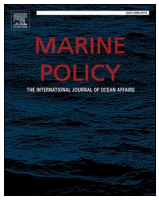
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A moving target: Achieving good environmental status and social justice in the case of an alien species, Rapa whelk in the Black Sea

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ABSTRACT

The invasive Rapa whelk, *Rapana venosa* in the Black Sea presents a complex governance problem posing a diverse set of positive and negative impacts on marine ecosystems as well as on coastal communities. While some marine scientists perceive the Rapa whelk as a fishery to be sustainably managed, others are more concerned about the threats it poses to biodiversity and ecosystem integrity. Fishers themselves are divided regarding the dominant fishing method used to harvest, namely, dredging, which damages benthic habitats and negatively impacts already over-exploited commercial fish stocks of the Black Sea. Dredging is also the main impediment to achieving Good Environmental Status based on the Marine Strategy Framework Directive of the European Union. While the economic profits of its fisheries are predominantly prioritized by Black Sea countries, social justice aspects of its fisheries in terms of providing livelihoods to marginalized coastal communities should not be overlooked. The presence of a diverse set of stakeholders with differential views and needs makes it integral to utilize integrated participatory approaches in the governance of its fisheries in the Black Sea, such as ecosystem-based management and co-management. Establishing and maintaining social justice while adhering to the EU's Good Environmental Status principles is a moving target that policy makers, marine scientists and other relevant stakeholders should opt for in managing the complex governance issues that invasive species such as *Rapana venosa* pose.

1. Introduction

Invasive alien species (IAS) are known to cause major damage to ecosystem and biodiversity around the world, and the rate of introductions along with their impacts are to increase into the future [18], especially due to the highly interconnected global economy [63]. Their negative impacts are well documented, and it is understood that certain invasive species can drive large economic losses with repercussions for society and the local economy [70]. In the European Union, for instance, annual costs of IAS are estimated to be at least around €12.5 billion [43], however, some alien species contribute to economies by their materialization of new commercial fisheries [40,59], while others lead to socio-ecological conflicts severely compromising the well-being of coastal communities [28]. Thus, management and governance decisions around IAS can involve complex dilemmas, necessitating a deep understanding of the ecological, societal, and economic effects as well as stakeholder involvement, and participatory decision-making mechanisms [35,59].

Management and control of IAS often require coordinated efforts at local, national, and international scales. The European Commission, for instance, has specific criteria and indicators for the assessment of the Good Environmental Status (GEnS) specific to non-indigenous and invasive species within the EU's Marine Strategy Framework Directive (MSFD; European Commission 2008). Specifically, descriptor 2 within

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this framework requires non-indigenous species to be kept at such levels that they do not adversely change ecosystems. The GEnS concept is based on an ecosystem-based approach and management, however, the framework even acknowledges that a major challenge within this social-ecological context is "[t]he lack of knowledge on the links between potential measures, improvement of marine ecosystems and corresponding economic and social values" ([20], p. 29). Most importantly, the management of each particular IAS requires a unique arrangement of elements in a specific combination of well-identified problems and acceptance of management measures by all stakeholders [54].

In the case of the invasive veined Rapa whelk *Rapana venosa* Valenciennes 1846 (*Rapana* here after) in the Black Sea, the knowledge gaps on its effects on and links between society, ecology and economy likely impede its appropriate management. *Rapana* was first found in the Black Sea in 1946 from the Russian port in Tsermes Bay, and since the 1980s, has been subject to controversy surrounding its regional management and governance. Management complexities arise from its conflicting negative and positive impacts. As a voracious benthic predator especially to bivalves, it causes native biodiversity and abundance losses to mussels and oysters and further reduces vital ecosystem services bivalves provide in the Black Sea, such as water purification and habitat creation; as bivalves are important ecosystem engineers, their conservation should also be prioritized in an ecosystem-based management framework [3]. Contrarily, as a commercial fishery resource, the *Rapana* fishery provides considerable regional employment and revenue sources and hence are recognized as a priority species in the Black Sea [27]. Simultaneously, the *Rapana* fishery here contradicts several descriptors of the GEnS due to its complex matrix of negative impacts, the worst being the negative impacts from dredging them. However, the Black Sea is already under immense pressure from human activities: According to the FAO, it is one of the most overfished seas in the world, currently with 62.5% of stocks fished at unsustainable levels [23]. It is also naturally eutrophic, and as such, highly sensitive to increases in nutrient loading via pollution and industrialization [39]. Within the last century, the Black Sea has lost dozens of its predatory species and nearly all of its top predators leading to a trophic cascade [10,11,75], plus the arrival of several non-indigenous species (NIS) [71].

