Tackling The Marine Invasive Alien Species Problem in Critical Habitats in Need of Protection Status: The Situation on The Cyprus Northern Coast Littoral Zone

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By
Gökhan Tarı

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Prof. Dr. Candan Özoğul

Examining Committee in Charge:

We, the undersigned members of the Examining Committee, have carefully evaluated the thesis entitled "**Tackling the Marine Invasive Alien Species Problem in Critical Habitats in Need of Protection Status: The Situation on The Cyprus Northern Coast Littoral Zone"**, submitted by **Gökhan Tarı** for the degree of Doctorate of Science in Maritime Transportation Management Engineering. Based on our evaluation and the successful defense of the thesis, we hereby certify that the thesis meets the required academic standards and qualifies for the award of the degree.

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Gökhan Tarı, a **PhD** student at the **University of Kyrenia**, **Institute of Graduate Studies**, **Maritime Transportation Management Engineering Graduate Program** (student ID **K20190839**), has successfully defended the **thesis** titled " **Tackling The Marine Invasive Alien Species Problem in Critical Habitats in Need of Protection Status: The Situation on The Cyprus Northern Coast Littoral Zone**" This thesis was prepared in compliance with the relevant legislations and after fulfilling all the necessary requirements. The defense took place before the jury members, whose signatures are provided below.

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Date of Defense: 15/06/2023

To my dear wife and little son Cesur …

Declaration

I hereby declare that all the information presented in this document has been obtained and presented in accordance with academic rules and ethical conduct. Furthermore, I affirm that I have appropriately cited and referenced all external sources and materials used in this work, as per the requirements of these rules and guidelines.

Gökhan Tarı

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Abstract

A review report has been prepared by examining the research on habitat studies in the literature. This report provides detailed and chronological explanations of habitat classification procedures. The habitats along the northern coasts of Cyprus have been examined, and the locations and conditions of vermetid reefs have been reported. Emphasizing that vermetid reefs are included in the list of critical habitats and under protection, a draft proposal for conservation methods has been presented. During these studies, research has also been conducted on invasive alien species (IAS) encountered in these habitats. The effects of IAS on local habitats and other organisms have been investigated, and periodic counts and observations of their impacts have been conducted in designated areas. The impacts of species such as *Pterois miles* (Lionfish) and *Diadema setosum* (Sea urchin) have been detailed. In order to mitigate these impacts, efforts have been made to raise awareness among the local community and official institutions. In this regard, fishing competitions have been organized for these two species, followed by awareness campaigns on how to handle them properly for the local community.

These studies have facilitated the use, accessibility, and comparability of data, enhancing the quality and outcomes of the studies. Our study also highlights the importance of international classifications, such as the IUCN and EUNIS, in terms of conservation and sustainability. Specifically, our study addressed coastal analyses, marine biodiversity, habitat classification, and integrated coastal zone management in selected areas along the Cyprus coasts. We also included a comparison of marine biodiversity in the Istanbul Islands and data on initial sightings of invasive species in the Mediterranean. The outputs of this thesis aim to contribute to the conservation, development, and initiation of new projects studies in the significant marine areas of Cyprus.

2023, 249 Pages.

Keywords: *Biodiversity, Cyprus, Habitat, Invasive Alien Species (IAS), Vermetid*

Özet

Habitat çalışmalarına ilişkin literatürdeki araştırmaların incelenmesiyle bir inceleme raporu hazırlanmıştır. Bu rapor, habitat sınıflandırma prosedürlerinin detaylı ve kronolojik açıklamalarını sunmaktadır. Kıbrıs'ın kuzey sahillerindeki habitatlar incelenmiş ve vermetid resiflerinin konumları ve durumları raporlanmıştır. Vermetid resiflerinin kritik habitatlar listesinde yer aldığı ve koruma altında oldukları vurgulanarak, koruma yöntemleri için bir taslak öneri sunulmuştur. Bu çalışmalar kapsamında, bu habitatlarda karşılaşılan istilacı yabancı türler üzerine de araştırmalar yapılmıştır. İstilacı yabancı türlerin yerel habitatlar ve diğer organizmalar üzerindeki etkileri incelenmiş, belirlenen bölgelerde periyodik sayımlar ve etkilerin gözlemleri yapılmıştır. *Pterois miles* (Aslan Balığı) ve *Diadema setosum* (Deniz Kestanesi) gibi türlerin etkileri detaylı şekilde ele alınmıştır. Bu etkileri azaltmak amacıyla yerel topluluk ve resmî kurumlar arasında farkındalık oluşturma çabaları yürütülmüştür. Bu doğrultuda, bu iki tür için balık avı yarışmaları düzenlenmiş ve ardından yerel topluluğun bunları nasıl doğru şekilde ele alacağı konusunda farkındalık kampanyaları düzenlenmiştir.

Bu çalışmalar, verilerin kullanımını, erişilebilirliğini ve karşılaştırılabilirliğini kolaylaştırarak çalışmaların kalitesini ve sonuçlarını artırmıştır. Çalışmamız ayrıca, IUCN ve EUNIS gibi uluslararası sınıflandırmaların koruma ve sürdürülebilirlik açısından önemini vurgulamaktadır. Özellikle, çalışmamız Kuzey Kıbrıs kıyılarındaki seçilmiş alanlarda kıyı analizleri, denizel biyoçeşitlilik, habitat sınıflandırması ve bütünleşmiş kıyı bölge yönetimi konularını ele almıştır. Ayrıca İstanbul Adaları'ndaki denizel biyoçeşitliliğin karşılaştırması ve Akdeniz'de istilacı türlerin ilk gözlemlerine ilişkin verileri de içermiştir. Bu tezin çıktıları, Kuzey Kıbrıs'ın önemli deniz bölgelerindeki koruma, gelişim ve yeni çalışmaların başlatılmasına katkı sağlamayı amaçlamaktadır.

2023, 249 Sayfa.

Anahtar Kelimeler: *Biyoçeşitlilik, Habitat, İstilacı Yabancı Türler, Kıbrıs, Vermetid*

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Abbreviations Used

CIESM	Mediterranean Science Commission
CORINE	Coordination of Information on the Environment
EO	Earth Observation
EU	European Union
EUNIS	European Nature Information System
FAO	Food and Agriculture Organization
HELCOM	The Baltic Marine Environment Protection Commission
HELCOM HUB	The HELCOM Underwater Biotope and Habitat Classification System
IAS	Invasive Alien Species
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
IMO	International Maritime Organization
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
MARPOL	The International Convention for the Prevention of Pollution from Ships
MPA	Marine Protected Area
RAC/SPA	Regional Activity Centre for Specially Protected Areas
SPA	Specially Protected Area
TTX	Tetrodotoxin
UNEP	United Nations Environment Programme
WWF	World Wide Fund for Nature

Tackling The Marine Invasive Alien Species Problem in Critical Habitats in Need of Protection Status: The Situation on The Cyprus Northern Coast Littoral Zone

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A. Foreword

Natural heritage, which is the sum of natural features, geological and physiographic formations, and natural areas, is a product of the tectonic, biogeographic, and human history of a particular place and a subset of natural capital, that is, the total of important natural assets in the world (Beltran et al., 2020). Current conservation efforts can take many forms and shapes, including landscape, species, or habitat conservation, and the most important of these are protected areas. The biological diversity within and around protected areas is globally threatened by a range of human-induced pressures and threats (Hermoso et al., 2016). The response to these threats is partly dependent on funding and the institutional framework that supports their conservation and management (Covin and Slevin, 1989). Considering the threats and pressures on these areas alongside the institutional framework can provide a better understanding of the current status of conservation efforts in a particular area or country (Stern et al., 2005). Climate change will test the adaptability capacity of institutions and ecosystems (Berkes and Jolly, 2002).

Islands are isolated pieces of land, have limited resources, and are more vulnerable to externalities compared to the mainland (Thomas et al., 2020), therefore, understanding of conservation efforts is of utmost importance. Coastal, marine, and inland ecosystems of islands provide valuable regulatory, provisioning, and cultural services to over 500 million people (Assessment, 2005). However, the natural land cover of island systems has been largely altered under pressure from increasing human populations and associated exploitation of landmasses (Goudie, 2022). Most of the islands in the Mediterranean are biodiversity hotspots (Blondel), having shared commonalities before the advent of human settlement but also having distinct differences (Cuttelod et al., 2009).

B. Biodiversity

Biodiversity is a term used to describe the variability of all living organisms on Earth. Scientists have suggested that humanity's impact on the planet may be so permanent and widespread that it could create a new geological classification, the "Anthropocene epoch" (Groombridge et al., 2002). While this term has been accepted by geologists, the impact of humans on ecosystems and species can be observed everywhere, from plastic waste in Antarctica to declining ice caps in Greenland (Waters et al., 2016). Since 1950, scientists have classified the accelerated rates of global biological diversity and ecosystem loss (Zhou et al., 2006). The observed loss of biological diversity is combined with the local extinction of species at levels similar to biological extinction (Naeem et al., 2012). Scientists describe this as the sixth mass extinction event, equivalent to the loss of the dinosaurs (Wake and Vredenburg, 2008). The biological term was designed to address two concepts as a political issue to prevent the extinction of wildlife and living creatures worldwide. The term's acceptance as a global discourse is known to have been influenced by three ecologists. Thomas Lovejoy introduced the term "biodiversity" in the 1980s. Elliot Norse continued to define the concept as the diversity of genes, species, and ecosystems in a specific area. E.O. Wilson made the word so popular that in 1992, the United Nations (UN) codified the term "biodiversity" into the Convention on Biological Diversity, adopting Norse's definition (Genovesi, 2004).

The concept of biodiversity has recently been perceived more as a means of conservation, largely due to ongoing ecosystem degradation caused by human activities such as land use, invasive species, overuse, pollution, and climate change (Harrop and Pritchard, 2011). In addition, it contributes to an unprecedented level of species extinction (Rosendal, 2006). However, accurately measuring or detecting the extent of the actual and predicted damage has been proven to be almost impossible and problematic (Mazor et al., 2018). The main reason why the term biodiversity conservation has become so prominent is actually due to the fact that the harm caused by human activities cannot be calculated and is increasing. Biodiversity also provides economic and social benefits through its genetic resources. Economists have calculated that a thriving biota saves money in many areas such as clean air and water, fertile soil, wetlands, eco-tourism, and health costs (Snape, 2009). In this context, the loss of biodiversity must be understood as a global problem beyond the scope of a single nation and requires a global contribution to prevent ongoing destruction (Harrop and Pritchard, 2011).

There are several biodiversity indices that are used as tools to measure and monitor biodiversity. These indices can measure different aspects of biodiversity, such as species diversity, ecosystem health, and human interactions with biodiversity. These indices are important tools for understanding biodiversity loss, developing conservation strategies, and increasing biodiversity.

Some biodiversity indices include:

The Living Planet Index (LPI): is an index developed by the International Union for Conservation of Nature (IUCN) and the World Wildlife Fund to measure average population decline rates and track changes in the populations of various animal species (Loh et al., 2005).

The Species Richness Index: measures the diversity of species in a specific area and can be used to compare regional species diversity and evaluate biodiversity in different areas (Maggurran, 2021).

The Red List Index: developed by the IUCN, measures whether species are threatened or not and is used to determine the risk of extinction for species (Butchart, 2008).

These biodiversity indices are important for monitoring biodiversity loss and the effectiveness of conservation efforts. They can also be used to develop strategies for sustainable use of natural resources and conservation of biodiversity.

Biodiversity and the threats to it are unequally distributed, which makes prioritization essential to minimize biodiversity loss. To meet this need, conservation organizations have developed global priority templates (Brooks et al., 2006). Most templates prioritize irreplaceable areas; some are reactive (prioritizing high sensitivity), and others are proactive (prioritizing low sensitivity). These priorities provide significant convenience in terms of applicability. Our current best estimate of the number of eukaryotic species that make up the world's biodiversity is 8.7 million (Bravo et al., 2019).

Species interact in countless ways within different terrestrial and marine habitats to create complex ecological systems (Wilson, 2006). The United Nations Convention on Biological Diversity recognizes that the conservation of biodiversity is a common concern of humanity, considering the vital importance of these ecological systems in maintaining the biosphere's life-support systems. However, despite this collective sentiment, biologists warn that humanity's ongoing impact on the natural environment is causing a mass extinction event equivalent in scale to biodiversity loss (Gray and Milne, 2018).

Biodiversity conservation includes a series of strategies and practices aimed at preserving natural habitats, ecosystems, and species. Biodiversity conservation involves efforts at various levels to reduce the number of threatened species due to human activities and to protect biodiversity (Goldman et al., 2008).

Biodiversity conservation strategies are based on internationally established targets. Among these are the Biological Diversity Targets (Aichi Targets) adopted in 2010. These targets aim to reduce biodiversity loss, protect and sustainably use natural habitats, improve the status of threatened species, and increase awareness of biodiversity (Laffoley et al., 2017).

Biodiversity conservation strategies are implemented by international environmental organizations, governments, local communities, and civil society organizations. These strategies include creating protected areas, restoring natural habitats, protecting threatened species, making agricultural and forestry practices sustainable, preventing illegal hunting, and increasing awareness of biodiversity (Rands et al., 2010).

Main aspects of biodiversity conservation:

Ensuring the functionality of ecosystems: Biodiversity is an important factor in ensuring the functionality of natural ecosystems. Different species interact with each other within ecosystems and these interactions enable ecosystems to function in a healthy way. The loss of species in ecosystems can reduce their functionality and even cause the collapse of ecosystems in some cases (Mace et al., 2012).

Ensuring food security: Biodiversity is critical for food sources. Different plant and animal species are the essential components of agricultural products used to meet human food needs. Biodiversity loss can cause a decrease in genetic resources for agricultural products and lead to food security problems (Toledo and Burlingame, 2006).

Facilitating drug discovery: Biodiversity provides a source for drug development studies. For hundreds of years, drugs derived from plants and other natural sources have been used for medical treatments. Biodiversity loss can cause a decrease in these potential sources and adversely affect drug development studies (Hamdhani et al., 2020).

Providing economic value: Biodiversity provides an important source for tourism, hunting, fishing, forestry, and other industries. Biodiversity loss can decrease the economic value of these industries and even cause them to collapse in some cases (Keith et al., 2013).

C. Habitat

Habitat has a long history in biology and has been defined differently by various authors. The modern definition, based on Ernst Haeckel's 1866 definition, describes habitat as the mechanical basis for a species' life and reproductive efforts. Joseph Grinnell defines habitat as the combination of specialized physical factors for any stage in a species' life cycle. Habitat is crucial for biodiversity conservation and the preservation of species' resources. Understanding and managing habitat can be challenging for biologists. Habitat encompasses the resources and conditions necessary for organisms' survival and reproduction. Proper understanding of habitat is important for wildlife management (Haeckel, 1866; Grinnell, 1917).

Habitat use refers to how animals utilize the physical and biological resources available to them. Animals use habitats for various purposes such as feeding, sheltering, nesting, and escaping. These categories help divide the habitat, although there can be overlap (Noss, 1990). Different species may use the same habitat but for different activities, and environmental components can change seasonally. Habitat quality is essential for the survival and continuity of individuals and populations

(Hall et al., 1997). Habitat conservation is crucial for biodiversity preservation and ensuring species' survival. It originated from the concerns raised by Henry David Thoreau in the mid-19th century and gained significance in the 1960s with the increased risk of species extinction. Habitat conservation involves protecting natural areas, developing wildlife conservation programs, and managing habitats. The primary objective is to preserve species and maintain biodiversity (Ladle, 2011).

D. Habitat Classification

Habitat classification is a system used to define and categorize ecological areas based on their characteristics and the species they contain. Factors such as climate, topography, soil, vegetation, and human activities are considered in this classification. The International Union for Conservation of Nature (IUCN) has developed a widely used habitat classification system that divides habitats into 13 classes. Habitat classification is important for conservation planning, natural resource management, and biodiversity studies. It has evolved over time and is now based on multiple criteria, including habitat characteristics, species distribution, climate, soil, and human activities. The habitat classification system is a valuable tool used in various scientific disciplines and is widely accepted in conservation planning (Phillips, 2004). It helps in identifying habitats that require protection and developing conservation strategies. Habitat classification is essential for managing and conserving the diverse range of habitats found on Earth, and it plays a crucial role in the conservation of nature and the preservation of biodiversity (Strayer et al., 2003).

IUCN, or the International Union for Conservation of Nature, is a global organization dedicated to the preservation and sustainable use of natural environments. Founded in 1948 and headquartered in Switzerland, IUCN has played a significant role in issues related to conservation, biodiversity, and environmental policies. With over 1,400 members worldwide, IUCN collaborates with various organizations to protect and manage natural areas (Boitani et al., 2008).

Natura 2000, on the other hand, is a network established by the European Union (EU) to safeguard Europe's biodiversity and endangered species, as well as their habitats. Launched in 1992 under the EU Habitat Directive and Birds Directive, Natura 2000 encompasses special protection areas identified by EU member states. The network's creation and management are carried out by member states, with EU funds supporting their efforts. Natura 2000 plays a crucial role in conserving rare species and habitats, promoting sustainable resource use, and aligning with EU policies on natural areas and biodiversity (Güngöroğlu et al., 2018).

IUCN and Natura 2000 are instrumental in preserving natural environments and ensuring the long-term sustainability of ecosystems and species.

E. Integrated Coastal Zone Management

Coastal areas have historically been important for fishing and later gained significance as tourist destinations. However, the intensive exploitation of the coast and the neglect of its sensitive environment have raised concerns for its preservation. Integrated Coastal Zone Management (ICZM) aims to promote sustainable development and protect natural resources. The demand for seabed mapping has increased for effective coastal and ocean management, climate change research, and conservation efforts (Rodriguez et al., 2009). Geographic Information Systems (GIS) play a crucial role in ICZM studies for mapping and data analysis. Coastal management requires interdisciplinary solutions that consider technical, economic, and socio-cultural factors. Planning plays a strategic role in coastal zone management, with the development of planning approaches responding to environmental challenges and sustainability issues. International agreements and legal regulations, such as the United Nations Convention on the Law of the Sea and EU directives, emphasize the importance of coastal management and protection. Many countries have implemented coastal zone management regulations to address environmental protection, sustainable development, and the conservation of natural resources in coastal areas (Pinto et al., 2022; Clark, 1997).

F. Structure of the Thesis

Each section of the thesis is considered as a publication or in the process of being published. Below are the summaries of the sections:

Chapter I: Habitat classification is essential for ecological research as it allows for the organization, mapping, and analysis of ecological data. It was developed to describe and categorize environmental and species communities. However, challenges arise in habitat identification and classification, including the lack of a common vocabulary, difficulties in data collection for marine environments, and the absence of a comprehensive system for marine habitats. Reliable and accurate mapping and classification are needed to address these challenges and meet the increasing demand for habitat information. Published definitions and classifications in a common language are crucial for consistency and accuracy. Provides information on general terms, habitat, biodiversity, and classifications. Additionally, it discusses the state of the island of Cyprus in relation to these topics and highlights the lack of research in the region. Furthermore, a literature review is conducted to explore the development of habitat classification systems in Europe and the Mediterranean, as well as to discuss the previous studies that have been conducted. The chapter is summarized in the article titled "Review of Marine Habitat Classification Systems with a Pilot Study in the Littoral Habitats in Cyprus" which emphasizes the need to prioritize critical habitats in Cyprus and provide the necessary information for their conservation.

Chapter II: The study focuses on vermetid reefs, which are created by the *Dendropoma (Novastoa) petraeum* gastropod and the red algae *Neogoniolithon brassica-florida*. These reefs are commonly found in the Southern Mediterranean coasts and thrive in regions with winter surface temperatures above 14°C. They provide a complex habitat for a variety of species, resembling tropical fringing coral reefs. Vermetid reefs have existed since the Middle Miocene epoch and are used in paleoclimatology to measure oceanographic parameters like sea level. Additionally, they serve as a defense against coastal erosion, influence sediment transport, and act as carbon sinks. The study discovered numerous vermetid reef formations along the northern shores of Cyprus, covering a significant portion of the island. While the paper ''Distribution of vermetid reefs on the northern shores of Cyprus Island '' mainly focuses on the distribution of these reefs, it also includes an evaluation of selected reefs' vitality and investigates fish biodiversity through visual census methods.

Chapter III: Provides detailed information on the importance, scope, and conservation of biodiversity. The connections between living organisms are emphasized, and to highlight the effectiveness of biodiversity conservation, the article "Analysis of 70 years of change in benthic invertebrate biodiversity in the Prince's Islands region, Istanbul" was written. This publication compares the data from a biodiversity study conducted about 70 years ago in the island region with the current data. This comparison clearly shows the impact of population and sea traffic density on the living organisms and the region.

Chapter IV: The common goal of our two separate publications is the distribution and effects of invasive species in the Mediterranean. To enrich spatio-temporal information on the distribution of alien, cryptogenic, and neonative species in the Mediterranean and the Black Sea, a collective effort by 173 marine scientists was made to provide unpublished records and make them open access to the scientific community. Through this effort, we collected and harmonized a dataset of 12,649 records. It includes 247 taxa, of which 217 are Animalia, 25 Plantae and 5 Chromista, from 23 countries surrounding the Mediterranean and the Black Sea. Chordata was the most abundant taxonomic group, followed by Arthropoda, Mollusca, and Annelida. In terms of species records, *Siganus luridus*, *Siganus rivulatus*, *Saurida lessepsianus*, *Pterois miles*, *Upeneus moluccensis*, *Charybdis (Archias) longicollis*, and *Caulerpa cylindracea* were the most numerous. The temporal distribution of the records ranges from 1973 to 2022, with 44% of the records in 2020–2021. *Lethrinus borbonicus* is reported for the first time in the Mediterranean Sea, while *Pomatoschistus quagga*, *Caulerpa cylindracea*, *Grateloupia turuturu*, and *Misophria pallida* are first records for the Black Sea; *Kapraunia schneideri* is recorded for the second time in the Mediterranean and for the first time in Israel; *Prionospio depauperata* and *Pseudonereis anomala* are reported for the first time from the Sea of Marmara.

Chapter V: Our study conducted in two different reef areas along the northern coast of Cyprus is included. The introduction of alien species is probably one of the most important factors affecting native biodiversity in certain regions. The Mediterranean is considered the most affected sea in the world. Although many efforts to control several invasive alien species (IAS) have been carried out in the Mediterranean, complete success has not been obtained so far. In the eastern Mediterranean (Levantine Sea), the island of Cyprus is among the first places that marine species migrating across the Suez Canal are reported and known to have established. To test whether native species area able to restore ecosystems in the absence of IAS, removal experiments of two established IAS, the common lionfish *Pterois miles* and the long-spined sea urchin *Diadema setosum*, were carried out at two submerged rocky reefs in Cyprus where human activities are limited. A baseline period of three months was dedicated to characterizing the fish communities by visual censuses, followed by a middle period of four months of monthly removals which ended with the second and final characterization period of three months of the fish communities. While the removals of *D. setosum* were very effective maintaining low its abundance suggesting thus that the recolonization rate of the species is considerably low, the removals of lionfish seem to help the populations remain small, although recruitment rates are higher than *D. setosum*. Moreover, our results suggest that removal of these two species appear to help native fish recover while conversely affecting other alien fish in a negative manner. Monitoring of the two IAS along with the native flora and fauna is suggested in these two sites to identify seasonality and trends. The method employed here, can be replicated to other areas of similar characteristics.

