Pakistan J. Zool., pp 1-11, 2021. DOI: https://dx.doi.org/10.17582/journal.pjz/20200726170735

Review Article

Measures and Gap Analysis on the Impact of Non-Indigenous Species on the Black Sea Ecosystem

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Article Information
Received 26 July 2020
Revised 13 October 2020
Accepted 04 December 2020
Available online 27 December 2021 (early access)

Key words
Ballast water, Biological diversity, Ecologic impact, Marine, Non-indigenous species

ABSTRACT

Overseas transportation of non-indigenous species (NIS) and their permanent habitation of secondary regions pose a critical threat that adversely affects the marine environment and marine based economic activities and applications. The transportation of NIS causes a decline in fish industries, spoilage of culture fishing stocks, rising production costs, adverse effects on human health and changes in biological diversity. The most prominent alien species in Turkish Black Sea waters are species invasions which are witnessed in the Black Sea. The Black Sea, which has incurred significant losses in biodiversity due to the increasing eutrophication and various pollution related problems, have surfaced significantly and provided a considerably suitable environment to invasive NIS. In this study, measures and legal gaps are evaluated to reduce and control the entry and spread of NIS into the marine environment.

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INTRODUCTION

Fluctuations in water temperature and salt contents of the global seas, compounded by the large landmasses, have restricted species in specific areas and prevented them from diversification in various water masses. This resulted in formation of various natural bio-geographic regions. Before civilization and changes in patterns of transportation and intense methods of aquaculture farming, the movements of species outside their natural habitat were occurring due to natural phenomena such as currents and through the attachment of organisms on floating masses. The effects of various human activities on the transportation of species between bio-geographies have become increasingly more evident in recent years. Changes in ocean's currents, climatic and environmental conditions due to numerous external factors, coupled with activities such as shipping, aquarium fishing and aquaculture becoming widespread are changing the natural regional distribution of species, bio-geographies and biodiversity. These extensive factors are changing the paradigm of global ecosystem (Beken *et al*., 2014). This review highlights key factors that are impacting the non-indigenous species on the Black Sea Ecosystem and critically assess the mitigation place to safeguard the aquatic ecosystem around the globe.

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Different species in the aquatic ecosystem follow either primary transportation (relocation of a species from their natural habitat to another region) or secondary transportation (dispersion of the species to other regions from primary location). Aquatic organisms can be transported outside their own habitats through a wide variety of vectors. Some of these vectors include (i) ships (ballast water and sediments and biofouling on ship hulls), (ii) artificial canals and the alteration of natural waterways, (iii) fishing, (iv) aquaculture, (v) aquarium related activities and live bait trade, (vi) biological control, (vii) habitat management activities and (viii) research activities. Today, the Lessepsian migration due to the opening of the Suez Canal has been defined by marine researchers as the most significant biogeographic phenomenon witnessed in our oceans (Por, 2010).

Non-indigenous species (NIS; synonyms: alien, exotic, non-native, allochthonous) are species that have been transported to areas outside of their natural habitats by means exceeding from their natural distribution potential. These are transported to different regions as a result of voluntary or involuntary human activities (Olenin *et al*., 2010). Introduction of species due to a natural cause such as expansion of distribution range because of climate change or dispersal by ocean currents is not included in the definition of NIS, but dispersion through a man-made canal (Gollasch *et al*., 2006). After first introduction to a new environment, a NIS can continue spreading both by man-mediated and natural means leading to secondary introductions. NIS are considered to have a negative impact on the native ecosystem, can cause significant economic losses and can be a threat to public health (Galil, 2007).

The NIS causes permanent and negative effects in the general structures and food networks of habitats. In this section, we aim to identify major anthropogenic pressures contributing to NIS introductions. The impacts of these NIS on indigenous species and communities are described. Once NIS communities are established, removal is not an option, and the risks of biological control are huge if no natural predator(s) exist in the ecosystem.

This study assessed the impact of NIS in the Turkish Black Sea Water. For this purpose, a list of 27 NIS has been presented for a number far below that was proposed by the Black Sea Commission's Advisory Group on Conservation of Biological Diversity for several reasons. In the assessment, any species which is not large enough to be seen by the naked eye was excluded. Additionally, only Turkish waters was observed and only those taxa identified in the scientific literature as NIS were included in the analysis (MARinTURK, 2017).