The Bucharest Convention of 1992 (The Convention on the Protection of the Black Sea Against Pollution) and the EU Marine Strategy Framework Directive (MSFD) of 2008 are both relevant policy frameworks for the protection of the marine ecosystems in the Black Sea. However, the Black Sea is surrounded by both EU (Bulgaria, Romania) and non-EU countries (Turkey, Ukraine, Russia, and Georgia), as a result, there is a spatial mismatch over European legislation and the MSFD and the regulations of non-EU riparian states, which renders achieving common regional goals and GEnS in the Black Sea problematic. Therefore, how the different regimes and regulations of each state can collaboratively reach the goals of the MSFD under the shared framework of the Black Sea Convention still needs to be determined [55].

Emerging 'Blue Economy' and 'Blue Growth' initiatives can shift the management framework regarding marine resources in the Black Sea. They aim to shape a basin-wide strategy "to support sustainable growth in the marine and maritime sectors" in the Black Sea as a long-term strategy of the European Union (https://blackseablueconomy.eu/blue-growth). These new strategies assume, quite uncritically, that ecological sustainability and societal goals will go hand in hand, by focusing on creating win-win situations for the marine ecosystems and national and international businesses. Yet, the *Rapana* case in the Black Sea demonstrates that this is not an easy feat, given that invasive species, climate change and growing maritime trade interact to create unprecedented ecological and socio-economic complexities and uncertainties. As there is a diverse set of conflicting positive and negative social and ecological impacts associated with *Rapana* and its fisheries, there will consequently be winners and losers whenever a management plan is attempted regarding *Rapana*.

In the Black Sea region, *Rapana* management has three ideal trajectories depending on the stakeholder: an IAS to be controlled, a fishery resource of considerable economic value to be exploited in the short-term, or to be managed sustainably over the long-term. This is a typical case of a "wicked problem" in the management of biological invasions [22], where conflicts between views and objectives of different stakeholders render framing of the problem and identification of possible solutions very difficult [74]. As such, tension and conflicts emerge between different groups of resource users, marine scientists, and regulatory authorities in the countries surrounding the Black Sea. Moreover, the social justice dimension of the *Rapana* fishery in terms of providing livelihoods for small-scale fishers and marginalized communities is often overlooked, which can have severe repercussions for these communities [47].

Against this background, it is our aim in this paper to explore *Rapana venosa*'s invasion of the Black Sea leading to a highly complex management and governance problem entailing both positive and negative social and ecological impacts. We first provide background information on *Rapana*'s Black Sea population and fisheries, then explore its policy context by focusing particularly on the GEnS of the MSFD along with Blue Growth and the European Green Deal, specifically, we discuss which descriptors of the GEnS are violated by *Rapana* fisheries. Next, we analyze its direct and indirect effects on biodiversity, habitat integrity, and social issues, and then, conclude that *Rapana* presents a unique case of an invasive alien species in the Black Sea, necessitating the use of more integrated approaches such as co-management and ecosystem-based management due to its complex matrix of ecological effects and social justice issues.

2. Introduction of the *Rapana venosa* to the Black Sea and the development of its fishery

The Black Sea, an extension of the Mediterranean Sea located between Europe and Asia, is unique in hosting the largest contained oxygen-free, hydrogen sulphide (H_2S) rich waters below 150–200 m in depth. There is strong vertical stratification and Cold Intermediate Layer (CIL), an interesting hydrographic structure that is permanently present at about 50 m in depth, with an accompanying year-round water temperature of about ~8 ℃ [50]. This zone directly limits species diversity in the Black Sea [58]. The Black Sea is naturally eutrophic, rich in nutrients and primary productivity due to inputs originating from surrounding large rivers such as the Danube River [4]. Eutrophic waters, while productive, are highly vulnerable to increases in nutrient loading which can often cause harmful algal blooms and hypoxia, reinforcing more intense eutrophication [39]. The heavy industrialization period in the 1960 s around the Black Sea has severely contributed to eutrophication. Marine biodiversity is strongly influenced by nutrient enrichment levels and related trophic status, thus, naturally eutrophic waters, such as the Black Sea, are characterized by low biodiversity and high abundances, contrasting with oligotrophic waters as in the Mediterranean Sea, with its higher biodiversity and low abundances due to a higher degree of specialization [32,76].

