Manual of invasive alien species in the Eastern Mediterranean

M.F. Huseyinoglu, Y. Arda and C. Jiménez

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

Norwegian Embassy
Beirut

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IUCN is pleased to acknowledge the support of its Framework Partners who provide core funding: Ministry of Foreign Affairs, Denmark; Ministry for Foreign Affairs, Finland; Government of France and the French Development Agency (AFD); Ministry of Environment, Republic of Korea; Ministry of the Environment, Climate and Sustainable Development, Grand Duchy of Luxembourg; the Norwegian Agency for Development Cooperation (Norad); the Swedish International Development Cooperation Agency (Sida); the Swiss Agency for Development and Cooperation (SDC) and the United States Department of State.

IUCN is pleased to acknowledge the support of its Framework Partners of the Coastal Ecosystem Resilience project.

This publication has been made possible in part by funding from the Royal Norwegian Embassy in Beirut, Lebanon.

Published by: IUCN, Gland, Switzerland

Produced by: IUCN Centre for Mediterranean Cooperation, Málaga, Spain and IUCN Regional Office for West Asia, Amman, Jordan

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Recommended citation: Huseyinoglu, M.F., Arda, Y. and Jiménez, C. (2023). *Manual of invasive alien species in the Eastern Mediterranean*. Gland, Switzerland: IUCN.

Cover photo: *Plotosus lineatus* © Hasan Yokes

Layout by: miniestudio.es

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Preface

Marine invasive species can have a disastrous impact on biodiversity, ecosystems, fisheries, human health, tourism and coastal development, and they can be extremely difficult and costly to control. This manual is about the most common invasive alien species (IAS) in the Eastern Mediterranean Sea, mostly originating from the Red Sea, creating socio-economic and ecological impacts on various levels.

The manual highlights the current situation of IAS in the Eastern Mediterranean, and mainly focuses on the management measures of IAS, existing legislations and action plans, mitigation measures and implementation of the controlling procedures with different aspects and practices among various disciplines and across regions. The manual is designed for a varied audience from Marine Protected Area (MPA) managers to local authorities, from scientists to non-governmental organisations that are involved in the in the management of IAS.

Parupeneus forsskali **in Kas, Antalya (Photo: Murat Draman)**

Acknowledgements

This manual would not have been possible without the expert knowledge generously provided by the aforementioned contributors.

A special acknowledgement is extended to contributors for their assistance in the preparation of the final document. Photographs used in this guide were generously made available by many Mediterranean colleagues, scientists and divers, who are credited throughout the guide.

The manual was coordinated by Yaprak Arda (IUCN Centre for Mediterranean Cooperation) with the support of Mira Husseini and Ziad Samaha (IUCN Regional Office for West Asia) and editted by Emmi Lindqvist and Amelia Agranovich (IUCN Centre for Mediterranean Cooperation) within the framework of the Coastal Ecosystem Resilience project funded by the Royal Norwegian Embassy in Beirut, Lebanon.

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Lionfish (Photo: Murat Draman)

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Introduction

Biological diversity, which is defined as the variability among living organisms, is inherited through an arduous but a self-composing process and is passing through another period of rapid and irreversible loss. But for the first time in geological history, this is because of the activities of a single species inhabiting the world for only the last 300.000 years: *Homo sapiens*.

Biodiversity has various levels, including 8.7 million species (90% of which are still waiting to be discovered), the variety among the genetic pool and how all these organisms interact with each other, consequently creating the landscapes and habitats within (Verma, 2016). Catastrophic reductions of biodiversity (of >90% loss) have occurred at various geohistorical times, but then recovered and flourished with prosperity every time. Our current state of knowledge suggests that the historical period we are in is another one of these devastating periods of biodiversity loss at all levels (Ghaly, 2022).

One of the three major threats impacting biodiversity is the overharvesting of natural resources, such as overfishing or the overexploitation of renewables to the point of diminishing returns. Another significant factor is the destruction and fragmentation of certain habitats in which species used to thrive, through urbanisation and mass agricultural deforestation. Finally, the anthropogenic introductions of new alien species into different parts of the world through commercial transportation and recently constructed passageways (sometimes intentionally) has always been problematic in many ecosystems. Biological invasions are among the top drivers of biodiversity loss and, on occasions, species extinctions across the world. A 2016 study published in the journal *Biological Letters* showed that IAS are the second most common threat associated with terrestrial species that have gone completely extinct since 1500 (Bellard et al., 2016).

As its name suggests, the Mediterranean Sea (Medi-Terra) has been in between lands, mostly inhabited and civilised for millennia. Increases in recreational and industrial usage, coastal development, pollution and overfishing have been the harshest human activities in the Mediterranean, especially in the eastern basin, where the effects of climate change seem to be more pronounced than elsewhere. Recently, invasive alien species have been recognised as a major threat. The Mediterranean Sea is often regarded by the scientific community as the world's most invaded sea (Giakoumi et al., 2019a). IAS are species introduced into ecosystems outside their natural range, causing negative impacts on native biodiversity and major impacts on human health, livelihoods and food security. IAS undermine the progress towards achieving many of the UN Sustainable Development Goals. A further complication is the increasing rate of new introductions and the compounded impacts from IAS by climate change. The opening of the Suez Canal in 1869 increased the influx of IAS into the Mediterranean. It is estimated that 70-90% of the alien species in the Mediterranean Sea are coming from Suez Canal via increased commercial transportation and by actively swimming juveniles and adults or current drifting as an egg or a larva. Currently, based on scientific analysis, 838 alien species exist in the Mediterranean Sea, while it is estimated that the real number is as high as 1000. Among the affected areas are the seas around Turkey with a total of up to 539 IAS (404 species already having an established status). Of these species, 413 were recorded in the Levantine Sea and 253 in the Aegean Sea. Of the total amount of catch in the industrial fisheries of Iskenderun Bay, Turkey, 62% are alien species. Israel reported 452 alien species very recently. In spite of the difficulties to choose the criteria to consider a species as the "worst" alien species, the general consensus is that the algae *Caulerpa* spp., the lionfish *Pterois miles* and the pufferfish *Lagocephalus sceleratus* are among the most harmful and all are well established species in the Eastern Mediterranean Sea (Çinar et al., 2021; Zenetos et al., 2015; Zenetos et al., 2022).

IAS are not only an environmental problem, but can also impact economy and safety. Thus, a cross-sectoral approach must be taken to address the effects of these species. The approach must include the environment, human health, agriculture, fisheries, governmental departments (such as customs and transport), along with key private sector bodies and civil society in general. The most cost-effective measure to address the impacts from IAS is to prevent their introduction in the first place. This can be achieved by establishing effective and well-resourced biosecurity measures to manage priority pathways of introduction, supported by early warning systems and rapid removal capacity. In consequence, control, containment and – where feasible – eradication need to be undertaken to mitigate the impacts from established IAS, including those whose impacts are likely to increase due to climate change.

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Management measures of invasive alien species

Species invasions or bio invasions, have a worldwide extent and a vast financial and ecological impact. Almost all taxonomic groups encompass IAS, which have infiltrated and influenced native biota in almost every habitat on the planet. The ecological cost is the irreversible loss of native species and habitats, as well as annual economic losses of billions of euros.. Since IAS are not restricted by any national or regional political boundaries, coordinated national, regional and ultimately international intervention is essential. Pysek and Richardson (2010) state that managing IAS is one of the most difficult tasks for the conservation of native biodiversity on land, in freshwater and in the marine realm. After overexploitation, IAS have been identified as the second most prevalent cause of island endemics and mainland species extinction (Bellard et al., 2016), and their ecological consequences can spread across the food web and disrupt ecosystem functioning (Gallardo et al., 2016). In addition, invasive species have significant socioeconomic and health consequences (Vilà and Hulme, 2017), as well as the potential to deplete ecosystem services (Walsh et al., 2016). As a result, their management is critical for the conservation of biodiversity and human well-being. International institutions have expressly recognised the need to regulate and remove biological incursions and have established related targets (e.g. the Aichi Target 9 set by the Convention on Biological Diversity).

High environmental connectedness through the water medium endorses species dispersal in the marine environment, making efforts to manage biological invasions more difficult. The larger the invaded region and the greater the invader's dispersal capacity, the more difficult it is to manage the invader's population (Williams and Grosholz, 2008; Galil et al., 2015). As a result, when deciding how to control a biological invasion, it is critical to consider the size of the invaded area as well as the species' dispersal capacity. Unless and until solid evidence suggests otherwise, every alien species should be managed as though it is potentially invasive. Once an invasion process has begun and the IAS are in the process of becoming established, no control of alien species is feasible that would not also harm other components of the biota; therefore, the goal highlighted in the Convention on Biological Diversity (CBD) in art. 8(h), calling for contracting parties "as far as possible and as appropriate, (to) prevent the introduction of, control, or eradicate those alien species which threaten ecosystems, habitats, or species" can only be partially met, especially by the eastern Mediterranean countries where the existing invasion process is unmatched anywhere else in the world.

As long as the Suez Canal remains open, not much can be done to manage invasive alien species in the Eastern Mediterranean. A noteworthy increase in the number of introduced species due to the Suez Canal expansion is a result of sea level change through the canal over time, a decrease in the salinity level of hypersaline lakes (Bitter Lake) and a reduction in the freshwater outflows of the Nile following the construction of the Aswan Dam, which was a freshwater barrier at the entryway of the Mediterranean. Furthermore, global climate change will continue to increase the number of introduced species if aforementioned causes are not accurately and carefully monitored and necessary management measures are not taken (Çinar et al., 2021).

A comprehensive approach to invasive species management should consider the following factors: the expected impacts of these species on native ecosystems, the available technical intervention options, their likelihood of success and cost, the risks associated with management and the extent of public and stakeholder support for the proposed interventions (Hulme, 2006). The goal of this manual is to provide recommendations on how to prioritise management actions for the control of certain marine invasive species with an emphasis on the Eastern Mediterranean.

Depending on the status, there are numerous different ways to manage invasive alien species as stated below (Figure 1):

1. Prevention
2. Early warning/Detection
3. Removal
4. Control/Containment
5. Long term management - Exclusion
6. Mitigation
7. Adaptation

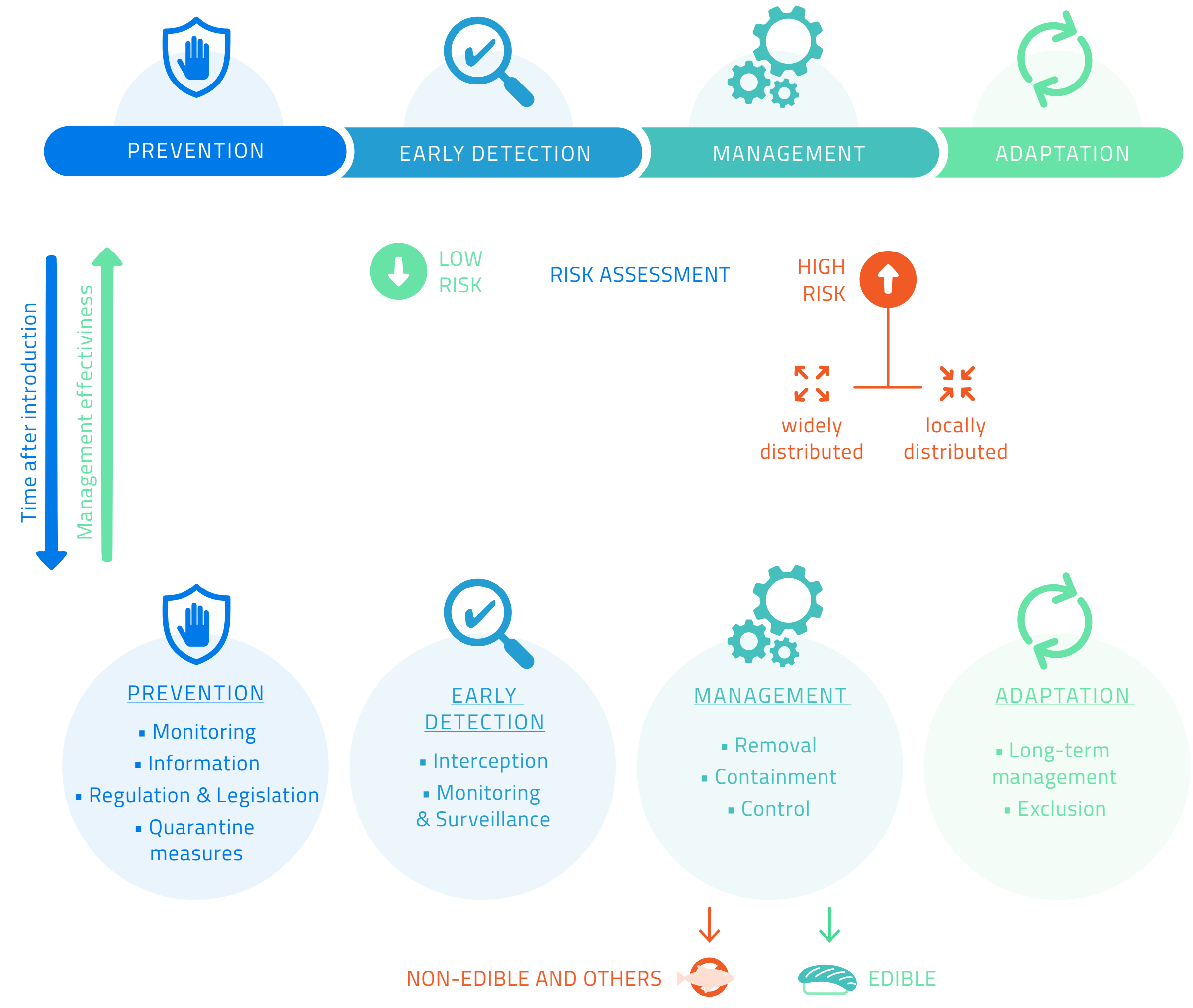


FIGURE 1: Management strategies for invasive alien species (© IUCN)

2.1 PREVENTION (BIOSECURITY)

The first line of defence is prevention, not enabling a potentially invasive species to establish itself in the first place. The most cost-effective way to handle the effects of IAS is to avoid their introduction. This can be accomplished by implementing effective and well-resourced biosecurity measures to manage key introduction channels, supported by early warning systems and fast eradication capabilities. Prevention also avoids species' impacts, whereas management after establishment generally occurs only after impacts have occurred. Prevention is accomplished by detecting entry points and establishing four barriers: 1) Pre-export control aims to prevent the export of known invasive species from places where they are established; 2) Pre-border control regulates importation to an island or country; 3) At-border control aims to prevent the arrival of species; 4) Post-border early detection and rapid response aims to detect and eradicate completely newly-arrived species before they spread far beyond the point of arrival, as treatment is cheaper and easier at that point. All four components are required for an effective biosecurity system (IUCN, 2018).

These actions have been designated as a worldwide priority by Aichi Target 9 and accepted by the Convention on Biological Diversity, which calls for the identification of critical invasion pathways and the implementation of countermeasures. Meeting this goal necessitates action at numerous geographical scales, from global to regional to individual protected areas or site-specific activities, as well as integrating the processes and responses occurring at the various scales (Kueffer et al., 2010). Invasive management in general has to transition away from long-term control and toward prevention, eradication and biological control, which can be considerably more efficient and enable for more problems to be addressed for a given budget. It is critical that IAS prevention and management methods take a cross-sectoral approach. Local volunteer organisations, fishers and wildlife enthusiasts can help monitor the coastal waters and provide additional information to aid in the early detection of new invasive species in some Mediterranean MPAs and other coastal areas. More importantly, the participation of local volunteers can have other benefits, such as fostering a sense of ownership and appreciation for the local marine environment (Cuthbert et al., 2022).

2.1.1
THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN MONITORING INVASIVE ALIEN SPECIES

Invasive species overtake natural communities, and many native species that cannot cope with how this spread affects their niches have become locally extinct or are in danger of extinction, particularly in island communities (Richardson et al., 2000; Pyšek et al., 2004; Richardson et al., 2011; Essl et al., 2018). With the development of satellite, mapping and photographing technologies, central and local governments can apply the data gathered by Geographic Information Systems (GIS) to infrastructure construction, environmental management, spatial planning, education, health, national security and economic planning to support the agriculture, forestry, tourism and transportation industries.