Although it has been reported that there are 30 species in the Black Sea (Zaitsev and Öztürk, 2001), the number of species was reported as 209 by the Black Sea Commission. However, the majority of these species have an unclear native range of distribution or are native for the Mediterranean. The checklist of marine NIS from the coast of Turkey published by Çınar *et al*. (2011) have included 20 species from the Black Sea coast, excluding fungi and phytoplankton. The main vectors responsible for the introduction of marine NIS to the Black Sea are maritime transport (via ballast water or fouling) and aquaculture (Fig. 1). The Rapa whelk, *Rapana venosa* originates from the Sea of Japan, Yellow Sea and East China Sea. It was first recorded in the Black Sea in 1947. Planktonic larvae may have arrived through ships' ballast water. The alien comb jelly *Mnemiopsis leidyi* has been introduced from the Atlantic coastal waters of USA most probably via ballast waters. The shipworm Teredo navalis is a wood boring bivalve mollusc which destroys wooden piers, docks and ships. According to the information given by Gomoiu and Skolka (1996), it has been suggested that the introduction of this species to the Black Sea has occurred via fouling and could date back to as early as 750-500 BC.

So-iuy mullet, *Liza haematocheila*, is the only non-indigenous marine fish species observed on the Black Sea coast of Turkey and it has been observed extensively on the Black Sea coast (Kaya *et al*., 1998). The entry of these species into the Black Sea and the Azov Sea has been through aquaculture (Starushenko and Kazansky, 1996).

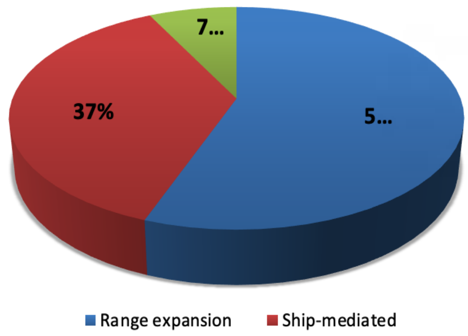

Fig. 1. Most likely method of non-indigenous species (NIS) introductions for the Turkish Black Sea coast.

The most important factor leading to the Mediterraneanization of the Black Sea biota is the warming trend in the Black Sea basin (Sezgin and Kıdeyş, 2010) which is supported by a study conducted by Shiganova and Öztürk (2010). The NIS inhabiting the Sea of Marmara appear to take advantage of this phenomenon and expand their distribution ranges towards the Black Sea via Bosphorus Strait as secondary introductions (e.g., The North Atlantic common starfish, *Asterias rubens*) (Karhan *et al*., 2007). It has been proposed that climate change may trigger host-pathogen dynamics (Harvell *et al*., 2002). It may also impact the success of an invasive pathogen species by affecting the host-pathogen relationship (Lafferty *et al*., 2004). If the ecosystem is under increased pressure of other factors (over-fishing, eutrophication, pollution, habitat destruction etc.), it may become more susceptible to invasion by opportunistic NIS (Corrieroa *et al*., 2016).

THE IMPACT OF NON-INDIGENOUS SPECIES (NIS)

The impact of NIS at a level that causes a reduction in environmental quality is defined as biological pollution. The magnitude of the impact can be classified under three main headings: great impact causing serious adverse results, impact causing small and yet permanent damage or impact causing short-term damage. These impacts include ecological impact, environmental and economic impact, economic loss, impact on public health, and predation.

Ecologic impact

The impact of invasive NIS on the ecosystem can be summarized as (i) competing with native species for location and food, (ii) predation effect on native species, (ii) alteration of habitat and environmental conditions, (iii) alteration of the food chain and in turn the entirety of the

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ecosystem, and (iv) decreasing biodiversity. The damage caused by invasive aquatic organisms is almost always irreversible and their harmful effects generally escalate continuously.

Environmental and economic impacts

Once NIS have established their habitat, eradication of the species is mostly impossible and requires a collaboration of all the countries found in the basin to implement a collective eradication procedure. Therefore, it is suggested that prevention rather than eradication is the most effective means of control. The NIS are considered to have a negative impact on the native ecosystem, can cause significant economic loss and can be a threat to public health.

The economic impact caused by invasive NIS may present itself in a number of ways. The various effects caused by these species can be summarized: (i) Replacement of indigenous fish and other species by NIS, reduction in fish production or total collapse of the fishing industry due to alterations in the habitat and environment, (ii) The effects of outbreaks, especially of toxic and harmful algae on aquaculture activities may in some instances lead to fish farms going out of business, (iii) The physical effects of fouling organisms on coastal facilities, activities, industry, and maritime commerce, (iv) The threat faced by holiday resorts and recreational tourism facilities of going out of business due to foul odours and deterioration of physical conditions at beaches caused by the outbreak of toxic and harmful algae, (v) Costs resulting from the impact of invasive NIS and pathogens on human health namely, monitoring, analysis, diagnostics and treatment costs and social losses incurred due to illnesses and death of productive individuals of society, (vi) Secondary economic losses incurred as a result of ecological impact and reduction of biodiversity, (vii) Costs resulting from struggling against or controlling invasive aquatic organisms.