Chapter VI: Two different areas, Alsancak and Esentepe, on the northern coasts of Cyprus were selected for our study, where we examined the temporal changes in tidal currents on the coastal platforms. The focus of this study was on the temporal and structural characteristics of vermetid reefs and the associated organisms, which are unique to the Eastern Mediterranean coasts. Additionally, we observed the fluctuations in the populations of living organisms in the pools located in the coastal areas during the tidal period. Our main objective was to investigate the impact of various factors, including temperature, salinity, air exposure, drying, and humidity, on the organisms inhabiting the coastal area. This research sheds light on the significant influence of the physical environment on the biodiversity and ecological dynamics of the studied region.

Chapter VII: The study focused on six sites along the north coast of Cyprus, selected based on diverse habitat characteristics, recreational use, fishing pressure, oceanographic conditions, and notable landmarks. Transects measuring 200 meters in length were established at each site, spaced 500 meters apart and perpendicular to the shore. GPS coordinates were recorded for each transect. Diving teams conducted surveys along the transects, documenting habitat characteristics, depths, and collecting samples of sediment, dominant invertebrates, and algae. Additional examinations were conducted between transects to assess habitat continuity. The supralittoral zone showed limited variation and low biodiversity due to the homogeneous ground structure and high temperature. Overall, 22 coastal habitats were identified, consisting of 11 littoral and 11 infralittoral habitats. The maximum depth recorded was 17.4 meters, with the lower limits of the infralittoral zone and circalittoral habitats excluded from the research. The findings contribute to the understanding of coastal habitat diversity and provide valuable information for conservation and management efforts.

G. Statement of Purpose

The scientific research conducted in the northern coastal waters of Cyprus is relatively low due to various reasons. However, recent studies have been conducted on marine ecosystems and aquatic flora and fauna. A review has been prepared by examining the research in the literature on habitat studies. Taking into account the absence of such a study specifically focusing on the habitats along the northern coasts of Cyprus, this review aims to serve as a reference for future studies in this area. The procedures for habitat classification have been detailed and presented chronologically. Within this scope, the habitats along the northern coasts of Cyprus have been examined and documented in a report, specifically highlighting the locations and conditions of vermetid reefs found along our coasts. Emphasizing that vermetid reefs are included in the list of critical habitats and are under protection, a draft proposal for conservation methods has been submitted to the relevant authorities.

During these studies, various investigations and analyses have been conducted on the invasive alien species (IAS) encountered within these habitats. The visible effects of these organisms on local habitats and organisms have been researched, and periodic counts of IAS species, along with their publications and impacts, have been observed in designated areas. Among the well-known species studied in this research are *Pterois miles* (Lionfish) and *Diadema setosum* (Sea urchin). The invasive policies and their impacts on habitats have been detailed. In order to mitigate these impacts, efforts have been made to raise awareness among the local community and official institutions. As part of this awareness campaign, fishing competitions have been organized for these two species on specific dates, followed by organizing events to educate the local community on how to prepare and consume them immediately after fishing.

Despite the contributions of over 50 scientists in marine sciences on the island, research is limited and insufficient due to political uncertainty, geographical challenges, and limited funding and resources. To address these limitations, it is crucial to improve political stability, enhance international collaborations, increase financial resources, and develop research infrastructure. This will allow for more comprehensive studies to understand the rich marine ecosystems and biodiversity of Cyprus and develop sustainable management strategies.

The limited and inadequate nature of protected areas in Cyprus makes it challenging to support natural habitats. The need for protection becomes even more crucial as many organisms and habitats, such as *Posidonia oceanica* and vermetid reefs, exist within extensively recreational areas. Despite the increasing human activities in these areas, it is important to emphasize that no concrete steps have been taken for coastal area management.

Therefore, our collaborative aim in this study is to highlight the adoption and implementation of coastal area management policies, particularly focusing on critical habitats. We have examined general studies related to habitats and created a summary, with a specific focus on vermetid reefs and their distributions. Additionally, we have been tracking the spread of invasive species in Cyprus and developing prevention methods. Studies have been initiated to assess the contributions of formations like flysch to the natural environment, aiming to protect them. Furthermore, through necessary investigations and research, coastal habitats in various parts of the island have been mapped, with the goal of serving as a reference for future establishment of protected areas and coastal area management.

Chapter I

Review of Marine Habitat Classification Systems with a Pilot Study in the Littoral Habitats in Cyprus

1.1. Introduction

Habitat classification is an important process for ecological research and conservation, as it helps to identify and describe different habitat types using a set of standardized terms and descriptors. While several marine habitat classification schemes exist, there is no universally accepted system due to the unique benefits and challenges of each scheme. However, in light of global environmental problems such as monitoring and protecting biodiversity, climate change, and biosphere integrity, there is an increasing need for reliable habitat mapping and classification at an appropriate spatial scale.

The article discusses the challenges and opportunities of applying a multidisciplinary approach to address environmental problems. It highlights the importance of natural habitats as the basic units for estimating biodiversity and the role of Earth Observation (EO) data obtained by satellite sensors in revolutionizing environmental science. Machine learning techniques, data mining, big data analytics, and ecological modeling can be applied to interpret ecological processes and identify solutions for environmental problems. However, the use of big data also poses challenges, such as dealing with issues at larger scales and wider timelines. The article suggests that new technologies based on EO data are likely to play an increasingly important role in ecosystem research, mapping, and monitoring in the coming decades.

Several scientific projects and studies have focused on using EO products to identify natural habitats and monitor conservation status. For example, multi-time high-resolution optical and multispectral optical data have been used to map grasslands using satellite data, while NDVI time series have been used to map forest communities. Coastal habitats have been mapped using spectral mixing analysis for phenological analyses using Sentinel-2 vegetation. Overall, the use of EO data provides a powerful tool for habitat classification and mapping, helping to support conservation efforts and better understand ecological processes.

Using the quantification of biodiversity as an indicator of biodiversity in habitats, especially on a small scale, is not a detailed inventory of biodiversity, since species or genus level biodiversity is better examined on a spatial scale through broad mapping (Ward et al., 1999; Cushman et al., 2008). Recently, some scientists have argued for the need to integrate the theory of Landscape Ecology with global technological and analytical approaches in the development of benthic landscapes, including sea floor mapping, quantification, and analysis of benthic structure of soft-sediment benthic areas (Zajac, 2008).

The current focus on terrestrial systems in habitat conservation, remediation, and management policies does not always translate to effective marine conservation. A spatially achievable and comprehensive habitat classification is necessary to establish appropriate conservation priorities for marine environments. However, detailed classifications can be cumbersome and fail to provide adequate tools for marine conservation and management, as different species communities can inhabit the same habitat type, leading to misleading interpretations of small-scale biodiversity distribution. Habitat identification and classification in coastal habitats face challenges such as a lack of a common vocabulary, difficulty in collecting data in challenging marine environments, and the absence of a single and comprehensive system for the identification and classification of marine habitats. (Fraschetti et al., 2008; Airoldi et al., 2005; Terlizzi et al., 2007; EUNIS, 2021; Connor et al., 2004; Diaz et al., 2004).

In this study, an investigation was carried out in terms of the historical development processes of habitat definitions and the historical development, scope, and applicability of national or international agreements, conventions or protocols that emerged with them. The various kind of problems different habitat classifications face and the difficulties of researchers and those who want to reach and obtain information are discussed. Emphasis was placed on researchers' need for a clear, understandable, and publicly accessible source of information, as well as applicability and stability for conservation and follow-up strategies. The main purpose of the research is to reveal that all these different habitat classifications should be combined through a common language. In addition, some national or international projects, studies, procedures, or agreements that assist habitat classification are also included. Furthermore, some national habitat classification systems that have been developed and habitat classification systems created in accordance with other classifications are mentioned in terms of being more comprehensive.

The International Union for Conservation of Nature (IUCN) Red List of Ecosystems is a widely accepted habitat classification system that represents a turning point in the Red List's history. It has evolved significantly over the past decade and is becoming an increasingly powerful tool for conservation planning, management, monitoring, and decision-making. The European Red List of habitats assesses spatial symptoms of habitat collapse using the reduction of occupancy over time as the main criterion, along with records of occurrence and abundance of plant species (Rodrigues et al., 2006). Continental-scale vegetation databases were established in 2010, which led to the renewal of the classification of the European Nature Information System (EUNIS), a comprehensive hierarchical pan-European system for habitat identification (Janssen et al., 2016). However, clearly defined units with a consistent ecological and biogeographic background were formed later, which were useful for assessments. Despite its limitations, the Red List is an irreplaceable source of information needed to assess and monitor environmental or adverse conservation situations (Bijlsma et al., 2018; Glöckler et al., 2012; Chytrý et al., 2016; Bruelheide et al., 2019; Davies et al., 2004; Moss, 2008; EUNIS, 2021; Chytrý et al., 2020).

The EUNIS habitat classification is a system developed by the European Environment Agency for the evaluation of ecosystems and habitats relevant to policies (UEPNC, 2021). It was initially created for European seas in the mid-1990s, and a comprehensive revision was made in 2016 to improve interregional consistency. This revision removed ambiguities and overlaps in species definitions and extended the classification to cover the entire continent of Europe and adjacent seas (Davies et al., 2004). The update also enhanced features of the deep-sea part of the system and included ecosystems native to the Mediterranean, Baltic Sea, and Black Sea (Mo et al., 2012). The EUNIS habitat classification is widely used and recognized as the most comprehensive and widespread pan-European classification system for marine benthic habitats. It has also been adopted in the European Red Habitat List (Evans et al., 2016). The EUNIS habitat classification system provides a common European reference for habitat classification, which is necessary for geospatial mainstream data exchange and policy decision-making (Sokołowski et al., 2021; Strong et al., 2019; Chytrý et al., 2020; Gubbay et al., 2016).

Although IUCN and EUNIS classifications are generally accepted, there are regional classifications used in Europe that support these classifications. Despite the fact that the scope of these classifications is limited, they function in many contexts such as conducting and supporting regional studies and protection activities. In addition to these, it has many benefits such as the initial data entry among the generally accepted classifications. The scope and purpose of other classifications are indicated in their development process. Although there are various classifications in this context, it should be noted that the scope, definitions, and developments of the generally accepted habitat classifications also progress in parallel. This progress is further underlined since it is supported by researchers in a constant flow of knowledge. Essentially, the purpose of definitions in habitat classifications; it stands out as being simple, understandable, and accessible to everyone.

The Mediterranean is a region of high biodiversity. This diversity also comes along with it a series of complexity. On the other hand, it is subjected to ever-increasing human pressures. As a result, strategies and plans to protect and improve ecosystems should be a priority in environmental policies. A monophonic habitat classification system is needed to map, monitor, and inventory habitats to ensure common and shared frameworks and a coherent interpretation of Mediterranean habitat types (Montefalcone et al., 2021). Due to these reasons, habitat classification is highly required. It is very important for the classifications to be clear and comprehensible for the previous and future studies. It is equally important to collect and compare these classifications in a common data network. Despite this, since there is no single classification from past to present, IUCN and EUNIS classifications have come to the fore in this context, especially within the scope of Europe. As a result, many studies are based on these two classifications.

Habitat classification in the Mediterranean and Europe began to form and develop from the beginning of the 19th century. These studies were needed to aid further research and identify species. In essence, habitat classification emerges as a system that is constantly being developed, since different sampling and classification will be required according to different species and systems.

Since the development of classification systems is directly proportional to the support of research, the benefit of regional and national organizations that support researchers is an undeniable fact. Today, two different organizations, EUNIS and IUCN, which support, protect and systematically store and share such research from the Mediterranean and European regions, have developed a habitat classification system that has been generally accepted. These two major organizations lead the studies in the Mediterranean and Europe. Our research has been about EUNIS and IUCN, as other regional and local classification systems are mostly based on specific studies and species.

It is more appropriate to utilize a study and research on a generally accepted habitat classification in terms of comparison of different studies, accessibility, and data storage. For this reason, the EUNIS classification system was used in the study we carried out within the scope of the BAP project in Cyprus between 2019 and 2021. It is aimed to gain better importance and protect the habitats in the region by making the research we have done by using this system easier to understand and access by many different scientists. In this study, examples of marine habitats according to EUNIS are also included, and the general summary of the study and a few examples are given in fourth section below.

In this study, researchers carried out on the classifications are valid especially for the European or Mediterranean part of the habitat definition. Research includes topics such as how classifications describe habitats, what they cover, and their emergence and development. The main reason for the need for habitat classification was also emphasized.

1.2. Habitat classification: Definitions and Purpose

Over time, classification systems have become more sophisticated and are now widely used in biodiversity conservation and management. The development of habitat classification systems has faced several challenges, particularly in marine environments, including the lack of a common vocabulary for habitat types, the difficulty in collecting data on habitat distribution and extent, and the absence of a single and comprehensive system for identifying and classifying marine habitats (Pérès & Picard, 1964).

The IUCN Red List of Ecosystems is the most widely accepted habitat classification system and is becoming an increasingly powerful tool for conservation planning, management, monitoring, and decision-making. The European Environment Agency's EUNIS habitat classification is also widely used and is probably the most widespread pan-European classification system for marine benthic habitats (Connor et al., 2004).

Classifying habitats is important because it allows scientists and policymakers to understand how different species are distributed and how they interact with their environment. This information is critical for effective conservation and management of marine and terrestrial ecosystems (Valentine et al., 2005).

Habitat classification is a critical tool for the effective management and conservation of biodiversity. It helps to ensure that habitats and ecosystems are protected, monitored, and managed effectively (Diaz et al., 2004). Habitat classifications allow for the identification and prioritization of areas for conservation, providing a framework for policy development and implementation. Additionally, they help to assess the condition and health of ecosystems and to identify threats and pressures on biodiversity, which can then be addressed through targeted conservation measures (Moss, 2014). Ultimately, habitat classification is an essential element of biodiversity conservation and sustainable development efforts, helping to ensure the long-term health and wellbeing of our planet and its inhabitants.

The use of RLE-related data in sustainable management of ecosystem services is important because many ecosystem services are closely linked to biodiversity and ecosystem function. The RLE protocol can help identify and prioritize areas where ecosystem services are most at risk, which can guide management strategies to sustainably use these services. For example, RLE assessments have been used to inform management decisions related to water resources, carbon storage, and cultural heritage (Keith et al., 2015). The integration of RLE with other tools, such as ecosystem services assessments and spatial planning, can enhance decision-making and management outcomes (Keith et al., 2015; Bland et al., 2017).

In addition, RLE assessments can contribute to the development of national and international policies related to biodiversity and ecosystem conservation. The results of RLE assessments can inform the identification of Key Biodiversity Areas (KBAs) and the establishment of protected areas, which are crucial for biodiversity conservation (Keith et al., 2015). The RLE protocol can also help to identify ecosystem types that are underrepresented in protected areas and therefore in need of additional conservation measures.

Overall, the IUCN RLE protocol plays an important role in the conservation and sustainable use of ecosystems by providing a standard method for assessing and comparing risks to ecosystem collapse and by identifying ecosystems most at risk. The use of RLE-related data in sustainable management of ecosystem services and policy development further highlights the importance of this protocol in promoting ecosystem conservation and management.

The International Union for Conservation of Nature (IUCN) Red List of Ecosystems (RLE) approach emphasizes four qualities in designing habitat protection and monitoring policies: generality, precision, realism, and simplicity (Keith et al., 2015). This tool has a sound conservation rationale and addresses multiple biodiversity levels in conservation planning (Boitani et al., 2015; Noss, 1996). By identifying large biota communities that require protection, especially between large-scale landscape and marine areas, and using them as a reference for little-known narrow-scale ones, the RLE approach provides a comprehensive assessment of ecosystem risks (Margules & Pressey, 2000). Unlike taxon-level assessments of population-to-population interactions, ecosystem-level assessment can address ecological processes, such as abiotic components of landscape and marine areas, that are critical for maintaining ecosystem functions (Sabo, 2008). Moreover, most ecosystem functions rely on common species that are central to the identification and risk assessment of ecosystems but are rarely included in the analysis of threatened species (Gaston & Fuller, 2008; Keith et al., 2013).

In addition to supporting conservation efforts, accurate habitat classification is also essential for effective management of natural resources. For example, knowledge of the specific habitats used by commercially important fish or wildlife species is critical for developing sustainable fishing or hunting practices. Habitat classification can also inform land-use planning decisions and help guide restoration efforts in areas that have been degraded or impacted by human activities (Davies et al., 2004).

Furthermore, a standardized and internationally recognized habitat classification system can facilitate communication and collaboration among researchers, conservationists, and policymakers at the regional and global levels. This can lead to more effective conservation strategies and better-informed decision-making processes.

Several national and international habitat type classification systems have been developed for monitoring and identification of habitats. However, reporting at the European level is difficult as these systems have many similarities, but their scopes are not the same. To address this issue, the Coordination of Information on the Environment (CORINE) program proposed a list of priority habitats that require specific conservation interventions, which is included in the European Union Habitats Interpretation Manual. The EUNIS habitat classification aims to create a set of European reference habitat types that includes a description of all species and a hierarchical classification. This allows for comparable referencing and reporting of habitat data for use in inventory monitoring, evaluation, and biodiversity indicators.

In addition to these, there are local habitat studies that proposed simplified classification schemes applicable to specific regions. For example, a new and simplified classification scheme was proposed for Italian marine protected areas, which includes 94 of the 183 habitats included in the Barcelona Convention. Furthermore, guidelines have been issued in Croatia and Spain, listing habitats that require special protection. These classifications use hierarchical schemes and provide a description of all habitats.

Overall, habitat classification systems should be objective, scientifically based, and flexible to develop and accept new information. They should also be stable enough to support previous work and similar systems. The goal is to provide a common and easy-to-understand language for the description of all marine, freshwater, and terrestrial habitats across Europe, while keeping the information open to everyone in a database that allows access to the internet portal.

1.3. The Past and Present of Habitat Classification

1.3.1. General Overview

The use of common terminology and a uniform classification system is crucial not only for identifying and protecting ecosystems, but also for effective communication among different stakeholders. It ensures that everyone involved in ecosystem management and conservation, including policymakers, scientists, and resource managers, has a common understanding of the habitats and their characteristics. This common understanding is essential for developing effective conservation strategies, such as habitat protection legislation, and for monitoring and reporting on biodiversity.

However, it is also important to recognize the limitations of classification systems and the assumptions that underlie them. Habitat classification schemes can oversimplify the complex ecological relationships and gradients that exist in natural ecosystems. For example, a habitat may be classified based solely on physical and environmental characteristics, but the biological community that inhabits it may be determined by other factors such as competition, predation, or symbiotic relationships.

Despite these limitations, habitat classification systems are essential tools for conservation and management of marine and terrestrial ecosystems. In Europe, several initiatives have been undertaken to develop habitat classification systems, including the EUNIS and IUCN systems. These systems have different data entry and operating systems, but they are both comprehensive and widely used in the region. Other organizations and conventions, such as JNCC and HELCOM, have also developed habitat studies to support ecosystem management and conservation. The development and adoption of common habitat classification systems and terminology are essential for effective ecosystem management and biodiversity conservation at both national and international levels.

1.3.2. International Union for Conservation of Nature (IUCN)

The IUCN Red List and the European Red List of Habitats are essential tools for assessing and monitoring the conservation status of biological species and habitats. These lists use specific criteria to evaluate the risk of extinction or subsidence for each species or habitat, respectively. This comprehensive inventory enables conservationists to prioritize conservation activities and allocate resources to address the identified threats.

The IUCN Red List is a global database that assesses the extinction risk of thousands of species and subspecies. It provides a robust and reproducible system for placing species into appropriate risk categories, ranging from "Least Concern" to "Extinct." This list is continuously updated, with new assessments and evaluations being added regularly.

Similarly, the European Red List of Habitats provides an overview of the risk of subsidence for marine, land, and freshwater habitats in the European Union and neighbouring regions. This list identifies habitats at high risk of subsidence and prioritizes conservation activities to address the identified threats.

Both the IUCN Red List and the European Red List of Habitats provide valuable information for conservationists, researchers, and policymakers. These lists enable effective conservation planning and management, which is crucial for preserving biodiversity and ecosystem services for current and future generations.

1.3.3. European Nature Information System (EUNIS)

The EUNIS habitat classification is a widely used system for reporting habitat and species data at the European level. It was developed by combining various habitat classifications, including terrestrial, freshwater, and marine classifications. The system is based on physiognomic and physical attributes, along with some floristic criteria, and is designed to be accessible to a wide range of biologists and conservationists.

Earlier classifications, such as the Corine biotope classification, relied heavily on traditional phytosociology, which can be difficult for non-experts to understand. The EUNIS classification system aimed to simplify the descriptions of habitats while still maintaining their scientific accuracy. This resulted in a system that is still somewhat transitive but provides a comprehensive framework for reporting habitat data.

The EUNIS classification system is organized into levels, with Levels 1-3 for terrestrial and freshwater habitats and Level 4 for marine habitats. The system is based on physiognomic and physical attributes, with some floristic criteria. The lower levels of the classification system are largely adopted from other systems but may require revision to fit within the EUNIS framework. Crosswalks connecting regional habitat systems to EUNIS are recommended for handling small regional variables.

The development process of the EUNIS classification continued beyond the initial release in 2000. In 2004, definitions were extensively revised up to level 3 to provide more clear and concise explanations for terrestrial and freshwater habitats. The marine section of the classification has also undergone significant changes since its inception in 1998. Baltic and Mediterranean marine habitats were added in response to conventions and workshops, and further revisions were made based on user feedback and updates to related classification systems such as the Corine Land Cover nomenclature and the EU Habitats Directive. The EUNIS classification is a constantly evolving system, and regular updates are necessary to ensure its accuracy and relevance.

The EUNIS habitat classification system is a valuable tool for various applications related to habitat management and conservation in Europe. It provides a standardized way of identifying and classifying different types of habitats, which helps in monitoring and managing them effectively. The system takes into account various parameters, such as substrate type, dominant lifestyle, humidity, typical depth zone, human use, and impact, to characterize different habitat types. The hierarchical key used in the classification system helps in organizing the habitats in a structured manner, and the notes provided with the criteria serve as a guide for interpretation, especially in areas where the boundaries between habitats are not clear-cut. Overall, the EUNIS habitat classification system plays a crucial role in assessing the condition and trends of nature, supporting biodiversity assessments, and enabling the development of networks for habitat conservation and management at a European level.