Spatial technologies affect our lives today. They reduce the complexity of information and reveal new perspectives to managers, administrators and researchers who use the data available through GIS to conduct their analyses. GIS is a powerful tool for monitoring biodiversity (Esra et al., 2015). A joint United Nations Environment Programme (UNEP) and World Conservation Monitoring Centre in 1994 was the first project to propose using information systems to protect biodiversity (Biodiversity data management capacitation in developing countries and networking biodiversity information). Today, GIS analyses reveal new, invaluable perspectives to researchers, especially in determining the location, distribution and follow-up of the species. As with any research methodology, however, the quality of the data obtained in GIS analyses and the appropriateness of the selected method of analysis impacts the reliability and transferability of findings. Nevertheless, GIS provides decision-makers with essential information about the conservation of biological diversity (Kayi, 2021; Bingül et al., 2016).

The ongoing development of remote sensing and GIS technologies coincide with innovations in data collection. The opening of new communication channels between researchers and the public and decreasing costs make it easier to obtain large data sets. Scientists and experts are able to make efficient use of digital opportunities to collect data sets and manage them with a goal for common understanding. Organisations such as IUCN's Invasive Species Specialist Group are working to collect data on a common platform. There are many web-based mapping systems that document invasive species like EDDMapS and ImapInvasives and enable citizens to participate in scientific studies without years of specialised training by helping to gather bigger, better data sets.

Remote sensing technology has also proven to be a powerful tool to track biological invasion in recent years (Joshi et al., 2004). Some of its well-documented benefits include multi-band data, multi-time coverage and cost-effectiveness (Van der Meer et al., 2002). Integrated GIS and remote sensing are consistently applied to map the distribution of plant and animal species, their ecosystems, landscapes, bioclimatic conditions and factors that facilitate invasions (Stow et al., 2000; Los et al., 2002). Geographic information systems can represent the spread of IAS over time and their distribution in the region in a simple and understandable way. This clearer and more accurate picture helps decision-makers to better understand the complex data gathered to track invasive species, their relations with local species and their distribution, behaviours and effects on the region. Better and more comprehensible data fosters more sustainable policies and regulations. Indeed, there are 13 clear and important benefits to GIS and IAS studies, namely;

1. Access to a long-term, centralised database of marine IAS species
2. Access to a single database of groups from different disciplines
3. Ability to track the spread of IAS in the long-term
4. Identification of movement paths of IAS and their transport mechanisms
5. Identification of transport risks of IAS
6. Evaluation of impact on local activities
7. Evaluation of relationship with native species
8. Ability to track adaptation to regional conditions
9. Ability to track response to climate change
10. Ability to track changes in ecosystem functions
11. Ability to monitor effect on water quality
12. Evaluation of damage caused by IAS to the region
13. Preparation and presentation of important data for analyses

GIS is an invaluable tool to fight threats of IAS because it produces more comprehensible results at lower costs (Çabuk, 2015). Indeed, GIS approaches generate user-friendly and understandable results in many topics and fields that make our daily lives easier and more sustainable (Koçak, 2009). GIS is used in more than 100 disciplines, but its role in the early detection, control and prevention of the spread of IAS is paramount (Bingül et al., 2016).

2.2 EARLY DETECTION

Early warning and rapid response to bio invasions is a critical pillar of an effective management plan since it is far more operative and cost effective than suppressing IAS once they have established themselves. Early detection of an IAS can mean the difference between being able to achieve viable goals (eradication) and having to resort to a containment strategy that usually necessitates a long-term financial commitment. Early detection demands a coordinated structure for surveillance and monitoring operations, identifying invading species, assessing dangers, sharing information, developing warning lists and selecting and enforcing appropriate remedies. The public's support, as well as contingency planning and financial mechanisms, are critical. The ability to quickly impose efficient management of newly arrived IAS at the earliest possible time after their introduction into the territory must be increased and improved. Rapid detection and response can, nonetheless, be beneficial in eradication efforts that are predicted to be difficult, such as those targeting marine species (Oceana, 2012).

To detect the existence and abundance of IAS early, concentrated surveys of the species with the greatest invasive potential and knowledge of the most sensitive areas are required. Because invasive behaviour for the same species may vary across the region, particular interventions for specific regions should be endorsed. Cooperative monitoring surveys with research or community groups (such as diving clubs) could also help to detect new and increasing IAS populations. Marine monitoring is costly and time-consuming, but training volunteers to conduct marine surveys can dramatically improve both prevention and early detection of invasive species, while also compensating for the with limited financial support.

2.3 REMOVAL

Removal or eradication refers to the total removal of an invasive species from a location. When prevention, early detection and fast reaction measures are ineffective, eradication may be the best choice for managing established species and permanent control (Wittenberg and Cock 2001). It must be taken into consideration that if alien species are neglected or go unreported until they have established themselves in the local ecosystems, eradication will become difficult, costly or impossible. When a critical species is recognised at an early stage of colonisation and has a limited spatial distribution, eradication of some species may be achieved, whereas a big initial expenditure in eradication or biological control may result in a more cost-effective long-term result.
For the management of IAS, many nations have already developed Risk Analysis (RA) and Environmental Impact Assessment (EIA) methods, which are mandated by specific international instruments. The challenge will be to apply these to IAS prevention, eradication and control (Genovesi and Monaco, 2014). Measures of risk analysis should be used to identify and evaluate the relevant risks of a proposed action involving alien species, as well as to determine the appropriate measures to be implemented. EIA plays an important role in deciding whether or not to carry out specific processes or activities (Shine et al., 2010).

It is critical to assess relevant policies, legislation and institutions in order to detect conflicts, gaps and inconsistencies, as well as to reinforce or adopt effective national measures for the prevention, eradication and control of alien species. It is advised that priority IAS eradication programs be promoted, considering their potential or current impact on biodiversity, food security and human well-being, and to give priority to crucial regions such as islands, protected areas and key points of entry such as ports. Because the control of hazardous invasive species can generate advantages that are for the public good, it necessitates public investment in prevention, eradication, control, mitigation and adaptation (Shine et al., 2010).

2.4 CONTROL

After an IAS has become lastingly established or extensively spread, the only steps that may be possible to prevent the species' further expansion and negative impact on the environment are control approaches. Response and management control mechanisms for marine species by responsible authorities, on the other hand, are little understood, and measures that work in one region may not work in another. Coordination with many stakeholder groups, as well as expert consultation and assistance, are required to discover cost-effective and realistic solutions to some of these invasions. Species that cannot be eradicated, particularly those that have spread widely, should be considered candidates for biological control, genetic techniques or similar means of achieving permanent population or impact reduction (IUCN, 2018).

Many ways for controlling IAS are available; these tools can be used individually or in various combinations (Wittenberg and Cock, 2001). Given the high complexity of the ecology of invasive species and affected habitats, control methods must be implemented with the up-to-date scientific understanding available. Mechanical control involves directly removing the species by hand or with appropriate tools and devices, such as harvesting vehicles or traps; biological control involves the intentional use of populations of natural enemies of the target IAS or intentional release of a natural enemy to control the species. It is critical to guarantee that the species utilised for biological control does not become invasive in turn. If the target species already has well-studied control agents available, biocontrol can be inexpensive. Consider some of the appropriate targets, and use publicity to inform of the importance of biocontrol by demonstrating accomplishments and sound science. A control project that can successfully be completed (not just with successful control, but also with no negative consequences), has the potential to drastically alter public opinion.

If an invasive species has already spread, species-specific biological management may be the only viable option. Economic assessments of effective biological control programs have revealed a good cost-benefit ratio, despite the fact that some failed attempts had severe environmental consequences. Modern biological control safety standards are extremely stringent, requiring great specificity of the agents recommended as well as intensive laboratory and field screening procedures. Biological management is frequently the only long-term self-sustaining method that is also the least intrusive in locations where biodiversity is highly valued (CBD/COP/14/INF/9, 2018).

2.4.1 MARINE PROTECTED AREAS AND BIOLOGICAL INVASIONS

Marine Protected Areas (MPAs) form the cornerstone of marine conservation. They have emerged as a prominent management tool for the conservation and recovery of marine ecosystems and their ecosystem services (Lubchenco and Grorud-Colvert, 2015; Sala and Giakoumi, 2018). Despite the availability of a large amount of information on MPAs, the effects of protection on marine IAS remain largely unknown (Burfeind et al., 2013; Ardura et al., 2016; Giakoumi and Pey, 2017).

Different mechanisms could explain how MPAs can control the presence and reduce the impacts of IAS within their borders. First, vectors of alien species are expected to be fewer in MPAs because many human uses, such as aquaculture and marine traffic, are forbidden or restricted (Ardura et al., 2016). Secondly, based on the 'biotic resistance hypothesis' (i.e. ecosystems with high species richness are more resistant to invaders than those with low biodiversity; Levine and D'Antonio, 1999), the high native species richness within MPAs could prevent the penetration and settlement of alien species. Thirdly, the restoration of top-down regulation processes (e.g. restoration of top predators' populations) in MPAs could help control the population of some alien species inside MPAs (e.g. Mumby et al., 2011 but see also Hackerott et al., 2013). On the other hand, several mechanisms could support the opposite argument that MPAs favour the spreading of alien species. For example, according to the 'biotic acceptance hypothesis', ecosystems can accommodate the establishment of alien species and their coexistence with native species, and based on a rich-get-richer pattern, areas with high native species richness could support high numbers of alien species (Stohlgren et al., 2006; Fridley et al., 2007). Moreover, alien species could thrive well in MPAs, mainly because they would benefit from harvesting bans and restrictions applying within the MPA (Burfeind et al., 2013). Lastly, MPAs may have no effect on alien species as most of them have dispersal mechanisms that expand beyond the MPA boundaries (Burfeind et al., 2013).

Assessing the effects of MPAs on invasive species is crucial for the effective management of existing MPAs as well as for the optimal site selection for future MPAs (Giakoumi et al., 2016). If MPAs prove to have no effect or favour the settlement and expansion of IAS, then the location of new MPAs in impacted areas should either be avoided (Boudouresque and Verlaque, 2005) or complemented with other management measures for the mitigation of invasive species' impacts (Thresher and Kuris, 2004; Giakoumi et al., 2019).

2.5 CONTAINMENT

Containment refers to keeping an IAS inside a specific area. Species that cannot be eradicated with the resources available (Cacho and Pheloung, 2007), but have not expanded widely, or that are useful or important to people and hence cannot be destroyed or controlled biologically, should be contained within enclosed areas if possible. A successful eradication program frequently necessitates containment intervention. A program of this nature must be science-based and have a reasonable likelihood of success. It is critical that all key stakeholders participate in the process. The public's support and acceptance of eradication measures is also critical (McNeely et al., 2001). Monitoring and control are frequently required and restoration of impacted systems is a significant issue.

2.6 LONG-TERM MANAGEMENT AND EXCLUSION

Long-term management of an established IAS population, including exclusion from specific areas, should logically be regarded as the last alternative for managing the invasive species when eradication, containment and biocontrol have all been acknowledged as impractical with realistic resources. In this scenario, the management goal has to be more specific. Once two critical questions are answered, i.e. "Why it is necessary to control the species?" and "Does it have to be managed in certain areas?", then it would be possible to (1) select the best strategies and (2) decide where to use them. As an example, it can be possible to utilise chemical, physical or genetic approaches. According to the choices made, long-term expenditures may be necessary and the level of control that can be attained is determined by the available financial resources.

Management of established invasive species should involve several steps or actions to decrease or eliminate the impacts of established invasive species, such as eradication, biological control, confinement, exclusion, physical-chemical control or impact mitigation. Observance and regular monitoring are key components of any sound IAS management program, and such action can result in lower cost and resource use than initiating a long-term control program after an alien species is established. It is important to design and implement exclusion projects for appropriate situations, including the exclusion of selected invasive species from sites of exceptional conservation value (e.g. no-take marine reserves).

2.7 MITIGATION

Where control of an invasive species' population is too expensive or difficult through any of the ways mentioned above, mitigation of its impacts through methods other than managing the invasive species itself can be considered (IUCN, 2018). Mitigation can reduce or eliminate the chance of a species establishing or spreading, as well as minimise or remove the presence of an IAS. Mitigation might take the form of eradication (total elimination of the IAS), containment (keeping the IAS within defined borders) or suppression (reducing population levels of the IAS to an acceptable threshold) (Hulme, 2006). The determination of the management goal is a vital initial step in a mitigation program. Creating a platform for IAS mitigation and monitoring on a regional scale through cross-sectoral and interagency research and management can be an important tool.

2.8 ADAPTATION

As a result, IAS populations are expected to evolve adaptations that will lead to exponential growth and further spread in the near future. Adaptation entails changing one's behaviour in order to lessen the impact of an invading species. Adaptive management, also known as 'learning by doing', provides an appropriate framework for developing collaborative and transdisciplinary approaches aimed at overcoming the difficulties connected with IAS (Allen, 2000; Johnson et al., 2015). Adaptive management entails describing dynamic models of the case-study system that are parameterised with empirical data and recursively updated by monitoring the system's response to management actions. This technique assists in dealing with uncertainties, quantitatively combines current knowledge, addresses the various characteristics of IAS management and assesses the efficacy of measures.

- The relevant environmental, social, cultural and economic impacts of IAS, including their spatial and temporal distribution;
- The spatio-temporal dynamics of the target species, with a focus on understanding and forecasting how dispersal and population recovery after management shape reinvasion and spread;
- The relationship between the abundance of the focal IAS and its relevant impacts in the focal areas;
- Economic methods to estimate both the benefits and costs of interventions to spatially develop and rank prioritisation of cost-effective actions to manage interventions associated with IAS in space and time.

Adaptive management provides an opportunity to increase objectivity and demonstrate whether the control of an invasion effectively contributes to the conservation objectives of native biological diversity or if additional restoration practices are required for the affected environment to regain its resilience.

Recommendations

1. Availability of taxonomic knowledge
2. Application of molecular tools (if possible)
3. Common guidelines for surveillance and monitoring
4. Regional early warning and monitoring protocols
5. Standardisation of data and information systems
6. Cautious choice of indicators
7. Multi-vector management
8. Cooperation with stakeholders
9. Implementation of a 'united authority' approach

Lionfish (*Pterois miles*)
in Cyprus with its magnificent
body features and color pattern
(Photo: Mehmet Ali Kiran)

3

Invasive alien species of the Eastern Mediterranean

3.1 EDIBLE IAS

The exploitation and consumption of IAS have become increasingly popular as a means of putting pressure on IAS populations and transforming these species into a food supply and economic advantage for local communities (Giakoumi et al., 2019a; Giovos et al., 2019). Despite this, managers have been hesitant to advocate and create methods for exploitation of IAS in the Mediterranean Sea, often due to a common belief that all IAS have negative consequences based on misconception or misdirection (Figure 2).

Before supporting the sustainable exploitation of “questionable species”, a complete assessment of IAS consequences on ecosystem services to the Eastern Mediterranean region is required, including impacts on other fisheries. A risk assessment has to be applied for the targeted species in order to define if the species is low or high risk based on their impacts on biodiversity, habitat, ecosystems, socio-economy and human health. If the targeted species is considered to be low risk, regular monitoring and surveillance protocols can be implemented. If the targeted species is considered to be high risk, the distribution patterns (e.g. locally or widely spread) must be determined in order to choose the removal methods, amount of effort and related cost analysis. If the species can be removed by existing fisheries techniques, they can be promoted in fisheries markets as alternative options to the consumers. If special methods or techniques are required for the removal, certain protocols and regulations can be developed in collaboration with authorities, decision-makers, NGOs, fishers and related stakeholders.

Key action points:

- Target the IAS early to reduce the ecological and socio-economic impacts
- Evalute the current status of the species
- Set thresholds for environmental, economic and social impacts and assess the performance of management activities
- Monitor the species at selected locations with standardised protocols
- Include the targeted species on the agenda for regional cooperation
- Rapidly develop opportunities for commercial and recreational uses
- Focus on regulations needed to allow removals and consumption
- Create a supply chain for products
- Implement education and training programmes
- Engage public interest with opportunities to take part in activities, such as degustation and removal festivals

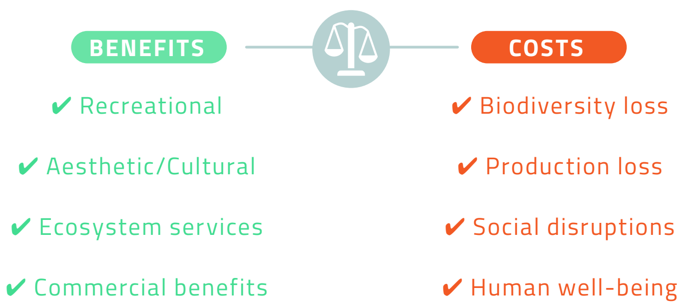


FIGURE 2. The costs and/or benefits an IAS can have to the environment (© CBD)

A juvenile lionfish (Photo: Mehmet Fatih Huseyinoglu)

3.1.1
LIONFISH IN THE EASTERN MEDITERRANEAN SEA

Scientific name: *Pterois miles*
Common name(s): Lionfish, turkey fish. Lionfish is a common name for several species from the teleost fish family of Scorpaenidae.