One distinct IAS in the Black Sea is *Rapana*, which is native to Asian Pacific waters from Japan to Korea to Taiwan [36]. Its first record in the Black Sea was in 1946, from the Russian port in Tsermes Bay, however, one later study aged an 11 year-old specimen in 1953, thus back-adjusting the proximate first record to 1942 [9]. Within a decade, it spread along the Caucasian and Crimean coasts including the Sea of Azov [64]. It has since then expanded its range to include Sea of Marmara, Aegean Sea, Adriatic Sea and Mediterranean Sea, and has invaded Chesapeake Bay on the eastern coast of the United States [33]. There have also been sightings and reported egg masses from the Rio de la Plata region in South America, the French Brittany coast [5], the North Sea [42], and southernmost coast of Brazil [72] (Fig. 1). Examining the genetics of its native range (the Far East: Sea of Japan, Yellow Sea, East China Sea and Bohai Sea) reveals that the species has considerable

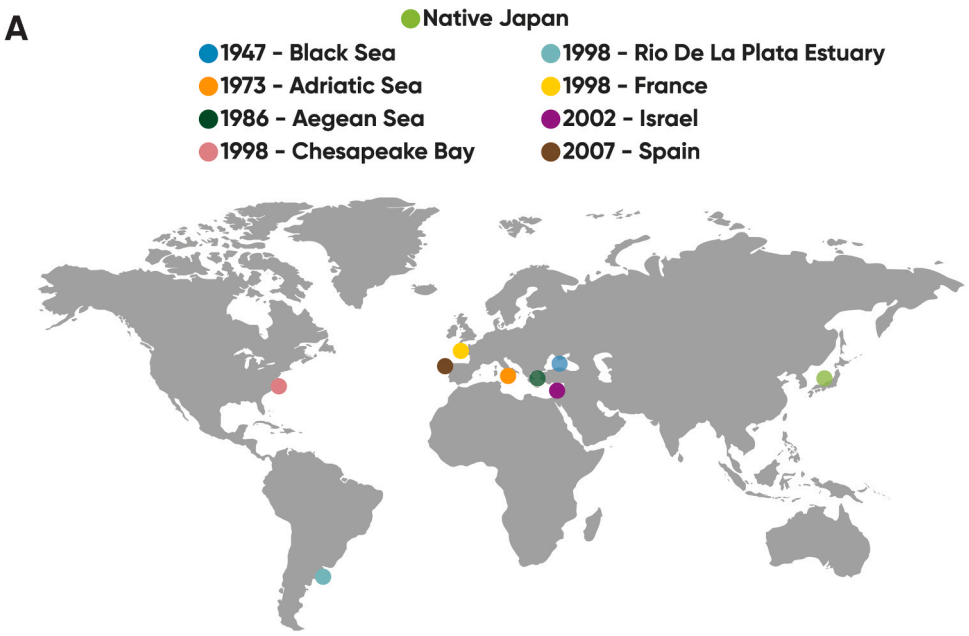


Fig. 1. *Rapana venosa*, native area and historical introduction worldwide.

genetic variation there, starkly contrasting the Black Sea population, having no genetic diversity. This suggests that the invasion came from just a couple of individuals from Japan with the same haplotype [8]. The Black Sea population served as a source for subsequent introductions in Europe and America by various transfer pathways, with shipping and aquaculture usually assumed to be the major culprits [68]. Many EU member states (Slovenia, Croatia, Greece, France, Spain, UK, Belgium, Netherlands, Germany, and Denmark) may also soon find this invader in their waters under current climate projections [77].

According to FAO global fisheries catch statistics, *Rapana* fisheries were negligible before the Black Sea fishery commenced. Until the 1980s, total catches were less than 200 t annually, mostly from Korea ([25,60]; Fig. 2a), where the species was of little importance in its native range. However, during the 1980s, relations between Turkey and Japan ameliorated, and Japanese officials, being aware of the increasing Black Sea *Rapana* abundance in the Black Sea, opened up their domestic market for its exports to compensate for the depletion of their own highly valued local gastropod stocks [34]. Japanese experts first assured that meat quality, safety and processing measures of *Rapana* were adequate [7,14], and designed their export market accordingly. Currently, the Black Sea hosts the only *Rapana* fishery globally and catches about 35,000 t annually ([23]; Fig. 2b), and mainly exports the inner sea snail meat portion, but also sometimes the shell and operculum.

According to the limited reports on *Rapana's* stock status in the Black Sea, it has been assigned to be "sustainable", indicating its catch is around maximum sustainable yield with acceptable fishing pressure [26, 73]. As there is no regional Black Sea demand for this species, nearly all catch is exported to Japan, South Korea, and also to some European countries like Germany where it is generally consumed by the Korean community. For the *Rapana* meat, there are five-class price categories which are size-based, with value increasing with size. While larger specimens are demanded by Japan [34], a series of profitable years induced intense fishing effort in the Black Sea, which led to a size reduction in shell lengths in recent decades [2,6,14]. This led to sharp declines in total revenue some years due to the lower size-price relationship, even as landings continuously increased each year. A sharp decline in total revenue during the 2000s improved into the 2010s (Fig. 2c), as the *Rapana* export markets opened up to other Far East countries, namely Korea, and Philippines [34].