1.3.4. Other Habitat Classification Systems

The use of a single classification for all marine habitat maps may seem like a reasonable request, but in reality, different applications require different schema declarations. For example, biological conservation, landscape ecology, environmental monitoring, marine spatial planning, and fisheries management may all require different schema declarations. This has resulted in the emergence of multiple habitat classification systems (HCSS), reflecting the fundamental challenge of dividing natural continuities and environmental gradients into separate and meaningful classes. Furthermore, the number of HCSS has increased as individual schemes address specific biogeographic areas (Lund & Wilbur, 2007; Greene et al., 2008).

Interestingly, despite the fact that the main physicochemical variables known to describe habitats are well established, most marine mapping studies record the same parameters, and these parameters are predominantly of physical nature, most classifications in schemes differ significantly. This can significantly affect the spatial representation of habitats on final maps, preventing the merging of adjacent maps and altering management outcomes based on these maps. Therefore, it is essential to choose the appropriate HCSS for the specific application to ensure that ecologically and biologically important areas are adequately represented on the final maps (Gregr et al., 2012).

In addition, data flows from other information sources to these two main October habitat identification systems, which are generally accepted and used. Although this data flow appears to be one-sided at first glance, data flows can be one-sided due to the generality of IUCN or EUNIS-supported programs, protocols, or protections. In addition, support for larger projects such as communities or organizations such organization or guards, based directly or indirectly, supports the development of these systems (E.g., European Union funds, such as many national or international science funds). Some of these organizations, works, or contracts.

The Regional Activity Centre for Specially Protected Areas of Special Purpose (RAC/SPA) and the Helsinki Commission (HELCOM) are both intergovernmental organizations working towards the protection of marine environments in their respective regions. RAC/SPA operates under the framework of the Barcelona Convention and focuses on the Mediterranean region, while HELCOM focuses on the Baltic Sea region. Both organizations work towards promoting knowledge about marine and coastal biodiversity, developing marine and coastal protected areas, and protecting endangered species and habitats (Notarbartolo, 2007). They also aim to reduce the impact of human activities on the marine environment and ensure the sustainable use of marine resources. The activities of RAC/SPA include research, inventory, mapping, monitoring, and technical support, while HELCOM addresses all sources of pollution from land, air, and sea. Both organizations contribute to the implementation of sustainable development strategies and programs in their regions (Plan, 2006).

The HELCOM Underwater biotope and habitat classification system (HELCOM HUB) provides a framework for identifying and classifying biotopes in the Baltic Sea, allowing for comparison of biotopes in different regions. The hierarchical and organized structure of the system helps to ensure that biotopes are classified to the lowest possible level, allowing for more accurate and detailed analysis of changes in the Baltic Sea ecosystem (The Helsinki Convention, 2021).

The Natura 2000 network has faced some challenges, particularly in ensuring the effective management and monitoring of protected areas, as well as in promoting public awareness and participation in conservation efforts. However, efforts are being made to address these challenges through improved governance, funding, and stakeholder engagement. The network has also been successful in promoting cooperation among member states and in ensuring the sustainable use of natural resources in protected areas, such as through eco-tourism and other forms of nature-based tourism (Natura, 2021). Natura 2000 is also an important example of how international conventions and regional cooperation can be used to promote and achieve sustainable development goals (Abkan, 2012).

The WWF is also known for its iconic panda logo, which has become synonymous with the organization. The panda was chosen as a symbol because it is an endangered species and is widely recognized around the world. The WWF works to protect many other species as well, including tigers, elephants, rhinos, and whales, among others. The organization's conservation efforts are focused on preserving biodiversity, protecting ecosystems and natural habitats, and promoting sustainable development practices (WWF, 2021).

The WWF also works to raise awareness about environmental issues and to advocate for policies and practices that promote sustainability. This includes working with governments, businesses, and communities to promote sustainable development, reduce greenhouse gas emissions, and protect natural resources. The organization also works to educate the public about the importance of conservation and sustainable living, and to encourage people to take action to protect the environment (WWF, 2021).

The Ramsar Convention has been signed by 170 countries and has designated over 2,400 wetland sites for inclusion in the Ramsar List. The total area of the designated wetlands is over 250 million hectares. The Convention emphasizes the importance of wetlands as habitat for a variety of plant and animal species and recognizes the valuable ecosystem services provided by wetlands, such as water purification, flood control, and carbon storage. The Convention also highlights the importance of involving local communities in wetland conservation and management. The Ramsar Secretariat, based in Switzerland, supports the work of the Convention and provides technical assistance to member countries (Ramsar, 2021).

The Convention, Protocol or agreements mentioned above directly and indirectly contribute to the habitat identification systems. An example of this is the arrangement of information and data obtained by most researchers according to habitat systems through projects they have implemented or supported.

The most basic factor in habitat classification is to provide sustainable ecosystem by using a common language. This factor has led to difficulties in research, identification, or conservation as there were no general classifications in the past. This is due to the fact that scientists use their own definitions and classifications, since a common classification and definition is not used. It was an undeniable fact that each of his studies, conservation and sustainability research included their own definitions and coding, and that it would bring a great confusion as in other disciplines. In this context, as in other branches of science, people have come together on common grounds that using a common language will produce more accurate, realistic, and practical solutions. Common habitat classification initiatives at the European level started in the early 1980s and the establishment of the European Environment Agency, which was established in the mid-1990s, allowed for continuous work and development in this regard. These common denominators have developed from past to present locally, regionally, and generally, and have formed a common structure. For the Mediterranean and European region, these structures are known and used as EUNIS and IUCN. Since these two classification systems, which are generally used, are independent from each other and have different data entry and operating systems, and differ in terms of scope and qualities, the preferences of users, that is, researchers, also change in these directions. Researchers generally choose between two types of habitat systems based on their classification scope and support, based on past studies in the region they work in. Although these two classification systems have undergone many revisions from the past to the present, it should be emphasized that since the ecosystem is a living structure and there are many living species that we have not yet identified and encountered, it will develop today and in the future.

1.4. Case Study: Mapping Littoral Habitats in Cyprus

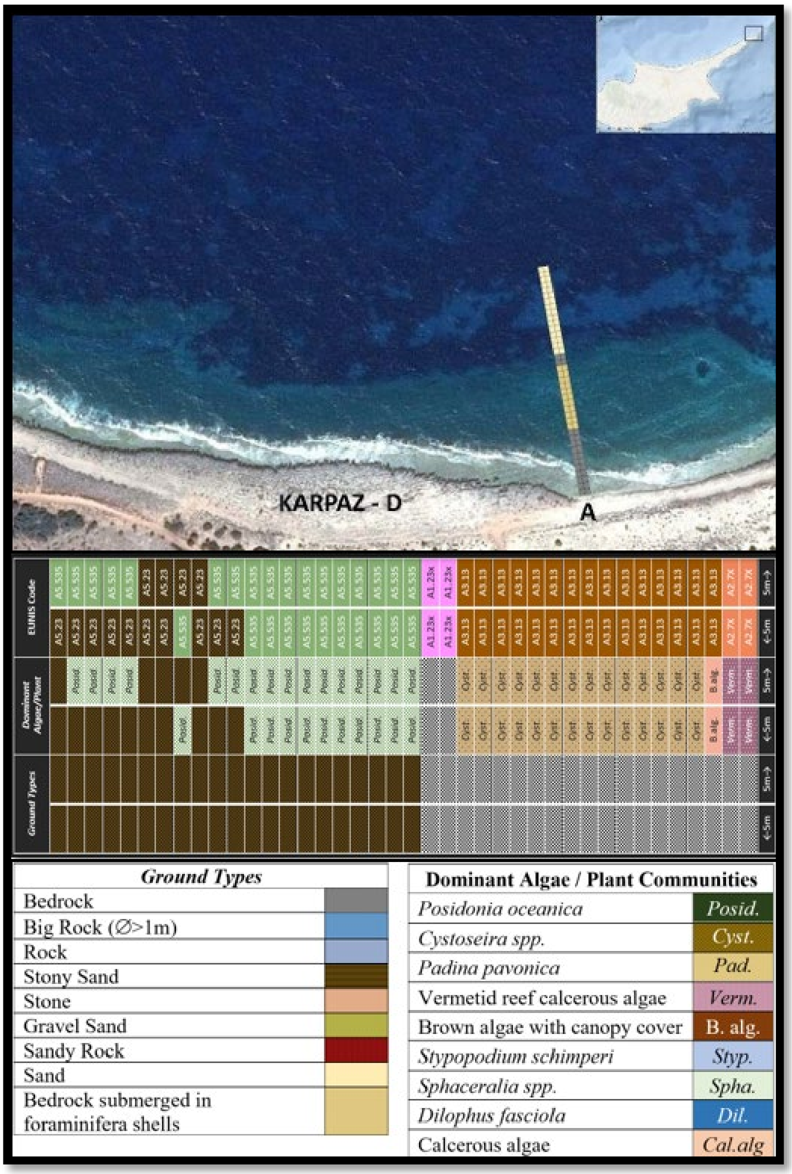
Cyprus is the third-largest island in the Mediterranean Sea and has a unique geological structure with a 782 km coastline (Delipetrou et al., 2008). The IUCN Red List has become an increasingly powerful tool for conservation, management, monitoring, and decision-making, and is the most accepted authority on biodiversity conservation. The marine habitat classification study focuses on how to use biodiversity data management systems and marine habitat classification concepts as data. The IUCN Red List of Ecosystems is a global standard for ecosystem risk assessment that seeks generality, certainty, realism, and simplicity in its criteria (Rodrigues et al., 2006). The importance of high-resolution maps, spatial and thematic resolution in the management applications of habitat maps, has been emphasized. Recommendations for habitat mapping surveys and classifications have been given in recent studies. The EUNIS system was developed under the Barcelona Convention and has been further expanded thanks to recent revisions (Montefalcone et al., 2021).

Through literature, very limited number of studies conducted in Cyprus is present. In a study related to identification and conservation of Cyprus's halophytic plant diversity and coastal habitat species, habitat types of protection concerns were identified (Öztürk et al., 2010). Habitat types and biodiversity of marine vertebrate species were studied by applying "Natura 2000 Network" method resulted that a reassessment should be carried out to cover other habitat species and biodiversity in the Mediterranean (Çiçek, 2010). Another field study to map the surface structures of the sea floor and benthic areas by a side-scan sonar along with underwater photos and video recordings, resulted with morphological and seabed classification maps to determine the distribution of coastal habitats in Cyprus (Ilhan et al., 2013). 10-year satellite-tracking report in the nesting area to determine conservation methods for *Caretta caretta* was conducted to determine the habitat uses of marine vertebrates and determine conservation methods accordingly (Snape et al., 2016). Several monitoring protocols related with remote sensing tools were used to record and assess the degree of protection of 13 different habitat species under the Natura 2000 network within 19 areas in Cyprus (Tzirkalli et al., 2018). The validity of *Posidonia oceanica* mapping via optical satellite imagery in the Limassol - Akrotiri Bay region was conducted recently (Yfantidou et al., 2019). Study on the underwater cave habitats in Kakoskali emphasized that the area should be protected from fishing pressure, and then the regulation and monitoring of recreational activities should be followed (Jimenez et al., 2019). The distribution of vermetid reefs, which form a biostructure and support a rich biodiversity and ecosystem services were identified on the northern coastline of Cyprus and an exemplar fish biodiversity survey on a selected reef was conducted (Huseyinoglu et al., 2020).

With an aim to investigate and map littoral habitats in selected areas in Cyprus, a field campaign was held in Kormakitis, Kyrenia, Rizokarpaso and Famagusta (Tari, 2020). Habitat types were determined by underwater visual census methods on a total of 20 transects of 10 m x 200 m, to be able to map the habitats and to be analysed in accordance with the EUNIS protocol. Standard scuba equipped divers filmed each side of the transect line; therefore, 5x200m sized habitats on each side of the transect line was recorded. Each time there was a change in habitat type on the route, divers collected benthic, algae cover samples to be identified in the laboratory. Supralittoral regions were also examined following a certain methodology. The surveys were carried out in a total area of 50 m2, 5 meters to the right, 5 meters to the left and 5 meters towards inland from the beginning of a transects. In order to evaluate the continuity of the habitats recorded alongside the transect lines, two teams also recorded the habitats between the 100 and 200 m marks of the neighbouring transects. A sample investigation of a transects among the 20 others are presented below (Figures 1).

Figure 1.

Sample of transect Karpaz-D



Note: Sample of transect Karpaz-D, detailed mapping common habitat types and legend of the habitat tables: definitions of the relevant data. Top picture is the aerial view of the sampled transect with the habitat data imprinted on. Middle section denotes the ground types, dominant algal cover and EUNIS habitat codes and bottom section is the legend.

The results of the field studies on the northern coast of Cyprus are available in the distribution and descriptions of the charts above. Figure 1 shows data from a transect in the Rizokarpaso region. These data were recorded using the underwater visual census (UVC) method on a line 200 meters long from the coastal line. The counts are recorded as scuba and with video, controlled and created together with data. In addition, depth and coordinate information in scuba method are taken simultaneously and included in the data October. In Figure 1, it indicates the ground structure in the transect A, and in Figure 2, it indicates the dominant plant communities on the transect. These abbreviations and colours are described in the table in Figure 1.

Detailed mapping determined the status of the habitats and their possible threats. Common habitat types were A3.13, A5.13, A5.23 and A5.535 according to EUNIS habitat classification (Davies et al., 2004). A notable abundance of invasive alien species, such as Pterois miles, Siganus rivulatus, S. luridus, Sarcocentron rubrum, Torquigener flavimaculosus and Diadema setosum were present in almost all the transects. A remarkable density of the vermetid reefs were identified. In addition, foraminifera deposits, especially at the most extreme points of the northern coastal areas, are very dominant in the littoral and supralittoral sections of coastal zone. This density has even turned the bedrock into sandy beaches by the invasive alien foraminiferan species, Amphistegina lobifera and Amphisorus hemprichii.

1.5. The Future of Habitat Classification

One of the greatest awareness created by global climate change is the understanding of the value and importance given to the oceans. The fact that humans who believe aquatic animals are limitless and invincible, have begun to recognize this dilemma in recent years demonstrates how severe the situation has become. Consequently, many national and international projects and protection areas supported by people, groups, organizations, or governments come to the fore today.

It is of great importance that approaches such as Marine Protected Areas (MPA) and Coastal Area Management System (ICZM) are gaining in value and importance. As of today, thanks to all these supporting elements we have mentioned, habitat classification systems have come to the fore as never before, MPA and ICZM have begun to shape many marine-related planning and formations, the most important ones like this one. In terms of planning and creation of such planning and formations, it must be connected with a scientific fact. It is possible to reach these scientific facts with the help of habitat classification systems, as we mentioned, with a correct, conscious, and common language.

Although habitat classification systems have been used since the beginning of the 19th century and have developed until today, they still continue the process of development today. The use of more general habitat classification systems today than in the past also shows that this information is more general and meets on a common denominator. Considering the fact that the current situation of our seas is getting worse day by day, it should be noted that our need for habitat classification systems will increase even more.

1.6. Conclusion

The term "habitat" is essential in conveying concepts such as ecosystems, biodiversity, ecotones, and biotopes for data management purposes. Having a clear understanding of these concepts can reduce complexity and increase positive feedback in Environmental Management, Research, and education. Recent advancements, such as the publication of species locations in online databases, provide new opportunities for mapping and analyzing marine biogeographic regions. The inclusion of ecological classifications in these analyses allows for linking species phylogenies to ecological adaptations and ecosystem function. However, achieving this on a global scale requires ecologists to be clear about what concepts they classify and why they classify them. To achieve this clarity, an online peer-reviewed dictionary of proposed terminology can reduce alternative uses of terms and provide a glossary for data management (Dallimer et al., 2012; Wunder et al., 2014).

Ecological processes play a critical role in diagnosing threats to individual species and resolving potential management conflicts for co-existing species, supporting the "adequacy" of conservation decisions. Additionally, ecosystems and places have value and meaning for people, even if they do not recognize all component species. Human well-being depends on ecosystems for many ecological services, making ecosystem-level assessments valuable communication and educational tools to support biodiversity conservation, macroeconomic planning, and sustainable land and water management (Costanza et al., 2014).

The identification and typification of marine habitats and their benthic communities is a consistent tool to explain the demarcation of marine protected areas and settled anthropogenic impacts. Therefore, a standard habitat classification needs to be developed for conservation assessment and long-term monitoring of areas (Costello et al., 2005). The formation of multiple habitat identification and classification has negative consequences for the progress and stability of research. The main reason for these is the lack of a common definition. While making a research different protocols, contracts or agreements defined in different ways, since the researcher would choose which one to do first, and if it would fit its own investigation of definitions, in addition, the protocol you want to apply in any part of the acceptance of the research, faced as many factors as possible the foreground. It is for these reasons that the common language is a great lack for people, and it is for these reasons that it is becoming much more accepted in the scientific world. For this reason, even comparing studies in different regions is almost impossible.

As can be seen from this study, which we conducted based on regions i.e., Mediterranean, there are some protocols, contracts or agreements that come to the fore in general. It should be noted that these are based on methods of protecting ecosystems. In fact, since this approach is based on common attitudes and goals, there are many scientists who advocate and support that these definitions and classifications should be published as a common language in advanced processes. At the heart of this idea, for many reasons mentioned above, the most important is, of course, to create a common and understandable language and to ensure that progress based on science reaches and supports more people. This kind of study means that all scientists are fed from a single database. In such a situation, it is inevitable that the research that has been done and will be carried out will progress steadily and decisively.

Chapter II

Distribution of Vermetid Reefs on the Northern Shores of Cyprus Island (2020)

Journal of Wildlife and Biodiversity, https://doi.org/10.22120/jwb.2020.127523.1139

2.1. Introduction

Vermetid reefs are biological constructions by two species: a sessile marine gastropod, *Dendropoma (Novastoa) petraeum* (Monterosato, 1892), and the red algae *Neogoniolithon brassica-florida* ((Harvey) Setchell & Mason, 1943) common in the Southern Mediterranean coasts (Chemello 2009). In the Mediterranean, they can be found in latitudes with winter surface temperatures higher than 140C (Chemello and Silenzi 2011). Rugosity and structural rigidity of the reef bioconstructions are usually accompanied by the complexity of brown and red algae species, making them an extremely suitable habitat for many smaller species belonging to a variety of taxa, thus, creating a unique rich ecosystem. Vermetid reef developments can only be found in the lower mesolittoral and upper infralittoral sections on rocky coasts with increased exposition to wave activity, making them functionally similar to tropical fringing coral reefs (Milazzo et al. 2014). They are known to exist from the Middle Miocene epoch to the present, through an evolution of two different reef-building genera: while Petaloconchus was the major component of vermetid reefs until the Holocene, it was replaced by Dendropoma almost completely for reasons still unknown. Since CaCO3 shells of *D. petraeum* and the surrounding seawater are in isotopic equilibrium, the reefs are extensively used in paleoclimatology for the measurements of physical oceanographic parameters such as sealevel associated with the intertidal or immediate subtidal zone (Vescogni et al. 2008). Moreover, vermetid reefs prevent chemical and physical coastal erosion and the contribution of bioeroding species like grazers, micro, and macroborers. They also modulate sediment transport and act as carbon sinks (Milazzo et al. 2016).

An extensive abundance of vermetid reef formations of various sizes is found to be present in the northern shores of Cyprus island in the Eastern Mediterranean during this study, which revealed the locations of the reefs on the northern coast covering from East to West of almost all the island, and vitality of some selected reefs were evaluated. This paper aims to present the distribution of the vermetid reefs in the region without a thorough evaluation of the aliveness of *D. petraeum*, and to demonstrate fish biodiversity investigation on selected reefs by visual census method.

2.2. Material and methods

The study area covers more than 200 kilometers of coastline on the northern shores of Cyprus island (Fig. 2). In 2017, the northern shores of the island were divided into 14 sections. Groups of two to three people instructed on vermetid reefs were assigned to each specific section, and they walked the shores. They took the reefs pictures they came across and recorded the coordinates with the free mobile phone application, "MyGPSCoordinates." However, it must be noted that some sections of the coastline were not accessible by walking, and those parts are not could be evaluated. In situations where authors were doubtful about any of the reef pictures (Fig. 2.1), they visited the validation sites.

During the second leg of the project, the presence of the great abundance of vermetid reefs along the northern coast was confirmed. The livelihood of the vermetid reefs at the tip of the Rizokarpaso peninsula was evaluated by the visual census method.

Underwater visual census methods are scientifically based on in-situ visual counts of marine species. These methods can be designed in a variety of ways, and the most common of which is by either snorkelling or scuba diving conducted by specially trained researchers. A total of 4 scubas and two freediving sessions were carried out in the vermetid reefs at the tip of the Rizokarpaso peninsula. Two scientific divers on each group logged the data by swimming through a 300m transect line. Obtained data were noted on the tablets suitable for writing underwater. After each dive, all groups were gathered to write down a report based on the data collected underwater. In this project, ESRI

ArcGIS software was utilized for visualization and spatial data analysis and to specify geographic patterns in the distribution of abundance, subject to further statistical analyses. Marine categorization data was collected during the fieldwork following the Standard Data Format developed within the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, an annex of the Barcelona Convention. The biodiversity database was prepared in a .mdb file format in the M.S. Access environment. The abundance and range of the vermetid reef formations were shown on detailed maps suited to the ArcGIS 10.2 software during the fieldwork. For visualization purposes, reefs were mapped and interpolated to a grid surface of 20 seconds latitude x 20 seconds longitude cells with 30 meters depth contour. Raster data were transferred from Google Earth with KML format. Storing information on a layer basis with individual or collective manner is the critical process of illustrating spatial information of vermetid reefs. These layers have been produced in ArcGIS to identify the locations of the reefs. The last output data are shown on the Google Earth layer in ArcGIS.

2.3. Results

Locations for the vermetid reef formations are given (Figs. 1.4-1.7). Since the study area is more than a 200 km patch distributed along East to West, the map is divided into four sections for visualization convenience.

Figure 2.

Study area with the presence of vermetid reefs indicated with red circles

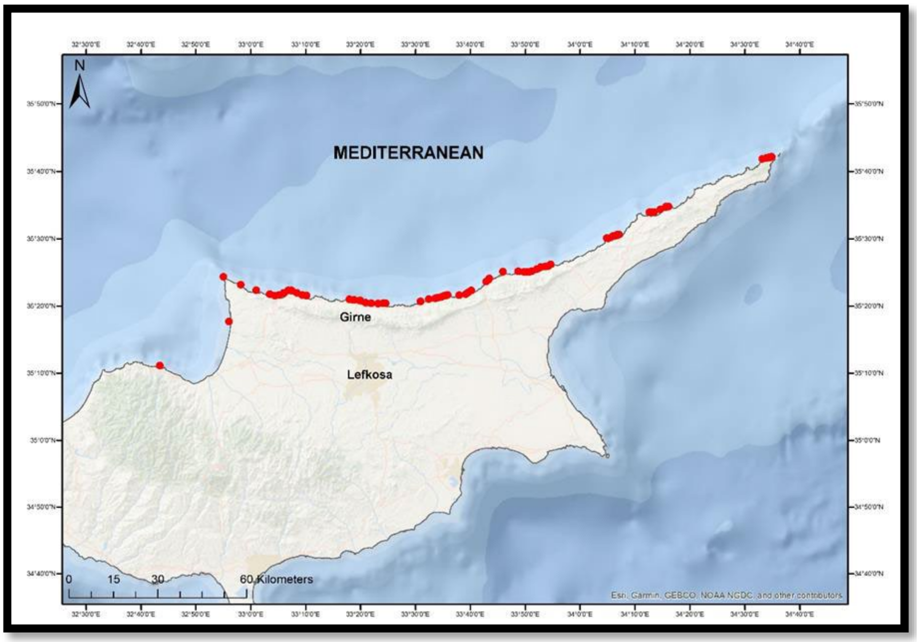


Figure 2.1.