It is possible to provide numerous examples of economic losses incurred by various countries as a result of the damage caused by these species. One of the two most classical examples regarding the economic impact caused by aquatic organisms is Dreissena polymorpha. The costs associated with the attempts made at controlling the European Zebra Mussel i.e. Dreissena polymorpha population that has invaded the inland waters of the United States of America between 1989 to 2000 has reached to 750 million to 1 billion USD. Other known example include *M. leidyi* that has invaded the Black Sea after being transported from the coasts of North America.

The species that has first been recorded in the Black Sea in 1982 is believed to have been transported with ballast water (Olgun *et al*. 2008). The species that feeds on zooplankton can consume amounts of zooplankton up to ten times its own size. The species reproductive qualities (being a hermaphrodite and able to inseminate itself) make it convenient for the species to multiply rapidly (Beken *et al*., 2014). The total density of the species in the Black Sea in 1989 has reached 1 kg/m2. It is believed to have depleted the plankton stocks of the Black Sea, causing the collapse of the commercial fishing industry. It is estimated that costs incurred by the Turkish coastal fishing industries as a result of the damage caused by this species has reached hundreds of millions of USD (Kıdeys, 2002).

Economic loss

The alien comb jelly, *M. leidyi*, has been introduced to the Turkish water from the Atlantic coastal waters of USA, most probably via ballast waters. In the Black Sea, population growth has led to changes in the ecosystem (Kıdeyş, 1994). The most important indicator is the sharp decline in Icthyoplankto fauna (Gordina *et al*., 2001). From the mid-1980s to the early 1990s, the Turkish national economic loss was estimated to range from US$240 million to US$309 million (Caddy, 1992). However, for the entire Black Sea fishery, this was stated to be US$1 billion per year (Campbell, 1993). While enormous Turkish dominance of the Black Sea fishery could be considered, most of these losses are attributable to a decline in the Turkish anchovy fishery.

R. venosa is not consumed in Turkey but has an important economic value. Due to overfishing, the total catch per year has decreased significantly. In recent years, it has increased to 7000-8000 tonnes / year (Uyan and Aral, 2003). To protect the stocks, fishing R. venosa with beam trawl is prohibited within 500 m of the coast and collection for commercial purposes is prohibited all along the Turkish coastline during spawning season (15 April – 31 August). This legal protection status prevents R. venosa from eradication and enhances the formation of stable populations (Beken *et al*., 2014).

Impact on public health

Various invasive species that are usually transported in ballast tanks of seagoing vessels act as an intermediate host for medically important pathogens, toxic algae and parasites. Ballast water, collected from partially treated or untreated waste may contain pathogens that cause illnesses. The discharge of contaminated ballast water into ports causes the sea water and the organisms living in the region to become contaminated and posing a risk to human health (Star et al., 2011). It was stated by Williamson *et al*. (2001) that Vibrio cholorea was brought along with ballast water that caused an epidemic in Latin America.

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There is widespread consensus that a strain of Vibrio cholorea of Asian origin has caused an epidemic in Latin America was originally brought by ballast water. In 1991, an outbreak of a cholera epidemic has been witnessed in Peru causing sickness in millions of people to become ill and the loss of more than 10,000 people's lives. In the following 4 years, the Latin American government has spent approximately 200 billion dollars in order to improve the quality of their drinking water and sewer systems (Low, 2003). Likewise, some invasive NIS can act as an intermediate host for various parasites that may cause illnesses in humans. The Eriochoeir sinensis is an important example for lung parasites (Baxa *et al*., 2003). Furthermore, seafood obtained from coastal waters before they are thoroughly cooked can cause cholera and various other intestinal diseases (Joachimsthal *et al*., 2004) in human. The *R. venosa* is an active predator of epifaunal bivalves including Mediterranean mussel in the Black Sea. It was found that *R. venosa* juveniles consume variety of species including barnacles, mussels, oyster spat, and oysters (ICES, 2004). However, it has serious impacts on natural and cultivated populations of oysters and mussels (Savini and Occhipinti-Ambrogi, 2006).

IMPACT OF NON-INDIGENOUS SPECIES ON TURKISH BLACK SEA

The seas surrounding Turkey exhibit differences in current number of NIS, their transportation vectors and their level of impact according to the location, physical characteristics, and the levels in which they are affected by anthropogenic pressure. When the main vectors related to NIS transported to our national shores were evaluated, the Suez Canal ranks at the top of the list with a ratio of 66% due to the location of the country. This is followed by ocean going vessels with a ratio of 30% and the proportions of these vectors for each sea are shown in Figure 2.