The *Rapana* introduction into other seas around the world did not lead to any economic value, but rather losses. For instance, the ecological impacts of *Rapana* in Chesapeake Bay include heavy predation on native hard-shell clam, *Mercenaria mercenaria* leading to losses of around US $3 million year^{-1} to its fisheries. In the Adriatic Sea, it added costs to squid fishers from using their nets as a spawning substrate making them much heavier [67]. Mussel farming using the hanging rope technique is negatively affected by *Rapana* as well [68]. Therefore, *Rapana's* impacts are quite negative in terms of ecological, social and economic aspects, as would be expected from an IAS in those regions. The Black Sea *Rapana* fisher is the unique case of economic value for this IAS.

3. The policy context: Good Environmental Status of the EU Marine Strategy Framework Directive, the Blue Economy and European Green Deal

The policy context of *Rapana* fisheries can be evaluated within the EU MSFD, in particular, the GEnS approach, and the Blue Economy and Blue Growth agendas of the EU complemented by the recent European Green Deal. Additionally, in 2018, the General Fisheries Commission of the Mediterranean (GFCM-FAO) reported that *Rapana* has become one of the eight priority species in the Black Sea, for which specific fisheries advice is to be produced by consultations with experts and managers and based on a combination of information, socioeconomic importance and conservation concerns [27]. Following this decision, in 2020, *Rapana* stock assessment surveys by Black Sea riparian countries were initiated to provide management recommendations regarding its sustainable exploitation.

The EU MSFD [52] aims at achieving or maintaining GEnS in the territorial waters of the EU Member States by 2020. The GEnS concept requires that the "environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations" (MSFD 2008/56/EC, Article 3). Currently, the *Rapana* fishery and the main fishing method used in the Black Sea, namely, dredging, does not support Descriptor 1 of the GEnS, referring to the maintenance of "biological diversity in its natural state", as dredging