Patches of vermetid reefs in Kyrenia, Cyprus

Note. *Dendropoma petraeum* individuals. Furthermore, since some of the reefs could not be accessed by citizen scientists, they are not included in the results.

Figure 2.2.

Locations of vermetid reefs, between 35°26' N, 33°58' E and 35°41' N, 34°35' E.

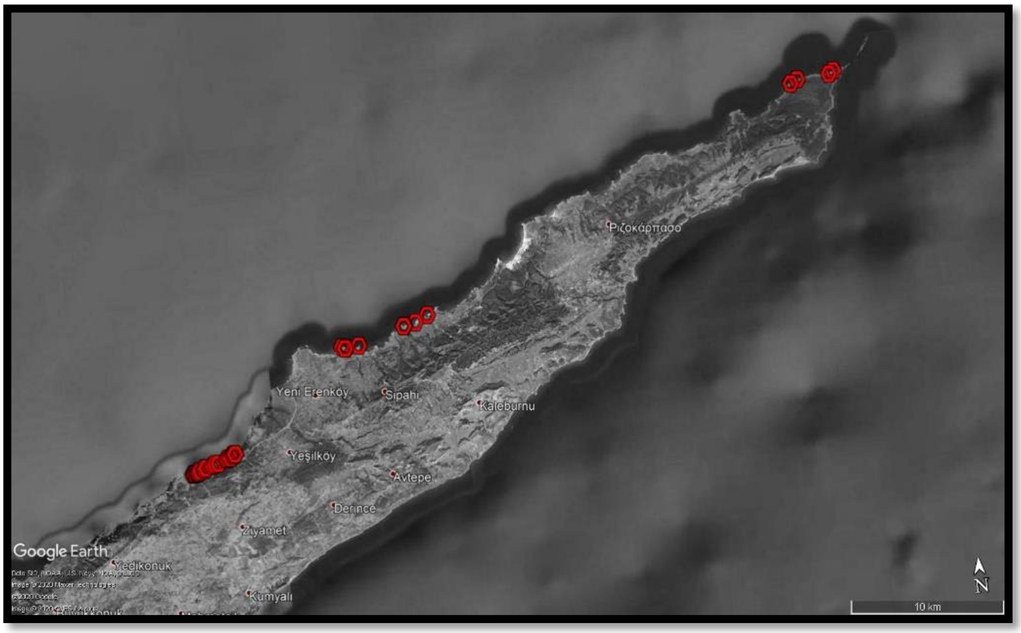


Figure 2.3.

Locations of vermetid reefs, between 35°19' N, 33°28' E and 35°28' N, 34° 2' E.

Figure 2.4.

Locations of vermetid reefs, between 35°23' N, 32°57' E and 35°20' N, 33°30' E.

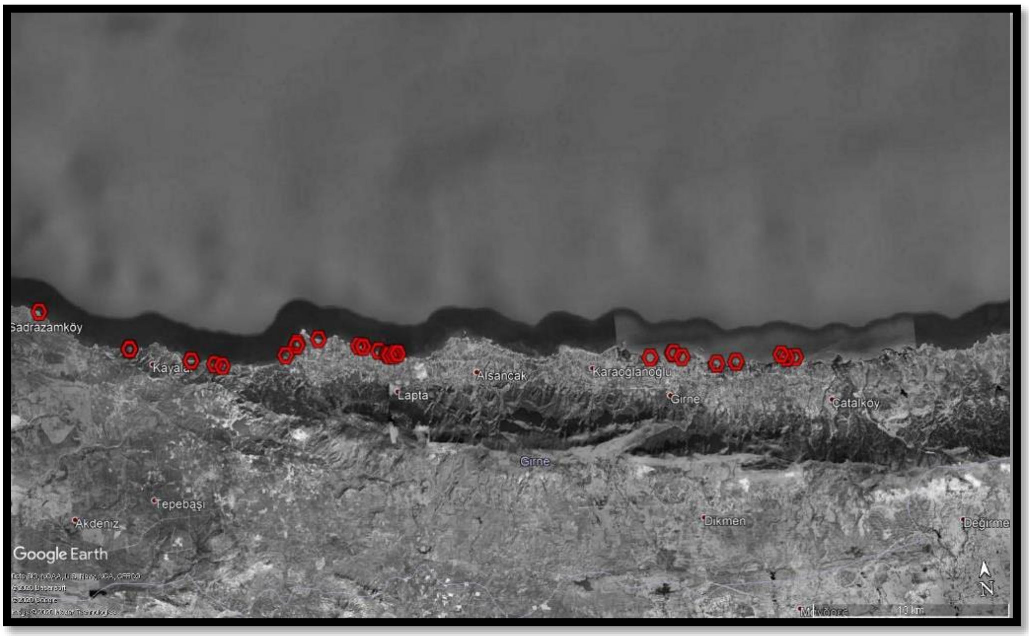
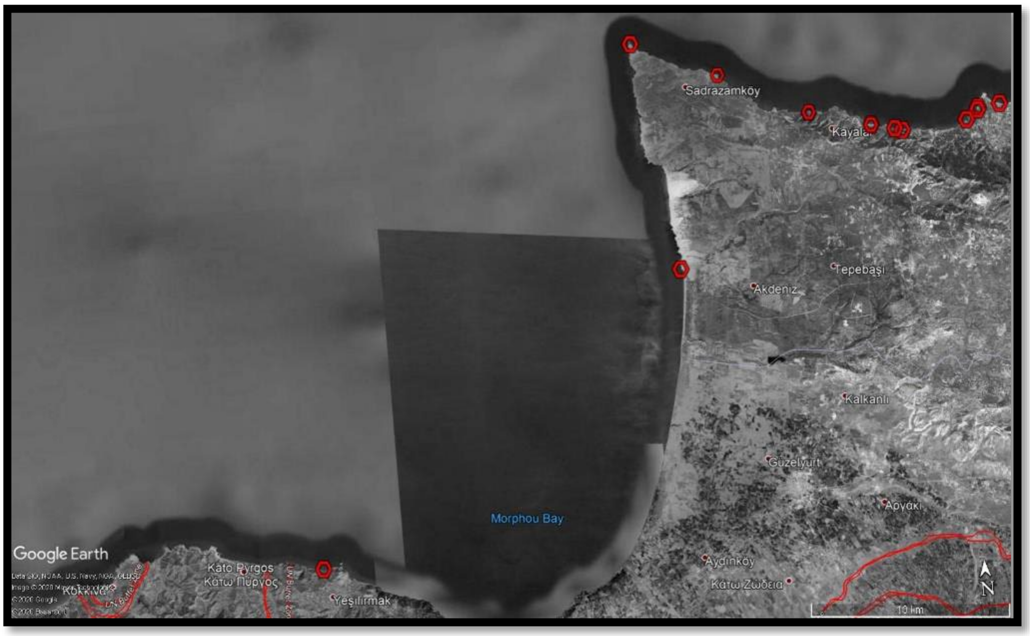


Figure 2.5.

Locations of vermetid reefs, between 35°10' N, 32°42' E and 35°21' N, 33° 7' E.



In this project, GIS and satellite photos were used to analyze the distribution of vermetid reef data in situ surveys. A total of 65 vermetid reef patches were identified in the study area. The approximate area of detected vermetid reefs is 1,15 km2. According to the satellite images, there are more vermetid reefs in the region, and its distribution reaches half of the northern coasts of Cyprus.

Vermetid reef forming a complex of bioconstruction species are some of the only real reef-forming species in the Mediterranean, along with the antherozoid *Cladocora caespitosa*. Some other organisms, such as serpulid worms and red coralline algae, along with the contribution of bivalves, bryozoans, and corals, are also capable of building more than 22 different types of biogenic reefs along the Mediterranean coast (Milazzo et al. 2016). Vermetid reefs are an important habitat in terms of species biodiversity (Donnarumma et al. 2014, Milazzo et al. 2016); a study of the structure of the fish community associated with a vermetid reef at Shiqmona, Israel, revealed the highest fish biodiversity (36 species) of any habitat along the Mediterranean coast of Israel (Goren and Galil 2001). During the course of the project, the extensive emphasis was given to a 4 km long vermetid reef at the end of Rizokarpaso peninsula, the easternmost part of the island. Fish species determination by visual census method revealed the presence of 63 species (Table 2). During the preliminary evaluation of the aliveness of *D. petraeum* specimens, a great number of live mollusks could be observed on several portions of the reefs.

Table 2.

Fish species recorded in Rizokarpaso vermetid reef

Acanthuroidei
Siganus luridus
Siganus rivulatus

Atherinomorpha
Atherina boyeri
Atherinomorus forskali
Tylosurusacus imperialis

Anguilliformes
Gymnothorax unicolor
Muraena helena

Beryciformes
Sargocentronrubrum

Blenniidae
Aidablennius sphynx
Coryphoblennius galerita
Lipophrys canevae
Lipophrys trigloides
Parablennius incognitus
Parablennius zvonimiri

Callionymidae
Clinitrachus argentatus
Tripterygion delaisi
Tripterygion melanurus

Carangoidei
Caranx crysos
Echeneis naucrates
Pseudocaranx dentex
Seriola dumerili

Clupeiformes
Sardinella aurita

Gobiidae
Gobius bucchichi
Gobius cobitis
Gobius geniporus
Gobius paganellus

Labridae
Corisjulis
Pterogogus trispilus
Sparisoma cretense
Symphodus mediterraneus
Symphodus tinca
Thalassoma pavo
Xyrichthys novacula

Mugilidae
Mugil cephalus

Percoidei
Apogon imberbis
Boops boops
Cheilodipterus novemstriatus
Diplodus annularis
Diplodus puntazzo
Diplodus sargus
Diplodus vulgaris
Lithognathus mormyrus
Mullus surmuletus
Oblada melanura
Parupeneus forsskali
Pempheris mangula
Sarpa salpa
Spicara maena
Spondyliosoma cantharus
Upaneus pori

Pleuronectiformes
Bothus podas

Pomacentridae
Chromis chromis

Serranidae
Epinephelus costae
Epinephelus marginatu
Mycteroperca rubra
Serranus cabrilla
Serranus scriba

Scorpaeniformes
Pterois miles
Scorpaena maderensis
Scorpaena scrofa

Sphyraenidae
Sphyraena viridensis

Syngnathiformes
Fistularia commersoni

Tetraodontiformes
Torquigener flavimacul

2.3.1. Conclusion

Vermetid reefs support a rich biodiversity and ecosystem services and other previously mentioned significant factors, making their imminent protection necessary. However, surprisingly, no detailed identification or coding for vermetid reefs is available in the well-established European Nature Information System (EUNIS). Since they are littoral biogenic reefs, they should be listed under A2.7, containing two biological subtypes; littoral Sabellaria reefs (A2.71) and mixed sediment shores with mussels (A2.72), encompassing the littoral biotope dominated by the honeycomb worm *Sabellaria alveolata*, and littoral Mytilus edulis- dominated communities (EUNIS 2020). Considering that A2.7 type habitats are protected by Council Directive (1992) on the conservation of natural habitats and of wild fauna and flora, a new series of definitions should be introduced for this habitat type. Moreover, although both vermetid reforming species, *D. petraeum* and *N. brassicaflorida* are included in the annexes of the Bern Convention (La Marca et al. 2015), and in Annex II (Endangered or Threatened Species) of the Protocol for Specially Protected Areas in the Mediterranean (SPAMI

Protocol of the Barcelona Convention), there is no accepted protection status for vermetid reefs up to date. A quick action to protect the vermetid reefs in Cyprus should be taken as early as possible. A detailed study on the livelihood percentage of the reefs is necessary.

Chapter III

Analysis of 70 Years of Change in Benthic Invertebrate Biodiversity in the Prince's Islands Region, Istanbul (2021)

Regional Studies in Marine Science, https://doi.org/10.1016/j.rsma.2021.102003

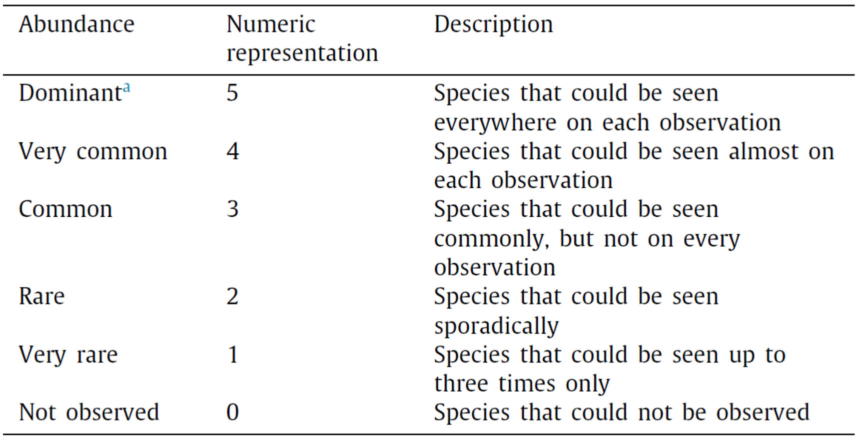
3.1. Introduction

Anthropogenic impacts on the environment are probably the only threat responsible for the extinction of a countless number of species, and unfortunately, this trend has an increasing rate (Steffen et al., 2016; Tilman et al., 2017). Various components of biodiversity, such as the direct supply of food, aesthetical enjoyment, ecosystem services are the direct values, whilst the genetic diversity of species can be regarded as a potential value (Ehrlich and Ehrlich, 1997), therefore biodiversity is treated as a global resource, being indexed and preserved for future generations. Unlike similar resources, loss of biodiversity is irreversible with unpredictable consequences because most of the global biodiversity is unstudied (Wilson, 1989). The contribution of biodiversity to the welfare of human beings has become a key argument for maintaining and enhancing biodiversity, especially in managed ecosystems (Paul et al., 2020).

Historically, marine biodiversity has naturally demonstrated a general but slow trajectory of increase, with punctuational mass extinctions at the evolutionary scale and by disturbances at the ecological scale. Synergic human threats, including overfishing, habitat destruction, introduction of alien species, global warming, and pollution have caused a rapid decline in global marine biodiversity, as it can be measured through species extinctions, population depletions, and community homogenization (Sala and Knowlton, 2006). Since the loss of marine biodiversity is directly linked with human proximity, it is most intense adjacent to the impact zone of the big cities, such as the following examples. Throughout China, the expansion of urban areas into biodiversity hotspots has increasingly threatened habitats critical for the conservation of biodiversity (McLaren, 2011). Likewise, Indian coastal areas are under similar threats (Nagendra et al., 2013). Although biodiversity near Istanbul, Turkey is understudied, particularly in historical terms, the changes over the last few decades are far from obscure. For example, only 29 species were found in a recent study on the seasonal seine net fish catch composition in Istanbul (Uzer et al., 2017). This is a very small number compared to other smaller cities along the Mediterranean coast, such as 46 species in Alexandria, Egypt (Akel and Philips, 2014); 60 species along the central coast of Portugal (Cabral et al., 2003); 62 species in the Aegean Sea, Greece (Katsanevakis et al., 2009); 70 species in the Aegean Sea, Turkey (Akyol, 2003); and 91 species in the eastern Adriatic Sea, Croatia (Škeljo et al., 2011). The Sea of Marmara is connected via the Bosphorus strait to the brackish waters of the Black Sea which has a very high freshwater influx (Bethoux and Gentili, 1999). Likewise, it is connected via Dardanelles to the northern Aegean Sea which has a 31% salinity at the surface (Poulos et al., 1997) and 39% at the water column deeper than 50 m (Velaoras et al., 2013). Despite the lack of sufficient methodological studies in the region in the past, it can be considered as a unique region harboring a variety of habitats and ecosystems (Albayrak et al., 2006). The Prince’s Islands region is situated approximately 10 km south of the entrance to the Bosphorus strait from the Sea of Marmara which is in fact the center of the megapolis of Istanbul (Fig. 3). Over the last 70 years the resident population of the Prince’s Islands, as one of the 39 districts of Istanbul, has been fluctuating in the range of 10.400 to 19.800 (with a mean value of 15 600) (Nüfusu, 2021); whereas, the population of Istanbul has increased from 1.17 million to 15.5 million (TUIK, 2021) as shown in Fig. 3.1 Furthermore, the summer population, as roughly estimated from the reports of the local government, has increased significantly in accordance with the city’s ever-growing population. Consequently, the adjacent aquatic ecosystems became heavily polluted by domestic and industrial discharges, severely affecting marine ecosystems. Considering the fact that the region is subject to very strong currents (Jarosz et al., 2011), the effects of local pollution from the islands can be estimated as minimal. Moreover, starting from the phytoplankton blooming season of the spring months, the Sea of Marmara witnessed an extreme outbreak of mucilage or ‘‘sea snot’’ formation, possibly the worst ever (Savun-Hekimoğlu and Gazioğlu, 2021), severely affecting the already damaged ecosystems. Along with intense concerns from public and government sections, the scientific community also showed uppermost interest in the event; mucilage formation was monitored for three months by classification of Sentinel-2 satellite images (Acar et al., 2021). A study identified a total of 47 phytoplankton species and zooplankton belonging to eight different groups (Amoebozoa, ciliata, cladocera, copepoda, foraminifera, nematoda, nauplii larvae and veliger larvae) in the mucilage aggregates (Balkis-Ozdelice et al., 2021). The outbreak has affected benthic species by not only a thick cover on the benthos, but also on the surface and through the water column (Özalp, 2021). An extensive biodiversity study on the benthic invertebrate animals was conducted in the region between 1946–1952, and more than 1000 species from 13 phyla were recorded (Demir, 1952). Among others, the study referred to 20 species of Cnidarians, 30 species of Echinoderms, 118 species of Molluscs and 10 species of Sponges. Another study was conducted between 1997 and 1999 with a similar approach in the region (Huseyinoglu, 1999). Along with the stations on the islands, a station in the middle of the Bosphorus Strait was added due to its proximity to the research facilities and the ability to better reflect the corresponding locality with Demir's study. Additionally, the joined efforts in 2014 presented the marine biodiversity across most invertebrate taxa inhabiting the seas surrounding Turkey (Çınar et al., 2014; Öztoprak et al., 2014; Öztürk et al., 2014; Topaloğlu and Evcen, 2014). The aim of this paper is to analyze the marine biological diversity of the region for the past 7 decades with a temporal context using data from 3 time-domains: Mid-twentieth century (cc. 1950), turn of the millennium (cc. 2000) and most recent data compiled from the literature.

Table 3.

Numerical representation of the abundance



Abundance	Numeric representation	Description
Dominant[a]	5	Species that could be seen everywhere on each observation
Very common	4	Species that could be seen almost on each observation
Common	3	Species that could be seen commonly, but not on every observation
Rare	2	Species that could be seen sporadically
Very rare	1	Species that could be seen up to three times only
Not observed	0	Species that could not be observed

Note. [a]Only three species fall under this category: *Asterias rubens*, *Mytilus galloprovincialis*, *Marthasterias glacialis*.

3.2. Methodology

3.2.1. Study area, time domains and abundance

Demir’s study was conducted in the ‘‘coasts of the islands (Prince’s) and Bosphorus’’. Therefore, our study area correspondingly covered mainly rocky marine habitats, located in the Princes’ Islands region between 40◦50’–40◦55’E and 28◦55’–29◦10’N with an additional station (Bebek) in Bosphorus (Demir, 1952). The region includes five inhabited islands (Buyukada, Sedef Adasi, Heybeliada, Burgazada, and Kinaliada) and two non-inhabited islands (Yassiada and Sivriada). The islands are situated 6–12 km SSW from the Asian coast of the mainland of Istanbul (Fig. 3). This study analyzes the biological diversity among and across selected phyla in a temporal aspect. Data from three-time domains are constructed accordingly that they are comparable and compatible. From Demir’s expressions in his study (1952), the abundance of each species was quantified and numerated under six categories as ‘‘not observed’’, ‘‘very rare’’, ‘‘rare’’, ‘‘common’’, ‘‘very common’’ and ‘‘dominant’’. Likewise, the data between 1997 and 1999 (Huseyinoglu, 1999) was constructed accordingly. These categories were numerically represented as shown in Table 3.1. Finally, the Turkey checklists were filtered by location, with only species found in the Sea of Marmara being chosen.

Between 1997 and 1999, rocky habitats with usual steep dropoffs were chosen for the study among four phyla: Cnidaria, Echinodermata, Mollusca and Porifera. A number of 104 investigatory dives were realized to a depth of up to 50 m. Scuba equipment with standard air was used for the dives, therefore bottom times were generally very short. However, this enabled the researchers to spend short bottom times on each depth, while still investigating the benthic habitats, thanks to the high downslope. Researchers used plastic slates writable underwater and cameras to record the species. Dataset from the chapters of the special issue of Turkish Journal of Zoology (Çınar et al., 2014; Öztoprak et al., 2014; Öztürk et al., 2014; Topaloğlu and Evcen, 2014), were used as the latest pool for the records of species, and literature was surveyed for the years after the checklists for the new records. Unfortunately, checklists do not include abundance data, therefore it was used as a reference for the existed/existing species within the region. Another problem to be resolved was the species name changes, merges and divergences during the past decades. World Register of Marine Species was based as a reference for the names of the species (WoRMS, 2021). Approximately, %28 of the species names stayed the same up to date and %48 of them have changed during the past decades. The rest of the names were subject to species convergences and taxonomical uncertainties.

Figure 3.

