast Water tank shall be considered to meet the standards. But if the ship can demonstrate that at least 95 percent volumetric exchange is met pumping through less than three times the volume it may be accepted " (BWM – Guidance, EMSA, 2019)

There are 3 different systems – methods that are approved by the International Maritime Organization to comply with the D – 1 standards :

- The Sequential method : During this particular process, the ballast water tank firstly gets completely emptied and after it gets re – filled with replacement ballast water in order to achieve a least amount of 95% volumetric exchange. Ballast water in every tank must be discharged up until suction of the pumps is lost and strimping pumps have to be used in order to avoid situations where some micro – organisms are still stuck in the bottom of the tank. The emptying of the tanks can be either individually or in pairs. After the completion of the process, the tank is again re – filled with new water.
- The Flow – through method. During this process, the replacement ballast water gets pumped into a ballast tank that is intended for carrying the ballast water. That allows the water to flow through overflow or through other arrangements, so as at least 95% volumetric exchange of ballast water to be achieved. The minimum amount of times that pumping through the volume of each and every ballast tank must happen is three, in order to meet the D – 1 standard.
- The Dilution method : During this particular process, the replacement ballast water is filled through the top of the ballast tank. That ballast tank is intended to carry the ballast water and at the same time there is a synchronous discharge of water from the bottom

side, but at the exact same flow rate while maintaining a constant level inside the tank throughout the whole ballast water exchange operations. Likewise, the flow – through method that process has to happen three times. At the process, most of the times, there are two ballast pumps that are used simultaneously, the one as the filling pump and the other as the suction pump. Again, is of extreme importance the filling level in the tank to be constant and the volume of both pumps needs to be precise.

Then, the D – 2 regulation is a standard set by the Convention for the Ballast Water Performance, which establishes the maximum quantity of viable organisms that can be discharged and it also includes some specific indicators related to microbes that are detrimental to human populations. Vessels that conduct ballast water management must comply with the following instructions (as stated into the BWM – Guidance, EMSA,2019)

" 1. Ships conducting Ballast Water Management in accordance with this regulation shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension; and discharge of the indicator microbes shall not exceed the specified concentrations that are described below
2. Indicator microbes as a human health standard, shall include but not be limited to:
• toxicogenic Vibrio cholerae (O1 and O139): < 1 cfu per 1 g (wet weight) zooplankton samples,
•escherichia coli: < 250 cfu per 100 ml,
• intestinal Enterococci: < 100 cfu per 100 ml. " (BWM – Guidance, EMSA, 2019)

The BWM Convention also has established a schedule for the implementation and once it enters into force, obliges every individual ship to comply with the D – 2 regulation standards up until the 8th of September 2024. To this date on, all vessels falling under the Convention must comply. Previously, from the 8th of September of 2017 the schedule requires the ships to act as following :

- New vessels must meet D – 2 Standards
- All vessels must carry : The Ballast Water Record Book, a Ballast Water Management Plan and an International Ballast Water Management Certificate
- Vessels that already exist should at least meet the D – 1 Standards of Ballast Water Exchange and furthermore to Choose between the installation of a Ballast Water Management system or meet the D – 2 Standards (not mandatory until the compliance date)

3.5 Ballast Water Treatment System

To begin with, in order to be in compliance with the D – 2 Regulations Performance standards, it is almost inevitable for vessels to use and install a new Ballast Water Treatment system. Having said that, the ship owners' need to ensure that their vessels comply with all of the rules and regulations that are set by the International Maritime Organization, started the implementation of this new technology called Ballast Water Treatment System onto their vessels. There are several different 'technologies' available for ships in the market, but there are numerous factors that must be taken into account such as financial issues (cost of implementation) , environmental issues (environmental friendly systems) etc. More specifically some of these factors that must taken into consideration are :

I. Crew safety
II. Cost – effectiveness
III. Environmental issues
IV. Difficulty and process of installation of the system
V. Availability of space on board the Vessels
VI. The effective it has on ballast water micro – organisms

After these considerations are thought and analyzed from every ship management company or ship owner then the same if not more attention needs to be paid on the type of system or technology they will select. The main types that will be explained thoroughly below are : Filtration Systems / Physical Separation, Chemical Disinfection (Oxidizing and non – oxidizing biocides) , Ultra – violet irradiation, De – oxygenation , Heat Treatment , Acoustic Treatment, Electric pulse and Magnetic Treatment.