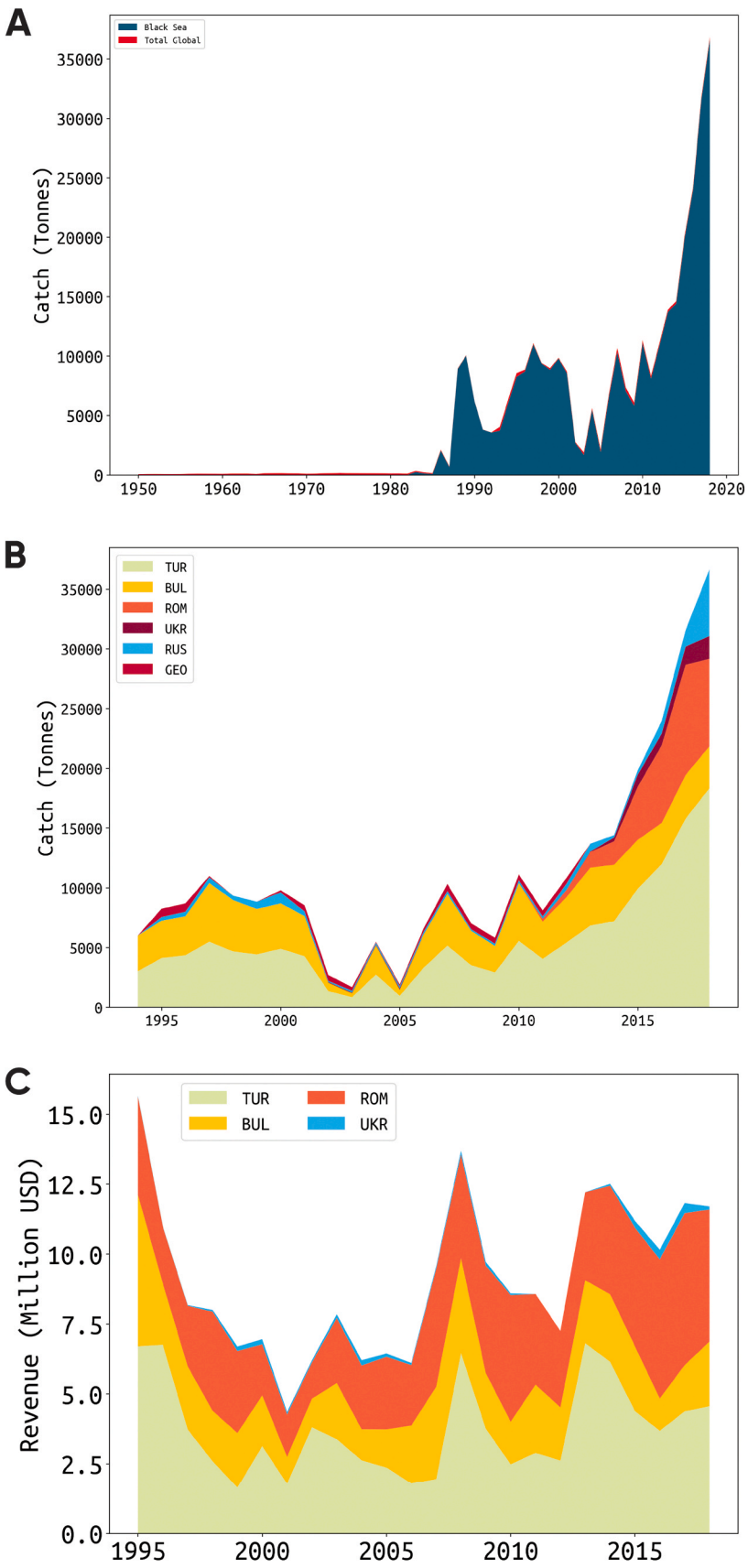


Fig. 2. A) Total catch and Black Sea catch from 1950 to 2018 (total catch is almost equal to Black Sea catch, [25]), B) Catch in Black Sea countries from 1994 to 2018 [25], and C) Revenue in US$ according to Black Sea countries, 1994–2018 [60].

impairs biological diversity in the Black Sea. Descriptor 3 which states that "all commercially exploited stocks are fished within safe limits characterized by age and size structures that are indicative of healthy stocks" is also violated, as *Rapana*'s mean size has considerably decreased, even though higher fishing pressure had disguised the lower value of the catches. Descriptor 4 of the GEnS requires that "all elements of the food web are maintained at normal abundances that support their long-term sustainability"; Yet, dredging for this species puts enormous pressure on already overexploited commercial species on the Black Sea coast. And, perhaps most importantly, the current state of its fisheries highly contradicts the Descriptor 6, which states that "the structure and integrity of the seafloor are safe-guarded with benthic ecosystems not disrupted." In fact, the only descriptor the *Rapana* fishery somewhat supports is Descriptor 2, requiring that "non-indigenous species are kept at levels that do not harm the ecosystem". This is supported by *Rapana* fishery exerting control over *Rapana*. Yet, there is a contradiction with respect to this descriptor as well, since *Rapana* is a non-indigenous species that negatively affects the native mollusc community through predation, while its fishery has negative impacts on other commercial taxa. As *Rapana* is also a commercial fishery resource, it is highly controversial whether more focus should be paid to its non-indigenous species impacts or to its fishery status.

On the other hand, the European Green Deal and the current Covid-19 crisis have paved the way for a stronger emphasis on the need to integrate socio-economic issues such as employment creation and economic growth with "protecting and restoring nature and fighting climate change" within the Blue Economy and Blue Growth [21]. However, these targets are also contradictory as *Rapana* fisheries offer employment generation and economic profits which could be a target for cooperation among the countries surrounding the Black Sea; However, exploiting this species using dredges, as is the common practice in Bulgaria and Turkey, for instance, substantially damages the benthic habitat and ecosystem integrity. Therefore, while *Rapana* stocks have been evaluated as "sustainable", this does not imply ecological sustainability is ensured. This trade-off between economic profits and ecosystem health in the case of *Rapana* fisheries poses a big challenge with respect to the Blue Economy concept in the Black Sea. Furthermore, the Farm to Fork Strategy which is at the heart of the European Green Deal also requires "food systems [to be] fair, healthy and environmentally friendly" [19] and considers biodiversity loss an impediment to resilience of food systems. In such context, preventing and reversing biodiversity loss is a moving target due to the diverse positive and negative impacts of *Rapana* and its fisheries on the marine ecosystems in the Black Sea.

4. Ecological and social impacts of *Rapana* and its fisheries

4.1. Direct impacts of Rapana on biodiversity and habitat loss

As an IAS, the *Rapana* invasion has severely affected various native species by predation. The IUCN refers to *Rapana* as "one of the most unwelcome invaders worldwide" [29]. The United Nation's Food and Agriculture Organization (FAO) has identified *Rapana* as a highest risk IAS, and hence, prevention rather than mitigation is mandatory in new (currently uninvaded) seas, and control measures should be undertaken when *Rapana* has established itself in marine ecosystems [24]. In the Nature Conservancy's database, *Rapana* has the highest ecological impact score of 4.0 [51], since it disrupts ecosystem processes and exerts wider abiotic influences.