IDENTIFICATION: *Pterois miles* is a marine, reef-associated Actinopterid fish, living in the Indian Ocean and the Red Sea, south to Port Alfred, South Africa and east to Sumatra, Indonesia. It has 13 dorsal spines, 9-11 dorsal soft rays, 3 anal spines and 6-7 anal soft rays (Eschmeyer, 1986). It is a very attractive reddish to tan or grey-coloured fish with wing-like patterns of stunning fin structures; it is very resilient and tolerant to various water parameters and environmental conditions, and it is spectacularly colourful. Therefore, it is one of the most popular aquarium fish among the hobbyists of the world. However, these properties make this species very dangerous as well: (i) its colour and pattern scheme is a warning that it is highly venomous, to an extent that on rare occasions, it can kill a human with a weak immune system; (ii) its resilience and tolerance make it a very persistent species which can withstand various and even ever-changing conditions in different ecosystem types; (iii) having a high reproduction and feeding rate, it can sweep ecosystems easily particularly in the absence of frequent natural predators or another successful species which feeds on its eggs, larvae or juveniles (Hüseyinoglu and Öztürk, 2018).

INFORMATION: Starting from 2012, lionfish sightings increased along the anticlockwise circulation pattern of main Eastern Mediterranean currents. With the bitter example of the Caribbean invasion by this fish, scientists have a common concern regarding this species to be a problem for the rest of the Mediterranean. In consequence, numerous scientific research programs and public awareness campaigns dealing with the lionfish are being conducted in the Levantine countries (Hüseyinoglu and Öztürk, 2018).

It is known to be one of the most successful and aggressive invading fish species, damaging ecosystems through predation and niche occupation. First recorded in 1985 in Florida (Ruttenberg, 2012), the lionfish extended to the Western Atlantic coasts in the 1990s and the rest of the Caribbean during the last 15 years. The most likely vector of introduction is the aquarium trade by intended and/or unintended release, although ballast water transportation cannot be ruled out (Johnston and Purkis, 2011). A complete removal of lionfish from invaded ecosystems is impossible; however, it is still top priority in terms of ecosystem services recovery (Albins, 2015).

The lionfish has been recently established in the Levantine basin, which may unfavourably affect not only the struc-

In Cyprus, lionfish is intensely targeted by spearfishing enthusiasts. (Photo: Mehmet Fatih Huseyinoglu)

ture and function of local ecosystems, but also the economy, fisheries, biodiversity and even human health. So far it is understood that this undesired introduction is probably a recent event, and the current lionfish populations in the Mediterranean are a product of multiple invasion events via the Suez Canal. Its range expansion speed is remarkably high; the species crossed the eastern basin just within two years, reaching Italy and Tunisia. The *P. miles* individual recorded off the Israeli coast during 1991 (Golani and Sonin, 1992) was an indication of a single species record. Subsequently, several Eastern Mediterranean countries effectively responded to the accelerating lionfish invasion (Bilecenoğlu, 2017). It is worth mentioning that some scientists are doubtful about an invasion comparable to the Atlantic, since computer modelling predicts low connectivity between potential lionfish habitat along the Mediterranean coastline, so the basin is not considered to be particularly conducive to the establishment of lionfish (Johnston and Purkis, 2014). However, more recent research suggests the opposite (Schickele et al., 2021). Moreover, current observations from various parts of the Mediterranean Sea indicate an increasing abundance of *P. miles*, whose establishment success may be attributed to the combination of its life history characteristics. Furthermore, natural biological controls, such as the presence of top predators and diseases are quite rare, making lionfish a hard to beat opponent. *P. miles* has been constantly expanding and establishing, invading new areas, as documented by numerous reports from countries of the Eastern Mediterranean. The species is currently considered as established in all of the Eastern Mediterranean basin (Kletou et al., 2016) raising serious concerns for the potential impacts on the local marine ecosystems and the native species, given the experience from other regions (Albins and Hixon, 2008).

MANAGEMENT STRATEGY: To the best of our knowledge, none of the Eastern Mediterranean countries attempted to eradicate the lionfish during the initial phases of the invasion due to a variety of expected reasons. In fact, eradicating lionfish (or any other successfully established marine invasive alien species) with currently available tools and technology is almost impossible (Côté et al., 2014). Common problems require regional and international cooperation, but many Mediterranean countries face similar constraints in the invasive species efforts, such as low public awareness (the situation in Lebanon has been examined by Azzurro and Bariche, 2017), inadequate monitoring capacity, absence of clear and agreed priorities for action, lack of effective emergency response measures, outdated or inadequate legislation and poor coordination between government and other stakeholders (Genovesi and Shine, 2004).

Acting for invasive alien species through gastronomy is a popular approach both in terrestrial and aquatic ecosystems (Nuñez et al., 2012). In the case of lionfish, promoting targeted removals for consumption in the context of food/cooking festivals is extremely attractive and has gained the attention of citizens, especially in the Caribbean and nearby areas (Frazer et al., 2012). Such campaigns, when designed properly, have been proven valuable tools for lowering the expansion rates of *P. miles* and *P. volitans* by turning these unstoppable predators into a delicacy and at the same time enhancing participation and promoting citizen stewardship. The "Lionfish Removal and Awareness Day Festival" in Florida is a successful example, in which scuba divers, celebrity chefs, conservationists and the general public come together in a festival where everyone can taste a big variety of lionfish dishes, and where the public can learn about the problem and jointly move towards mitigation. Different recipes have been developed and a lot of chefs have mastered gourmet lionfish dishes, while the public continues consuming the species year-round. Experiences from the West Atlantic invasion was applied for the first time in the Mediterranean Sea in Cyprus (Jimenez et al., 2016). A lionfish removal competition, which is held periodically in Cyprus, is becoming increasingly common with the participation of interested stakeholders including divers, authorities, NGOs and the local public. With this competition, divers are encouraged to eradicate only lionfish; applying a specific method by pole spear fishing is highly effective. However, it must be taken into consideration that lionfish could soon re-invade; therefore, coordinated monitoring and further targeted removal events might be necessary. In addition, the fish collected are then cleaned and served to the participants, after being informed about the lionfish. Since the dorsal, anal and pelvic fins have venomous spines, they should be handled very carefully. Thanks to these events, lionfish is now a well demanded fish in Cyprus. Moreover, jewellery and accessories made from dried fins and spines have been on sale in the western Atlantic for years and now a few countries in the Eastern Mediterranean have also started producing similar garments, such as earrings, pendants and cocktail sticks. It is also proposed that lionfish should be included on the EU list of invasive species of concern (EU Regulation 1143/2014) and regional management actions are needed.

***Siganus luridus* (Photo: Hasan Yokes)**

3.1.2.
THE STORY OF AN INVASION: **THE MARBLED AND THE DUSKY SPINEFOOT** IN GREECE

Scientific name(s): *Siganus luridus* and *Siganus rivulatus*
Common name(s): Marbled and the dusky spinefoot

One of the most intriguing aspects of ichthyology is common names. Every species has different names in different locations and languages. For the most common species, sometimes these names originate from the ancient times. For others, these are relatively new. In this latter category, one can find IAS that make an appearance in a new area and people (fishers in particular) use their imagination and creativity to find names for them. As an example, the family Siganidae are called rabbitfishes due to the similarity of their snout with that of rabbits (Froese and Pauly, 2022). In Greece, there are currently two species of Siganidae: *Siganus rivulatus* (Forsskal & Niebuhr, 1775), known as the Marbled spinefoot and *S. luridus* (Rüppell, 1829), known as the Dusky spinefoot.. The first one to arrive in the Greek waters was *S. rivulatus*, reported in 1925 from the island of Symi (south-east Aegean Sea; Dodecanese Islands) (Zenetos et al., 2020), and due to its resemblance to the native *Salpa sarpa* (Linnaeus, 1758) salema (salpa in Greek), it was called "agriosalpa" (wild salpa). The second one was first spotted in 1964 in Tilos island (south-east Aegean Sea; Dodecanese Islands) (Kavalakis, 1968), located approximately 35 km west of Symi. *Siganus luridus* has a dark khaki colour and a roundish shape. An anecdotal version of the story behind its common name says that in the eyes of the Greek fishers it looked very much like the helmets worn by the German soldiers during WWII. Hence, they called it "germanos" (German). In the following years, fishers and others started calling both species "germanos" and in order to tell them apart, they used the epithet "white" and "black", for *S. rivulatus* and *S. luridus* respectively.

Schools of *Siganus rivulatus* juveniles over *Cystoseira* spp. beds in Rizokarpaso, Cyprus (Photo: Mehmet Fatih Huseyinoglu)

IDENTIFICATION: Both *Siganus* species have 13-14 dorsal spines, 10 dorsal soft rays, 7 anal spines and 9 anal soft rays; however, *luridus* has 13 vertebrae, while *rivulatus* has 23. Therefore, *S. luridus* is shorter and stockier than *S. rivulatus*. The upper body of *S. rivulatus* is grey, green or brownish in colour and the lower body is iris iridescent silver or golden, with colour patterns extending to the fins. *S. luridus* is silvery to brown and even dark greenish, with regional variation in color (Woodland, 1990). Both species have native ranges in the Western Indian Ocean, several locations in East Africa and the Red Sea (Woodland, 1990).

INFORMATION: These two species have entered the Mediterranean through the Suez Canal and have invaded the entire Eastern and Central Mediterranean with the exception of the northern Aegean Sea. The two spinefoots have been expanding in the Greek seas with a rather slow rate until the early 2000s. Since their first appearance in Greek waters, there were only very few new records of them. But in the beginning of the 22nd century, theya population explosion began. They became widespread in the Aegean, and with a time-lag in the Ionian Sea (Figure 3). *Siganus luridus* expanded faster than *S. rivulatus* and made its first appearance in the Ionian Sea in 1973, in Oxia island, at the outskirts of Patraikos Gulf (Central Ionian Sea) (Zenetos et al., 2020). On the contrary, it took *S. rivulatus* 83 years to expand its distribution to the west, with its first record from the Ionian Sea dating to 2008 from Sapientza island, in Messiniakos Gulf (South Ionian Sea) (Bardamaskos et al., 2009). Today, both species have very well-established populations in the central and southern parts of both the Aegean and Ionian Seas (Figure 2), whereas their records in the northern parts of the Greek seas are sporadic (ELNAIS, 2022).

Both species are herbivores, and the only other purely herbivore fish found in the area was the native salema. However, *Siganus* spp. not only feed on algae, but they graze with very high intensity on underwater vegetation creating barrens (i.e.areas that completely lack algal coverage). Apart from the direct effect on the algal communities, there are several other impacts of spinefoots' feeding habits, such as alteration of the rocky infralittoral food webs, habitat loss for a wide variety of animals, loss of spawning and recruitment grounds for fishes and the extirpation of other fish species (Sala et al., 2011; Giakoumi, 2014; Katsanevakis et al., 2015, 2020). Apart from their impacts on the environment, the spinefoots have significant effects on ecosystem services too. Fishers complain about the fact that the spinefoots are traumatogenic, and their sting is a really painful one, though not life-threatening to adult humans, and the swelling caused can last several hours (Galil, 2018). The species use their venomous spines in defence, and one should be careful when fishing and handling them. In certain areas of the country, their density is quite high and they are being caught in substantial amounts in fishing nets (Corsini-Foka et al., 2017; Brodersen and Vassilopoulou, 2018). In some regions, where the species do not have high commercial value, these high densities are problematic for the fishers as they are being negatively affected by these big catches. Small-scale fishers report that if they catch spinefoots, then the amounts of other species caught are significantly reduced. Moreover, it is very difficult to disentangle these fishes from their nets (Galanidi Bingkiol, 2019; Galanidi et al., 2019). This has two main negative results. Firstly, the fishers have to cut the meshes of their nets in any attempt to remove the spinefoots caught. This results in destroyed nets that need to be fixed in order to be used again for fishing. In

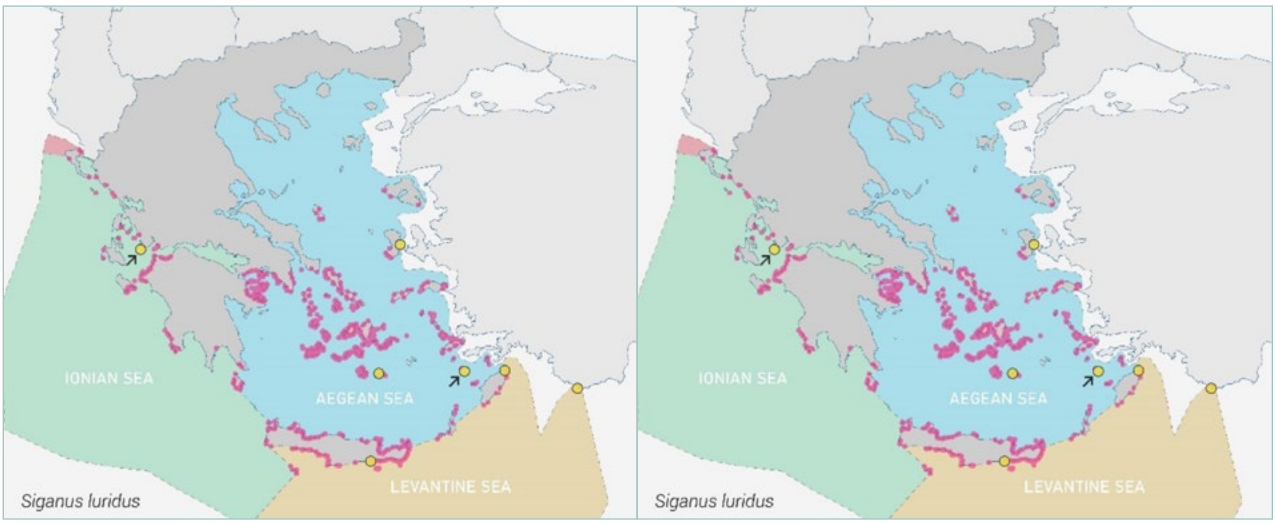


FIGURE 3. Spatial distribution of *S. luridus* and *S. rivulatus* in the Hellenic Seas. Yellow points refer to records before 2000, whereas red ones refer to records after 2000. Dotted lines and different sea colours indicate the marine strategy directive assessment areas of the marine territorial waters of Greece (MinEnv Greece, 2012). Arrows indicate the first appearance of the species in the Aegean and Ionian Seas. (ELNAIS, 2022)

some cases, fishers report that the damages are so extensive that the nets cannot be repaired and need replacement. Secondly, the time needed to remove the fish from the net (handling time) is substantially increased. All the above – i.e. high catches, increased handling time and damaged nets – lead to loss of income, and at the same time increase the cost of each fishing operation without the equivalent in financial gain (Galanidi Bingkiol 2019; Galanidi et al., 2019).

MANAGEMENT STRATEGY: Both species are edible and very highly esteemed elsewhere, like Cyprus, where they are sold as first quality fishes. Moreover, a recent study has shown that both species, and especially *S. rivulatus*, are exceptionally rich in omega-6 fatty acids, and especially arachidonic acid (ARA) (Grigorakis and Kotsiri, 2021; Grigorakis et al., 2022). ARA is an essential fatty acid for the development and good health of the human brain, and hence both species are high quality food and can be cooked fried or grilled. Unfortunately, Greek consumers in most regions do not include these species in their dietary preference and therefore consumption is rather low. Indeed, the two species are not commercially exploited in most areas of Greece where they are fished as only in a few areas are they considered as commercial. The species are being sold in the Dodecanese Islands (where they are mostly appreciated) and to a lesser extent in Crete and the Cyclades, with a value ranging between €5-15 per kilo. In the areas where they are consumed, there is a developing métièr (i.e. fishers know where, when and how to catch them) that could lead to increased income for the fishers. Indeed, in the Dodecanese Islands, people savour their taste and fishers earn good money out of exploiting them. However, as the species have become invasive in other areas of the Greek seas, this local trend should be expanded. And it is generally acknowledged that a well-organised campaign to inform the consumers would increase the commercial exploitation of these two species. Towards that direction, recently the Greek Ministry of Fisheries funded a project (4ALIEN; www.4alien.gr) that aims to gain knowledge on the spinefoots' biology, ecology and distribution, to explore ways of raising awareness and getting consumers to know and include them in their list of preferred fishes. In the southern coastline of Turkey, both of the species are the primary catches of the small-scale fishers and they are also highly preferred by locals. Annual festivals targeting spinefoots are being organised in collaboration with fishers, NGOs, local authorities, related stakeholders and the public to promote the fish not just for the locals, but for visitors as well. The price/kg of the species is increased annually, consequently increasing the incomes of the fishers. These kinds of festivals should be organised in the Eastern Mediterranean on a regular basis and should be coordinated with other countries.