The study area

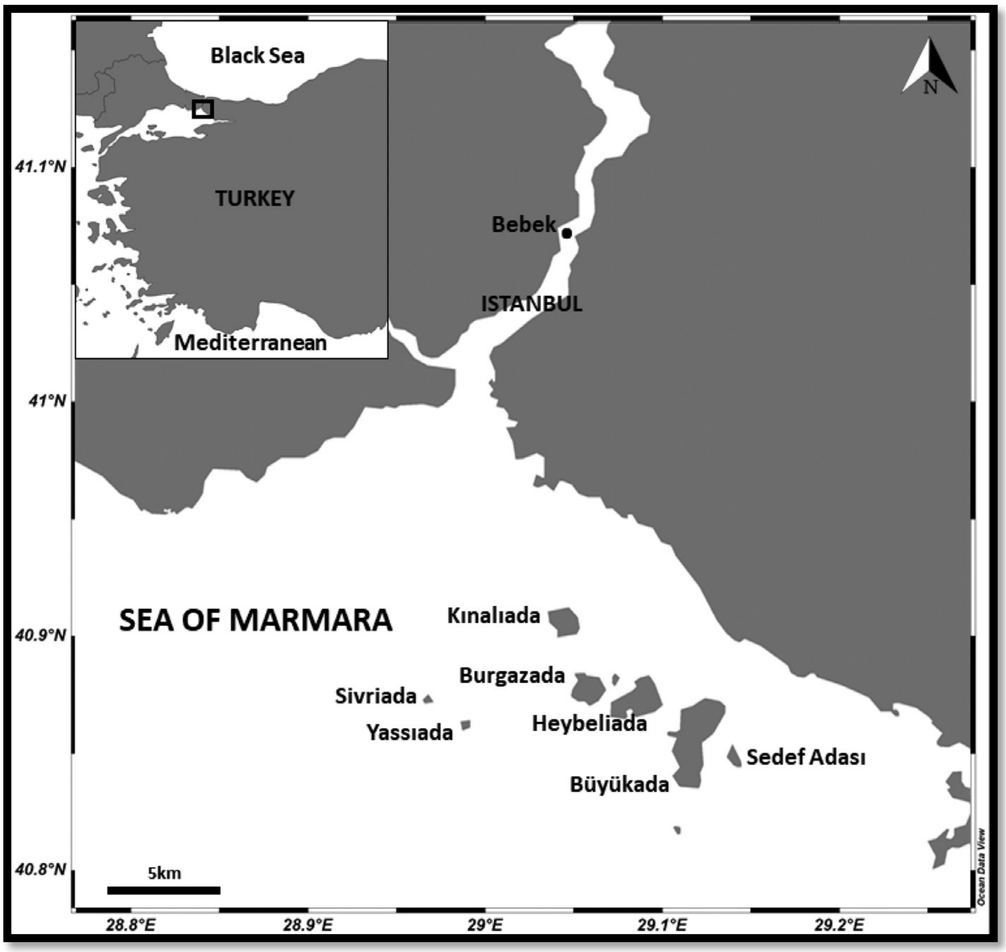
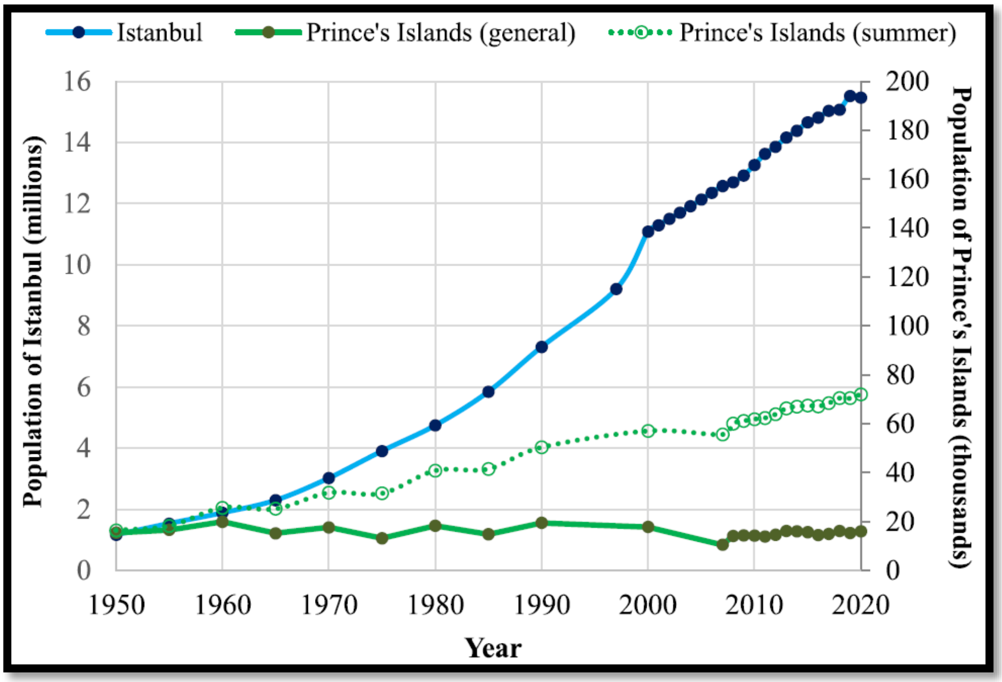


Figure 3.1.

Populations of Istanbul and Adalar District including the study area (Nüfusu, 2021; TUIK, 2021).



The methodology we used, however, differs considerably from Demir (1952). 1950's inventory was based on a range of sources, such as specimens obtained from fishermen's trawl combings, dredge samplings, local collections, and previous reports. He also used various tools such as pickaxe, shovel, scoop, rake, hammer and chisel to extract samples from both hard and soft substrata. While Demir investigated all habitat types including seashells in the coasts, boat lines, supralittoral sections, pier polls, man-made structures, muddy and sandy habitats and etc., our study was limited to scuba diving in rock habitats between 0–50 m depth. Our study will be abbreviated as 1999 for the remainder of the text for ease of presentation in tables, figures and text.

Being well aware of the limitations, imposed by this methodology, we have two main assumptions: (i) Since the study regions exactly overlap, a very high percentage of the species, especially the ones inhabiting the rocky reefs and the soft habitats nearing them should also have been observed, and (ii) we investigated only the abundance of species from four selected phyla, which would reflect the overall biodiversity patterns and which were relatively easy to identify and spot during scuba dives.

3.2.2. Biodiversity indices

In this study, we aimed to demonstrate the changes in the patterns of biodiversity in a temporal context spanning a timeline of 70 years. A number of indices have been introduced in recent years with the goal of assessing functional dissimilarity amongst communities both spatially or temporally. Pairwise dissimilarity indexes are based on the number of species present in both spatio-temporal dimensions: the number of species present in the first dimension but not in the second and the number of species present in the second dimension but not in the first (Baselga and Freckleton, 2013). Accordingly, Bray–Curtis dissimilarity index (Eq. (1)) and Marczewski–Steinhaus dissimilarity index (Eq. (2)) were used to measure the degree of dissimilarity to compare the species in the 1950s and in 1997–1999 in the same region (Lengyel and Botta-Dukát, 2021). The value of the index closer to 1 indicates that there is a high degree of dissimilarity whereas the value of the index closer to 0 means that there is a high degree of similarity.

$$\text{Bray-Curtis index} = \frac{\sum |x_i - x_j|}{\sum (x_i + x_j)} \tag{1}$$

$$\text{Marczewski-Steinhaus index} = \frac{\sum |x_i - x_j|}{\sum \max(x_i, x_j)} \tag{2}$$

Where, xi and xj represent the abundance level for each individual species in the 1950s and 1999 respectively.

In addition, Simpson's diversity index (Eq. (3)) was also used to quantify the biodiversity in these two different timelines.

$$\text{Simpson's diversity index} = 1 - \sum \left(\frac{n}{N}\right)^2 \tag{3}$$

where n corresponds to the number of individuals for each species and N corresponds to the total number of all individuals. The resultant number ranges from 0 to 1, with 0 indicating minimal diversity (all individuals in a given location are of the same species) and 1 indicating the greatest diversity (Thukral et al., 2019).

3.2.3. Exploratory data analysis

Another approach used in this study was statistical analysis, which was applied to understand the basic characteristics of the dataset and the presence of significant patterns in the data. Among the statistical techniques, exploratory data analysis has been popular since the 1970s and is often used for large datasets with no predetermined knowledge (Tukey, 1977). It might rather be difficult to deduce essential information from a column of numbers or an entire spreadsheet because looking at plain numbers to gain insights can be tedious or overwhelming. On the other hand, exploratory data analysis, which is a task under data mining, can help to visually analyze complicated datasets and extract useful information or significant patterns hidden from naked eyes. In this work, column graphs, box and whisker plots and bubble charts were used as a part of exploratory data analysis. Particularly, box and whisker plots were applied to observe the distribution of change of abundance (output variable) against phylum or class type (input variable). First, a particular input variable is categorized (such as phylum type) and these categories are indicated on the x-axis of the graphs while the values of the output (such as the abundance value) are shown on the y-axis. The ‘‘X’’ markers on the box and whisker plots correspond to the mean of the output achieved by each input variable while the upper quartile (75th percentile of the data), median (50th percentile of the data), and lower quartile (25th percentile of the data) are represented by the horizontal lines at the top, middle, and bottom of the boxes, respectively. In addition, the whiskers are also drawn upward from the upper quartile to the highest data point within 1.5 times the box width (interquartile range) and downward from the lower quartile to the lowest data point within 1.5 times the box width (interquartile range) (Walpole et al., 2012). Outliers are data points that are outside the range of the whiskers and are not shown on the figures in this study for clarity.

A bubble chart is a very useful type of scatter plot where the relative sizes of the bubbles represent the number of data points corresponding to a particular level of the input. They may provide an effective comparison of the levels of the inputs (Microsoft, 2021). In this study, bubble charts were implemented to observe the change of abundance against the number of species in each phylum. For this purpose, the change in the level of abundance (from −5 to +5) was put on the x-axis and the numbers of species corresponding to each level were indicated by the sizes of the bubbles.

3.3. Results and discussion

3.3.1. Overview of the biodiversity in the Prince's Islands region

From the results obtained as will be presented through this section, the benthic biodiversity around Istanbul is close to a collapse. The numbers of species in all taxa have been dropped to alarming levels. Table 3.1 summarizes the dissimilarity and diversity analysis, where Bray–Curtis values are calculated as 0.375, 0.411, 0.554 and 0.652 for Cnidaria, Echinodermata, Mollusca and Porifera, respectively, whilst Marczewski–Steinhaus values are 0.545, 0.582, 0.713 and 0,789 for the same phyla order, respectively. These two sets of values indicate that there are medium to low levels of similarities between the two-time domains. On the other hand, Simpson's Diversity index values are 0.919, 0.950, 0.988 and 0.825 in the 1950s, and 0.909, 0.924, 0.963 and 0.333 in 1999 for Cnidaria, Echinodermata, Mollusca and Porifera, respectively. Accordingly, the 1950s are found to have a higher degree of diversity compared to 1999 for all the species under the four phyla.

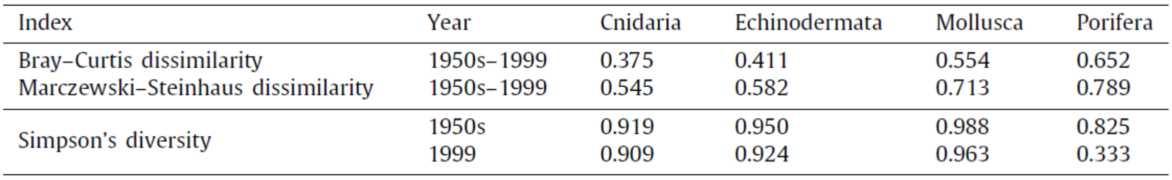
3.3.2. Exploratory analysis

The change of abundance patterns of the species under four phyla from 1950s to 1999 is observed through box and whisker plots in Fig. 3.2 The values in the y-axis should be interpreted in such a way that a positive number indicates an increase in abundance, whereas a negative number shows a decrease in abundance. The horizontal lines in the boxes represent the median of all the species under each particular phylum while the bottom lines of the boxes indicate the first quartiles, and the top horizontal line of the boxes imply the upper quartiles; as a result, half of all the species lie in the box. Moreover, the upper limit and the lower limit of the vertical lines attached to the boxes (whiskers) show the upper extreme and the lower extreme of the dataset. The boxes in Fig. 3.2, indicate that the abundance of all the species under the four different phyla decreased from the 1950s to 1999 and the most significant decrease can be observed for the species under the phylum Porifera. Among the four phyla, although the median of the change of abundance has a negative value for Echinodermata, two species in this phylum show an extremely significant increase in abundance as shown by the upper extreme value of 5. One of these two species is a recent invasive alien asteroid *Asterias rubens* from the Atlantic Ocean first recorded by Albayrak (1996).

Likewise, Fig. 3.3 shows the change of abundance from the 1950s to 1999 for the observed species in twelve classes. The boxes in the figure indicate the distribution of 50% of the dataset while the ends of the vertical lines correspond to the upper and lower extremes. Accordingly, the boxes of all the classes have a negative change in abundance except Anthozoa, Asteroidea, Holothuroidea and Echinoidea. Moreover, the median lines (the horizontal lines within the boxes) correspond to a change of abundance smaller than or equal to zero with only one exception (Holothuroidea). This is a further proof of the general decrease in the abundance of almost all the species in the region of study. The order Cephalopoda, which includes economically important octopuses, squids, and cuttlefish, appears to be completely collapsing as evidenced by the 6 species in the 1950s with abundance ranging from 2 to 4 to no records in 1999.

Table 3.1.

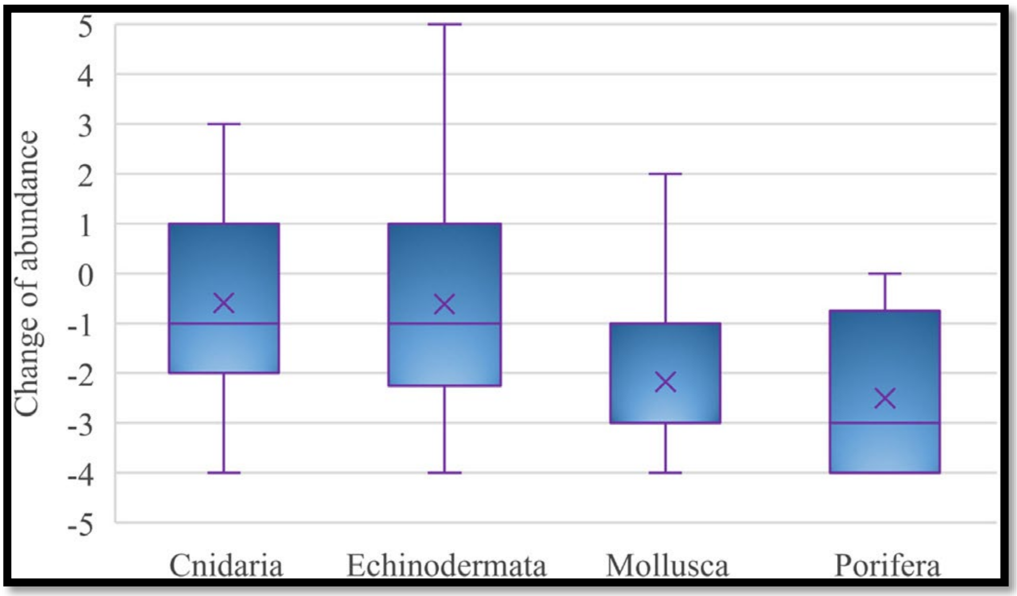
Dissimilarity and diversity analysis



Index	Year	Cnidaria	Echinodermata	Mollusca	Porifera
Bray–Curtis dissimilarity	1950s–1999	0.375	0.411	0.554	0.652
Marczewski–Steinhaus dissimilarity	1950s–1999	0.545	0.582	0.713	0.789
Simpson's diversity	1950s	0.919	0.950	0.988	0.825
	1999	0.909	0.924	0.963	0.333

Figure 3.2.

Change of abundance from 1950s to 1999 for the observed species in four phyla



Boxes in the figure indicate the distribution of 50% of the dataset while the ends of the vertical lines correspond to the upper and lower extremes. Accordingly, the boxes of all the classes have a negative change in abundance except Anthozoa, Asteroidea, Holothuroidea and Echinoidea. Moreover, the median lines (the horizontal lines within the boxes) correspond to a change of abundance smaller than or equal to zero with only one exception (Holothuroidea). This is a further proof of the general decrease in the abundance of almost all the species in the region of study. The order Cephalopoda, which includes economically important octopuses, squids, and cuttlefish, appears to be completely collapsing as evidenced by the 6 species in the 1950s with abundance ranging from 2 to 4 to no records in 1999.

Fig. 3.4 shows the change of abundance in more detail for the observed species in four different phyla by bubble charts; in which the relative sizes of the bubbles indicate the number of species corresponding to a particular level of abundance change. For the phylum Cnidaria, the level of abundance of 9 out of 17 species is observed to decrease, no change is detected for 4 species and only the abundances of 4 species seem to increase (Fig. 3.4a). Likewise, the abundance of 14 out of 26 species under the phylum Echinodermata decreased, 4 showed no change and 8 species increased (Fig. 3.4b). On the other hand, the abundance levels of the species under Mollusca and Porifera decreased significantly as indicated in Fig. 2.4c and d respectively.

3.3.3. Analysis based on the checklists

In this section, the numbers of species that were observed between the 1950s to 1999 are compared with the total number of species that have been recorded in the checklists. Fig. 3.5 shows the number of species and their changes in abundance in this period of time compared with the total number of species that are not observed but available in the checklist. Data is presented in logarithmic scale for ease of comparison. The species having a decrease in abundance are high in number compared to species with no change and increase in abundance. This is more apparent in the phylum Mollusca; such that, out of the 87 species, 68 show a decrease in abundance. On the other hand, two species under Echinodermata, *Asterias rubens* and *Marthasterias glacialis* show an extreme increase in abundance. The figure also shows that only a small percentage of the species in the checklist were observed in the study region. For instance, out of the 1065 species 978 species were never observed for Molluscs. However, it must be noted that the checklists include the whole Sea of Marmara, while both studies (Demir, 1952; Huseyinoglu, 1999) were conducted in a small section of it with maximum anthropogenic pressure. A thorough investigation on molluscs and their shells remains are suggested for future studies.

Fig. 3.6a shows that 17 out of 196, 26 out of 91, 87 out of 1065 and 6 out of 129 species were observed during the time range of study for the phyla Cnidaria, Echinodermata, Mollusca and Porifera, respectively. It is found that the early recorded species were observed more compared to the recently recorded species in the checklist as given in Fig. 3.6b. This indicates that the recently discovered species are probably rarely encountered species.

Fig. 3.7 shows the change of abundance of the species against their dates of first record. As it is given in the figure, the boxes of all year ranges correspond to a decrease in abundance except the species recorded in the years between 1850 and 1900. On the other hand, the upper whiskers (indicating the upper quartile of the data) lie in the positive change region for the species recorded in the year between 1750 to 1800 and 1800 to 1850. This means that nearly three-quarters of those species are declining in abundance while only one-quarter show an increase in abundance.

Finally, Fig. 3.8 demonstrates the changes in the numbers of species in different habitat types. It can be deduced here that molluscs inhabiting hard substratum such as rocks, boulders, algae-covered hard surfaces etc. as well as soft habitats, such as sand or mud are close to a collapse. The numbers of the species showing an increase, decrease and no change in abundances under Cnidaria and Echinodermata seem to be almost the same for hard substratum. However, species under Mollusca and Porifera are found to decline significantly from the 1950s to 1999 in this habitat. On the other hand, the abundances of all the species under all four phyla decreased sharply in the same period of time on soft substratum. It should also be noted that all the species under Porifera disappeared completely in this habitat. Historically, records of 18 species under the molluscan class Cephalopoda are present in the Sea of Marmara (Öztürk et al., 2014). Out of the 6 species observed in the 1950s, none of them could be recorded in 1999. Furthermore, out of the 6 Porifera species, 5 could never be observed in 1999.

Figure 3.3.

Change of abundance from 1950s to 1999 for the observed species in twelve classes (numbers in parenthesis show the number of species in each class).

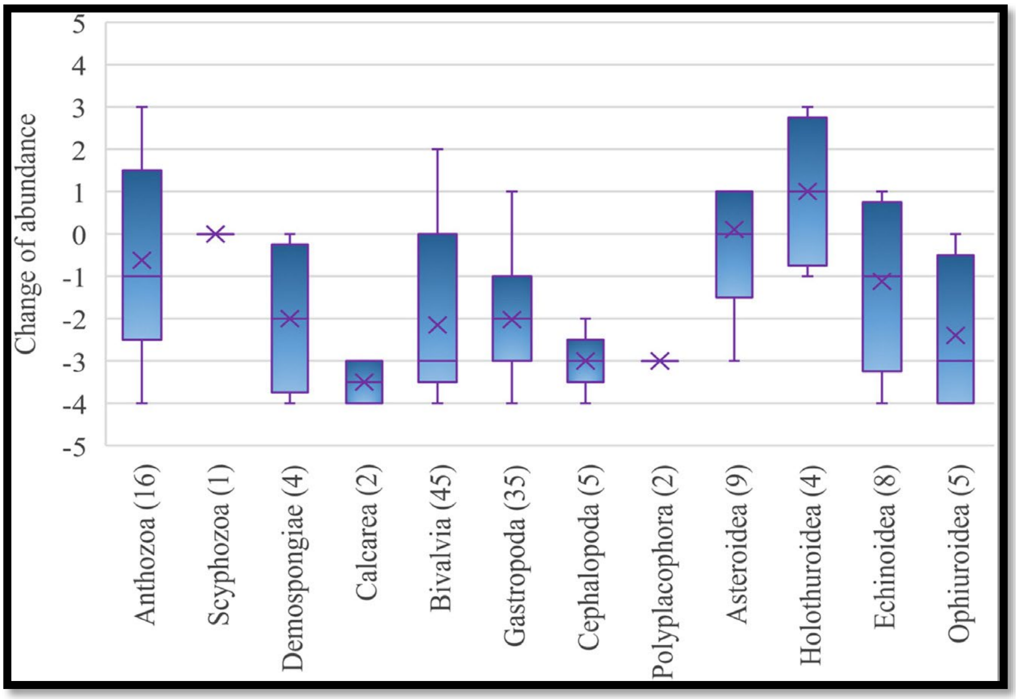
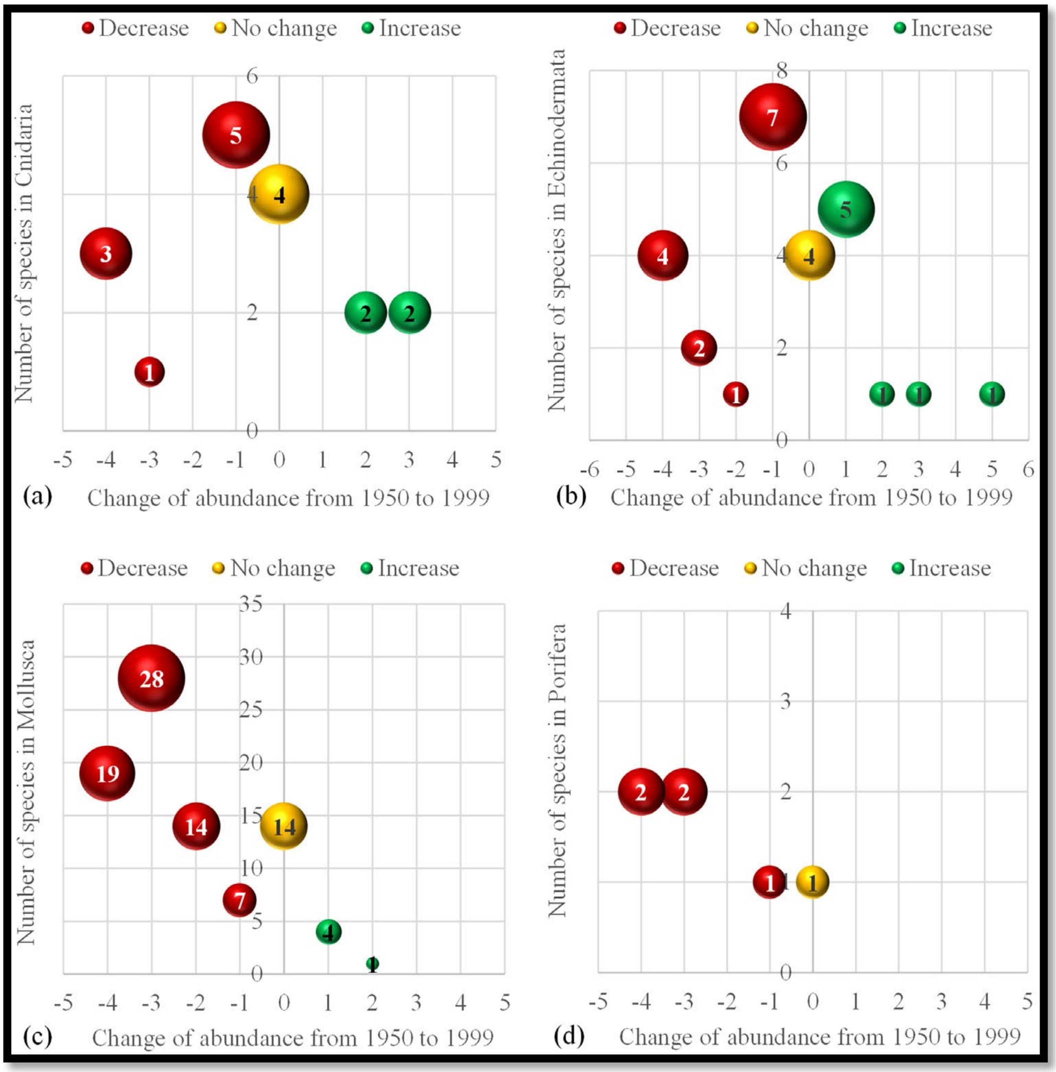


Figure 3.4.