The most recognized examples of invasive characteristics of alien species in national waters are attributed by the species invasions of the Black Sea. The Black Sea has incurred significant losses in biodiversity due to the increasing eutrophication and various pollution related problems. In recent years, these complications have provided non-indigenous invasive species a considerable suitable environment to habitat.

When NISs were examined in the Black Sea, it was revealed that the most effective vectors in the transportation of the NIS are shipping activities at a ratio of 80%. This could be attributed to the fact that the Black Sea is an inland sea (Fig. 2). The second most effective vector was the species brought to the Black Sea for culturing purposes, either voluntarily or by accident.

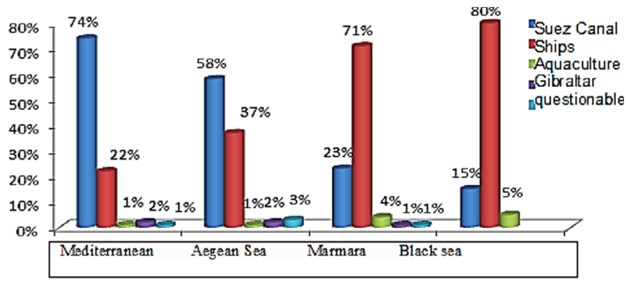

Fig. 2. Turkish shores, non-indigenous species vectors distribution ratios related to each sea (Cınar *et al*., 2011).

In the study presented by the Black Sea Commission, the numbers of species recorded in the entire Black Sea were 55 invasive NIS and 217 NIS. However, only a total of 20 NIS are recorded in the Turkish shores of the Black Sea and 17 of these species are transported as a result of shipping activities. Other species were brought in through aquaculture activities and by passing through the Suez Canal. It is highly probable that the secondary mode of transportation for these species through the Suez Canal were again shipping activities. Severn invasive NIS found in the Turkish shores of the Black Sea are considered to be among the "Worst 100 Invasive Species" (Streftaris and Zenetos, 2006).

A relatively low number of species in the Turkish shores of the Black Sea whereas high number in in Black Sea may indicate scarcity of information in this region. The period when the largest number of NIS has been reported in the shores of the Black Sea ranged from 1990-2000 and around eight new NIS have been recorded during this period (Fig. 3). However, only four NIS were recorded between 2000-2010.

It is plausible that the reason for the shipping related species invasions witnessed in the Black Sea is because of the tankers sailing to the Northern Black Sea ports to carry petroleum instead of the maritime traffic in our national ports. When the amount of ballast water carried in national ports throughout the Black Sea was evaluated, it was observed that the amount of ballast water equals (~7%) to the Black Sea. This indicates that a vast majority of the carriage of ballast water takes place in the ports of other Black Sea countries.

Majority (81%) of all maritime traffic in the national ports are located in the Western shores of the Black Sea and 97% of all maritime traffic in the national ports are located in the Eastern shores of the Black Sea. The rest of traffic occurs in the national waters of other Black Sea countries (Olgun *et al*., 2008). Turkish Black Sea ports that swift largest amount of ballast water carriage occurs

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are the Black Sea Eregli, Samsun and Trabzon ports (Beken *et al*., 2014). Most of the marine NIS recorded on the Turkish Black Sea coast showed a wide distribution pattern along the coastline. The distribution ranges of a few NIS introduced from the Sea of Marmara (as secondary introductions) are limited to the Prebosphoric region.

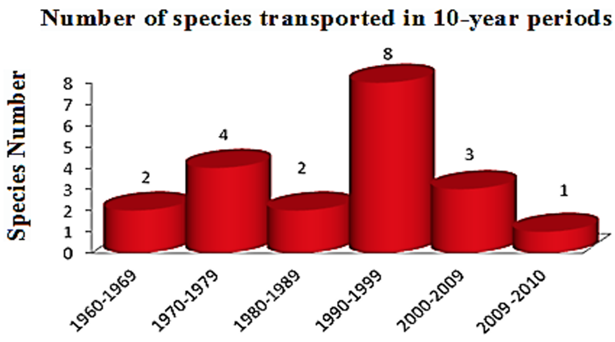

Fig. 3. Black Sea recorded number of species ın past decades (Beken *et al*., 2014)

Approximately 67% of the NIS are commonly observed on the Turkish coastline, amongst them ~15% are rare. The exact distribution ranges of the remaining ~18% are unknown. Fifteen NIS have been first recorded in the Mediterranean or from the Sea of Marmara, then they further dispersed into the Black Sea by range expansion or secondary transport via shipping. The second important vector is ship-mediated transport, either by fouling (carried on the external hulls of ships) or in ballast waters, which seems to be the most probable vector for ten NIS species recorded in Turkish Black Sea waters (MARinTURK, 2017). Only two NIS have been introduced for mariculture. The largest NIS group observed on the Turkish Black Sea coast is phytobenthos, followed by Crustacea and Mollusca (Fig. 4).