3.1.3
GOATFISHES IN THE EASTERN MEDITERRANEAN

Scientific name(s): *Upeneus molluccensis*, *Parupeneus forsskali* and *Upeneus pori*
Common name(s): Goldband goatfish, Red Sea goatfish and Por's goatfish

IDENTIFICATION: *Upeneus molluccensis* is a small fish which can reach to 22.5 cm, but a typical size is around 18 cm (Bilge et al, 2014; Lee, 1974). It inhabits coastal habitats in large schools on sandy and muddy plains (Frimodt, 1995).

***Upeneus molluccensis* from New Caledonia (Photo: G. Mou Tham)**

Parupeneus forsskali is a larger fish reaching a total length of 28 cm (Burgess et al, 1990) and it is one of the most common goatfish in the Red Sea, patrolling the sandy areas between coral reefs (Kumaran and Randall, 1984).

***Parupeneus forsskali* from the Red Sea (Photo by Rich Stuart-Smith; (Photo: Rich Stuart-Smith)**

Upeneus pori is another Lessepsian goatfish which can reach up to 19 cm in size. Similar to other goatfish species described above, *U. pori* also prefers soft bottoms, such as sand and mud.

Upeneus pori **(Photo:J.E. Randall)**

INFORMATION: Native species of goatfishes such as *Mullus surmuletus* and *M. barbatus* have been among the most desired and sought out fish in the Mediterranean Sea (Pavlov and Emel, 2018). They are commercially important and the two species have been significant game fish in the past (Froese et al., 2022). However, since the mid-20th century, more than a few goatfish species have entered the basin via the Suez Canal to colonise parts of the Eastern Mediterranean. The goldband goatfish, *Upeneus molluccensis* has an Indo-West Pacific distribution from the Red Sea to New Caledonia and north to Japan in its native range (Uiblein and Heemstra, 2010). *Upeneus molluccensis,* was first reported from the Mediterranean from Palestine (Haas and Streinitz, 1947) and has colonised the eastern Mediterranean since. A more recent goatfish, which is commercialised even wider, is a relative, the Red Sea goatfish*, Parupeneus forsskali*, which also entered via the Suez Canal and established in the Eastern Mediterranean. The first confirmed record in the Mediterranean was from Beirut, although it has been spotted by visual sighting from southeastern Turkey (Bariche et al., 2013). *Parupeneus forsskali* has replaced the native goatfish in many locations and has been an important commercial fish in the eastern basin (Evagelopoulos et al., 2020). Por's goatfish, *Upeneus pori,* is another Lessepsian goatfish which has a Western Indian Ocean native distribution, reaching from the Red Sea to Oman, Madagascar and South Africa (Randall, 1995). Despite its first record dating back to 1989 (Ben-Tuvia and Golani, 1989), it is suggested that it has not been established as successful as *U. molluccensis* or *P. forsskali* (Deidun et al., 2018).

MANAGEMENT STRATEGY: *Upeneus molluccensis* is used commercially for human consumption, as fish meal and its roe are also valued (Frimodt, 1995). *P. forsskali* is also being consumed in great quantities, especially in the eastern parts of the Eastern Mediterranean, where it is abundant. However, these species are not very well known and consumed in the western parts of the Eastern Mediterranean. In response, many stakeholders, mainly fishers, have been creating new consumer markets for the goatfish species. The low market price of IAS was mentioned by respondents as a major driver of discards, and its limited targeting by fishers.

3.1.4
SAURIDA LESSEPSIANUS

Scientific name: ***Saurida lessepsianus***
Common name(s): Lizard fish

IDENTIFICATION: *Saurida lessepsianus* (Russell et al., 2015) is a ray-finned fish from the family Synodontidae, widely distributed in the Western Indian Ocean (Russell et al., 2015). It is a medium-sized fish, growing up to 28 cm, usually inhabiting depths up to 100 m but generally much shallower (20-30 m) waters. The species dominates certain types of ecosystems such as sand and mud flats.

INFORMATION: The lizard fish, *Saurida lessepsianus,* is a recent Lessepsian that entered via the Suez Canal. Its name derives from its resemblance to a lizard ("sauros" in Greek) (Romero, 2002). The spawning season of *S. lessepsianus* is prolonged and occurs nearly all year round, in the Gulf of Suez with two peaks in December and May (Amin et al., 2007). In the Mediterranean, the spawning season off the coast of Israel lasts from March to December (Golani, 1993), whereas at Iskenderun Bay, Turkey, spawning occurs mainly in two seasons: May-July and September-November (İşmen, 2003).

Saurida lessepsianus **from Red Sea, Egypt, Suez (Photo: S. Bogorodsky)**

MANAGEMENT STRATEGY: *S. lessepsianus* is reported to be important in the trawl fishery of the Gulf of Suez and the Mediterranean coast of Egypt, where it is in a state of high overfishing and severe overexploitation. In other parts of the Mediterranean, it was rather uncommon until 1955, when it started to appear in large quantities in bottom trawl catches (Ben and Glaser, 1974; Bilecenoğlu, 2010); catches have since remained high, with some fluctuations (Golani, 1993). It is also reported to be an economically important fish in the Mersin and Iskenderun Gulfs, Turkey, and is among the most common species caught in the trawl fishery, comprising almost one-third of the commercial trawl catch in the northeastern Levant (Gokce et al., 2007). There is potential for fishers to become part of the management solution to IAS. In instances where fishing effort can play a role in the management of IAS that are invasive, for example, a market-based management approach to increase demand for selected IAS is strongly recommended. Like the majority of IAS, the range expansions of goatfish species should be continuously monitored based on standardised protocols.

3.1.5 RANDALL'S THREADFIN BREAM, *NEMIPTERUS RANDALLI*

Scientific name: ***Nemipterus randalli***
Common name: Randall's threadfin bream

IDENTIFICATION: *Nemipterus randalli* is a small to medium-sized, silvery pink-bodied ray-finned fish from the Nemipteridae family with a native distribution in the West Indian Ocean. It has a total of 10 dorsal spines, 9 dorsal soft rays, 3 anal spines and 7 anal soft rays. Its pectoral and pelvic fins are very long, reaching to or just beyond the level of origin of the anal fin. The upper lobe of its caudal fin produces into a long, trailing, light red filament (Russell, 1990).

INFORMATION: The first record of a nemipterid species from the Mediterranean Sea was an unconfirmed report of *Nemipterus japonicus* as a Red Sea immigrant (Fischer and Whitehead, 1974). It was further described from a single individual of *N. japonicus* captured by a trawler at a depth of 55 m at the southern edge of Haifa Bay in Israel (Golani and Sonin, 2006). Closer examination of this specimen and description shows it to be a misidentification of *Nemipterus randalli*. This was confirmed by examination of the specimen in the Hebrew University Fish Collection, Jerusalem (HUJ 19280) and three others (HUJ 19423, HUJ 19450 and HUJ 19517) collected at a depth of 35–50 m off the coast of Israel between Ashdod and Tel Aviv. It was concluded that previous reports of *N. japonicus* from the Mediterranean Sea, including the unconfirmed record (Ben-Tuvia, 1973; Eggleston and Krebs, 1974), can be referred to as *N. randalli* (Lelli et al, 2008).

Nemipterus randalli specimen caught in Gokova Bay, Türkiye (Uyan et al., 2019)

MANAGEMENT STRATEGY: Some invasive fish species which are mistakenly assumed to be of economic importance compete with native species of commercial value to eventually affect them negatively (Gülşahin and Soykan, 2017; Grabowska et al., 2019). *N. randalli* is caught and sold as the native common pandora, *Pagellus erythrinus,* in southern coastal regions of Turkey (Yapıcı, 2017). 22% of total catch by Akyaka Fisheries Cooperative in Turkey, engaged in catching activity in Gökova Bay, has been reported as *N. randalli* (Uyan, 2017). Like the majority of IAS, the range expansions of *N. randalli* should be continuously monitored based on standardised protocols.

3.2 NON-EDIBLE AND OTHER IMPORTANT IAS

Not all IAS are eligible for consumption or have socio-economic value. For non-edible species, the main management goals are to monitor their status, control their populations and find alternative possibilities to integrate them into the local economy and national and regional action plans.

Key action points:

- Target the species rapidly to reduce the ecological and socio-economic impacts
- Set thresholds for environmental, economic and social impacts and assess the performance of management activities
- Monitor the species at selected locations with standardised methods
- Focus on legal actions and regulation
- Engage public interest with opportunities to increase awareness
- Implement education and training programmes
- Include the targeted species on the agenda for regional cooperation

Stypopodium schimperi **in a vermetid pool on the Lebanese coast (Photo: Ali Badreddine)**

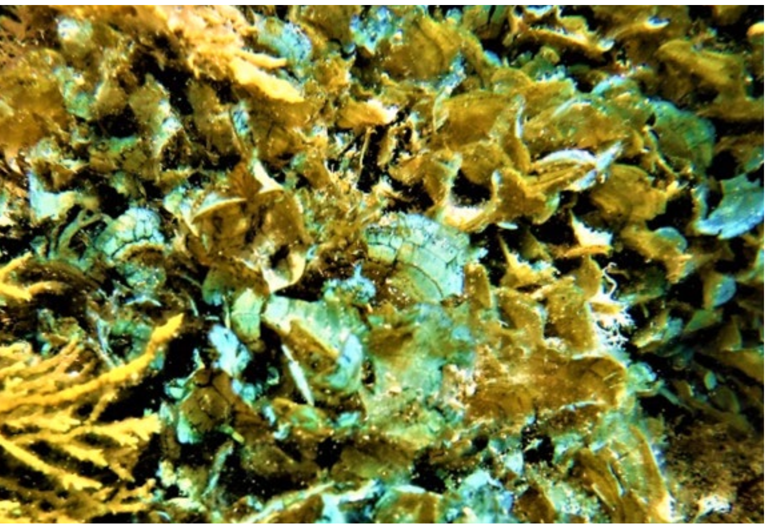
3.2.1 NON-INDIGENOUS MARINE MACROFLORA IN LEBANON WITH A SPECIAL FOCUS ON *STYPOPODIUM SCHIMPERI*

The marine flora along the Lebanese coast has been subjected to only a limited number of studies. In 1976, a list of the marine macroflora of the Lebanese coast was created (Basson et al., 1976). Subsequently, 190 taxa with six alien species of macrophyta, including cyanobacteria, were listed in 1976. The list has grown to 243 marine macrophyta, with 17 recently added IAS (Bitar et al., 2017). Since then, the number of marine macrophyta, including NIS especially with Indo Pacific origin, is still expanding along the Lebanese coast (Belous and Kanaan, 2015; Kanaan et al., 2015; Badreddine et al., 2018).

The marine macroflora present in Lebanon, consisting of a total of 29 species, are represented by three Ochrophyta (*Padina boergesenii, Spatoglossum variabile* and *Stypopodium schimperi*), 13 Rhodophyta, 12 Chlorophyta and one Streptobionta (Bitar et al., 2017; SPA/RAC-UNEP/MAP, 2021). Among them, 13 species represented by *Asparagopsis taxiformis, Caulerpa taxifolia* var. *distichophylla*, *Cladophora patentiramea*, *Codium arabicum*, *Codium parvulum*, *Galaxaura rugosa*, *Halophila stipulacea*, *Hypnea cornuta*, *Laurencia cf. chondrioides*, *Lophocladia lallemandii*, *Stypopodium schimperi*, *Ulva lactuca* and *Womersleyella se-*

tacea are potentially invasive species and several of them already occupy extensive stretches of the Lebanese coast. It should be emphasised that five IAS, represented by *Asparagopsis taxiformis*, *L. Lallemandii*, *S. schimperi*, *W. setacea* and *H. stipulacea* are listed on the International Union for Conservation of Nature's (IUCN) blacklist of invasive species (Otero et al., 2013).

Stypopodium schimperi is the most toxic macrophyte species among the IAS recorded on the Lebanese coast. In addition, *S. schimperi* is the second most invasive marine macrophyte to be identified in Lebanon, after *U. lactuca* (Bitar et al., 2017). *Stypopodium schimperi* is a species that lives in tropical and subtropical seas and can be observed annually. The species migrated from the Red Sea via the Suez Canal and arrived in the Mediterranean Sea. *Stypopodium schimperi* was first reported on the Syrian coast in 1979, as was *S. zonale* (Mayhoub, 1989, as *Stypopodium fuliginosum)*. Afterwards, the species invaded the Haifa Bay and the neighboring area (Lundberg, 1996, as *S. zonale*; Hoffman, 2014). Currently, *S. schimperi* appears to have adapted successfully to the Levantine environment, particularly the Lebanese shore. It has already invaded various coastlines, including Syria, Libya, Egypt, Greece and Turkey (Bitar et al., 2000, 2017). In Lebanon, *S. schimperi* was first found in May 1991 at Barbara and subsequently, in 1995, at Hannouch (misidentified as *S. zonale*). It has established itself throughout the whole Lebanese coast since 2000, from the sea surface to 45 m deep, displacing native benthic communities (RAC/SPA-UNEP/MAP, 2014; SPA/RAC-UN Environment/MAP, 2017, 2018a; SPA/RAC-UNEP/MAP, 2021).



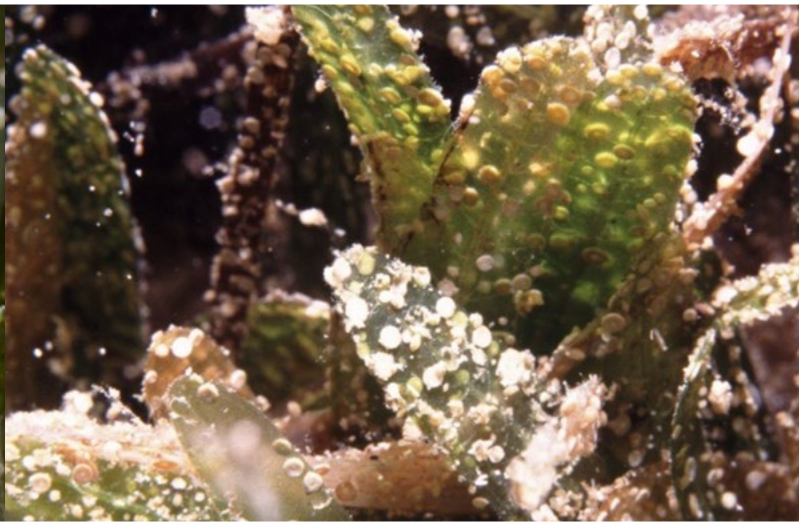
Close up of *Stypopodium shimperi* (Photo: Ali Bedreddine)

From an ecological point of view, *S. schimperi* has already invaded large areas in several communities, where it seasonally replaces local populations of *Halopteris scoparia*. The invasion begins with spots about 50 cm in diameter inside the native communities. From a morphological standpoint, *S. schimperi*'s tails are fan-shaped, similar to the indigenous peacock *P. pavonica*. Most individuals range in size from 5 to 15 cm, whereas large individuals measure up to 20 cm. When immersed in seawater, they are distinguised by their luminous, bright turquoise colour. Unlike *P. pavonica*, *S. schimperi* does not calcify. Its life cycle resembles that of other Dictyotales members.

Along the Lebanese coast, the growth season of *S. shimperi* extends from late February to September. The adult members appear between April and May. Large volumes of seaweed debris have been seen on the bottom and along the coast throughout June and July. Populations decline as of the end of August, and the algae become scarce. Finally, it almost vanishes in November (Bitar et al., 2000). *Stypopodium* is poisonous to many herbivores. A substance called stypodione may be manufactured from *Stypopodium*. The substance inhibits cell division in sea urchin embryos and marine mammals. Although the active mechanism is unclear, stypodione has medical and economic potential.