Before, analyzing all these treatment systems one by one, there will be presented an image of a typical treatment system of a vessel.

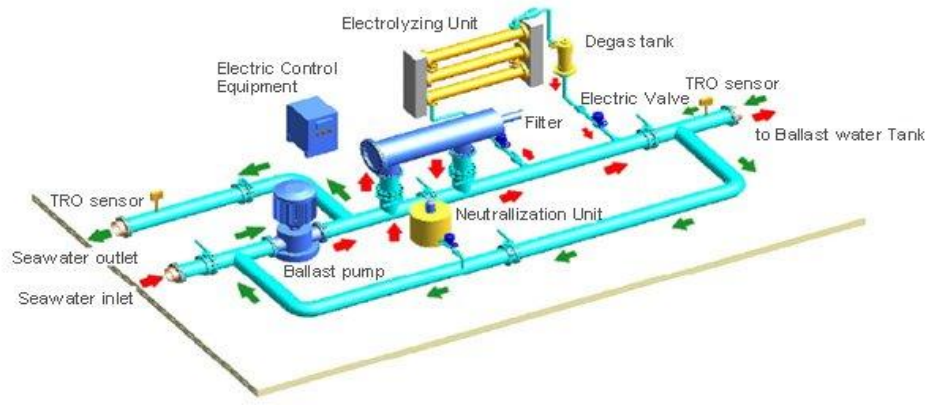


Image 8 : Ballast Water Treatment system, Image credits : envipure.com (2019)

The majority of the ballast water treatment systems of all vessels, most commonly use two or three different types of disinfection methods at the same time. Usually the treatment methods are divided into two stages where at the first stage there is a physical separation and during the second stage one of the available disinfectant technologies.

3.5.1 Filtration Systems / Physical Separation

This system is separating the marine micro – organisms and solid materials from the ballast water by using some surface filtration systems or simply ‘sedimentation’. Those solid materials that are filtered and the backwashing water after the filtration procedure are usually discharged in the same place that ship intakes ballast water or are treated further on board the vessels before discharging. The most common equipment that are used for that technology are:

1. Screens , either fixed or movable, which are used for the removal of solid materials from ballast water with automatic backwash. This equipment is environmental friendly because it does not require the usage of toxic and chemicals to the ballast water that after will be discharged into the sea – waters. Screen filtration has a better use when removes solid materials that are larger in size and they are pretty effective on that , but as they are not very handy in removing smaller sizes of solid particles, screen filtration alone is not sufficient for the treatment of ballast water.
2. Hydro – cyclone , is an equipment that separates suspended solid materials from ballast water as well and likewise with Screens, is not particularly successful on removing solid materials of smaller size. The hydro – cyclone uses a high velocity centrifugal force to rotate the sea – water and separate the materials and is also very easy to install and operate on board the vessel.
3. Coagulation , that method is mostly used before the filtration process and in contrast with the two equipments above, that particular method deals with solid materials of smaller size and succeeds to ‘join’ them together in order to increase their size. Therefore, with that size increase of the suspended solid particles, the efficiency of hydro – cyclone or screens is massively being increased. Coagulation of smaller sized materials into small ‘flocs’ is called flocculation, where flocs are set to be easily removed from ballast water. The negative aspect of coagulation is that an additional tank is required for this procedure, so in vessels with limited space, that method is prohibited.

4. Media filters, these filters are better suited for vessels because of their smaller size and low density compared to other filtration systems. They are used in order to filter the small size suspended materials.

3.5.2 Chemical Disinfection (Oxidizing and non – oxidizing biocides)

Biocides have been tested and analyzed as disinfectants that remove invasive species and micro – organisms from the ballast water. These biocides can also 'inactivate' these invasive species and when they are used into ballast water they have to be effective and easily removable, because the sea – water can become toxic in nature. So, before the discharge of the ballast water these biocides must have been removed if not being effective. Biocides regarding their main functions are divided into two categories, Oxidizing and Non – oxidizing.