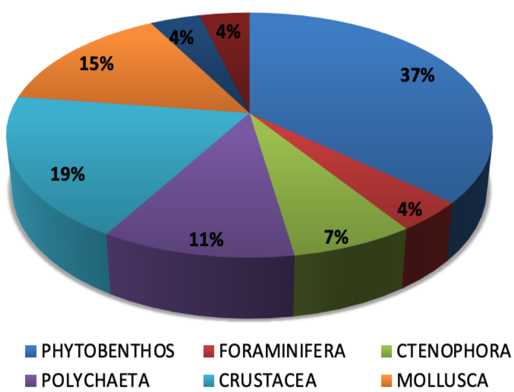

Fig. 4. Composition of NIS groups ın Turkish Black Sea waters.

It is not possible to assess the impact of every NIS on the native ecosystem due to lack of information. However, there are enough examples how a NIS can negatively affect the native biota and fisheries economy. On the other hand, most of the studies concerning NIS impact are on economically important species. It remains elusive how non-indigenous of algae, the largest NIS group, alters the littoral community structures. Thus, the real extent of the impact of NIS may be beyond our current understanding. Although the number of new NIS records per year for the Turkish Black Sea coast is decreasing, the total number of NIS was increasing (Fig. 5).

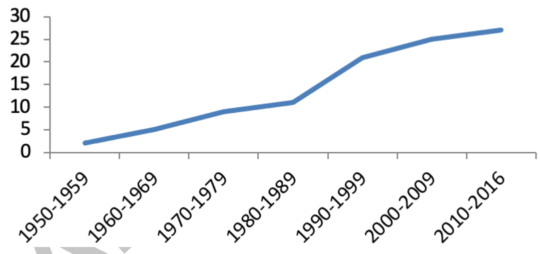

Fig. 5. Cumulative number of NIS species recorded in Turkish Black Sea waters (MARinTURK, 2017).

Habitat loss or damage due to coastal construction, landfill and fishing activities, high nutrient and pollutant levels are caused by domestic wastewaters, deep sewage discharges and farming industry. These pollutants are persistently prevalent especially in the Central and Eastern Black Sea coasts, which have threatened the biodiversity and integrity of the habitats, making the ecosystem more prone to invasion. The NIS have been identified during fieldwork for the 'Marine Integrated Monitoring Project' since 2011. Marine monitoring programmes, like other environmental monitoring programmes, have represented a compromise between frequency and spatial coverage/ resolution within a given budget. However, neither the current total budget has been calculated, nor the overall costs of the proposed revisions. Therefore, the decisions will need to be made on the importance assigned to various monitoring elements and the routes of funding. The Turkey is also in a transition phase concerning environmental monitoring, which has seen some the major improvements in the last 5-10 years as short-term project-based monitoring has been converted to continuous monitoring (sub-) programmes which are driven principally by legislative changes. A group of competent authorities exists in Turkey concerning marine monitoring and management. Thus, in some cases the authority/responsibility remained unclear. However, it is clear that improved coordination of monitoring programmes would benefit larger communities provided that wider sharing of the data is practiced. In

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the 2017, macroalgae monitoring study (Fig. 6), in the Black Sea, where the land-based effect was observed, the pressure of Ulva and Cladophora and blue green algae (*Cyanophyceae)* species from green algae *(Chlorophyta)* were observed (Beken *et al*., 2017).

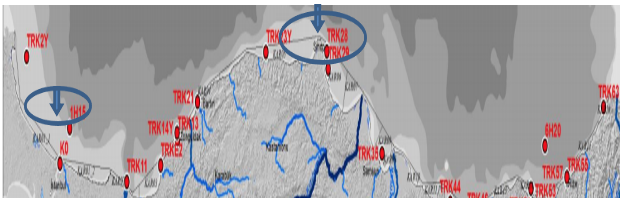

Fig. 6. Turkey Black Sea waters 2017 sampling station map.

When the jellyfish distribution along Black Sea coasts was analyzed on species basis, *Aurelia aurita* reached the highest biomass and was distributed only in the area between İnceburun and the Bosphorus. Ctenophora species *M. leidyi* and *P. pileus*, like *A. aurita*, were distributed in the west of İnceburun, while *B. ovata* distributed in the east. Within the scope of monitoring programs, it is suggested to identify high-risk areas for NIS, increase the frequency of NIS monitoring and better monitor high-risk (subsequent pest) species.