Change of abundance from 1950s to 1999 for the observed species in: (a) Cnidaria, (b) Echinodermata, (c) Mollusca and (d) Porifera.



3.3.4. Recent species records

During the study (Huseyinoglu, 1999), we recorded 7 species that were not mentioned in the inventory compiled by Demir (1952). There were three species from the phylum Cnidaria: *Paramuricea clavata* was first recorded by Öztürk and Bourguet (1990). Since it is a common species attaching itself on the rocky reefs in the western Atlantic and the Mediterranean Sea, the species is likely a recent immigrant through the Aegean Sea. *Parazoanthus axinellae* is another common cnidarian with a distribution in the Atlantic and the Mediterranean Sea. Its first record in the Sea of Marmara dates back to the 19th century (Ostroumoff, 1896). Cereus pedunculatus is also a common cnidarian in the Atlantic Ocean and the Mediterranean Sea, however, the first record for this species in the Aegean Sea is by Coşar (1974) and in the Sea of Marmara by Gokalp (2011) in a field guide for recreational divers. Although it did not include a complete species description, its first mention in the Sea of Marmara is in fact by Huseyinoglu (1999).

Figure 3.5.

Number of species and their changes in abundance from 1950s to 1999 compared with the total number of species that are not observed but available in the checklist

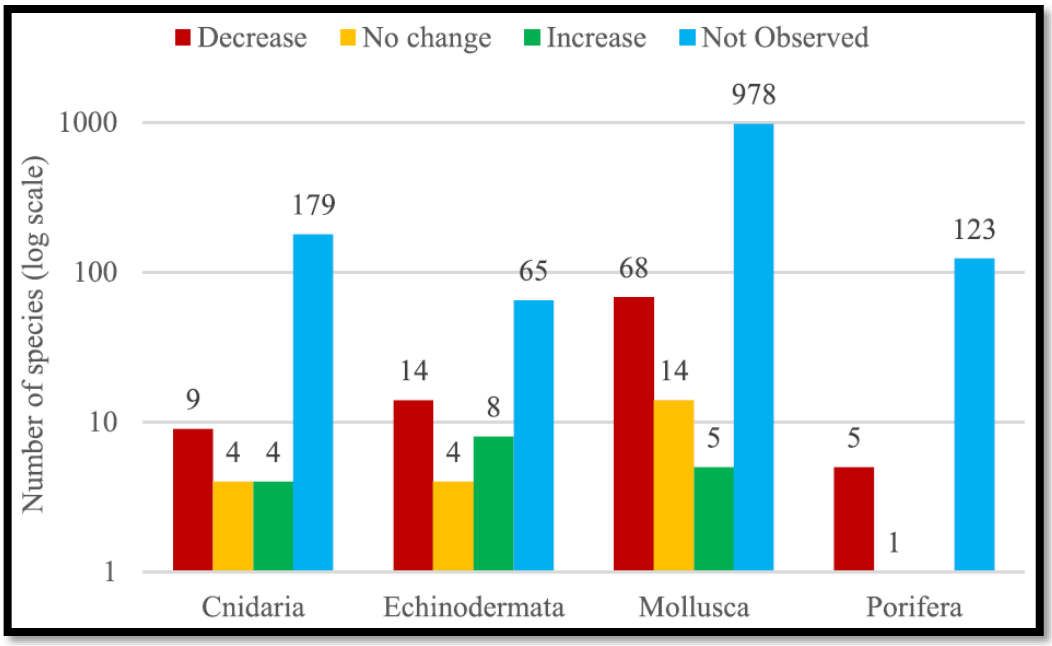


Figure 3.6.

Comparison of the number of species in the checklist that are observed and not observed according to (a) phylum and (b) year of first record

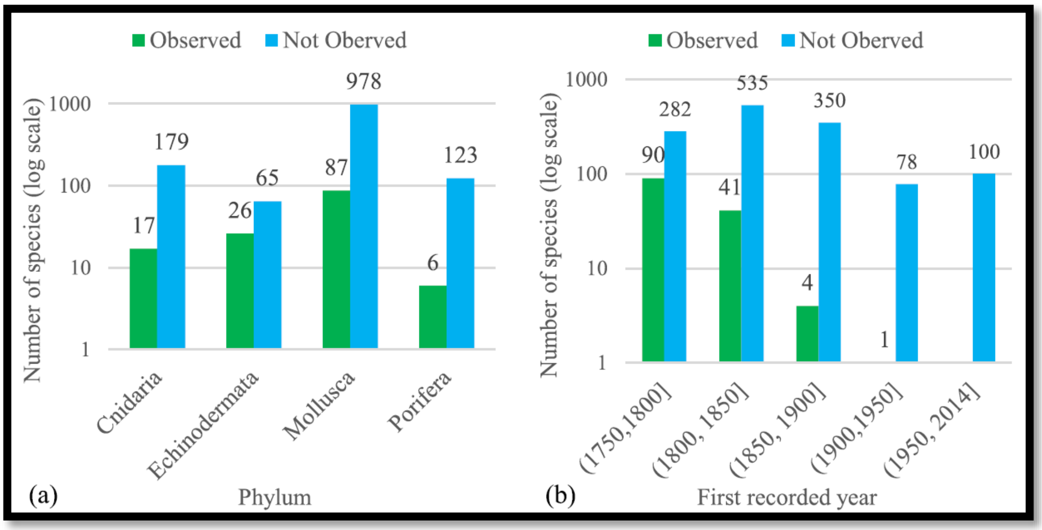


Figure 3.7.

Change of abundance from 1950s to 1999 for the observed species corresponding to the date of the first record year of the species

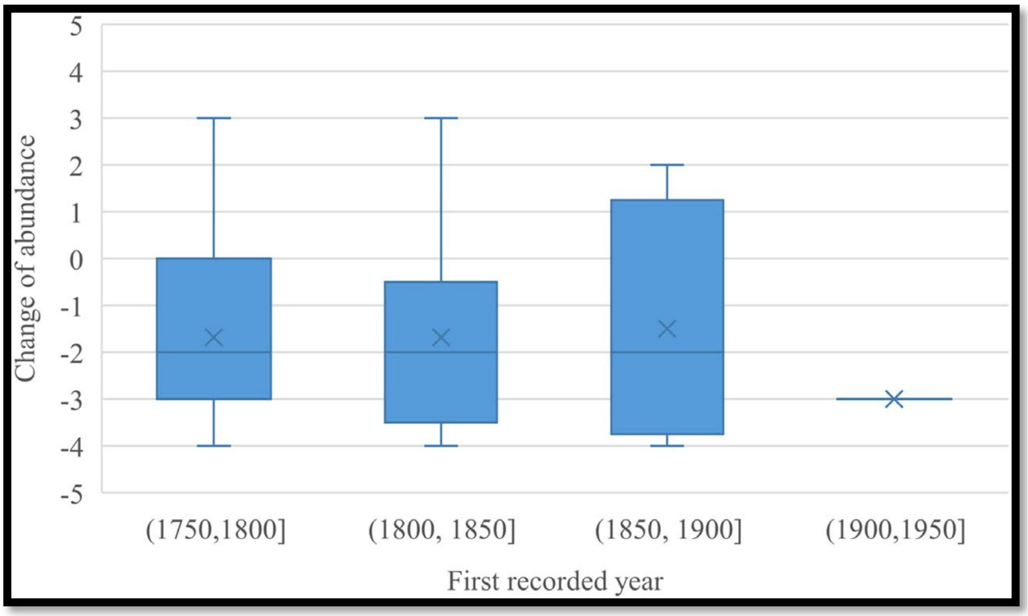
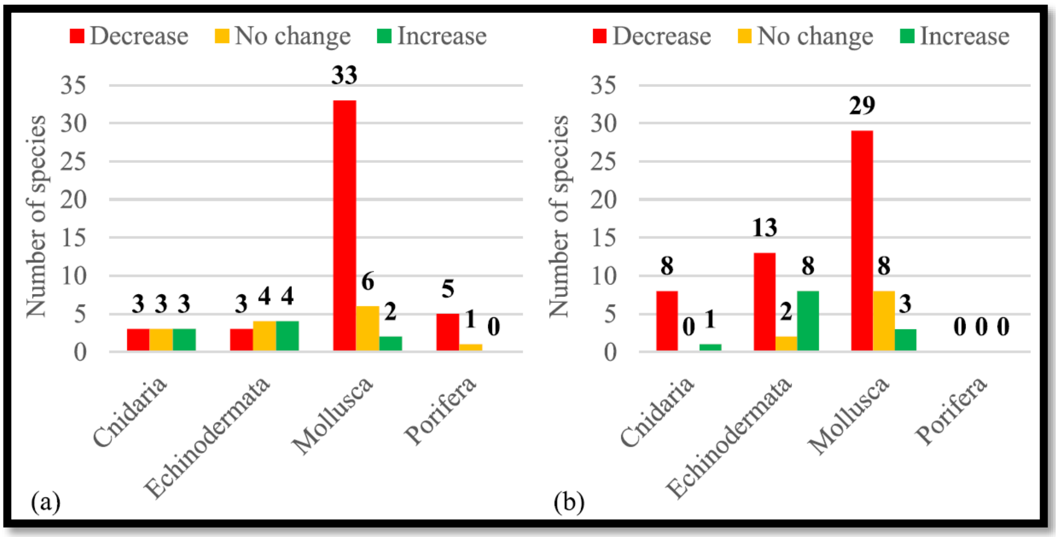


Figure 3.8.

Change of abundance from 1950s to 1999 for the observed species in the habitat (a) hard substratum, (b) soft substratum



Among the two species from the phylum Echinodermata, *Asterias rubens* is an invasive alien species, possibly transported via ballast as a larva from the northern sections of the Atlantic Ocean. Its first record from the Sea of Marmara is by Albayrak (1996), almost concurrently with the time of the study (Huseyinoglu, 1999) and in the Black Sea by Karhan et al. (2009). Since the larvae and the adults do not survive in temperatures above 20 ◦Celsius (Binyon, 2009; Villalobos et al., 2006), its distribution is limited to the Black Sea and the Sea of Marmara at the moment. The other echinoderm is the ‘‘edible sea cucumber’’ *Parastichopus regalis* with a distribution of the Mediterranean Sea, British Isles, Bay of Biscay, Mauritania and Gulf of Mexico. Its first record in the Sea of Marmara is from the 19th century by Colombo (1885). The remaining new additions are two molluscs, among which Atrina fragilis was first recorded in the Sea of Marmara and the Aegean Sea by Demir himself (Demir, 2003). We strongly believe that this species was misidentified in the 1950s by Demir, because it was rather common in our study (Huseyinoglu, 1999), which is in fact its first mention in the Sea of Marmara. Finally, *Rapana venosa*, an invasive alien species of large gastropod of Pacific origin, is believed to reach the Black Sea by means of attaching its wave action-resistant eggs or adults onto ship hulls (Fischer-Piette, 1960). It expanded its invasive range into the Sea of Marmara and was recorded concurrently by Albayrak and Balkıs (1996) before our study (Huseyinoglu, 1999). It is being collected by commercial divers for more than two decades for exportation purposes (Janssen et al., 2014).

A variety of new records among the four phyla in the Sea of Marmara was reported since the publication of the checklists (Çınar et al., 2014; Öztoprak et al., 2014; Öztürk et al., 2014; Topaloğlu and Evcen, 2014). A study in the easternmost basin (Isinibilir et al., 2015) identified 4 new Cnidarian species: *Podocorynoides minima*, *Koellikerina fasciculata*, *Gastroblasta raffaelei* and *Discomedusa lobata*. A scleractinian *Madracis pharensis* was collected from coralligenous and rocky habitats at five different sites in Dardanelles on the opposite side of the Sea of Marmara basin (Ozalp and Alparslan, 2015). A temperate northeastern Atlantic species of the hydrozoan *Aequorea vitrina* was recorded in the vicinity of Bosphorus strait and the Prince's Islands (Yilmaz et al., 2017). A recent study (Ocaña and Çinar, 2018) conducted in 24 stations through the Sea of Marmara described two new genera, 6 new species and three new anthozoans from Cnidaria: *Marmara musculata*, *Diadumune turcica*, *Calamactinia incubans*, *Charisactis tetiana*, *Epizoanthus arenaceus*, *Rolandia coralloides*, *Epizoanthus marmarensis* sp. nov., *Scolanthus mediterraneus* sp. nov., Virgularia sp. First record of the scyphozoan *Cotylorhiza tuberculata* in the Sea of Marmara was given near the Prince's Islands region (İşinibilir, 2020). Moreover, an unidentified Drymonema sp. was recorded in Istanbul, the first record from the genus in the Sea of Marmara (Öztürk, 2020).

A study in the soft bottom bathyal zones of the Sea of Marmara at two stations at 500 and 1000 m, identified two species (*Akritogyra conspicua* and *Liostomia hansgei*), which are new records for the marine molluscan fauna of Turkey and four species (*Benthonella tenella*, *Odostomia silesui*, *Syrnola minuta* and *Crenilabium exile*) are new records for the molluscan fauna of the Sea of Marmara (Doğan et al., 2016). The mythilid *Arcuatula senhousia* was first recorded in the Sea of Marmara (Öztürk et al., 2017). A study conducted in the shallow depths identified 12 new mollusc species:

Aplysia depilans, *Flabellina affinis*, *Dendrodoris grandiflora*, *Felimare orsinii*, *Limacia clavigera*, *Trapania maculate*, *Haminoea orbignyana*, *Haminoea orteai*, *Atys macandrewii*, *Philine angulata*, *Aglaja tricolorata*, *Pleurobranchus membranaceus* and *Thuridilla hopei* (Artüz et al., 2018). Another new record from the shallow *Cyctoceira barbata* beds, *Alvania mamillata* was reported recently (Bitlis, 2019).

Futhermore, a study conducted at 23 stations throughout the Sea of Marmara identified 12 new species from Porifera: *Ascandra contorta*, Paraleucilla magna, Polymastia penicillus, *Chalinula renieroides*, Haliclona (Halichoclona) fulva, Haliclona (Rhizoniera) sarai, *Raspailia (Parasyringella) agnata*, *Timea stellata*, *Crambe crambe*, *Pleraplysilla spinifera*, *Spongia (Spongia) nitens* and *Aplysilla sulfurea* (Topaloğlu, 2016). *Stelligera stuposa* was recorded which is a new record for the Sea of Marmara as well as Turkish sponge fauna (Topaloğlu, 2016).

Finally, only one new record claim from the phylum Echinodermata is present in the literature after the recent checklist (Öztoprak et al., 2014). *Diadema setosum*, an invasive alien lessepsian echinoid was first recorded in the Mediterranean Sea in Kas, Turkey (Yokes and Galil, 2006), and has invaded especially the southeastern part of the basin (Vafidis et al., 2021). It was claimed to be recorded in the eastern connection of the Sea of Marmara to the Aegean Sea (Artüz and Artüz, 2019). However, the figure supplied by the authors in their publication, which is the basis of their record, include two thermophilic species, the lessepsian mollusc *Cerithium scabridum* and native Mediterranean bivalve *Ostrea stentina*, with documented distributions up to the Aegean Sea in the north, which makes this record highly doubtful (Cinar et al., 2021; WoRMS, 2021). Moreover, shallow habitats in the Sea of Marmara including the straits system are excessively covered by dense alga populations and barren hard bottoms typical in the southern Aegean Sea coasts such as the supplied figure (Artüz and Artüz, 2019) do not exist in the Sea of Marmara.

3.4. Conclusion

As a consequence of the enormous population growth in Istanbul during the last 7 decades, marine biodiversity came close to a collapse. Anthropogenic factors responsible for this collapse are generally linked to one another and the common denominator to blame is this increase. Population led to urbanization and industrialization, enabling huge amounts of discharges into the Sea of Marmara. Rivers carried polluted sediment-rich waters into the sea, converting most of the habitats into mud and silt-covered plains, affecting mainly the sessile benthic species. Another short-term solution for the increase in visibility and odor problems due to discharges was the ‘‘Deep Sea Discharge’’ which in turn ruined the already damaged ecosystem. Although results of a recent study (Turkdogan-Aydinol et al., 2012) show that deep-sea discharges and sea currents contribute to the dilution of coliform concentration in a positive way, nearing rivers continue to carry the unwanted bacteriological load into the Sea of Marmara (Altuğ and Hulyar, 2020). Nevertheless, locations near coastal zones of the Prince’s Islands have acceptable values required by the regulations, pollution arising from sea discharge both at the Sea of Marmara and from the Black Sea is particularly responsible for the extreme contamination (Orhon et al., 2021).

Extreme recreational usage and coastal structural developments affected fragile habitats. Overfishing and overharvesting marine resources left irreversible damages to many fish and shellfish populations. Turkish nationally reported fisheries data, compared over a 50-year period from 1967 to 2016, documents the rapidly declining abundance of marine resources in the Sea of Marmara: 19 commercial fish species were extirpated (i.e., earlier present, and now absent from reported catch data), and another 22 species became commercially extinct (i.e., whose catch declined by 80.0–99.9%) (Ulman et al., 2020).

Growing maritime traffic, which is responsible for 71% of the transported invasive alien species via ballast waters and hull attachments into the region is the main vector of various colonizations (Cinar et al., 2021). Some of these species established their populations exceptionally well in the new habitat, such as *Rapana venosa*, which is presently found in all marine habitats ranging between the Black Sea and the north Aegean Sea (Yokeş, 1996), became so abundant that the species is collected by commercial divers to be directly exported (Janssen et al., 2014). Also, *A. rubens* is now the dominant species in the Prince's Island region and Bosphorus extensively feeding on various mollusc species including commercially important *Mytilus galloprovincialis*. Although it is difficult to hold the new species particularly responsible for changes in biodiversity, their impact might be far from negligible. Moreover, climate change took its toll: the warm-spell duration and the numbers of summer days, tropical nights, warm nights, and warm days have increased, while the cold-spell duration and number of ice days, cool nights, and cool days have decreased, the diurnal temperature range has increased across the whole Marmara Region, altering current regimes and converting habitats (Abbasnia and Toros, 2019). And very recently, the mucilage outbreak was the ''coup de grace'' to the extremely disturbed ecosystem, as a consequence of all the factors explained above.

Despite the huge differences in methodology and samplings between Demir's and our study, we believe that the two datasets were comparable in terms of abundance and location. Compiling all data from historical times to the present, we could analyze the most up-to-date inventory of all the species in four phyla: Cnidaria, Echinodermata, Mollusca and Porifera. We used exploratory data analysis, a data mining task, that can aid in the visual study of complex datasets, to observe the change of abundance levels and presence information of the species. Numbers demonstrated an unfortunate decreasing, if not a collapsing trend, which can in fact represent especially the benthic biodiversity in the Prince's Islands and Bosphorus region. Moreover, it is also possible that we never encountered some species because they became extremely rare. Another factor to be taken into account is the fact that most species in these 4 phyla are cryptobenthic, so it is extremely difficult to see them during scuba dives opposite to random samplings with beam trawl or dredge, so it is quite complicated to make a full comparison. Nonetheless, we present one of the most comprehensive and up-to-date analysis of the benthic invertebrate biodiversity among 4 phyla in the Sea of Marmara.

Chapter IV

Mediterranean and Black Sea Records of Marine Alien, Cryptogenic, and Neonative Species (2023)

BioInvasions Records, https://doi.org/10.3391/bir.2020.9.2.01

4.1. Introduction

Biological invasions have been a major focus of marine scientists and managers in the Mediterranean and Black Seas because of their severe impacts on marine biodiversity and ecosystem services (Micheli et al. 2013; Katsanevakis et al. 2014a, b; Azzurro et al. 2019; Tsirintanis et al. 2022). Furthermore, an increasing number of neonative species (i.e., range-expanding species that track human-induced environmental change; sensu Essl et al. 2019) have invaded the Mediterranean Sea through the Gibraltar Strait or the Black Sea through the Dardanelles Strait and the Sea of Marmara (e.g., Azzurro et al. 2022). Facilitated by climate change, alien and neonative species have contributed to great shifts in native ecosystems (Katsanevakis et al. 2018; Albano et al. 2021; Steger et al. 2021), the gradual tropicalization of the Mediterranean Sea (Bianchi and Morri 2003; Por 2009; Bianchi et al. 2018; Peleg et al. 2020), and mediterranization of the Black Sea (Kideys et al. 2000; Boltachev and Karpova 2014; Eyuboglu 2022). The latest reviews report a 40% increase in the established alien species in the Mediterranean Sea since 2010 and a steady increase in the Black Sea over the last five decades (Băncilă et al. 2022; Zenetos et al. 2022). Thus, the need arises for an improved theoretical and practical understanding of range shifts and biological invasion dynamics through space and time, the mechanisms of related impacts, and the functional role of alien and neonative species as drivers of change in the Mediterranean and Black Seas. This will contribute to effective regional conservation planning (Mačić et al. 2018) and prioritizing and implementing effective mitigation actions (Giakoumi et al. 2019), aiming to protect biodiversity and safeguard marine ecosystem services.