Oxidizing Biocides

Oxidizing Biocides are known to us as chlorine, bromine or iodine and they are disinfectants that are used to inactivate invasive species from ballast water. They affect the cell membrane and the nucleic acids of the micro – organisms, they destroy their organic structure and that is why they are extremely effective. On board the vessel the most common procedures of utilizing the oxidizing biocides are, Chlorination, where chlorine inside the water destroys the micro – organisms. Ozonation, where ozone gas inside the ballast water by an ozone generator, de – composes in order to destroy invasive species. Moreover, oxidizing biocides like dioxide of chlorine, paracetic acid and hydrogen peroxide are used as well for the inactivation and killing of micro – organisms.

Non – oxidizing Biocides

Non – oxidizing Biocides are the disinfectants that interfere with functions of micro – organisms such as the metabolic or neural or reproductive function. Invasive species affected by these non – oxidizing biocide are strained and therefore destroyed. The biocides that are non – oxidizing and are most commonly used into ballast water treatment systems are only a couple such as Vitamin K or Menadione. Menadione produces toxic by – products and there are ongoing researches for more non – oxidizing biocides to be utilized for the ballast water treatment method.

3.5.3 Ultra – Violet Irradiation

The Ultra – Violet Irradiation (UV), is used for destroying and inactivating invasing species inside ballast water. These UV lamps produce ultra – violted rays, that affects the DNA of the micro – organisms and turns them into harmless and non – reproductive species. They surround a small chamber where the ballast water goes through. It is been one of the most successful methods internationally for water filtration purposes and is highly effective against the majority of the marine species. The Ultra – violet irradiation is performed two times during loading and discharging operations.

3.5.4 De – Oxygenation

This ballast water treatment technology, as the name suggests, de – oxygenates the ballast water by purging the oxygen out of the water and the tanks in order to asphyxiate the invasive species and the micro – organisms. This method is getting achieved by injecting, usually, nitrogen or some other inert gas right above the water level inside the ballast tank. It required approximately two to four days for the nitrogen to asphyxiate the marine species. So, for vessels with short shipping time this system is not suitable. Furthermore, the De – Oxygenation technology is perfectly fitted for vessels that have already installed an inert gas system and therefore no further space of the installation of this system is required.

3.5.5 Heat Treatment

This ballast water treatment system is about heating the ballast water up to a temperature in which the invasive species cannot survive and is appropriate for the killing of these organisms. These temperatures are usually between 35 and 45℃ and should be maintained for some time in order to be effective. Most of the times, another heating system can be used to heat the ballast water inside the tanks and even the ballast water can be used for the cooling of the vessel's engine therefore disinfecting some organisms from the heat that have been acquired from the engine. For the fact that this technology requires time for the killing of the species and moreover increases the rust inside the tanks, it turns it to a non – typical method of ballast water treatment.

3.5.6 Acoustic Treatment

This method otherwise called Cavitation, uses ultrasonic energy in order to produce high energy ultra – sound to invade and kill the organism's cells inside the ballast water. This high pressure, ballast water treatment cavitation technology usually is used alongside and in combination with

another method. Acoustic treatment is being achieved with converters of mechanical and electrical power that produce high frequency vibrations.

3.5.7 Electric Pulse

Electric pulse or plasma treatment for ballast water is still at its premature stage and is still developing. In this method, bursts of high energy are used in a pulse electric field technology, where metal electrodes are being utilized and produce these energy bursts inside the ballast water tanks, with high density and pressure in order to destroy and inactivate micro – organisms. In the plasma technology, high energy pulses are provided to certain mechanisms that are placed in the ballast water, which generate a plasma arc that ultimately kills the invasive species.

3.5.8 Magnetic Field Treatment

Finally, the magnetic field treatment uses the coagulation technology that has already been mentioned above. Coagulants mixed with magnetic power are added to ballast water tanks. That leads to the creation of magnetic flocs that also include marine micro – organisms . Then, magnetic disc is used to divide the magnetic flocs from the ballast water.