3.2.2. INVISIBLE STALKERS: FORAMINIFERAN INVASION

Foraminifera, which are mostly marine and benthic, are single-celled eukaryotic organisms living at all depths in all oceans. They are highly significant regarding biostratigraphy, paleobiogeography and paleoclimatology studies and their existence in rock formations gives clues to oil explorers by means of estimating the formation mechanisms and chronology of the rocks where the exploration takes place. They feed on algae and diatoms, and they have shells made of various materials and chemical structures, such as existing sand or silt particles, calcite, aragonite, organic compounds and even remains of other previous organisms such as protists and echinoids (Langer et al., 2012). Fossilised remains can be found within sediments dating back to the Cambrian era and up to 545 million years old. Currently, more than 50.000 species have been identified, about 80% of which are extinct. Their shells are usually around 1 mm in length and the first known mention of them can be found in Herodotus' writings (Weinmann et al., 2013).



Amphisorus hemprichii **and** ***Amphistegina lobifera*** **on** ***Halophila stipulacea*** **leaves in Bodrum, Türkiye. All three species are IAS. (Photos: Hasan Yokes)**

Whilst large-bodied species such as molluscs, crustaceans, echinoderms and particularly bony fish are easy to observe and publicly interesting, small-bodied taxa are generally understudied and omitted. Millimeter-sized foraminifera exist in very high abundance in the Mediterranean Sea. The alien foraminifer species which are widely distributed in the Eastern Mediterranean, such as *Spiroloculina antillarum*, *Coscinospira hemprichii*, *Peneroplis pertusus*, *P. planatus*, *Sorites orbiculus*, *Astacolus insolithus*, *Siphonina tubulosa*, *Amphistegina lessonii* and *Amphistegina lobifera* are generally accepted to have recently entered the Eastern Mediterranean via the Suez Canal. However, their presence in sediment samples aging back to the Middle Pleistocene-Late Pleistocene and Holocene, rules out the 149-year-old Suez Canal to be responsible for their introduction (Zenetos and Galanidi, 2020). An introduction via the connection occurring in the Gulf of Aqaba – Dead Sea Fault Line or Arabian Gulf – Mesopotamia Basin seems more probable. On the other hand, genetic evidence suggests that recent populations of *Amphistegina lobifera* from the Eastern Mediterranean and Gulf of Aqaba are genetically identical, proving that the recent Mediterranean population has been reintroduced via the Suez Canal. Thus, it is suggested that the population introduced via Gulf of Aqaba-Dead Sea Fault Line has vanished due to environmental changes that occurred in the past, but the invasion took place and was established once again after the opening of the Suez Canal. Therefore, the origins of the recent foraminifer species in the Eastern Mediterranean can be dated back to the Middle and Upper Pleistocene, or they may also be recent introductions. Their status can be enlightened by more specific research, mainly by genetic analysis (Zenetos et al., 2008).

Apparently, only one specific species, *Amphistegina lobifera,* causes severe ecological impacts and meets the criteria definition of an invasive alien. This species actively generates carbonate, and camouflages its way to the new ecosystem that results in decreasing the native habitat and diversity of local species. The proliferation and rates of recently observed range extensions, provide strong support for previous species distribution models, and corroborate findings that rising water temperatures, global climate change and the extension of climate belts are major drivers fuelling the latitudinal range expansion of larger symbiont-bearing and smaller epiphytic foraminifera (Stulpinaite et al., 2020). Likewise, in the entire Eastern Mediterranean coast, *A. lobifera* is the most abundant foraminifer species found in hard substrate, reaching abundances of almost 180 specimens/g in Israel (Hyams et al., 2002).

A close-up photograph of the beach sand from Rizokarpasso, Cyprus, comprised mainly of ***Amphistegina lobifera*** **tests. (Photo: Mehmet Baki Yokes)**

Octopus hiding under live *Amphisorus hemperlischii* mat. (Photo: Mehmet Baki Yokes)

Identification of a variety of 44 species and two cryptogenic taxa were revealed by a recent survey and re-evaluation of alien benthic foraminifera that is currently present in the Mediterranean Sea. This reduces the number of previous recordings of alien foraminifera and is mainly due to new occurrence records, new findings in the fossil records, erroneous identifications and evidence predating the presence of alien species prior to the opening of the Suez Canal. The revised list of acknowledged alien species consists of both larger symbiont-bearing and smaller benthic foraminifera, including 16 hyaline-perforate, 3 agglutinated and 25 porcelaneous taxa. The vast majority of alien foraminifera recorded so far have become established in the Eastern Mediterranean Sea, primarily along the Levantine coasts (Stulpinaite et al., 2020). *A. lobifera* is observed almost everywhere on the Aegean and Mediterranean coasts of Turkey, and even in the Sea of Marmara (Meric et al., 2004). It forms extensively dense populations along the coasts of Antalya, located in southwestern Turkey (Meric et al., 2002). The density of living individuals on the rocky substrate can reach up to 230,000-310,000 individuals/m^2. The high ratio of tests in the sediment (>350 specimens/g; 0.75g tests/g) results in large amounts of sand formation, changing all the habitat type and coastal structure (Yokes and Meric, 2004). *A. lobifera* populations of Kas, Turkey had been followed between 2002 and 2008. Scuba diving was the main method to examine the rich sediments, and core samples were taken from various sites and depths. Then, the core samples were sliced into 2 cm thick samples, 1 g of sediment was weighed from each slice and *A. lobifera* contents in each sample were counted. The first scouts of this alien species were found at the bottom of the core samples, represented with very few individuals. Unexpectedly, the size of this alien population had not shown much change for a certain period. However, at the 25th cm from the core surface, a rapid increase in population density was significantly observed. The cause of this abnormal population expansion remains unknown, but it indicates a certain triggering occurrence during that matching period.

In recent surveys in southwest Turkey, the deposition of the tests belonging to two foraminiferan species, *Amphisorus hemprichii* and *Amphistegina lobifera,* was found to be 2-4.5 cm/year. The local rocky sea bottom thickness is measured around 60-80 cm. Such population density is not observed elsewhere in the Mediterranean. Even though this situation is considered to be beneficial for the sand-dwelling native species, the original native habitat structure in this specific area is rocky. Waves carry foraminifera tests to the shores where they accumulate in small bays, consequently changing gravel shores to sandy beaches. This extensive deposition of tests is creating an immense ecological problem by changing the whole habitat structure, while ultimately altering the species composition of the coastal ecosystem in the long run (Titelboim et al., 2019). The high sea water temperatures observed in this region may suggest that *A. lobifera* prefers high water temperatures, which may limit its distribution in the Mediterranean. In another study, the occurrences of living amphisteginids are delimited by the 14°C winter isotherms. According to the laboratory experiments, it is observed that *A. lobifera* cannot perform any activity in temperatures below 12°C (Zmiri et al., 1974). However, its presence in the northern Aegean Sea and in the eastern Sea of Marmara shows that this species can adapt to much lower temperatures, and thus may be dispersed to western Mediterranean in time. Records from Malta support the idea that its invasion in the Mediterranean has not yet finished (Yokes et al., 2007).

Furthermore, there is an obvious ongoing process of destruction of the coastal ecosystem along the southwestern coasts of Turkey, where the damage is directly caused by the increased population of the Erythraen foraminifer *A. lobifera*. It has been known that some of the alien species demonstrated unusual population explosions in a very short amount of time, soon after they were first recorded in the Mediterranean in 2004 (Meric et al., 2004). The analysis of the core samples showed that the *A. lobifera* population has been stable for a certain amount of time, before a rapid expansion occurred. A change in environmental conditions, such as nutrients, temperature or the chemical composition of sea water, could be the reason of this proliferation. Further analysis of the experiments for age determination and mineral composition will reveal the reasons of this unique case and discover the environmental history of the research area as well as the fate of the native biota.

In summary, although foraminiferans can be regarded as harmless sand particles, their extensive increase in abundance demonstrates a change in habitat types, altering the flow of ecosystem dynamics in the Eastern Mediterranean. Rocky ecosystems are being converted into sandy ecosystems by means of the overpopulation of the dead (and live) tests of these small animals. Existence of such amounts of sand might also create grounds for the angiospermic plant *Posidonia oceanica* roots to help attach rocks (Badalamenti et al., 2015), consequently supporting *Posidonia* distributions to increase on originally rocky areas. Supralittoral regions are similar to this, where the gravel and pebble beaches are converted into whitish sand beaches. Another problem on the estimation of the changes in foraminiferan abundance is the scarcity of studies on foraminiferan composition prior to the Suez Canal's opening. As a result, the scientific community might sometimes be unable to determine whether a species is alien or native. Some opinions suggest that foraminifera should even be removed from alien species lists.

A remote sandy beach in Rizokarpaso, Cyprus. Core samples show that the original bed rock and clay floor starts after an up to 80 cm thick layer of foraminifera tests. (Photo: Mehmet Baki Yokes)

P. lineatus in its natural range in Lembeh, Indonesia (Photo: Hasan Yokes)

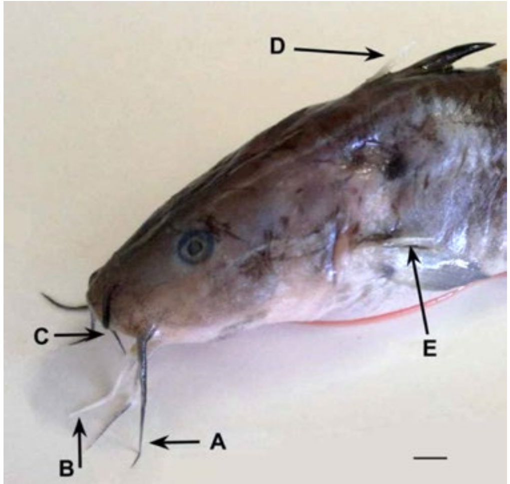
3.2.3.
STRIPED EEL CATFISH, *PLOTOSUS LINEATUS* IN THE EASTERN MEDITERRANEAN

The eel catfish family Plotosidae consists of 41 species, half of which inhabit freshwater habitats. *Plotosus lineatus* (Thunberg, 1787) is the only marine Plotosid Lessepsian species that has been considered to arrive to the Mediterranean via the Suez Canal. It is a small to medium-sized, scaleless demersal fish with an elongated body that is compressed posteriorly. When it comes to physical characteristics, it has a brown body with two slender white stripes that start at the snout and cross above and below the eyes. Additionally, the ventral surface is white with brownish red. Moreover, it has a serpentine body and a tapering tail. This species is distinguished from all other Mediterranean species by the four pairs of barbells surrounding its mouth (Randall, 1995; Golani, 2002; Golani et al., 2013).In its natural range, *P. lineatus* is a benthic inshore fish that lives on soft bottoms, rocky reefs and coral reefs. It may be found on open shores and in tidal pools. In its juvenile stages, it gathers in dense groups of approximately 100 individuals that form a shape of a ball, while the adult fish generally live in solitude or in small groups. The behaviour of juveniles gathering in densely packed schools can be assumed as mimicking large animals. Individuals usually reach up to 25 cm in length and can grow to a maximum length of 32 cm. Furthermore, *P. lineatus* feeds on crustaceans and to a lesser extent on molluscs, worms and small fishes.

Plotosus lineatus captured from Eastern Mediterranean off the Syrian coast (Ali et al., 2015)

Plotosus lineatus is an extremely venomous species that can cause injuries including swelling, severe pain, low blood pressure, heart failures that may lead to paralysis and even more serious injuries that can be fatal. Stings from *Plotosus lineatus* may result in death (Nelson et al., 2016), however, no deaths were officially recorded to date in the Levant (Doğdu et al., 2016, Ali, personal communication). The poison is injected from the venom glands to the body by the spines located in front of the first dorsal fin and the pectoral fins. Several cases of injury were recorded in Syria, which resulted in need of immediate medical treatment. It is essential to emphasise to proceed with caution when dealing with individuals of *P. lineatus*, even after the death of the fish. *Plotosus* is widely distributed in the Indo-Pacific, generally found in shallow coastal areas, moving towards estuaries, including brackish and freshwater areas in Japan, Samoa and east Africa (Golani et al., 2013). The species was previously investigated in the Red Sea (Goren and Dor, 1994), then recorded in the Great Bitter Lake (Chabanaud, 1932). As being the only representative of Plotosidae in the Red Sea, it finally entered through the Suez Canal into the Mediterranean Sea, where it was first recorded in Israel (Golani, 2002). The second well-documented record was taken in 2013 off the Egyptian coast of El-Arish (Temraz and Ben Souissi, 2013), while several specimens were captured in 2014 off the Syrian shore (Ali et al., 2015). The species migrated towards northern coastal areas and in 2016 the species was observed in Iskenderun Bay, located in eastern Turkey (Doğdu et al., 2016), as well as towards western areas, the Tunisian coast being its westernmost extension range in the Mediterranean Sea. Recently, in April 2022, a fisher cought 17 specimens of *P. lineatus* in Cyprus (Tiralongo et al., 2022). This catch suggests that *Plotosus* expansion is extending in all areas of the Levantine Sea.

Plotosus lineatus was initially discovered on the Syrian shore in 2014, and was documented in 2015. Based on a decade of routine monitoring in Syrian waters, four specimens were captured off the Syrian coast in May 2017. Similar records reported from Lebanon and Israel indicate that the species is now successfully established along the coastlines of the Eastern Mediterranean. This is also consistent with reports from fishers and divers (from the Syrian coast) who have locally seen and located schools of this species (Azzurro and Bariche, 2017). According to local news, Syrian fishers captured 20 specimens of *Plotosus lineatus* on 7 July 2017 in a single bottom cage in the city of Lattakia by 35°36'N and 35°45'E. The establishment of a viable population confirms a realistic possibility, since this model demonstrates that the species has found acceptable environmental circumstances to reproduce in Syria (Ali et al., 2017).



***Plotosus Lineatus*: Head of specimen captured from Syrian coast, showing maxillary barbell (A), mental barbel (B), nasal barbel (C), first dorsal fi spine (D) and pectoral fin spine (E). Scale bar = 10 mm. (Ali et al., 2015)**

Unfortunately, the species is locally not preferred for human consumption and has low commercial value, which results in specimens often discarded at sea when caught by fishers. The species is an insatiable medium-sized predator that feeds on crustaceans, molluscs and fish (Doğdu et al., 2016), which can cause pressure of competition for food along with local species using similar niches and ontogenetic alterations (Ali et al., 2015). Consequently, local biodiversity could be under threat by *P. lineatus*. The reason why *P. lineatus* is listed as one of the top 100 invasive species in the Mediterranean could be explained by these unfavourable patterns (Streftaris and Zenetos, 2006). *P. lineatus* should be monitored on a regular basis to act on its adverse effects on the local environment and economy in order to avoid a severe invasion in the Eastern Mediterranean (Ruttenberg et al., 2012; Azzurro and Bariche, 2017).

3.2.4.
NON-INDIGENOUS MOLLUSCS IN THE EASTERN MEDITERRANEAN: CHALLENGES AND OPPORTUNITIES FOR THEIR DETECTION

Molluscs were among the earliest invaders detected after the opening of the Suez Canal. This might be because they were indeed among the first to cross the canal and settle in the Mediterranean, or they enjoyed higher detectability due to size of many species and their attractiveness. Additionally, the durability of their shells – that make them discoverable even after the mollusc dies – facilitates collection and reporting. Still, when exactly a species successfully entered the Mediterranean will probably never really be known. It is acknowledged that some characteristics of molluscs make them particularly useful targets for studying biological invasions.

First, the very early detection of the mussel *Brachidontes pharaonis* in 1876 or of the pearl oyster *Pinctada radiata* in 1878, less than ten years after the canal was opened in 1869, suggests that some molluscs were indeed the first to successfully make their way into the Mediterranean (Zenetos et al., 2010, 2012; Galil, 2012). This is not trivial as the length of the canal, slightly less than 200 km, the limited means of dispersion of molluscs (mostly their larvae) and the former high salinity of the Bitter Lakes could have been an unsurmountable barrier for many organisms. Second, shells have fascinated humankind since immemorial times. Many early naturalists routinely brought shells back from their exotic voyages and enabled malacologists to witness the biotic enrichment that was happening in the Levantine Sea. Large size and beauty without a doubt facilitated their prompt reporting. Last, and in contrast to many other marine organisms, shells persist long after the mollusc dies. Additionally, the shapes and colours of shells are so informative that in most cases they enable unambiguous species identification. In contrast, many invertebrates like polychaete worms, jellyfish and sponges have either no skeletal parts that survive their death, or they are too inconspicuous to be easily identified by a general naturalist. Even vertebrates like fishes leave bones, teeth and otoliths that require an expert for identification, but for molluscs a good field guide and a keen eye for comparing specimens with illustrations may suffice.