Rapana has depleted large stocks of commercial bivalves, especially the Mediterranean mussel (*Mytilus galloprovincialis*) and local oyster (*Ostrea edulis*) populations, along with their associated coastal communities in the Black Sea since its expansion in the 1950s [66,79]. Its predation on native molluscs negatively affects Black Sea biodiversity and reduces the associated ecosystem services provided by bivalves, such as water filtration and purification, coastal protection, ecosystem engineering and habitat provision [41].

Despite these negative ecosystem impacts on native mollusc abundances and biodiversity, *Rapana*'s abundance and distribution generates a positive effect on an unusual predator-prey relationship with a bivalve species, the inequivalve arc *Anadara inaequivalvis,* another Indo-Pacific IAS introduced during the 1970s in the Black Sea. Although its invasion level and ecosystem impacts are not well known, habitat preferences of this infaunal bivalve do overlap with *Rapana* [65]. In laboratory experiments, three prey choices (*A. inaequivalvis*, *Ruditapes philippinarum*, and *M. galloprovincialis*) were offered to *Rapana*, and *Rapana* strongly preferred *Anadara inaequivalvis* [68], demonstrating *Rapana* likely provides some control on the invasive *A. inequivalvis*, while potentially decreasing pressure on native mussel species, if *A. inequivalvis* are indeed sufficient enough in abundance.

4.2. Indirect effects of Rapana fisheries on biodiversity and habitat integrity

A decomposition of *Rapana* fishing methods around the Black Sea shows that *Rapana* fisheries mainly use dredging or beam-trawl methods (both terms actually representing the same fishing type; 74% in Romania, 90% in Ukraine, and over 95% in Bulgaria and Turkey of *Rapana* fisheries use these methods to harvest *Rapana*) [13]. Dredges or beam-trawls, despite being small in size, are a destructive fishing type that cause damage to other taxa as they scrape the seafloor (namely, small benthic organisms) as the diamond mesh opening becomes clogged with specimens during towing [17,64]. During dredging many overexploited commercial species are often caught incidentally such as *Scopthalmus maximus*, *Scorpaeana porcus*, *Trachurus mediterraneus*, *Gobius niger*, *Solea solea*, *Raja clavata*, *Trigla lyra* [6,12,61], as an alarming consequence. Other fishing methods include pots and hookah in Turkey (a surface supplied hose for divers) and scuba diving in Bulgaria and Romania. While *Rapana* fisheries in Bulgaria and Romania commenced with scuba divers in the 1990s, beam trawls were later permitted at the beginning of 2010s [61]. It should be commonly known that 74% of *Rapana* are caught under 10 m in depth [64], which makes hookah and scuba diving feasible methods which have no ecosystem impacts to the seafloor and zero bycatch, thus are ecologically friendly fishing alternatives to dredging,

4.3. Governance and social justice issues

Rapana presents a challenging governance problem for marine scientists, fishers, NGOs and policy makers in Black Sea riparian countries. Some scientists perceive it as a marine resource to be sustainably managed and are worried about overfishing it, while others are more concerned about the biodiversity threats this invasive alien species is posing [47]. As an export commodity not consumed domestically in the countries surrounding the Black Sea, government authorities prioritize *Rapana's* profitable exploitation over other governance concerns. As a result, in 2017 total Black Sea exports of *Rapana* (mainly from Turkey and Bulgaria) reached US$ 12.5 million [56]. Having a similar short-term interest, owners of *Rapana* processing factories from the Black Sea coast of Turkey lobby regulatory authorities for less stringent regulations for its fishery in order to maintain their export profits without any forethought towards the species' possible long-term sustainable harvest [47].

In the 1980s, when small-scale fishers in Turkey discovered they could profit from abundant *Rapana* catches, smaller vessels (5–7 m) with weaker engines (around 9 HP) and low technology were generally used for fishing in the Black Sea region of the country. However, in the 1990s, boat sizes as well as engine power of vessels started to increase in the Black Sea, and medium-sized (8–16 m) multi-purpose boats with stronger engines started to be more commonly used [48]. Due to its profitability, other sectors such as trawlers, purse-seiners, and socio-economically and politically marginalized ethnic communities

living in the region entered the fishery. The *Rapana* fishery provided substantial opportunity to marginalized ethnical communities to escape severe poverty by new income provision [47]. Additionally, poor rural women from the Turkish Black Sea region, deprived of their agricultural production opportunities by neoliberal agricultural policies, began to work as unskilled seasonal labor in *Rapana* processing facilities [31]. Similarly, in Bulgarian processing facilities mainly poor female workers are employed seasonally [38].