4. The Ballast Water Management Convention and its Application in the Mediterranean Sea

The Ballast Water Management Convention, was the first formal activity from the International Maritime Organization regarding ballast water, even though the problem of invasive species and bio – diversity has been addressed and identified many years before, as we previously analyzed. The regulations and guidelines, which were developed for the prevention and minimization of the ballast water issues, that all maritime companies and their vessels, had to adopt, obey and include into their daily routines, were something that referred to everyone internationally. Every sea – going vessels that met certain criteria had to adapt and follow these regulations once the convention entered into force. But, the Convention also highlighted and emphasized on each country – member regionally, to individually make concerned efforts for the prevention of the ballast water management issues. The country – members of the region of the Mediterranean Sea, took immediate action and in the context of regional effort, as noted by the International Maritime Organization, and contracted the Barcelona Convention in 2009, just 5 years after the introduction of the Ballast Water Management Convention. The contracting parties created an action plan for the "Mediterranean Strategy on Vessels' Ballast Water Management" plan that operate among the Mediterranean Sea, the North – East Atlantic and the Baltic Sea. So, the Regional Marine Pollution Emergency Response Centre (REMPEC) was assigned as the Regional Coordination Organization for the Mediterranean Sea. The Mediterranean Sea is one of the top high – priority regions regarding the ballast water of the vessels and the transfer of aquatic organisms. Researches has shown that, in the last years, the amount of invasive species has continued to increase and still arise as a concern that poses a real threat to the environment and non – native species in the Mediterranean region, to humans regarding health issues and also recreational activities.

4.2 Detailed Analysis of the Mediterranean Strategy on Ships' Ballast Water Management

4.2.1 The Strategic Priorities

The Mediterranean Strategy on ships' ballast water management plan was contracted in Almeria, Spain and takes into account all the available international and regional instruments, action plans, regulations that relate to the issues of the ballast water invasive species and the bio – diversity of the ecosystem. It is known as the Barcelona Convention. The main goal of the Convention was to establish special framework and regional regulations about the Mediterranean Sea, while at the same time adopting and operating under the requirements and standards of the Ballast Water Management Convention. For this purpose, the Barcelona Convention set eight strategic priorities, which will be thoroughly explained below.

1. Support international instruments developed to minimize the introduction of invasive alien species in the Mediterranean region, The impact of the invasive and alien species finally led to a huge response and address of the issue in the form of legal instruments and several programs that aim to the development of practical solutions. All relevant organizations and forums should be supported in order to deliver solutions and an invasive species – free Mediterranean region.

2. Maintain capacity-building activities and initiatives in the Mediterranean region, A new implementation project regarding Building partnerships to assist developing countries to reduce the transfer of harmful aquatic organisms through vessels ballast water, that initiated in 2008 by the International Maritime Organization and partners, will focus on the common "enemy" the invasive and alien species. The country – members of the Barcelona Convention have to all continue to enhance the capacity – building activities and initiatives in the Mediterranean region.

3. Develop advanced knowledge on environmental condition of the Mediterranean and ships' mediated introduction of invasive alien species, One of the most important and manyfaceted strategic priorities of the convention. Knowledge is one thing, continuing knowledge especially on environmental issues can lead to amazing results. The field of marine invasive species requires advanced knowledge and fundamentals as for the issue to be addressed properly and continuously. Progress needs to be made on the understanding of the issue and the strict relation of the maritime industry and the millions of transactions that daily happened across the world's seas and the problem of the alien species to the marine

ecosystem. As already mentioned, the Mediterranean region is a major shipping route worldwide, several invasive species have been found in the Mediterranean Sea, therefore giving proper and constant attention to development and raising environmental awareness will only make the situation better.