Consciousness of these very same three features is now helping scientists to improve knowledge on how the Mediterranean is being occupied with tropical species. Despite molluscs being among the first to enter the basin, they are certainly still coming in and at a high pace (Zenetos et al., 2022). The enlargement of the canal, which increases hydraulic and thus biological connectivity, climate warming, which enhances survival of tropical species in the Mediterranean and increasing marine traffic, on which species many often hitchhike, have caused a large increase in the number of species that have successfully entered the Mediterranean. Whereas some species are large, the largest share of biodiversity is small-sized. That is, many very small molluscs, some even as small as a grain of sand, quietly entered (and still enter) the Mediterranean but were likely discovered late because of escaped detection. Indeed, surveying the small-sized fauna requires an enormous time effort and a lot of expertise for identification, both in great shortage by scientists nowadays. An additional challenge is that the smaller the species, the more limited the available information for identification is. Most of the natural history knowledge is on European and North American seas. In contrast, the biodiversity of the tropical and subtropical oceans is still very poorly known, and even more so if the organisms are small and inconspicuous. Whereas great effort is being devoted to fill this knowledge gap, still it often happens that detected alien species cannot be properly identified or that, ironically, species new to science are first described from their invaded than from their native range.

Last of all, mollusc shells certainly are facilitating scientists' detection work. Whereas a living mollusc, like many other invertebrates, may live for a period of months up to a few years, their shells persist on the ocean floor for decades, centuries if not millennia. This durability also implies that shells accumulate in surficial sediments. Therefore, mollusc shells enable overcoming the idiosyncrasies of living populations (some even have boom-and-bust dynamics so that they can be over-abundant one year but totally disappear the following one) and their greater abundance in comparison to living molluscs enhances detection chances (Albano et al.,

Shells of the mussel *Brachidontes pharaonis*, one of the first IAS introduced through the Suez Canal, litter a beach in Dor, Israel. (Photo: Paolo Albano)

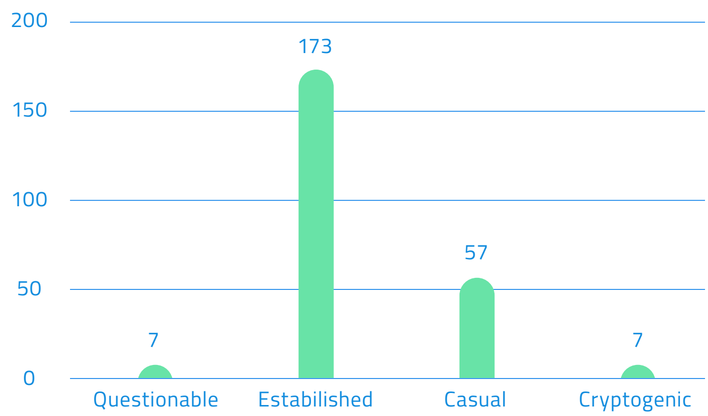


FIGURE 4. Invasion status of 244 non-indigenous molluscs that occur in the Mediterranean Sea. (Zenetos et al., 2022)

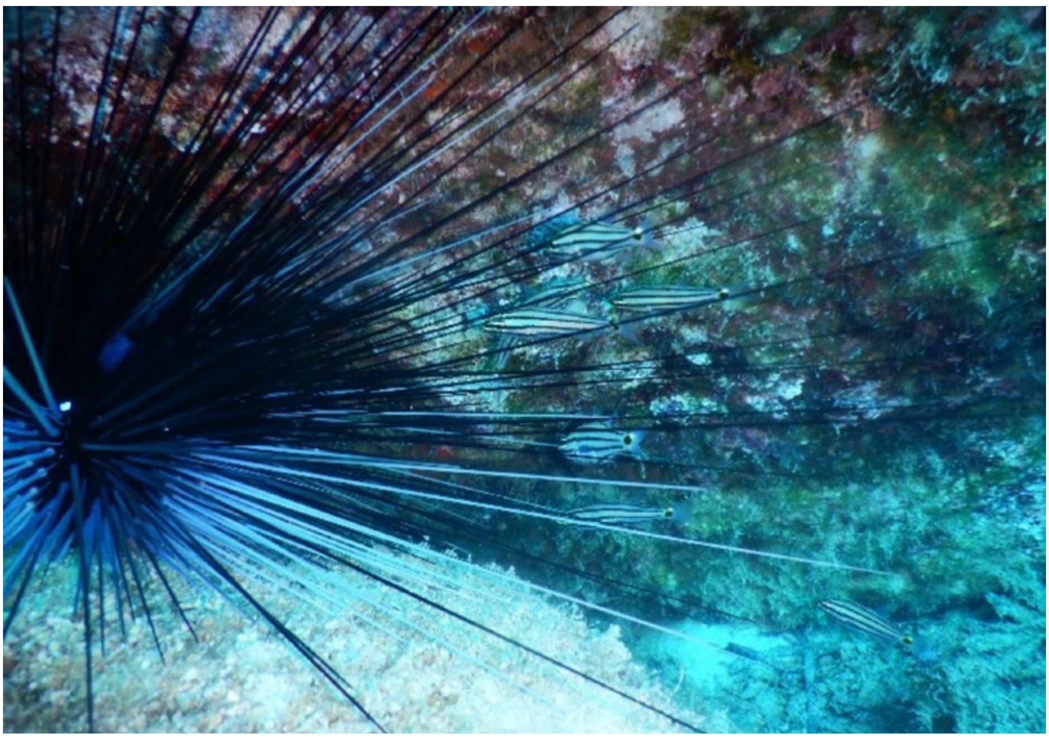
2021). These crafts of nature provide one of the best groups to inspect and predict the invasion of non-indigenous species in the Mediterranean Sea. As of December 2021, 244 non-indigenous molluscs are present in the Mediterranean Sea. Most of them (71%) are established, meaning that their populations are self-sustaining. Some of them (23%) are casual, meaning that it is still unknown if the reported organisms were members of a self-sustaining populations (Figure 4). Seven are questionable, that is their non-indigenous status still requires investigation, whereas seven more are cryptogenic, meaning their exact status as native or alien is not yet known.

3.2.5. NEEDLES IN A NEEDLESTACK: *DIADEMA SETOSUM*

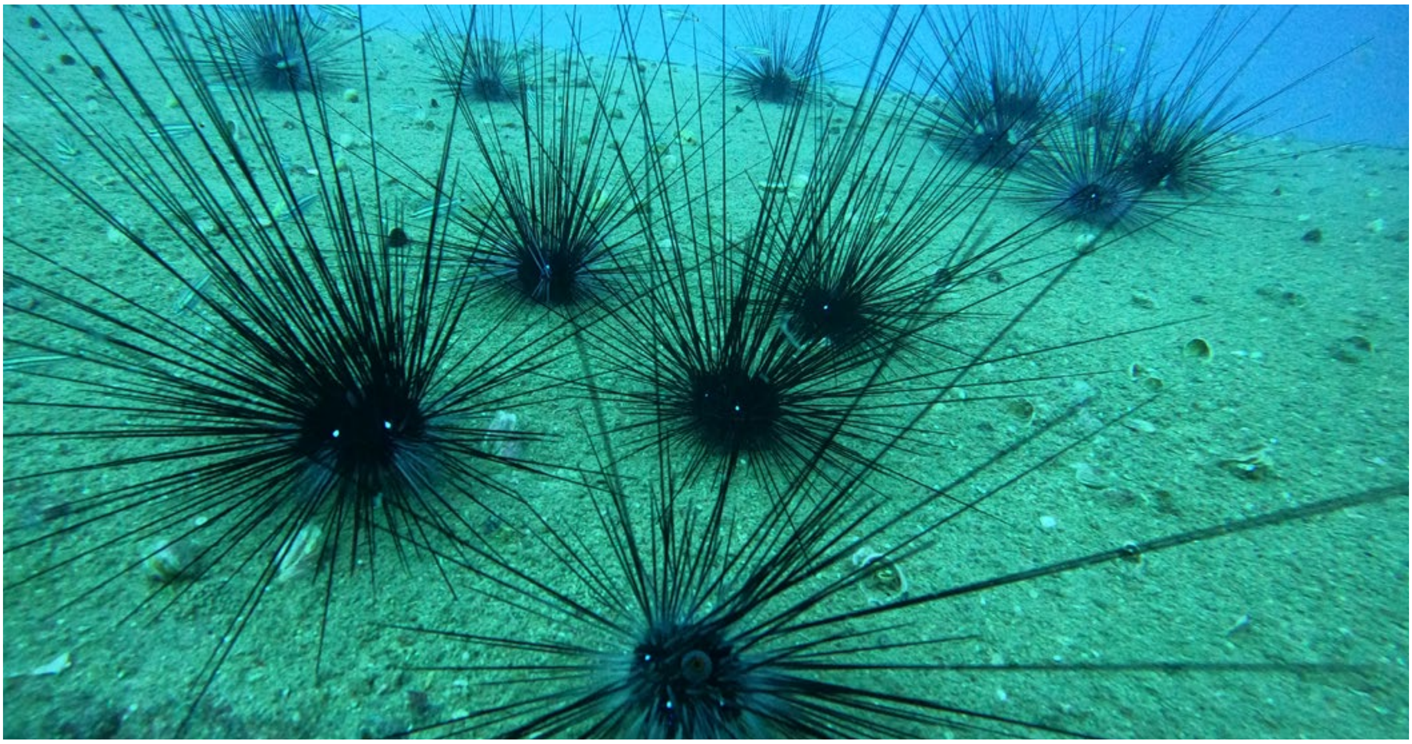
Diadema is an important genus containing nine tropical sea urchin species which are commonly seen and ecologically important. They prefer rocky habitats and reefs where they can hide under crevices and ledges (Muthiga and McClanahan, 2020). They are occasionally seen in large clusters in reefs and rocks. They are found at up to 50 m depth and they also provide shelter, previously unavailable, to native or alien species and their offspring.

The first record of *D. setosum* in the Mediterranean was in 2006 off the Kaş Peninsula in Turkey (Yokes and Galil, 2006). It is currently among the most frequently observed IAS in the basin and has invaded the Eastern Mediterranean basin since it was first recorded (Yokes and Galil, 2006). Up to this day, various records came from Lebanon in 2009, Turkey and Greece in the Aegean Sea in 2014, Cyprus in 2016, Israel in 2017, and finally, Libya and Egypt in 2022.

The diet of *D. setosum* in the Mediterranean has not been studied yet, but due to the high pressure it exerts on benthic communities, it has the potential to biologically erode the ecologically important rocky reefs in areas where they are concentrated, by turning them into barren areas. It is observed that these behaviors are severely harmful for the reproduction and development of some species. It is indisputable that an abundance of great density in certain areas



Twospot cardinal fish *Cheilodipterus novemstriatus* from the Indo-Pacific, among the spines of *Diadema setosum* in Cyprus. (Photo: Mehmet Fatih Huseyinoglu)



Diadema setosum **forms large clusters acting as microhabitats for adult fish such as** ***Chromis chromis*** **to find protection against predators. (Photo: Mehmet Fatih Huseyinoglu)**

would have a significant effect on the food chain in the ecosystem. Even though there is no scientific study on its diet in the Mediterranean yet, it is known as an alga scraping omnivore in its native range. At some localities in the Mediterranean, *D. setosum* has also been observed to be found nibbling on dead fish and carcasses.

The complex three-dimensional structure of sea urchin spines provides excellent shelter for juvenile fish and increases their survival rate. There may be many reasons for such associations, but factors such as the physical protection provided by sea urchins' spines must be a highly important factor for the host species (Coppard and Campbell, 2004). In the Mediterranean, three native sea urchin species (*Arbacia lixula, Paracentrotus lividus* and *Sphaerechinus granularis)* and six cryptobenthic fish species (*Apletodon incognitus, Lepadogaster candolii, Gobius bucchichi, Millerigobius macrocephalus, Zebrus zebrus and Tripterygion delaisi*) have been associated (Karplus, 2014; Giglio et al., 2018). Due to the discovery of *D. setosum* species in the Mediterranean in 2006, a different association between the host and urchin was reported for the first time in 2018 (Bilecenoğlu et al., 2019). During this study, the most common fish identified among *D. setosum* spines were *Chromis chromis, Thalassoma pavo* and the nine-striped cardinal fish with the Red Sea origin, *Cheilodipterus novemstriatus*. In addition, *Tripterygion melanurum, Gobius vittatus, Gobius bucchichi* and *Scorpaena maderensis* were also reported as associating species. It was concluded that *D. setosum* allows the host species to use its own defence mechanisms and provides shelter for the related fish species through its long and poisonous spines (Bilecenoğlu et al., 2019). It is certain that this finding has ecological consequences as small-sized fish, which are not normally under such protection, have absolutely increased in population due to the density of *D. setosum*.

D. setosum is mildly to moderately toxic and should be handled with extreme caution. Its venom is injected when the spines enter the body, causing symptoms such as pain and swelling. Moreover, its spines are immensely difficult to remove, as they are easily broken and then disintegrated in the flesh.

At the moment, no generally valid control program available for sea urchins exists. Regular monitoring on the population status and range expansion based on standardised protocols and also removal of the species at designated locations are being implemented at certain locations in the Eastern Mediterranean countries. These monitoring and removal protocols can be replicated to other regions in the Eastern Mediterranean. Sea urchins are a high-protein food source in many nations, as well as a potential source of biologically active compounds that could be employed in medicine (Rahman et al., 2014). Furthermore, sea urchins' reproductive organs have been a culinary delicacy in many parts of the world since ancient times. Sea urchins are considered a valuable delicacy in Asian and Western Hemisphere countries, and have long been a luxury dish, especially in Japan, where they are known as "uni." In addition to "sushi" being a worldwide known cuisine, using this kind of flavour more intensely in the Mediterranean culinary culture may also contribute to the control of invasive species.

3.2.6. PUFFERFISH *LAGOCEPHALUS SCELERATUS* AND EASTERN MEDITERRANEAN FISHERIES

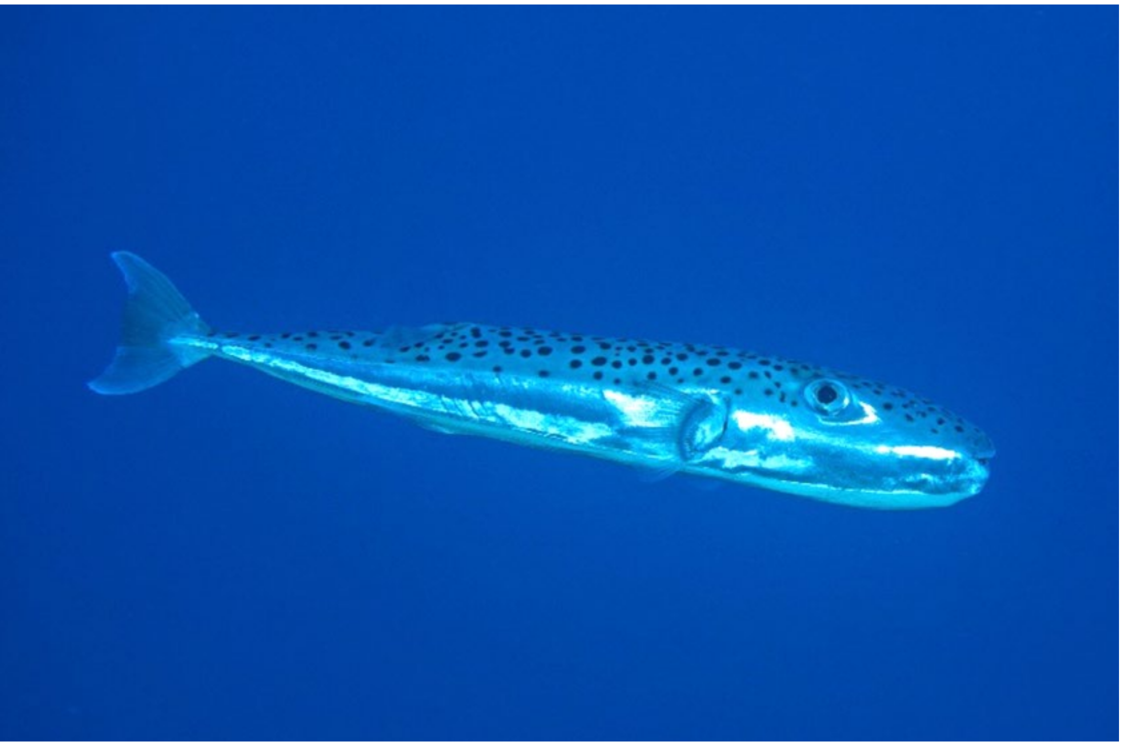
Lagocephalus sceleratus is a ray-finned fish from the Tetradontidae family, inhabiting offshore reefs and sandy bottoms, and caught in great numbers with trammel nets in the eastern Mediterranean. It has a total of 10-13 dorsal soft rays and 8-12 anal soft rays. It is greenish with brown or black spots above, and it has a silver band from mouth to caudal fin. Its belly is white and there is a silver blotch in front of its eye. Its flesh and organs contain tetrodotoxin, which can be fatal on consumption (Masuda et al., 1984).