Even though *Rapana* presents considerable economic benefits in a region where there are few, not all fishers agree about the use of dredging. Those adopting a long-term sustainability perspective, such as some small-scale fisher organizations in Turkey, environmental NGOs, and divers in Bulgaria have declared their concerns against dredging in their regions [38]. While dredging is the main concern for small-scale fishing cooperatives from the Black Sea coast of Turkey who are alarmed of the bycatch and associated ecosystem damage on other commercial fish species, *Rapana* divers are more concerned with decreasing *Rapana* size, and its revenue along with it [38]. Also, decreasing mean sizes have caused processing factories in the Eastern Black Sea region of Turkey to cease operating since 2004, as smaller specimens are not profitable to export [78]. Hence, Eastern Black Sea Turkish fishers had to instead target other species. While the decrease in mean *Rapana* size jeopardizes trade with Far Eastern countries, Turkish factory owners are also disappointed by recent more stringent monitoring and inspections, reducing the illegality of the fishery, and hence also their revenues [47]. Still, Turkey is the only Black Sea country that has adopted management measures for the *Rapana*, such as closed seasons, restrictions on beam trawl equipment, regional restrictions, and mandatory vessel registration (Under the Law 1388, No: 5/1, Circular 2020/20 [57]). In Bulgaria, a ban on beam trawling entered force in 2001, but was lifted in 2012 due to business interests and lobbying, again prioritizing the economic and social aspects over the ecological ones [38].

5. Discussion

Rapana is the only IAS of the Black Sea with a valuable commercial stock. Yet, the *Rapana* fishery is in conflict with the objectives of the EU GEnS framework due to its dominant dredging fishing method, which is often contested by different stakeholders even including some small-scale fisher organizations, NGOs and marine scientists. As the Black Sea is already an over-exploited sea suffering from numerous natural and human-induced impacts such as eutrophication, pollution and invasive species, dredging should be evaluated against other alternative ecologically friendly fishing methods, which can likely be viable alternatives if the fishery is to be sustained over the long-term. With increasing global mobility, bio-invasion frequencies are estimated to increase by 36% until 2050, especially for invertebrates in Europe according to recent models [69]. Additionally, it is understood that rapid biological change favors invasion success, as such change will make new niches available to newcomers. In fact, IAS are much more successful than native species on artificial substrates, such as those used to construct ports and marinas [1]. The term "integrative invasion science" proposed by [49] implies an emerging approach to biological invasions by focusing on the lessons learned from past and ongoing invasion events, and then identifying the species invasiveness and ecosystem invisibility levels through the invasion mechanism, finally reaching a synthesis for prediction of future scenarios [35].

A case of typical wicked problem in biological invasion, *Rapana* and its fisheries pose negative impacts in terms of causing biodiversity loss, negatively affecting over-exploited fish stocks, reducing ecosystem services, damaging benthic habitat and ecosystem connectivity, while at the same time its positive impacts include controlling other invasive alien species, sustaining a healthy fishery stock status, and providing socio-economic benefits and employment opportunities for coastal communities. Considering the criteria for a wicked problem referred by [74], the *Rapana* case best fits the following property: "*Each problem is essentially unique. The source of wickedness lies in the social complexity of the stakeholders, and this varies from case to case*" (p.65). This is because, in the case of *Rapana*, control measures repeatedly fail to achieve good environmental status, while the social context underestimates the importance of biodiversity/ecosystem issue. Here out of the three systems in conflict, the economic and social are currently valued higher than the environmental, which is a choice. However, only the environmental system will ensure the longevity of economic and social rewards over the long-term, which seemingly needs to be reminded. Since these contradicting priorities impact stakeholders differently, agreement on a management strategy will always cause some conflict to some [35]. Policy makers should therefore consider the viewpoints of the various stakeholders and include them in management plans and governance proposals when suggesting alternatives to dredging, in order to establish and maintain social justice.