4. Use risk assessment as a reliable tool to assist in ballast water management decision-making and in compliance, monitoring and enforcement procedures, Risk assessment is a really helpful and kind of a "new" tool in the Maritime Industry. It can be a real asset and really essential when used for the correct purposes. Risk assessment helps the vessels, the captains and the ship owners to ensure that all necessary provisions of the BWM and the Barcelona Conventions are all applied and adopted in an appropriate manner. Of course, it can be delightful in recognizing all the risks and the issues that the invasive species possess and come with. For example, the aspect of biological invasion of ports, of major shipping ports can be better understood and be minimized if risk assessment will be utilized. Some ports are more at risk than others, knowing that actions and measures could be immediately taken and part of the biological invasion can be prevented fast and proactively.

5. Decide upon voluntary regional arrangements in the Mediterranean and ensure sub-regional and national strategies are in line with these, The International Maritime Organization gave clear – cut guidelines to country – members at the BWM Convention. The invasive and alien species issues must be dealt not only through implementing and adopting the present guidelines. Each county – member individually and mainly with co – operation amongst each other in the same region, should address the issue, decide and ensure on regional strategies. All of the above, should of course be in a Voluntary note and for the benefit of each and everyone individually and of course, at the end of the day for the general good. The Mediterranean region and the countries that have their coast in the Mediterranean Sea should all be involved and consider assisting to the ballast water issues.

6. Consider other regional seas strategies and initiatives, The issue is a global one, which has occupied the World for about a Century, after its recognition as an issue and always remains a "silent enemy" for everyone. European Countries, that have their coast to the North – East Atlantic or the Baltic Sea or even the Black Sea are strictly related to the Mediterranean Sea. The ballast water exchange regulations adopted by them, or for example the Strategic Action plan for the Red Sea, must be considered, taken into account and understood for the harmonization of the ballast water management worldwide and regionally.

7. Keep the Strategy and Action plan under review and assess their implementation progress, The strategies and action plans are only the beginning and the "bureaucratic" part of a Convention. That alone, does not hold the power to address such important issues. Constant review, objectivity and periodical gatherings and meetings of the country – members, while exchanging opinions and experience will lead to a continuously evolving plan, that will strengthen from meeting to meeting and will only provide solutions and not more issues.

8. Work on the identification of adequate resources to implement activities under the Strategy and Action Plan, The long – term goal of the Barcelona Convention is to ensure the sustainability and the continuity of activities that are related to the Mediterranean Sea and its marine ecosystem. Identifying and securing resources for the implementation of those activities is a key element for regional activity centers.

(ANNEX I, Mediterranean Strategy on Ships' Ballast Water Management, Barcelona Convention, 2009)

4.2.2 The Action Plan

After the eight main strategic points were set, the contracting parties to the Barcelona Convention went on identifying the eight main measures / actions. It is of extreme importance for those measures to be in accordance with the above mentioned strategies and to be taken into consideration effective immediately at least at regional levels.

The eight main actions are:

1. Ratify the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), The BWM convention is like the "bible" of the ballast water management issues worldwide, its immediate ratification is absolutely essential. Therefore, the country – members have to form a national policy group in order to speed up the process of ratification of the BWM convention. The fastest the guidelines and the treatments standards enter into force, the better for the ecosystem worldwide and of course for the Mediterranean Region. Also, secondary regulations and technical aspects for enforcement of the Ballast water management plan, needs to be developed for the violators that does not comply with the Convention.

2. Adopt harmonized arrangements for ballast water exchange in the Mediterranean region, The Barcelona Convention, in line with the BWM Convention, urges the country – members to face the issue individually, to take action and not just sit back and relax once the BWM Convention Enters into force. Contracting parties must notify interested parties, for the harmonization of voluntary arrangements that relate to ballast water exchange in the Mediterranean Sea. Even though special requirements are not necessary to be established, adopting those voluntary arrangements for the Mediterranean Region is a solid first step.

3. Establish a solid Compliance, Monitoring and Enforcement (CME) system in the Mediterranean region, The CME system is a new mechanism that will make the Mediterranean Sea one of the premier regions, when it comes down to monitoring and complying with the BWM convention. It is an "extra" compliance mechanism that will make sure that guidelines by the International Maritime Organization are being followed and that the strategic points that were set by the Barcelona Convention are being met. It will require vessels to collect data on ballast water loading or discharges, it will audit ships and ensure that specified ports standards are being followed, is going to obtain and test ballast water samples and of course be in constant communication with the whole region of Mediterranean to ensure that there are no violations and legal matters of non – compliance.