The invasion of the Mediterranean Sea by this species during the last two decades has been the cause of widespread concern over fisheries sustainability, human health, and environmental impacts (Ulman et al., 2021). This has prompted great research interest, primarily in the areas of fisheries, ecology, toxicology and food science. Accordingly, the species is far better studied in the Mediterranean region than in its native range across the Pacific and Indian Oceans (Figure 5), with most publications from authors in Turkey and Greece. It is likely that the interest in the species has been because of the major economic and ecological impacts, driving a movement to find solutions to the problems surrounding the species colonisation, and a response to this through research.

In 2003, *L. sceleratus* was first reported in the Aegean Sea in Turkey (Akyol et al., 2005). Fishers in Cyprus estimate that they started to see *L. sceleratus* between 2005 and 2008 and by 2010 it was well established and already causing significant economic impacts to fisheries (Snape, 2010). By 2016, it was established in the Ionian Sea, Central Mediterranean and in 2017, it was recorded in the Strait of Gibraltar (Azzurro et al., 2020). Today the only regions where it has not been recorded are the northern most areas of the western basin off France and northern Italy, yet it is also present in the northern Black Sea (Ulman et al., 2021). It is likely that it will eventually colonise the entire basin and may spill over into the Atlantic Ocean (Schickele et al., 2021).

The most thorough and current review of the *L. sceleratus* biology and ecology in the Eastern Mediterranean where it is best established, was published recently (Ulman et al., 2021). The study paints a grim picture for the Mediterranean, both in terms of the impact of this species, and its extreme robustness as a population. *L. sceleratus* is one of the largest and most abundant invasive predatory fish in the Mediterranean obtaining a maximum weight of 7 kg or perhaps more, and is a generalist predator feeding on crustaceans, fish and cephalopods (Ulman et al., 2021). It can tolerate a range of temperatures, a great range of salinities and can proliferate in a wide range of Mediterranean habitat types.

FIGURE 5. Map of the global range of *Lagocephalus sceleratus*. Note that the species is now reported as far as the westernmost extent of the Mediterranean. (IUCN Red List of Threatened Species™, accessed 22 March 2022).



Lagocephalus sceleratus
in Bodrum, Türkiye
(Photo: Hasan Yokes)

Their high toxicity and ability to enlarge their bodies through puffing up makes them unattractive prey to Mediterranean predators. After undesirable experience or death, surviving predators quickly learn not to target the species. Only the loggerhead turtle (*Caretta caretta*) and the Mediterranean monk seal (*Monachus monachus*) (personal communication of Robin Snape to Ali Cemal Gucu in Karamanlidis and Dendrinos, 2015) are known to have preyed upon adult *L. sceleratus*, while two predatory fish species have been found to prey on juveniles (Ulman et al., 2021). The fact that most of the potential predator populations, such as sharks, cetaceans, sea turtles, large predatory fish and seals have decreased, probably facilitated the expansion of the species. Tetrodotoxin TTX is a potent neurotoxin where the name derives from Tetraodontiformes, an order that includes pufferfish. TTX concentrations are relatively high in practically all the edible tissues, and are above the lethal human dose (Ulman et al., 2021), totally precluding exploitation of *L. sceleratus* as a food commodity even as “fugu”, the Japanese pufferfish-based delicacy.

In Cyprus, *L. sceleratus* associated income losses are through government-led schemes, returning dried tails for a set subsidy. But despite their continued extraction, *L. sceleratus* still make up a large proportion of the landings. Almost ten years into the establishment of the governmental pay-per-tail scheme, a study in preparation observed 88 sets of trammel nets in Famagusta Bay, Cyprus, and *L. sceleratus* still dominated the total landings, representing 30% of the catch, 6% more than the target catch. Fishers have stated that the governmental payment scheme in the Turkish Cypriot community has not always had the budget to cope with the number of pufferfish tails returned. Given that this ongoing commercial eradication of pufferfish does not seem to be controlling their numbers effectively, collection and eradication schemes established by local associations and conservation groups to limit the impact of *L. sceleratus*, will have a negligible impact.

The species has huge negative impacts on fishers’ livelihoods even with payment schemes, mostly affecting small-scale fisheries communities using set nets and demersal longlines close to shore, which are already suffering economically through lack of management, underinvestment and the impacts of continued overfishing (Snape et al., 2018; Ulman et al., 2021). Fish caught in set nets, especially trammel nets, which are the mainstay of Mediterranean small-scale fisheries, are damaged due to *L. sceleratus* depredating caught fish and cutting through sections of net with their extremely strong teeth. In 2015 and 2016, along the southern Aegean and Mediterranean coast of Turkey, the estimated losses per fisher were US$ 370 to pufferfish related gear damage and US$ 353 to related catch loss (Ünal et al., 2015; Ünal and Bodur, 2017; Öndes et al., 2018).

According to the socio-economic research conducted in Turkey, the first study on pufferfish, especially on *L. sceleratus*, was carried out with 261 fishers in İzmir (Central Aegean Region) and Hatay (Eastern Mediterranean Region) between 2011 and 2012 (Ünal et al., 2015). Approximately 90% of Turkish fishers reported that pufferfish is a major problem, due to its negative impact on biodiversity and on lowering the catch per unit effort. Long-line, setline and gillnet fishers participated in the survey and the fishers' financial loss due to losing hooks and the extra labour time they spend to change the hooks is at a significant level, considering their annual income (Ünal and Bodur, 2017). According to the fishers' reports, the average annual loss caused by *L. sceleratus* is approximately €100 per fisher. The number of by-catch pufferfish on the Levantine coast is higher compared to the ones on the Aegean coast. Moreover, in the latter, the most bycatch was found in purse seiners and trawlers, whereas in the former, it was found in gillnets. It is stated by most of the small-scale fishers that pufferfish on the southern coast cause damage to their fishing gear and that these species also damage the target prey they catch (Öndes et al., 2018). Of the 506 fishers who participated in the research, all confirmed the financial and labour costs due to the issues related to pufferfish during the research conducted between the period 2016 and 2019. Decreased numbers of native species may cause invasive species to fill niches, which over time may cause the ecosystem to face irreversible impacts. There is a strong need to develop and implement a sustainable fisheries management model for this species of pufferfish, particularly in terms of the damage they cause to small-scale fisheries as a result of their spread over time (Öndes et al., 2018).

Besides the economic damage to fishers, despite the ongoing awareness efforts, dozens of deaths in the Mediterranean have been reported because of the TTX poisoning resulting from the consumption of the species (Ulman et al., 2021). In addition, incidents have been recorded of the species biting the fingers of bathers, resulting in the loss of digits in Turkey (Sümen and Bilecenoglu, 2019). Also, a school of large (60-90 cm) pufferfish were seen in Cyprus gathering around in less than 40 cm of water, causing panic and concern (Robin Snape, personal observation).

Lagocephalus sceleratus is in the family Tetradontidae which are considered to be a delicacy known as “fugu” in certain Asian countries. Only specially trained chefs can prepare this dish. In Eastern Mediterranean countries, currently consumption of this species is being approached with high precaution, but it should be discouraged completely given the toxicity. There are small initiatives of making handcrafted products such as wallets and purses from the skin of this species in some countries.

Lagocephalus sceleratus **dominated landings of a small-scale fishing vessel in Famagusta Bay. (Photo: Barbaros Öz)**

Diadema setosum can be found even at the sea surface in Gokova, Türkiye. (Photo: Murat Bilecenoglu)

4

Legislations and action plans for the management of invasive species in eastern Mediterranean countries

A current inventory of alien species in the Mediterranean, in addition to its scientific value, can meet the needs of legislative requirements and environmental management alternatives. This is especially important given the current emergence of a new generation of European Union (EU) political actions covering major maritime strategic objectives, such as the Marine Strategy Framework Directive (MSFD) (2008/56/EC), the European Strategy for Marine and Maritime Research (COM 2008(534)) encompassing the Marine Spatial Planning and the Ecosystem Approach (ECAP) within the Barcelona Convention by UNEP/MAP, and many initiatives of the UNEP RAC/SPA. Regulations governing alien species play a critical role in these policies (Zenetos et al., 2010).

This spatial and institutional environment necessitates the establishment of a multi-level governance system with a multifaceted coordination mechanism in which non-EU Member States can also participate. This is especially crucial in the Mediterranean, where the southern and eastern coasts are occupied by nations who are not EU members or have admission status. Furthermore, despite the fact that just seven of the 21 Mediterranean nations are UNEP/MAP Member States, the Barcelona Convention of the UNEP/MAP encourages the introduction of MSFD (2009) concepts that can be useful throughout the basin (Zenetos et al., 2010).

The new EU legislation concerning IAS is a ground-breaking and commendable attempt to set a common standard for combating IAS across political jurisdictions at a multinational scale. However, the regulation, underpinned by a list of IAS of EU concern, affords Member States a degree of operational flexibility and its successful implementation will be dictated by appropriate national enforcement and resource use. In evaluating this EU legislation, pragmatic recommendations are provided based upon a geo-political analysis of the pan-European capabilities to combat IAS and discuss measures to avoid the risk that the regulation will promote a piecemeal response by stakeholders instead of a truly collaborative effort. A major deficit in the funding mechanisms to support a comprehensive implementation of the legislation and emphasise the importance of consultation with the broader scientific community, including with key stakeholders, businesses and the general public are highlighted. The recommendations will create incentives for industries, raise awareness among citizens and stakeholders and help establish a social norm for the EU and further afield. The legislation offers a collaborative Europe the chance to demonstrate its commitment to tackling the problems of IAS and to achieve a successful conservation breakthrough of international importance.

The legislation (EU Regulation no.1143/2014) entered into force in January 2015 and is commendably underpinned by a consensus amongst scientists and policy-makers that prevention is the most important action. It introduces some novel elements including the promotion of early-warning and surveillance systems (Articles 16 and 22), the development of action plans to address priority pathways (Article 13), rapid eradications to prevent establishment and long-term mitigation and control mechanisms (Article 17). A list of the IAS to be covered by this legislation (hereafter referred to as the “Union list”) was completed in January 2016 and updated in August 2022. To facilitate these ambitious objectives of the regulations, the European Commission (EC) will be assisted by a committee composed of representatives of each Mediterranean state. An independent Scientific Forum, representing members of the scientific community appointed by each Member State, will advise this decision-making committee and provide scientific input relating to the application of the legislation, decisions concerning amendments to the Union list, risk assessments, emergency measures and rapid response eradications (Articles 27 and 28).

4.1 CYPRUS

As a part of the EU, Cyprus follows the general regulations and legislations of the EU despite the fact that a specific action plan does not exist. In the EU environment, approximately 12,000 species (terrestrial and marine) are identified as alien, of which 10-15% are estimated to be invasive. It has been estimated that at least €12 billion a year is spent to control these species and the damage they cause in Europe. Recognising the seriousness of the problem, the EU adopted Regulation 1143/2014 on the prevention and management of the introduction and spread of IAS (EU, 2014). This Regulation entered into force on 1 January 2015 and laid down rules for the prevention, minimisation and mitigation of adverse effects from the introduction and spread, whether voluntary or involuntary, of IAS on biodiversity in the EU.

Two years later, and by regulation 1141/2016 (EU, 2016) the first list of Union concern IAS was compiled. Through the Regulation, an initial list of 37 non-marine invasive alien species of Union concern has been issued, based on specific criteria and risk assessment, which was revised and updated by adding new species with negative impacts on biodiversity in the European Union. The following regulations 1263/2017 (EU, 2017) and 1262/2019 (EU, 2019), increased the list of Union concern IAS to 66 and for the first time in 2019 a marine species was included; the lessepsian fish *Plotosus lineatus,* striped eel catfish. The latter is a species also included in the list of the General Fisheries Commission for the Mediterranean (GFCM), along with six other fish species as of priority for monitoring. Within 2022, a further amendment of the Union concern IAS species is expected, with proposed marine species to be included. The species on the EU list are subject to prohibitions, restrictions and regulations aimed at the prevention, early detection, treatment and management of invasive alien species in the EU.

Serious measures must therefore be taken to control the import and establishment of these species and to deal with those who have already entered. All this of course involves informing the public about the dangers posed by illegal imports, possession and release of exotic species to the local environment and the creation of a database containing information of the types and geographical distribution and dispersion, as well as periodic inspections of premises in which alien species are likely found, such as nurseries, florists, aquariums, fish-farming units, laboratories, zoos and more.

4.2 GREECE

As an EU member state, Greece is obliged to implement the Regulation, but there was a delay in the process, which just started in February 2021. Towards addressing the obligations of the country regarding IAS, the Greek Ministry of Environment and Energy initiated an open call for tenders. A project was assigned to a group of experts, under the coordination of the National and Kapodistrian University of Athens, and will be concluded by 2022 (Arianoutsou et al., 2021). The main objectives of the project are: (a) the compilation of the national list of IAS and their spatial distribution; (b) the assessment of the risk they might impose; (c) horizon scanning for future potential invasions; and (d) the development of an effective monitoring scheme. In addition, within the project, proposals will be made on the administrative structures needed for the implementation of EU 1143/2014 and the accompanying regulatory actions. In the Greek National List of IAS, 22 marine species will be included (five algae, nine invertebrates and eight fishes) (Arianoutsou et al, 2022).

In parallel, an inter-ministerial decision was adopted in December 2021, in order to align with the European Regulation (Anonymous, 2021). This legal act comprises of 13 articles, that clearly define:

- The Central Administration is responsible for the implementation of IAS related National and European legislation. The administration will be assisted by an expert group of 20 participants from ministries, port authorities, custom authorities and the scientific community.
- Procedures for licensing of facilities or activities related to IAS, and the prerequisite approvals. In addition, rules of reciprocal fees, inspections, controls, violations and sanctions are also defined.
- The establishment and functioning of a complete and updated data base of IAS and their products, as an operational tool for action plans and management measures.
- The contribution of the general public, in the form of public consultation on planning, amending of reviewing action plans and management measures.
- Reporting.

Despite the lag in procedures and compliance to EU regulations regarding IAS, the marine NIS of Greece have been systematically monitored for approximately 15 years. In 2007, the ELNAIS network (Ellenic Network on Aquatic Invasive Species) was established. The initiation of ELNAIS was based on the need for national and international cooperation in research, information exchange, monitoring and management of marine NIS. ELNAIS includes validated records of marine NIS, both from citizen-scientists and scientific publications, and based on data included therein (September 2020), in the Hellenic seas 242 NIS have been recorded, with 16 of them considered as IAS (Zenetos et al., 2020). In addition, it has been evaluated that there are at least 45 more species expected to arrive in the marine waters of Greece (Karachle et al., 2017). Thus, under the umbrella of ELNAIS, experts and citizen science participants join forces to produce a wealth of information that supports national and European authorities and policy makers toward combating marine IAS in Greece and the Mediterranean.