Collective action amongst fishers and their incorporation into co-management practices are viable alternatives for the complex governance of *Rapana* fisheries. Although the current literature on Turkish fisheries suggests that collective action of fishers is quite limited [34,46], one can still argue that the political presence of small-scale fishers is not to be underestimated, at least in Turkey, as they have become more active in the last decade through their regional and central associations of fishing cooperatives [16]. Fisheries co-management can be defined as "the sharing of responsibility and authority between the government and the community of local fishers to manage a fishery" [62]. Yet, the prospects for co-management are still very limited in Black Sea fisheries, as government authorities are quite unwilling to delegate decision making power to fishers and prefer to rely merely on 'consultation' meetings with fisher representatives. However, any participatory deliberative co-management system necessitates the governments to provide more initiative to fishers in order to make them able to become part of the management and governance processes [62]. Without a meaningful participatory mechanism such as co-management, or even better- ecosystem-based management, focusing on the entire ecosystem rather than single-species, it is highly unlikely that a suitable solution based on some compromise by various stakeholders can be devised for the governance of *Rapana* in the Black Sea, given the expected priorities vary from economic to social to ecological, and all three cannot be achieved in unison in this case. This complex situation is in addition to the future unknown biological and climatic shifts (via climate change) that will occur in the basin. Moreover, the social justice dimension of *Rapana* fisheries in terms of providing livelihoods for marginalized communities including small-scale fishers can easily be overlooked, while a more participatory deliberation mechanism should meaningfully mobilize their views and needs. Recent initiatives bringing together different stakeholders in workshops such as presented by [38] to discuss different views and interests are valuable efforts that policy makers can build upon.

This case also highlights the need for concerted efforts of Black Sea countries in the management of *Rapana*. While the current conventions and frameworks have not yet been successful in establishing cooperation among Black Sea countries, scientific projects such as the BlackSea4Fish Project (http://www.fao.org/gfcm/news/detail/en/c/1320340) assessing *Rapana* stocks can contribute to a common understanding of *Rapana's* differential impacts among scientists, stakeholders and decision makers. Such projects can also contribute to improvements in terms of achieving GEnS in Black Sea countries. However, it has to be noted that the economic pressure via Blue Growth initiatives to exploit and utilize all marine resources in an economically profitable way can be in conflict with GEnS. Blue Growth is an ambitious concept assuming that economic growth and ecological sustainability can be achieved simultaneously, but scientists have raised serious concerns about this strong assumption pointing out that economic growth usually comes at the expense of marine ecosystems [15]. Moreover, the dominant fishing method to harvest *Rapana*, dredging, is incompatible with the principles

of European Green Deal in the Black Sea, which underlines the contribution of ecologically sustainable fisheries to the economic recovery from the current Covid-19 crisis.

6. Conclusion

Exploitation of marine resources should be based on the conceptualization that the economic system is embedded within a social system, which in turn is embedded in the ecological system [45,53]. In line with this understanding, this paper serves to contribute a deeper understanding in the complexities surrounding the *Rapana* case, an invasive alien species with a diverse set of positive and negative impacts on the marine ecosystems and coastal communities. The paper emphasizes that the question of how to manage *Rapana* fisheries goes far beyond a simple binary decision of whether or not to fish, given the complexity of the multi-scalar management and governance issues involving multiple stakeholders. From the perspective of integrative invasion science, Rapana is by far neither the first, nor the worst case of a biological invasion in the Black Sea. In the last century, the Black Sea has had several dozen NIS penetrate it, most of which arrived between 1960s and 1990s [71], the worst so far being the warty comb jelly (*Mnemiopsis leidyi*), due to its high consumption rates of fish eggs and zooplankton of over ten times its body weight per day [37] which caused a basin-wide fisheries crisis in the early 1990s from collapsing anchovy stocks- the largest Black Sea fishery [30,44]. Socio-ecological systems involving biological invasions are wicked problems subject to constant change and severe societal tensions, which make problem identification and successful management a difficult task [35]. As such, the present *Rapana* era in the Black Sea should be considered a pragmatic example stressing the importance of the need to decide on clear objectives in a participatory manner before developing integrated approaches amidst the additional alarming effects of climate change, globalization, and ongoing human alteration of ecosystems. It is important to note that while the social and economic aspects of this fishery will continue to vary over time, the fostering of the environment is the only aspect that will promote the longevity of the other two. Establishing and maintaining social justice while adhering to the EU's Good Environmental Status principles is a moving target that policy makers, marine scientists and other relevant stakeholders should opt for in the complex *Rapana* governance problem.

CRediT authorship statement contribution

Nazli Demirel: Conceptualization, Data curation, Supervision, Visualization, Writing - original draft, Writing - review & editing. **Aylin Ulman**: Conceptualization, Writing - original draft, Writing - review & editing. **Taner Yıldız**: Conceptualization, Data curation, Writing - review & editing. **Pinar Ertör-Akyazi**: Conceptualization, Writing - original draft, Writing - review & editing.

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