Although appropriate spatio-temporal data and information on the ecological characteristics of species are a prerequisite for effective management, they are often deficient in the Mediterranean and Black Seas (Levin et al. 2014). Hence, updated geo-referenced alien species records are valuable for assessing new species invasion progress and temporal dynamics (Katsanevakis et al. 2020a). Alien species records are often published when considered “first records” within a geographical region but rarely when a species is observed within its already documented invasion range. Consequently, spatio-temporal data of great value to researchers and managers remain unpublished and scattered in various repositories or personal files. Such information becomes even more valuable considering that the Mediterranean is warming at exceptionally high rates in comparison to the global ocean (Schroeder et al. 2016; Cramer et al. 2018; Pisano et al. 2020), whereas native species are becoming locally extinct (Rilov 2016; Albano et al. 2021) and may suffer high mortalities due to elevated temperatures and marine heatwaves (Garrabou et al. 2022). Consequently, even more suitable conditions are created for species of warm-water affinity to invade and replace native fauna (Bianchi et al. 2019).

A recent collective effort to compile such spatio-temporal information was made by Katsanevakis et al. (2020a). In that effort, 126 marine scientists from 16 countries contributed 5376 records of 239 alien and cryptogenic taxa from the Mediterranean, including one Mediterranean first record and nine first country records. Following that effort and expanding the geographical scope to cover the Black Sea, an invitation to submit unpublished alien, cryptogenic, and neonative species records was sent to marine scientists from all Mediterranean and Black Sea countries. This effort aimed to compile a second large open-access collective dataset, complementing existing information on alien and cryptogenic species in the region.

4.2. Dataset compilation

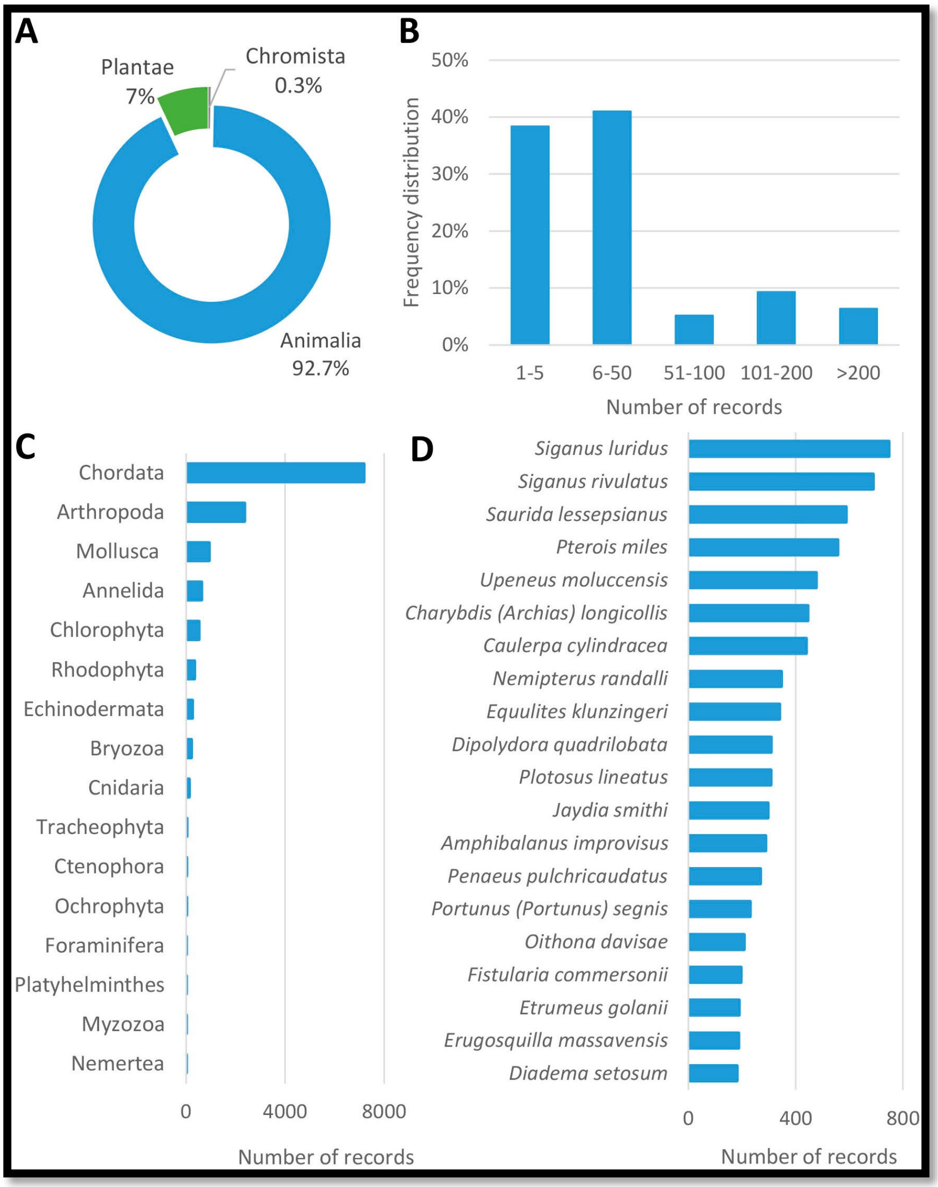
Overall, 173 scientists from 23 countries submitted their data, compiling a dataset of 12,649 records (see Supplementary material Table S4). Each Excel sheet line represents a specific record in space and time with relevant information. The required fields for each record were species name, species status, latitude, longitude, country, year, the observer of the record, the type of observation, and how it had been documented. “Status” refers to biogeographic status and was based on Zenetos et al. (2022) for Mediterranean records, Băncilă et al. (2022) for Black Sea records, and species-specific literature for debatable cases. “Status” took four possible values: “Alien” (sensu Essl et al. 2018), “Neonative” (sensu Essl et al. 2019), “Cryptogenic” (i.e., of uncertain biogeographic status; Carlton 1996; Essl et al. 2018) and “Data deficient” (for taxa for which an assessment of biogeographic status is unfeasible because of the lack of data; Essl et al. 2018). The “Observer” column has the name of the marine scientist(s) who identified the species. Records that a citizen-scientist had shared through an online platform like “Is it Alien to you? Share it!!!” (Giovos et al. 2019), personal communication, or a questionnaire are listed within brackets in the same column or within the “Comments” column. Only records adequately verified by scientists have been included; citizen science records that were not verified by marine experts were excluded.

“Type of observation” refers to the identification process for each record. Observations can be visual with or without photographic evidence (e.g., during SCUBA surveys or photo/video taken by a citizen), collected specimens by scientists, or even, for some fish species with no identification difficulties, answers to questionnaires by fishers.

Moreover, additional optional fields were available to include further information, exact or approximate date, depth of observation/collection, habitat, number of individuals observed or per cent substratum cover, and additional comments.

Figure 4.

Taxonomic coverage of the dataset



Note. (A) distribution pool by Kingdom; (B) frequency distribution of the number of records per species; (C) records by Phylum; (D) records by species (for the twenty most frequently observed species).

4.3. Taxonomic coverage

The compiled dataset included 247 taxa, of which 217 (88.38%) were Animalia, 25 (9.54%) Plantae, and 5 (2.08%) Chromista. Alien taxa were the majority (198); 31 species were classified as cryptogenic, 17 as neonative, and one as data deficient. Most records belonged to Animalia (92.7%), followed by Plantae (7%), and Chromista (0.3%) (Figure 4A). Most taxa (41%) were recorded between 6 and 50 times, while 37.3% less than six times (Figure 4B). In terms of Phyla, Chordata had the most records (7,180), followed by Arthropoda (2,359), Mollusca (925), and Annelida (621) (Figure 4C). Ninety per cent of the taxa were reported from 5 countries (Israel, Greece, Romania, Cyprus, and Italy). The five species with the highest number of records were all Osteichthyes, namely *Siganus luridus* (Rüppell, 1829) (748), *Siganus rivulatus* Forsskål & Niebuhr, 1775 (689), *Saurida lessepsianus* Russell, Golani & Tikochinski, 2015 (589), *Pterois miles* (Bennett, 1828) (557), and *Upeneus moluccensis* (Bleeker, 1855) (477) (Figure 4D). Identification was based on collected specimens for 61% of the records in the dataset, only visually for 29.1% (either in situ or through photos/video), and through questionnaires to fishers for 9.8%.

4.4. Spatial and temporal coverage

The temporal coverage of observations extended from 1973 to June 2022. Records between 2014 and 2021 constituted 95.2% of the dataset, with most from 2020 (3,026), followed by 2021 (2,520) and 2014 (1,410) (Figure 4.1A). Regarding spatial coverage, records came from 23 countries, with 11,119 records from the Mediterranean and 1,530 from the Black Sea (the latter also includes the Sea of Marmara and the Istanbul Strait). The highest number of records were reported from Israel (5,304), Greece (2,900), Romania (1,365), Cyprus (744), and Italy (727) (Figure 4.1B). The species reported in most countries were *Callinectes sapidus* Rathbun, 1896 (11), *Caulerpa cylindracea* Sonder, 1845 (10), *Brachidontes pharaonis* (P. Fischer, 1870) (9), *Siganus luridus* (9), and *Pinctada radiata* (Leach, 1814) (9) (Figure 4.1C).

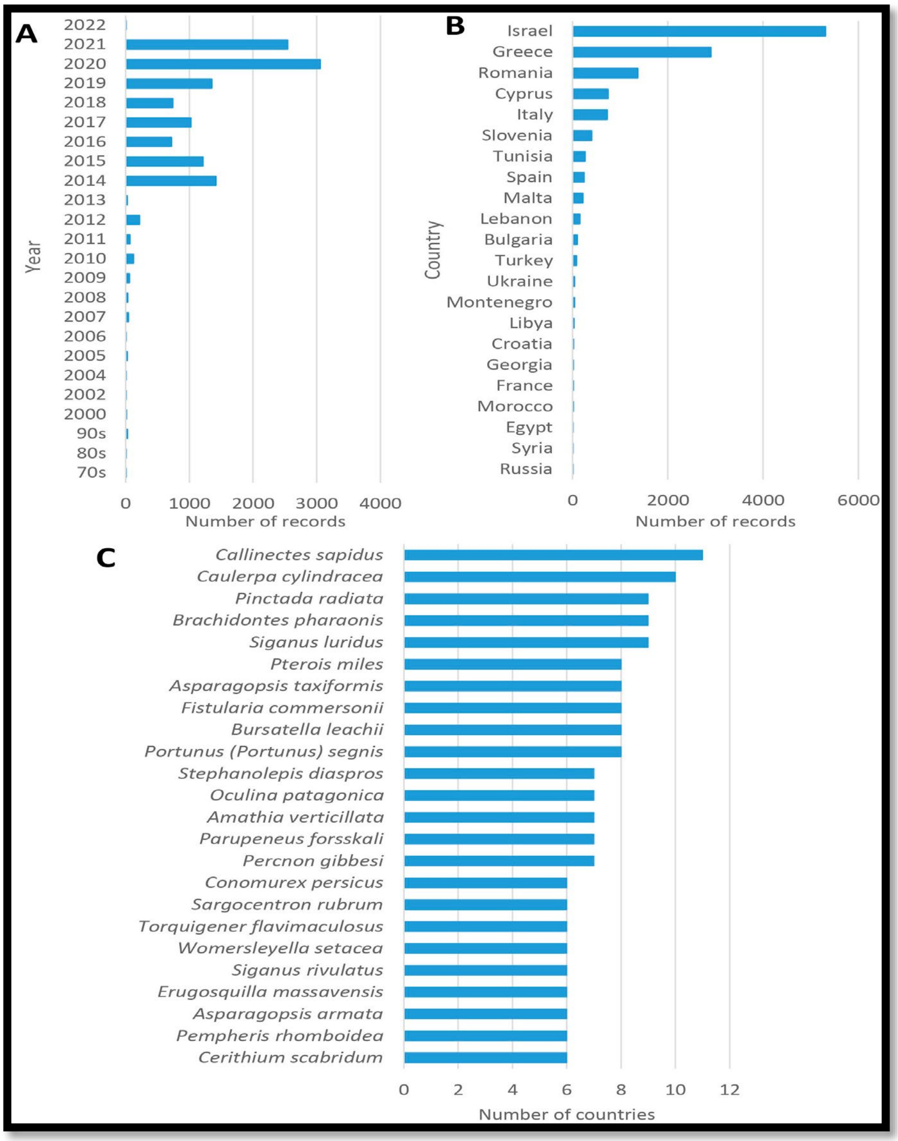
The records were unevenly distributed in the study area, as their spatial distribution is not only driven by the actual distribution patterns of the targeted taxa but is also influenced by the spatial variability of sampling effort and methodology and the uneven distribution of participating experts. A high concentration of records in the dataset is observed along the coast of Israel, in the South Aegean Sea and Cyprus, along the Romanian coast, but also, to a lesser extent, in Malta, Slovenia, and the Venice lagoon (Italy). Conversely, records were scarce along the Mediterranean coast of France, North Africa (except Tunisia), and the Black Sea coastlines of Turkey and Russia (Figure 4.2).

4.5. Remarkable new records of alien species

Among the records in the dataset, 20 are of particular importance. Most notably, the fish *Lethrinus borbonicus* Valenciennes, 1830 is reported for the first time in the Mediterranean (Tunisia), and the fish *Pomatoschistus quagga* (Heckel, 1837), the macroalgae *Caulerpa cylindracea* Sonder and *Grateloupia turuturu* Yamada, and the copepod *Misophria pallida* Boeck, 1865 are reported for the first time from the Black Sea (Crimea; Turkey; Romania). In addition, the red alga *Kapraunia schneideri* (Stuercke & Freshwater) Savoie & G.W. Saunders is reported for the first time in the Levant Sea (Israel; second time in the Mediterranean Sea). The polychaetes *Pseudonereis anomala* Gravier, 1899 and *Prionospio depauperata* Imajima, 1990 are reported for the first time in the Sea of Marmara (Turkey). Moreover, 12 first country records are included in the dataset: *Ampithoe valida* S.I. Smith, 1873 (Italy), *Amathia verticillata* (delle Chiaje, 1822) (Montenegro), *Antithamnion amphigeneum* A. Millar (Greece), *Clavelina oblonga* Herdman, 1880 (Slovenia and Tunisia), *Epinephelus fasciatus* (Forsskål, 1775) (Tunisia; third record in the Mediterranean Sea), *Dendostrea cf. folium* (Linnaeus, 1758) (Syria), *Ganonema farinosum* (J.V.Lamouroux) K.-C.Fan & Y.-C.Wang (Montenegro), *Marenzelleria neglecta* Sikorski & Bick, 2004 (Romania), *Macrorhynchia philippina* Kirchenpauer, 1872 (Tunisia), *Paratapes textilis* (Gmelin, 1791), and *Botrylloides diegensis* Ritter & Forsyth, 1917 (Tunisia).

Figure 4.1.

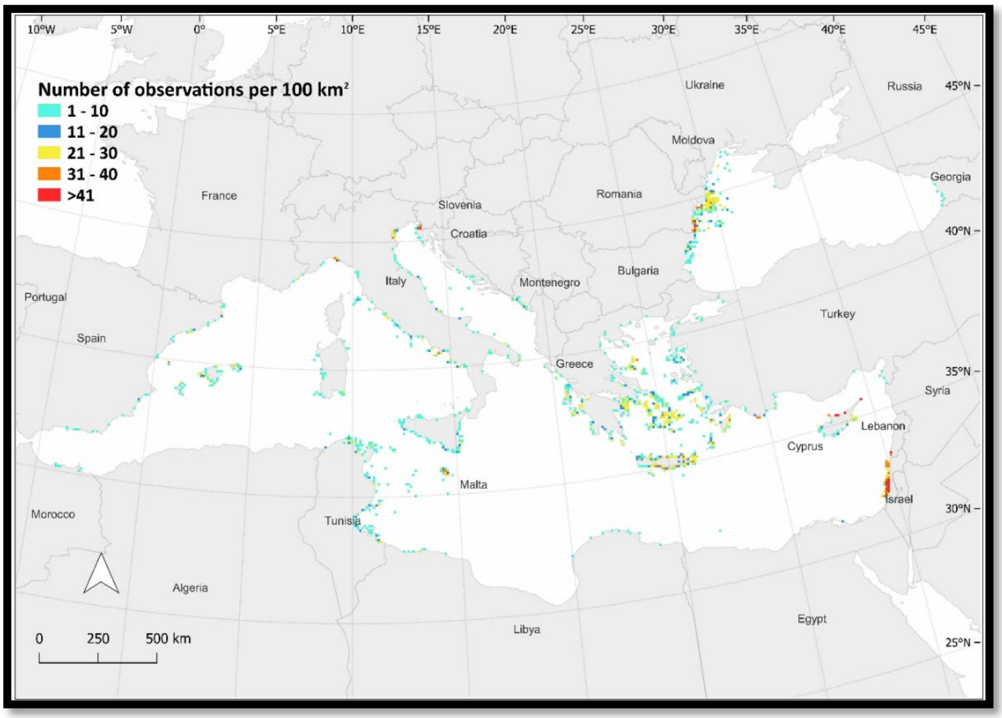
Spatio-temporal coverage of the dataset



Note. (A) temporal distribution of records; (B) records per country; (C) country-coverage of species (for species recorded in more than 5 countries).

Figure 4.2.

Number of aliens, cryptogenic and neonative records



Note. per 10 km × 10 km grid cell, included in the dataset.

The snubnose emperor *Lethrinus borbonicus* is the first representative of its genus in the Mediterranean Sea (Golani et al. 2021). It originates from the Western Indian Ocean, including the Red Sea and Arabian (Persian) Gulf to Reunion, and primarily occurs in sandy areas near reefs at depths of around 40 m (Carpenter and Allen 1989). The herein-reported specimen (Figure 4.3A) was captured on 20 March 2020 near the Marine Protected Area (MPA) of Zembra Island (eastern Tunisia) (37.11883°N; 10.7755°E) by a local fisher using gillnets at 75 m depth on a sandy bottom. It measured 203 mm in total length and weighed 122.6 g. The integrative taxonomic approach carried out on the sample confirmed the putative morphological identification. In particular, a 611 base pairs fragment of the cytochrome c oxidase subunit I (COX1) gene was amplified (GenBank accession number: OL441769), yelding a > 99% similarity with sequences of *L. borbonicus* from the Gulf of Suez (accession number: LC543919– LC543921), but also a 98–99% overlap with samples attributed to the congeneric species *L. lentjan* and *L. mahsena*. However, the inner surface of the pectoral fin base of the Zembra's specimen was covered with scales, thus excluding *L. lentjan*, and the specimen was characterized by

5½ longitudinal scale rows between the lateral line and the base of middle dorsal spines, thus excluding *L. mahsena* (that has 4½) (Carpenter and Allen 1989). Shipping is a potential pathway of introduction of this species around the Zembra MPA.

Figure 4.3.

Remarkable new records included in the dataset

Note. (A) *Lethrinus borbonicus*, a first record in the Mediterranean Sea, observed in Tunisia, recorded by Jamila Ben Souissi; (B) first record of *Pomatoschistus quagga* in the Black Sea, recorded by Evgeniia Karpova and Elena Slynko.

The quagga goby *Pomatoschistus quagga* is a small, benthic goby, often associated with seagrasses in the coastal zone of the northern and western parts of the Mediterranean Sea, including the Adriatic and Aegean Seas (Kovačić 2003). Among individuals of the genus *Pomatoschistus caught* with a hand net in June 2018 in the bay of Sevastopol in the Black Sea (44.574698°N; 33.404630°E), and after fixing it in 96% ethanol, one quagga goby was identified through an integrative taxonomic approach (Figure 4.3B). In particular, a 524 base pairs fragment of the 16S ribosomal ribonucleic acid

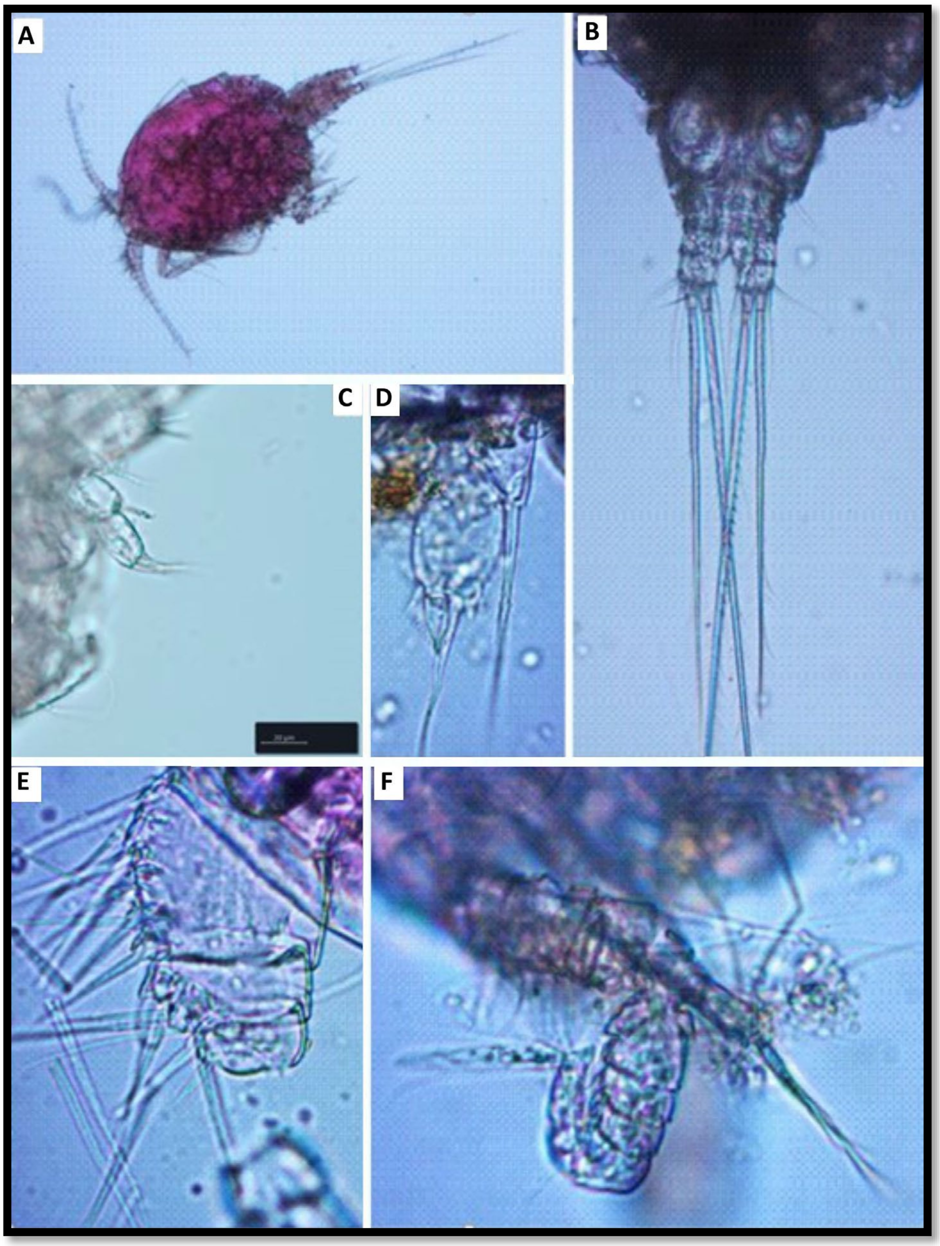
(16S rRNA) was amplified (GenBank accession number: MK457224), yelding > 97% similarity with three congeneric species, namely *P. bathi*, *P. minutus*, and *P. quagga*. However, its morphological features clearly pointed to *P. quagga*. In fact, it differred significantly from *P. minutus* in the number of scales of the lateral rows (32 versus more than 55) and it was characterized by the infraorbital row b that did not extend anteriorly below the infraorbital row a (versus *P. bathi* that is characterized by the infraorbital row b ending anteriorly under the infraorbital row a) (Kovačić 2008). This sighting constitutes the first record of *P. quagga* in the Black Sea. The preferred habitat of Pomatoschistus species, and specifically their epibenthic shallow-water lifestyle in open areas with soft substrates, implies that these fish rarely enter new water bodies. Like *Pomatoschistus bathi* Miller, 1982, the most probable vector for penetration of the quagga goby into the Black Sea is the natural introduction of planktonic larvae by the surface current, following the changing climate and the mediterranization of the Black Sea (Boltachev et al. 2016). Thus, the species should be considered as neonative in the basin.