NOTABLE SPECIES INVASIONS WITNESSED IN THE BLACK SEA

The *M. leidyi*, a zooplankton consuming species of ctenophore, is especially harmful in seas where production is abundant (Fig. 7). This as first recorded in the Black Sea in 1982 and is believed to have been carried from the shores of North America in ballast tanks of seagoing vessels (Kıdeys, 2002). The increasing density of the species has depleted the zooplankton stock in the Black Sea and has had a significant impact especially on anchovy fishing. Today, the loss incurred by the Turkish coastal fishing industry is estimated to have reached hundreds of millions of US Dollars. A medial rise in the number of zooplankton witnessed in 1994 has caused a secondary increase in the number of *Mnemiopsis* in the following year (Bat *et al*., 2011. Furthermore, the dietary consumption of eggs and larva by the species has caused a decline in the pelagic fish population resulting in significant losses to be incurred by the Turkish fishing industry. Furthermore, the fact that the species feeds primarily on herbivorous zooplanktons has resulted in an increase in the amount of chlorophyll, number of phytoplankton and primary production in the Black Sea. In 1992, three years after the increase witnessed in the population of *Mnemiopsis*, the eutrophication index throughout the Black Sea has reached its highest recorded level. In 1997, the introduction and settlement of a *Mnemiopsis* predator of the *Beroe ovata* in the Black Sea which was again transported with ballast water from the North Atlantic has caused the impact of the *Mnemiopsis* to decrease and has caused the ecosystem to recover. Due to the fact that *Mnemiopsis* is an important part of the *Beroe ovata*'s diet, we have witnessed a significant reduction in the numbers of *Mnemiopsis* approximately one year after *Beroe* has been introduced. This reduction has in turn caused a reduction in the number of *Beroe* and an increase in the numbers of zooplankton and anchovy populations and the populations of two species of Cnidaria namely *Rhizostoma pulmo* and *Aurelia aurita* (Kıdeys, 2002). According to the "2010 – Black Sea Pollution Monitoring Project" final report, it has been stated that the observation frequency of *M. leidyi'nin* which was 100% in the past years had fell to 0% in 2010. This sharp reduction of the observation frequency was explained by the existence of a *Mnemiopsis* predator *B. ovata* which had a recorded observation frequency of 7.4% (Beken *et al*., 2014).

Fig. 7. *Mnemiopsis leidyi* (photo; Tahsin Ceylan, tahsinceylan.com).

Rapana venosa

This species of sea snail has first been recorded in the Black Sea at the Novorosisk Gulf in 1946 and is believed to have been transported to the Black Sea from Japan by means of clinging to the hull of seagoing vessels (hull fouling). This species has caused serious damage to the oyster and mussel beds in both the Black Sea and the Azov Sea (Fig. 8). The commercial use of the species has balanced the *Rapana* population in the sea (Beken *et al*., 2014).

Fig. 8. *Rapana venosa* (photo; Tahsin Ceylan, tahsinceylan.com).

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THE NEED FOR RESEARCH

It is important to understand the baseline conditions in NIS as measurable and monitorable. Although there are numerous studies published on Turkish shores that provide records of NIS, the primary objective underlining this studies was to determine the groups of organisms that make up the regions' flora and fauna. A previous study conducted by Cınar *et al*. (2011) have examined a total of 290 publications from 1928 to 2011 NIS found along the Turkish shores. However, there appear to be paucity of information to determine targets for areas susceptible to the transportation of NIS, the determination of the current state of NIS and the monitoring of tendencies and introduction of new NIS. These studies were conducted in intervals, especially in the ports and marinas along shoreline where high levels of international maritime traffic occur. Furthermore, there is a need for scientific research and monitoring activities to be conducted along shores in order to fill the gaps regarding the content of NIS, their abundance, distribution, impact and to determine their current state.

The rising awareness of the damage caused by invasive NIS in recent years has led to the proposal of conducting Port Biological Baseline Surveys (PBBS) in ports to reduce risks associated with shipping activities which constitutes one of the most important vectors in the transportation of NIS and also to determine and monitor the current levels of biodiversity and to repeat such surveys at periodic intervals.

It is of great importance to determine baseline levels at ports for conducting risk assessment activities in yielding accurate results. Risk assessment activities are suggested especially by the IMO–Ballast Water Management Convention as an important tool to be used for the reduction of risks associated with invasive aquatic organisms. Areas where further research needs to be conducted on shores and NIS are summarized as: (i) Content, abundance and distribution of NIS in prioritized areas along with studies conducted to determine the current state of the environmental impact of such species, (ii) Scientific studies conducted with the aim of determining the distribution and environmental impact of NIS which are known to have settled on Turkish shores, (iii) Studies aimed at determining targeted invasive NIS which are known to be transported from ports of origin by means of carriage in ballast water in order to take the necessary precautions to prevent them from being transported to our shores where they are not wanted (studies aimed at determining targeted species should be supported with studies evaluating the biological characteristics of the species and their adaptation abilities in the new environments where they are transported or introduced).