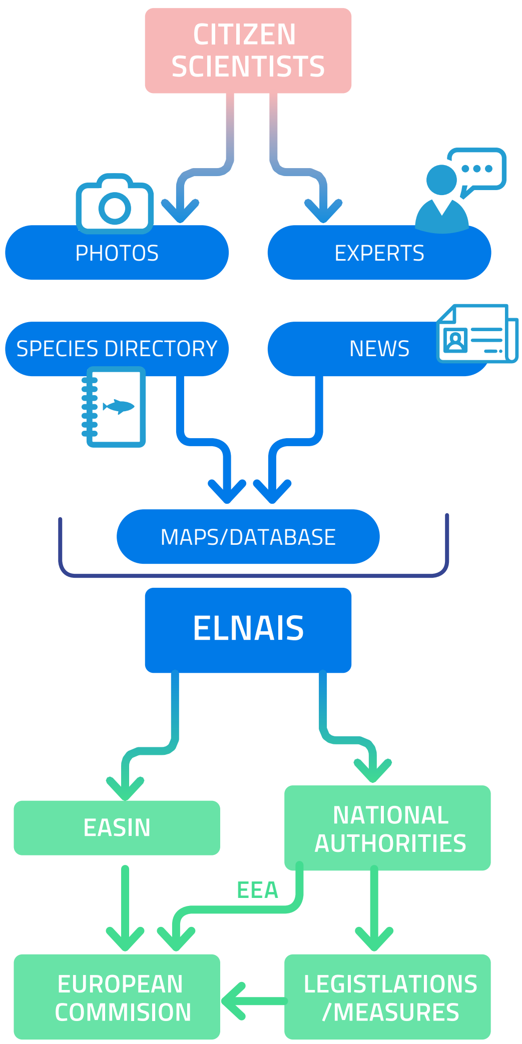


FIGURE 6. Schematic representation of ELNAIS network: input of information from experts and citizen science participants, and its contribution to national and international fora. (Figure from Zenetos et al., 2015 and Giovos et al., 2019; modified).

4.3 LEBANON

From a precautious point of view and following the Action Plan recommendations concerning species introductions and invasive species in the Mediterranean Sea, the National Action Plan on the introduction and invasive species in Lebanon was developed in 2018 (SPA/RAC-UNEP/MAP, 2018b). In addition, a National Monitoring Program for Marine Biodiversity in Lebanon was also designed, including an action plan and a strategy for sustainable monitoring of NIS along the Lebanese coast in the same year (SPA/RAC-UNEP/MAP, 2018a). As a result, an updated list and a general overview of all the NIS species along the Lebanese coast were presented, with a specific focus on the dangerous species. Thereupon, actions and recommendations for monitoring and evaluating the status of NIS along the Lebanese coast were offered. Accordingly, the program was mainly focused on the significance of:

- Monitoring of NIS species by: collecting and regular updating of data by the development of a National Inventory of marine NIS; developing accessible and standardised monitoring protocol; training national specialists to have taxonomic skills in most NIS groups; focusing on the surveillance of some dangerous NIS and their impacts on the local communities and ecosystems; divers' and fishers' participation and involvement in the monitoring programme for early detection of NIS.

- Awareness and communication by: focusing on publishing easy and friendly information of NIS on both social media and the field, with an emphasis on their impact on the native communities and the entire ecosystems.

- Ensuring a long-term monitoring and a long conservation strategy by: encouraging Lebanese researchers to conduct various types of studies regarding NIS in Lebanese waters; organise a number of activities addressed to schools, colleges, and university students to share NIS information in Lebanese waters; continue the effective cooperation between the Memorandum of Execution and national organisations such as SPA/RAC and IUCN, to grant projects allowing to monitor and evaluate the impact of NIS in the Lebanese waters; participate in several conferences, symposia, and workshops related to NIS; collaboration and connections with international organizations and other projects, aimed at monitoring of Mediterranean NIS.

Following the actions and recommendations of the National Action Plan on the introduction and invasive species in Lebanon in 2018 (SPA/RAC-UNEP/MAP, 2018b), and the National Monitoring Programme for Marine Biodiversity in Lebanon (SPA/RAC-UN Environment/MAP, 2018a), the Action Plan of Non-Indigenous Species in Lebanon should focus on:

1. Updating the list of marine fauna and flora along the Lebanese coast. This step allows classifying all NIS along the Lebanese coast as well as defining the most important marine species. In addition, it allows for the evaluation of the impact of NIS, especially the invasive ones, and maybe finding early solutions for avoiding/reducing the impact of NIS on some flagship species along the Lebanese coast.

2. Monitoring the NIS along the Lebanese coast: it is highly recommended first to update the list of NIS along the Lebanese coast. Within this step, it is highly recommended to classify and define the most dangerous NIS as well as NIS with economic value and those with high priority of monitoring.

3. Researching on non-destructive, time-effective, simple and cost-effective techniques. In this context, it is important to:
   - Develop, standardise and homogenise monitoring techniques based on Rapid Survey Assessment and focus on some areas (e.g. marinas and ports).

   - Understand the coastal ecosystems along the Lebanese coast and attribute any monitoring techniques according to these ecosystems. As an example, for evaluating the impact of NIS in the vermetid reefs it is recommended to understand the effect of the invasive *B. pharaonis* on the recruitment of the main reef builder species (*Dendropoma anguliferum*). Here, it is important to take the advice of national researchers to avoid any loss of time.

Within the monitoring process, it is highly recommended to integrate fishers into the monitoring program and to work on enhancing the link between researchers and fishers. This step guarantees the early detection of new NIS along the Lebanese coast and helps to anticipate the impacts of NIS with invasive characteristics on local communities.

FIGURE 7. Action Plan for Non-Indigenous Species in Lebanon (SPA/RAC, 2018)

Additionally, a link and communication and coordination with national experts is highly recommended, and should be enhanced as soon as possible (i.e. more collaboration means more solutions and fewer impacts of NIS). Also, an important step within the monitoring program is to train national experts on the taxonomy of species (Lebanon is missing marine taxonomist experts). In this context, a collaboration with other regional and international experts are also recommended. It is also recommended to encourage students to work on IAS topics and related subjects.

Citizen science is one of the most effective monitoring tools to detect newly introduced species and anticipate a possible invasion, as well as evaluate the status of other species. Based on this, some actions are recommended, such as:

- Training fishers, divers and volunteers on the taxonomy of selected NIS species, especially the dangerous ones (and those that should be evaluated)

- Regularly publishing layman articles and sample information on social media related to NIS along the Lebanese coast and their impacts

For guaranteeing sustainable monitoring of NIS, it is nationally recommended to:

- Always keep in mind that NIS is a type of biological pollution and measures to reduce the NIS impacts should be taken as soon as possible

- Give the monitoring of NIS, especially the dangerous and/or poisonous ones, a high priority e.g. in the framework of the coastal zone management

- Continue the effort for the accomplishment of the National Biodiversity Strategy and Action Plan (NBSAP): “By 2030, Lebanon’s biodiversity is sustainably valorised and managed for the protection and conservation of its ecosystems and of its habitats, and the provision of ecosystem goods and services.” (MoE/UNEP/ GEF, 2016)

- Encourage fishers to focus on NIS species, as many taste good, have economic value and can be regularly found

- Enhance the link with local communities to find a way to use the NIS as an important source of living (e.g. create accessories from NIS)

- It is recommended to encourage students, especially from university, to do research related to IAS

- The urgency to find indicators and set up efficient indices to evaluate the impacts of NIS and reduce their impacts

From a regional and Mediterranean level, it is highly recommended:

- To put more effort into research and to increase the knowledge on NIS in the Levantine Sea and their impact on the local communities. Furthermore, to conceive new rules and tools that may be applied to reduce their impacts by using practical tools

- To have a thorough survey of NIS along the entire Mediterranean (with a special focus on some targeted species) and specifically the Levantine Sea. This should be a priority in research programs, for a better understanding of the causes of loss, and in management programs, to better preserve threatened habitats.

- The need to continue the organization of workshops/symposiums related to NIS in the Mediterranean Sea (UNEP/MAP-SPA/RAC, 2009; UNEP/MAP-SPA/RAC, 2015b; UNEP/MAP – SPA/RAC, 2019), aims to enhance the link between researchers by sharing new ideas, tools and studies

- The need to specify common monitoring techniques of NIS

- The need to organise many workshops/trainings, in cooperation with Mediterranean experts, allowing to train and/or to share with the students and researchers the techniques to identify and monitor NIS

Finally, it is highly recommended to start the application of the actions and recommendations proposed in the National Action Plan on the introduction and IAS in Lebanon in 2018 (SPA/RAC-UNEP/MAP, 2018b), and the National Monitoring Programme for Marine Biodiversity in Lebanon (SPA/RAC-UNEP/MAP, 2018a) and updated the actions and recommendations with new data and new techniques (if needed).

Unfortunately, the monitoring of the NIS along the Lebanese coast, especially the macroflora ones, is scarce, mostly absent. It is limited to few studies from some local private universities and independent national experts. Currently, the NIS flora found on the Lebanese coast do not cause major problems, except for the *Stypopodium schimperi* algae, which can invade large areas in the region while producing well-established and seasonally dense covers. This flora must be monitored because it has high potential to alter the region’s natural biodiversity. However, *S. schimperi* requires special attention in order to track its expansion in the Eastern Mediterranean. It is important to emphasise that it contains a potent ichthyotoxin, stypoldione, which may partially explain its success (absence of predation). Finally, it is strongly advised to start implementing the actions and recommendations proposed in the National Action Plan and the National Monitoring Program for Marine Biodiversity in Lebanon to anticipate the effect of any introduced species and evaluate the impact on other species.

Moreover, in the absence of binding regulations on the introduction of new species into the territory, the ecological status in 2020 or in 2030, suggested by the Ministry of Environment in Lebanon Memorandum of Endorsement (MoE) concerning IAS, will automatically become worse than it is today.

4.4 TURKIYE

The constitution, national laws, by-laws, regulations, notifications and international conventions and protocols primarily govern environmental legislation in Turkey. The legal protection of species and natural assets within their native ecosystems began in 1937 with the Forest Law and Terrestrial Hunting Law, but it was only until the 1980s that the Turkish governments began to focus on environmental issues (Çinar et al., 2021). Since then, significant steps have been taken to align Turkey's legislation with both EU acquis and worldwide norms, but much more work remains to be done to achieve the desired levels. On a national level, Turkey does not currently have any laws that expressly target marine alien or invasive species, however, there are certain indirect judgments accessible, particularly on biodiversity and environmental issues that may be related to bioinvasions. The most prominent case is the Constitution of Turkey (adopted by the Parliament on 18 October 1982, law no. 2709), which mentions that the State shall ensure the protection of the historical, cultural and natural assets and wealth, and shall take supportive and promotive measures towards that end (Çinar et al., 2021). The fundamental legislative framework is given out in Environment Law (no. 2872, dated 11 August 1983), which emphasises the significance of environmental protection and prohibits all actions that impact biodiversity.

The General Directorate of Fisheries and Aquaculture (Ministry of Agriculture and Forestry) is the primary state institution in charge of fisheries and aquaculture administration and regulation. All activities are based on Fisheries Law No. 1380, which was enacted in 1971, and in which, rules and circulars are established to manage fisheries. Article 25 of the Fisheries Law contains remarks that may be related to alien species (all live import and export of aquatic products are subject to permission of the relevant Ministry) (Çinar et al., 2021). For the first time in Turkey's history, a recent incentive notification with short-term validity was published in the official gazette (dated 2 December 2020, no: 31322), allowing artisanal fishers to eradicate *Lagocephalus sceleratus* for a price of 5 TL (€0.52) per fish caudal fin from 2 to 31 December 2020. The notification promotes the removal of one million *L. sceleratus* in total, although the target number was not met and stayed around 46,000 individuals (Çinar et al., 2021).

There are two additional laws defining border controls on plant and animal species entering/exiting Turkey (Agricultural Plant Protection and Agricultural Quarantine Law and Animal Health and Surveillance Law), where any kind of transfer is subjected to Ministry of Agriculture and Forestry regulations. Relevant regulations focus mostly on terrestrial taxa and are only tangentially connected to marine invasive alien species, yet they serve as a significant baseline for species import and export at customs. The Turkish National Biodiversity Strategy Action Plan (NBSAP) was first published in 2008, in compliance with the Article 6 of the Convention on Biological Diversity (CBD). Following the Decision 10/2 of Cop X/2, the NBSAP was reviewed and an updated version regarding the 2018–2028 periods has been prepared. "Among the listed seven national objectives, the first one and its associated action directly focuses on alien and invasive species: National Objective (1)—Pressures and threats on biodiversity and ecosystems will be determined, reduced to the lowest level or removed totally; Action 1.2. Studies on improving the measures for identifying, monitoring, and controlling the entrance routes of invasive species and alien species and preventing entrance and habitation thereof will increasingly be continued (Çinar et al., 2021)."

There are many international agreements (binding/non-binding) and regulations referring directly or indirectly to alien species. Those sanctioned by Turkey are as follows: Convention on Biological Diversity, Ramsar Convention (The Convention on Wetlands of International Importance especially as Waterfowl Habitat), CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora), The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (Barcelona Convention). According to the Turkish legislation, endorsement of the above-mentioned conventions is not sufficient alone until the execution of the regulations has come into force (Çinar et al., 2021).

5

Conclusion

Detecting or managing invasive alien species is one of the most difficult tasks that humanity faces regarding biodiversity conservation. Particularly, the continuously connected nature of the marine realm enables IAS to move with ease through recent human-made corridors, such as the Suez Canal. The aquatic species living in the Red Sea appearing in the Mediterranean has fascinated scientists since the opening of the canal.

The Eastern Mediterranean is located just at the gateway of the Red Sea to the Mediterranean. Once an IAS is established, it is generally very difficult to control the populations, and total eradication is in most cases impossible. There are very few examples of successful eradication efforts of marine IAS (Bax et al., 2002; Culver and Kuris, 2000).

Siganus species started to be caught by the fishers in the 1940s. They were thought as just another wild form of *Sarpa salpa*. Pufferfish have tremendous negative impacts on fisheries to date. Lionfish and striped eel catfish have recently been introduced less than a decade ago and invaded the far eastern basin of the Mediterranean Sea. All these four fish are venomous, except for pufferfish which is extremely poisonous, pointing out the impacts on human health in addition to the ecological problems they create. The current number of alien fish species in the Mediterranean is approaching 200, while there are around 750 species of native fish species.

While mainstream organisms like fish are more closely followed, other taxonomic groups, such as molluscs, foraminiferans and crustaceans, are left unattended and have made their way into all levels of ecosystems, overpopulating native habitats and affecting flora and fauna by competing for resources and living space. These “silent IAS” even change habitat types when they die, through long lasting accumulations of their remains.

In a changing world, the management of invasive alien species will keep its validity, at least for another few foreseeable decades.

6

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Annexes

RELATED LEGISLATIVE FRAMEWORKS

- → Invasive Alien Species - Environment - European Commission
- → invasive_alien_species_implementation_report.pdf
- → Draft Programme of work of SPA/RAC for the biennium 2018-2019
- → CBD Invasive Alien Species
- → SDG Indicator Metadata
- → Aichi Biodiversity Targets

GLOBAL TRACKING AND INFORMATION DATABASES PREPARED FOR INVASIVE SPECIES (http://i-bil.com)

LOCATION	DATABASE	ADDRESS
Global	Global Invasive Species Database	http://www.iucngisd.org/gisd/
Global	Global Invasive Species Programme	https://www.gisp.org/
Global	Global Estimate of the Economic Cost of Biological Invasions.	http://invacost.fr/en/accueil/
Global	Invasive Species Compendium	https://www.cabi.org/isc/
Europe	Delivering Alien Invasive Species Inventories for Europe (DAISIE)	https://www.gbif.org/dataset/39f36f10-559b-427f-8c86-2d28afff68ca
USA	National Invasive Species Information Center (NISIC) of the United States Department of Agriculture	http://invasivespeciesinfo.gov
North America	Invasive and Exotic Species to North America	http://invasive.org
Hawaii and Pacific Islands	Hawaiian Ecosystems at Risk Project	http://hear.org
Europe and Mediterranean Basin	European and Mediterranean Plant Protection Organization (EPPO)	http://eppo.int
Belgium	Invasive Alien Species in Belgium	http://ias.biodiversity.be
UK	GB-Non-Native Species Secretariat (NNSS)	http://wwwnonnativespacies.org
North and Middle Europe	European Network on Invasive Alien Species (NOBANIS)	http://nobanis.org
Türkiye	MARIAS	https://www.istilacilar.org/

SUGGESTED TOOLS

- → GISD (iucngisd.org)
- → About GRIIS | GRIIS
- → EASIN - European Alien Species Information Network (europa.eu)
- → IUCN - MedMIS
- → MedPAN IAS Common Platform
- → Black List

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