4. Establish a survey, biological monitoring and risk assessment system for Mediterranean ports, The key words survey, biological monitoring and risk assessment are all three extremely important and was highlighted throughout the Barcelona Convention. Forming a regional biological monitoring system for the Mediterranean Region and taking actions like collection of data, reviewing the best practices, identifying new biological requirements, prepare and review the already existed monitoring programs and also implement and take notes of sub – regional commissions plans and actions, will only develop and further increase the chances and the prevention mechanisms for the ballast water issues. Risk assessment and its importance has already been mentioned and a regional plan can make all the difference that is needed, as new guidelines will already be prepared for ports, risks will already be identified and addressed before or at a time that they could be manageable.

5. Enhance expertise; facilitate knowledge transfer and capacity building in the Mediterranean region, The fifth action and measure is a rather challenging one, as nowadays worldwide everything with a financial aspect onto it has an asterisk. Developing self – financing mechanisms and maintaining an effective Capacity building program that will assist in implementing strategies and action plans is a tough task but through co – ordinated efforts these capacity building methods can cover many aspects that will cover various aspects. It will allow Mediterranean region states to communicate with each other and raise the awareness levels, it will enhance the research and development projects as well as the drafting of the national legislations, is going to improve the self – finance mechanisms and identify possible agencies and stakeholders that are willing and are able to assist on the formation of ballast water committees and working groups.

6. Enhance public awareness on ships' ballast water and invasive alien species issues, Everything that is available and can help towards the direction of increasing the public awareness to risks that are associated to ballast water invasive species and the ballast water issues should be taken into consideration. Brochures, posters , educational documents are the first part and consequently seminars, workshops, local case studies and translation of these awareness materials into local languages can all lead to humans finally understand the importance and the level of seriousness the ballast water issue possesses for not only the environment and the marine ecosystem but for its own personal health too.

7. Set-up a web-based Mediterranean mechanism for exchanging information, Action number 7 is a really important and clever mechanism adopted and introduced by the Barcelona Convention. Nowadays, everything happens through the internet and the advanced technology, an information exchange system among country – members will be established and is considered necessary. It will facilitate easy, safe and fast communication for the contracted parties, it will allow them to exchange information, always and at any time be updated and notified about everything. There is not a single more important thing in the modern world than fast information.

8. Incorporate the Action Plan evaluation within the Barcelona Convention reporting system and procedure, The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) , is responsible for implementing and coordinating both the strategic priorities and the action plan of the Barcelona Convention. The expertise and the

actions of REMPEC will further assist and accommodate the developments on the ballast water marine and invasive species issues on the Mediterranean Sea. Finally, it will review, monitor and assess the effectiveness of the action plan and if all contracted parties are in comply with these strategies and measures.

(ANNEX I, Mediterranean Strategy on Ships' Ballast Water Management, Barcelona Convention, 2009)

5. Conclusion

To sum up, the research aimed to identify the main causes of the ballast water invasive species to the environment and the marine ecosystem of the Mediterranean Sea. Based on a series of images, diagrams and graphs that helped us better understand the issues and the ballast water concept, the dissertation showcases the need for immediate action and raise of the awareness about issues as the ballast water. These issues are between us, in the everyday world, they affect our lives in a great deal and even though it does not lie on us to solve and minimize the problem, we can play our part on it. Citizens must understand the negative impact that even one untreated ballast water discharge into a foreign ecosystem can produce. People that their everyday life revolves around the marine ecosystem such as captains, ship owners, seafarers, fishermen etc should study, exchange information, comply and follow all the guidelines and regulations that the International Maritime Organization or other regional and appropriate organizations establish. Finally, The Ballast Water Management Convention and the Barcelona Convention that were analyzed into that research should be seriously taken into consideration, from people around the world and from the Mediterranean Region Habitants especially. Everything starts with one small action, reading and getting educated on an issue like the ballast water can make a huge, impactful difference in our daily routine and as a wise Chinese quote says “Big Changes start with small steps”.

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