The current program and suggestions for improvement are given in Table I.

Recommended measures for the prevention and management of the introduction and spread of invasive alien species are given in Table II.

MEASURES AND LEGAL GAP ANALYSIS

Most of the time, invasions of NIS cause irreversible effects and it is usually impossible to remove/wipe out a species that has settled in a new environment. However, the struggle against invasive species may sometimes be successful in the event that the species are detected at an early stage with limited distribution before they have settled into their new environment. The most efficient methods of preventing the transportation of NIS and their impact on the environment are the control and management of activities that cause their transportation and dispersion, management of vectors and the enhancement of environmental conditions.

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Table I. Current programme and suggestions for improvement of Black Sea.

Current programme	Suggestions for improvement
NIS monitoring is included in the Integrated Pollution Monitoring Programme, however, because NIS are major ecological and economic problems, more robust monitoring is required.	Baseline surveys are recommended, with specialist monitoring set up for a limited number of high-risk sites: ports, marinas, aquaculture sites, aquarium locations, etc. Diving clubs should be asked to monitor the distribution of invasive species. In order to do this, guidance should be produced, distributed, and an internet-based reporting system established.
Existing monitoring is limited, and almost all biological components are monitored within the Integrated Marine Pollution Monitoring Programme. NIS are identified/reported within each biological element (phytoplankton, zooplankton, macrozoobenthos, macrophytobenthos and fish).	All records must be geo- and depth- referenced. Data assessment/quality assurance should be undertaken by competent personnel only, on at least at 2-yearly basis. Internet based recording/reporting of diving clubs (geo- and depth -referenced data should be ensured, if possible complemented by photographs) Research projects should be considered to better understand the effects of climatic factors.

Table II. Measures for the prevention and management of the introduction and spread of invasive alien species.

Implementation of the Regulation (EU) No. 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species.
Develop a watch and alert system for NIS.
Setting up a system for prevention of expansion of non-native species on regional/global level (establishment of regional/global collaborative programme; Establishment of regional early alert and response system).
Development of invasive species action plans and a National Strategy on Invasive NIS
Enforce Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) and associated national regulations with respect to the control of invasive species.
Develop Aquaculture Code of Practice for Invasive Alien Species.
Develop/apply international and national regulations with regard to the movement of aquaculture species.
Maintain the regulation of trade (in relation to NIS).
Establishment of most significant NIS pathways and vectors and develop a risk-based approach for effective management.
Prevention of input of non-native species (undertaking risk assessments for intervention; aquaculture permits; Controls on NIS inputs).
Subsequent to the ratification of the International Maritime Organization (IMO) BWM Convention and its implementation under Turkish law by statute, Turkey will apply IMO and other relevant guidelines for the control and management of ship's ballast water to minimise the transfer of harmful aquatic organisms and pathogens.
Regulation of hull cleaning activities
Establishment and updating of strategy for ballast water treatment compliant with national accords)
Promote local action groups to engage the support of the voluntary sector in controlling invasive NIS and in promoting key messages.
Continue to promote awareness of invasive NIS to the public and marine/maritime professionals.

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Monitoring activities are a significant component of the precautions taken against the invasion of NIS and the distribution of species and the reduction of their impact. Monitoring activities provide a means of early detection of species invasions and allows us to take timely precautions. Monitoring activities are an important tool for the determination of the effectiveness of suggested vector management applications conducted in order to prevent new species invasions from occurring especially in areas where the probability of the transportation of species is relatively high.

The aim of the monitoring activities conducted include; (i) Early detection of the invasions of new species in order to take necessary precautions and the monitoring of the distribution of species that have already settled, (ii) Making observations to see is NIS are causing any problems, (iii) Checking the effectiveness of precautions taken against the invasion and settlement of NIS, if any precautions have been taken.

Matters to be considered during the determination of areas where the current state and impact of NIS are to be monitored are (i) areas where the primary stages of the transportation of invasive species occurs such as ports, marinas, areas where aquarium and aquaculture/seafood trade activities are conducted, (ii) specially protected areas (SPA) where important marine resources are found, (iii) "hot spots", and (iv) areas containing high levels of NIS. These areas should be given priority during the evaluation stage during the determination of areas that are to be monitored.

To reduce the impact of non-native species, it is necessary to determine basic conditions for monitoring the actions taken. For this reason, studies are conducted that include following activities aimed at determining the biological status of areas under high risk of transportation of NIS (i) The determination of the existence/absence of NIS, (ii) Determination of the abundance of NIS, (iii) Determination of the distribution of NIS, (iv) Researching the species' biological characteristics such as the choice of habitat within the environment, diet and seasonal development, (v) Determination of whether the species have any impact on other species and communities within the environment or the ecosystem.

The following goals are set for monitoring activities that are to be conducted after the baseline studies have been completed; (i) Monitoring of NIS that are transported to the environment, variations of the content of NIS over time, (ii) Variations in the abundance of species, variations in the area covered by the species or the density NIS within a certain area (decrease/increase), (iii) Measurements related to the dispersal rate of the species, (iv) Determination of the impact of the species and the rate at which dominant species are replaced by invasive species.

For the purposes mentioned above, Port Biological Baseline Surveys are conducted in the ports of numerous countries in recent years with the aim of determining NIS transported through maritime traffic and especially within the ballast water of ships (Hewitt and Martin, 2001). It is important to have knowledge about the baseline conditions in NIS to be measurable and monitorable. The scope of Turkish environmental legislation for prevention of NIS is restricted to prevention of the discharge of "dirty" ballast water and does not reflect the 2004 BMW (Ballast Water Management Convention) requirements which entered into force in September 2017. There is no legislation on "preventing", "eradicating" or "controlling" of the introduction of alien species that harm ecosystems, habitats, or species. This imparts a significant gap that no legislation on invasive species exists. This gap is object to be eliminated by the outputs of the "Project to Determine the Threats of Invasive Alien Species in Significant Biodiversity Areas" conducted by the Ministry of Forestry and Water Affairs in Turkey. Within this framework, a significant step to be taken to close this gap in the legislation to adopt the National Strategy Document to fight against invasive species, establish a coordination committee that involves responsible institutions and has decision-making authority concerning invasive species, ensure participation of NGOs and universities to this committee, and to define a single administrative authority having executive and decision-making powers.

Furthermore, it is required to add provisions regarding the methods of fighting against invasive species, research, and monitoring, as well as sanctions and responsibilities to the "Draft Law on Conservation of Nature and Biological Diversity"

There is no Turkish legislation on the Black Sea Biodiversity protocol for regulation of intentional introduction and prevent an accidental introduction of NIS or genetically modified organisms. One of the main vectors for the human introduction of NIS is through ballast water exchange/discharges of ships. There are three Ministries that would have a role in controlling and management of ballast water discharges: The Ministry of Environment and Urbanization (MoEU), The Ministry of Forestry and Water Affairs (MoFWA) and the Ministry of Transport, Maritime Affairs and Communications (MoTMC).

The biggest gap is coordination between institutions which has not yet been sufficiently achieved. This has led to numerous institutions and agencies which imprinted authority confusion on the subject in the country. Placing considerable emphasis on regional cooperation and coordination is understandable due to transboundary impact of marine pollution and knowledge and resource limitations. The marine environment is a transboundary media and pollution can easily cross borders between countries. Also pooling resources through experience-sharing, bringing together the best technical expertise and investing in joint research are crucial tools to ensure that marine strategies are coherent, consistent, and built on the best advice of the political and scientific community. Therefore, regional cooperation must be at the very heart implementation, and influence national implementation processes, rather than the other way around. Since the Ballast Water Management Convention brings new rights and obligations to the states for the protection of the marine environment, it is an advantageous to reduce the living creatures entering the waters of a country. According to the provisions of the convention, all ships will take necessary measures to ensure that the ballast waters they carry within a plan do not threaten the ports. They should consider a regional approach and starting with existing data, a national marine database and a GIS System should be established in line with the EU INSPIRE Directive. This should allow data from all national agencies/ministries, educational institutes, and regional authorities to be stored, assessed/analysed and compared. Responsibilities for system development, maintenance, security, data input and quality assurance should be clearly defined.

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ACKNOWLEDGEMENTS

This study was compiled within the scope of "Marine and Coastal Waters Quality Status Determination and Classification Project" supported by the Ministry of Environment and Urbanization and integrated marine pollution monitoring program in Turkish Seas. Institutional visits were made to discuss the current situation and the gap analysis on this issue and to consult.

Author would like to thank Ministry of Environment and Urbanization for their valuable comments and inputs that helped to increase the quality of the paper. Finally, special thanks to Mrs. Huri EYÜBOĞLU from the Ministry of Environment and Urbanism, who gently reviewed and made constructive comments on the study.

Statement of conflict of interest

The authors have declared no conflict of interest.

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