Misophria pallida is a hyperbenthic neritic copepod species in the Order Misophroida (Family Misophriidae Brady, 1878), widely distributed in the NE Atlantic, Mediterranean, and Red Sea. Despite Misophrioids apparent wide occurrence, they are quite rare with Boxhall (1984) stating that “most copepod workers have probably never seen one”. Misophroids present a peculiar combination of both podoplean body segmentation and gymnopleanlike characters, providing pieces of evidence for their ancestral evolution. Herein, we report the first record of M. pallida (Figure 4.4) in the Black Sea (44.75887°N; 30.11173°E) in six samples collected in June 2020 at depths of 50–55 m on mixed sediments (mud and shells). In total, 21 males, 12 females (five of which were ovigerous), and six juveniles were identified. This suggests that the species could develop large populations in Black Sea offshore deep habitats. We assume that the species entered the Black Sea only recently, possibly following an unusual climate-driven event that affected the subsurface circulation of the Mediterranean inflow into the Black Sea or through shipping. The recent first record of the hydrozoan *Podocorynoides minima* (Trinci, 1903) in the Black Sea, made in the summer of 2020, which could also have entered from the Mediterranean Sea (Muresan et al. 2021), supports our assumptions.

Two macroalgae reported from the Sea of Marmara, *Caulerpa cylindracea* and *Grateloupia turuturu*, are here first recorded from the Black Sea. Both species are included in the proposed inventory of alien marine species with reported moderate to high impacts on biodiversity and ecosystem services in the Mediterranean Sea (Tsirintanis et al. 2022). The green alga *C. cylindracea* ranks first among the ten worst invasive species in terms of reported negative impacts on biodiversity. It was first reported in the Mediterranean Sea from Tunisia in 1985 (Hamza et al. 1995). It is now widespread throughout the Mediterranean Sea, becoming one of the most invasive species of the basin (Verlaque et al. 2015; Katsanevakis et al. 2016; Zenetos et al. 2017; Morri et al. 2019), although its population dynamics are not yet fully understood (Piazzi et al. 2016). Çinar et al. (2021) have monitored the distribution of *C. cylindracea* along the Aegean coasts of Turkey since 1993 and noticed its considerable range expansion towards the northern Aegean Sea (Güreşen et al. 2015). The species was detected on 28 February 2020 in the Dardanelles Strait, Turkey (40.0464°N; 26.3463°E) on rocky substratum (Figure 4.5A). The rhodophyte *Grateloupia turuturu* was first detected in the Mediterranean Sea in southern France in 1982 (Riouall et al. 1985) and has spread across the Mediterranean basin (Verlaque et al. 2015). It reached the Turkish coasts of the Aegean Sea in 2015 (Çinar et al. 2021). This red alga was often misidentified as *Grateloupia doryphora* (Montagne) M.Howe (Verlaque et al. 2015). *Grateloupia turuturu* was detected on 26 June 2021 in the Sea of Marmara (40.4008°N; 27.9145°E) on rocky substrata where it was abundant at 0–1 m depth (Figure 4.5B).

Figure 4.4.

First record of Misophria pallida *in the Black Sea, recorded by Muresan Mihaela*

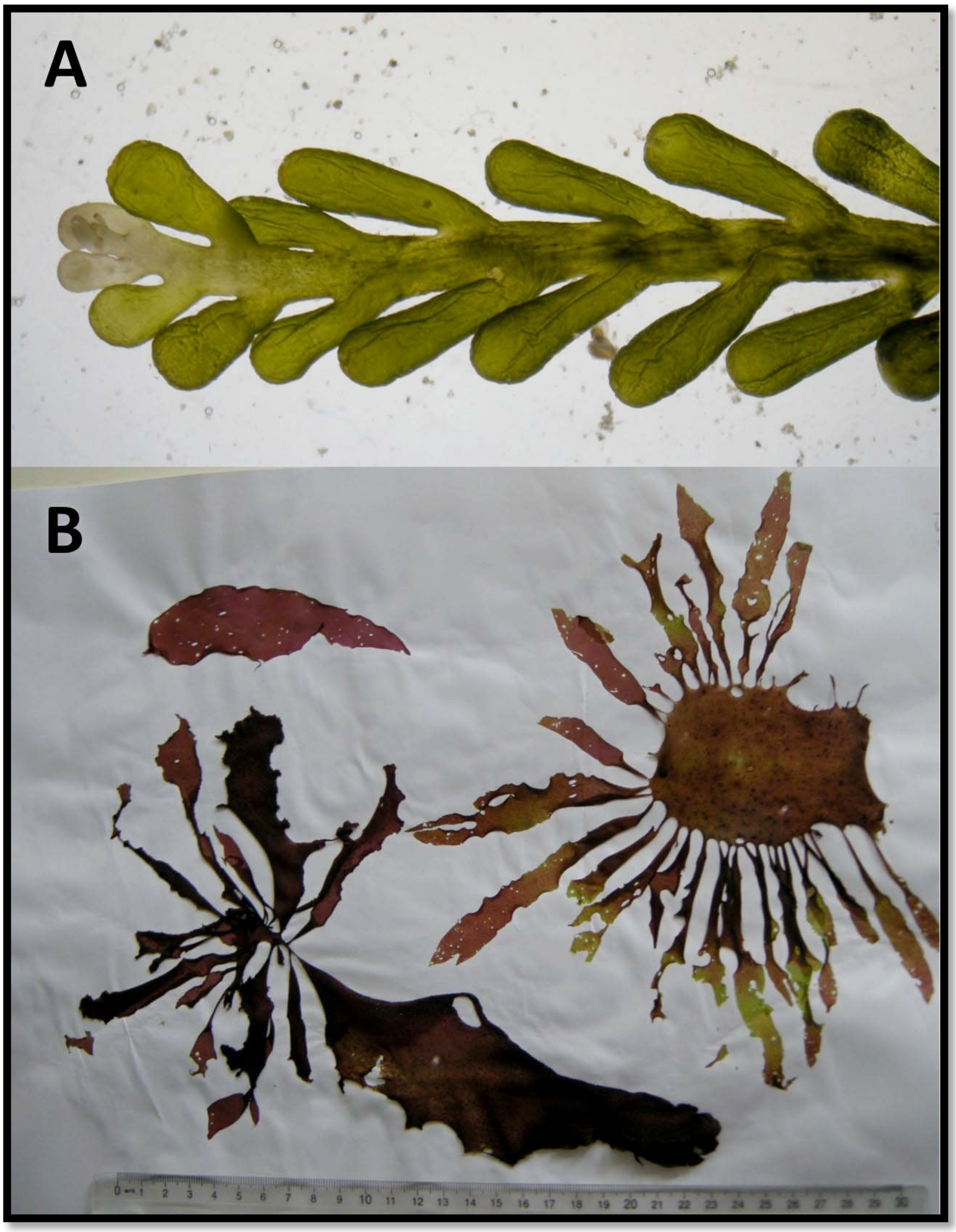


Note. (A) *M. pallida* male; (B) male abdomen and furca; (C) male P5 and P6; (D) detail P5 (protopodal segment with outer basal seta and 2 setae on inner distal margin); (E) geniculate part of A1 male; (F) details of 13 segmented A1 male.

Kapraunia schneideri (previously *Polysiphonia schneideri*) (see Díaz-Tapia et al. 2013), is a marine red alga that has a mainly central-western Atlantic and Caribbean distribution (Guiry and Guiry 2019). Since its erection, this species was collected from the northwestern Atlantic in Connecticut and the central-eastern Atlantic in southwestern Spain (Stuercke and Freshwater 2010; Díaz-Tapia et al. 2013). The first reported introduction of this Atlantic native species from the Mediterranean was from the north Adriatic Sea, specifically the Venice Lagoon, in 2016 (Wolf et al. 2018). However, in February 2014, specimens were collected from wave breaker rocks inside the marina of the city of Ashkelon, located on the southern Levantine Mediterranean shore of Israel (31.68080°N; 34.55400°E). These sterile specimens were initially identified as *Polysiphonia denudata* (Dillwyn) Greville ex Harvey based on cross-sections of the thallus showing six pericentral cells surrounding each central siphon. Further study of the reproductive and vegetative morphology of some newly collected specimens from the same site indicated that the tetrasporangia of this species are not spirally arranged and that the basal portion of the axes is ecorticated. Other vegetative features that agree with the species description of *K. schneideri* (Stuercke and Freshwater 2010; Díaz-Tapia et al. 2013) are: plants are up to 8 cm long, attached to rocks by rhizoids (Figure 4.6A) that grow from short, decumbent basal parts; rhizoids are cut off from pericentral cells (Figure 4.6C), and segments (Figure 4.6D) have six or seven (Figure 4.6B) pericentral cells. Molecular identification of specimens collected from the marina of Ashkelon in February 2020 (GenBank accession number: OP797406) confirmed the morphological identification. The fact that *K. schneideri* was found in harbours and marinas in the Venice Lagoon, in Barbate (Spain), and Ashkelon (Israel) (present work) points to vessels and recreational boats as the vectors of introduction of this species in the Mediterranean Sea.

Figure 4.5.

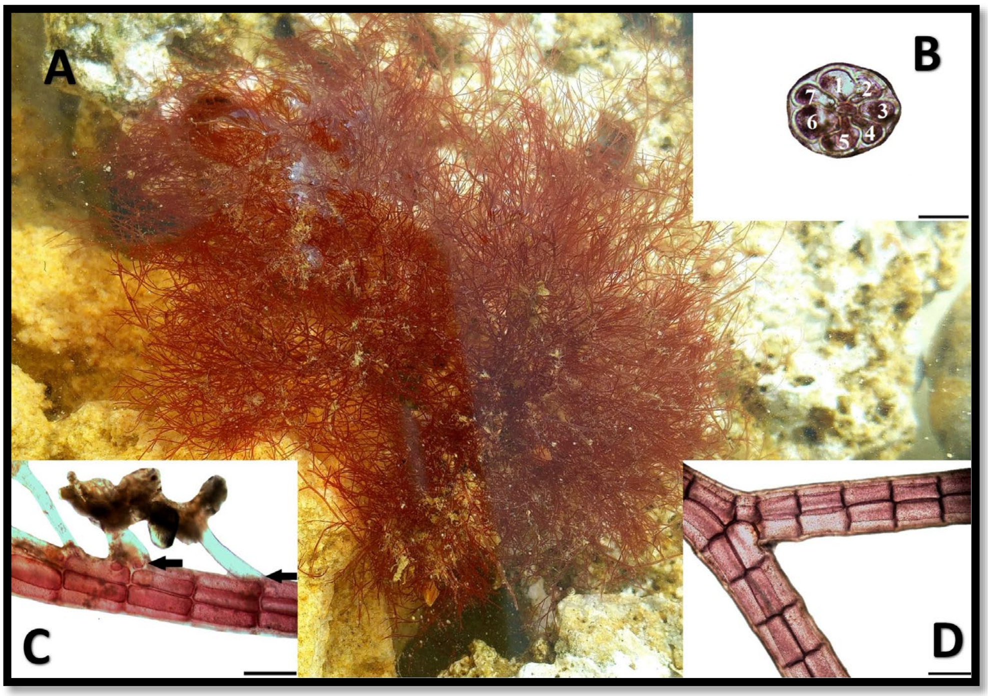
Remarkable new records included in the dataset



Note. (A) *Caulerpa cylindracea*, a first record for the Black Sea reported by Ergün Taşkın; (B) *Grateloupia turuturu*, also a first record for the Black Sea reported by Ergün Taşkın.

Figure 4.6.

Kapraunia schneideri

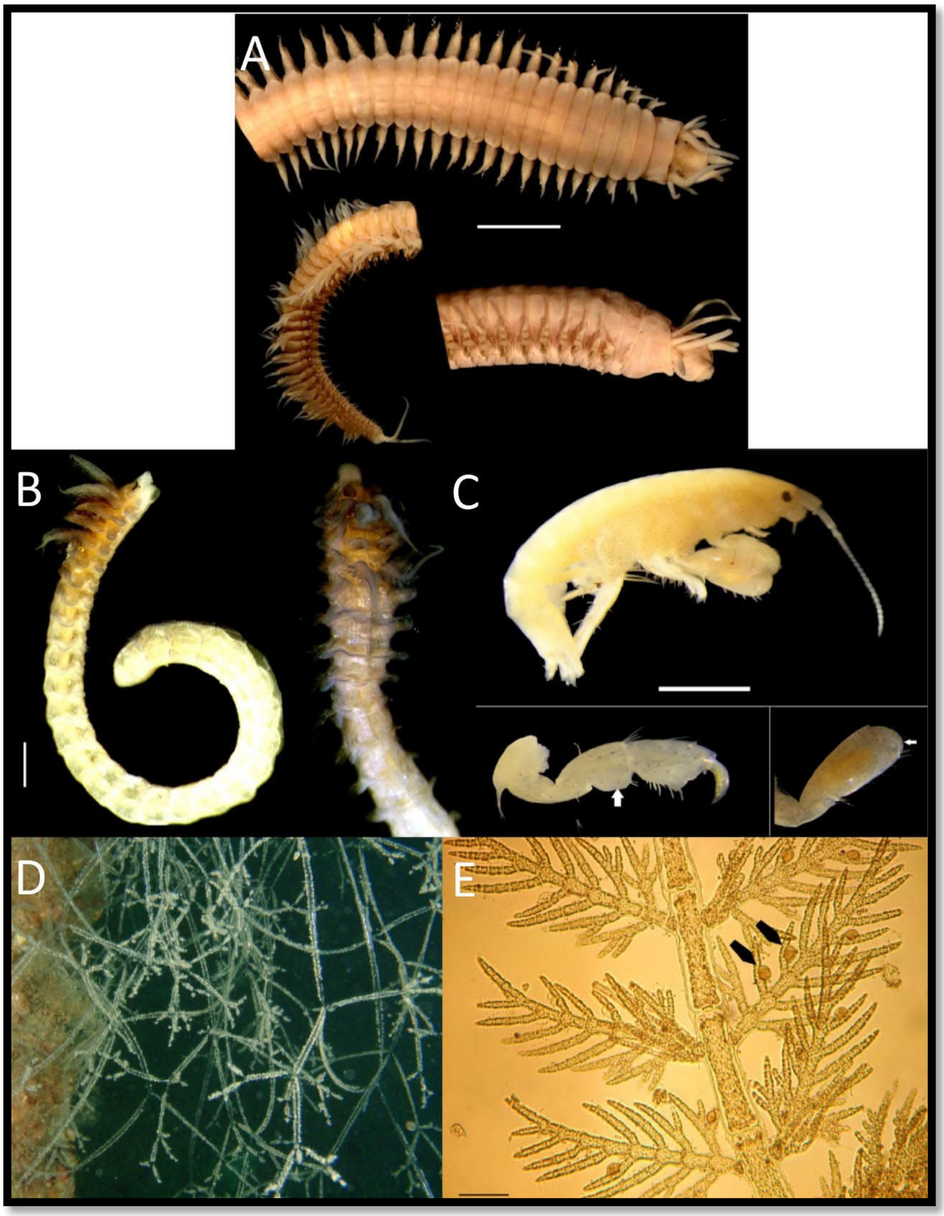


Note. (A) in situ; (B) Seven pericentral cells per segment of thallus; (C) Indicating rhizoids cut off from pericentral cells (arrows); (D) Segmented thallus; Sterile plant, scale bars 100 µm; a first record in the Levantine Sea, Israel and second in the Mediterranean Sea, recorded by Razy Hoffman.

Pseudonereis anomala is a nereidid species of Indo-Pacific origin, also found in the Red Sea. In the Mediterranean, it was first reported from the coast of Alexandria, Egypt, by Fauvel (1937) and has since expanded widely to become the most successful alien nereidid species in the Mediterranean Sea (Kurt et al. 2021). Ten *P. anomala* individuals were extracted from an assemblage dominated by *Mytilus galloprovincialis* Lamarck, 1819 and sampled just below the water surface on 21 December 2018, near the South entrance of the Istanbul Strait (41.02870°N; 28.98830°E). The morphological features of the specimens examined agreed with the original and subsequent descriptions of *P. anomala* (Figure 4.7A). This species is mainly characterized by homogomph falcigers in the notopodia, dorsal cirrus subterminally, a dorsal ligule foliose (twice longer than wide) and markedly longer than median ligule in posterior chaetigers, areas VI with cones only, and few paragnaths on areas VII–VIII (up to 20 paragnaths in a single band). *Pseudonereis anomala* is a new species to the marine fauna of Marmara Sea and the Straits System (Bosphorus).

Figure 4.7.

Remarkable new records included in the dataset



Note. (A) *Pseudonereis anomala* and (B) *Prionospio depauperata*, first records in the Sea of Marmara by Ertan Dağlı; (C) *Ampithoe valida* from the Venice Lagoon, top: male specimen (scale bar: 1 cm), low left: gnathopod 1 (the arrow indicates carpal lobe), low right: gnathopod 2 (the arrow indicates the process stemming from the central part of the propodus palm), first record from Italy by Agnese Marchini and Renato Sconfietti; (D) *Amathia verticillata*, a first record for Montenegro by Slavica

Petović; (E) *Antithamnion amphigeneum*, a first record from Greece by Konstantinos Tsiamis, whorlbranches (pinnae) with gland cells born adaxially (black arrows). Scale bar = 40 µm.

Prionospio depauperata was described from the coast of Japan by Imajima (1990). It was reported for the first time in the Mediterranean Sea in Izmir Bay (Dagli and Çinar 2009) and later found along the Levantine coast of Turkey (Çınar et al. 2014). On 13 December 2019, eight further specimens were collected near the south entrance of the Istanbul Strait (41.02130°N; 28.97630°E) at 15 meters depth, fixed and identified morphologically. The morphological features of the specimens examined agree with the original and subsequent descriptions of *P. depauperata* (Figure 4.7B). This species is mainly characterized by pinnate branchiae on chaetigers 2 and 5 and apinnate branchiae on chaetigers 3 and 4, large posterior eyes, dorsal crests extending from chaetigers 7 to 16, and no dorsolateral skin folds. It is a new species to the marine fauna of the Marmara Sea and the Bosporus Straits System.

Ampithoe valida Smith, 1873 (Figure 4.7C) is known from the Atlantic coast of North America (Pilgrim and Darling 2010). Faasse (2015) has reported this species in the western Mediterranean, from specimens collected in 2000 in Balaruc-les-Bains (Bassin de Thau), France. Here we report its presence in the northern Venice Lagoon (45.50550°N; 12.39050°E), accounting for the first record from Italy, based on two male individuals collected in June 2017 from the subtidal fouling community of a wooden pole. The European distribution of *A. valida* reflects the routes of introduction of Pacific oysters. The Ria de Aveiro (Cunha et al. 1999), Arcachon Bay (Gouillieux 2017), Berre Lagoon (Faasse 2015), as well as the Venice Lagoon (present work), are all brackish sites where Japanese oysters have been introduced for aquaculture, and which share several alien species of NW-Pacific origin, probably introduced along with imported shellfish stocks. The individuals collected present the diagnostic characters well described in Conlan and Bousfield (1982) and Gouilleux (2017), and especially the large posterior carpal lobe in gnathopod 1 and the transverse palm of male gnathopod 2, bearing a central process (Figure 4.7C). Previous records of the morphologically similar congener *Ampithoe ferox* (Chevreux, 1901) in Mediterranean aquaculture sites (e.g., Marchini et al. 2007) may be due to misidentifications of introduced populations of *A. valida*, and the first introduction event of this American amphipod could be backdated by several years.

Amathia verticillata is a bryozoan probably native to the Caribbean ecoregion (Galil and Gevili 2014) that uses its ability to produce vegetative fragments and shipping as its main pathway of introduction (as fouling) (Nascimento et al. 2021). First described from Italian waters (delle Chiaje, 1822) and long considered native of the Mediterranean Sea, *A. verticillata* is known from several localities in the basin (e.g., Galil and Gevili 2014). While surveying the Boka Kotorska Bay, Montenegro (42.431767°N; 18.691783°E) on the 1st of August 2016, extensive colonies of this cryptogenic bryozoan were observed and collected for identification (Figure 4.7D). This is the first record of *A. verticillata* in Montenegro. *Antithamnion amphigeneum* is a minuscule filamentous red alga which is an alien in the Mediterranean Sea, originating from the Indo-Pacific region. The species was first reported for the Mediterranean Sea from Algeria in 1989, possibly introduced through shipping (Verlaque et al. 2015). Since then, it has also been recorded from Spain, Morocco, Monaco, France, Italy, and most recently from Montenegro (Mačić and Ballesteros 2016, and references therein). The species was found as an epiphyte on the alien alga *Dictyota cyanoloma* Tronholm, De Clerck, A.Gómez-Garreta & Rull Lluch (Figure 4.7E), located in the upper sublittoral zone at a semiexposed shore in March 2013, near the port of Argostoli (Kephallonia Island, Ionian Sea). This finding represents the first record of the species in Greece and the Ionian Sea and its easternmost distribution record in the Mediterranean Sea.

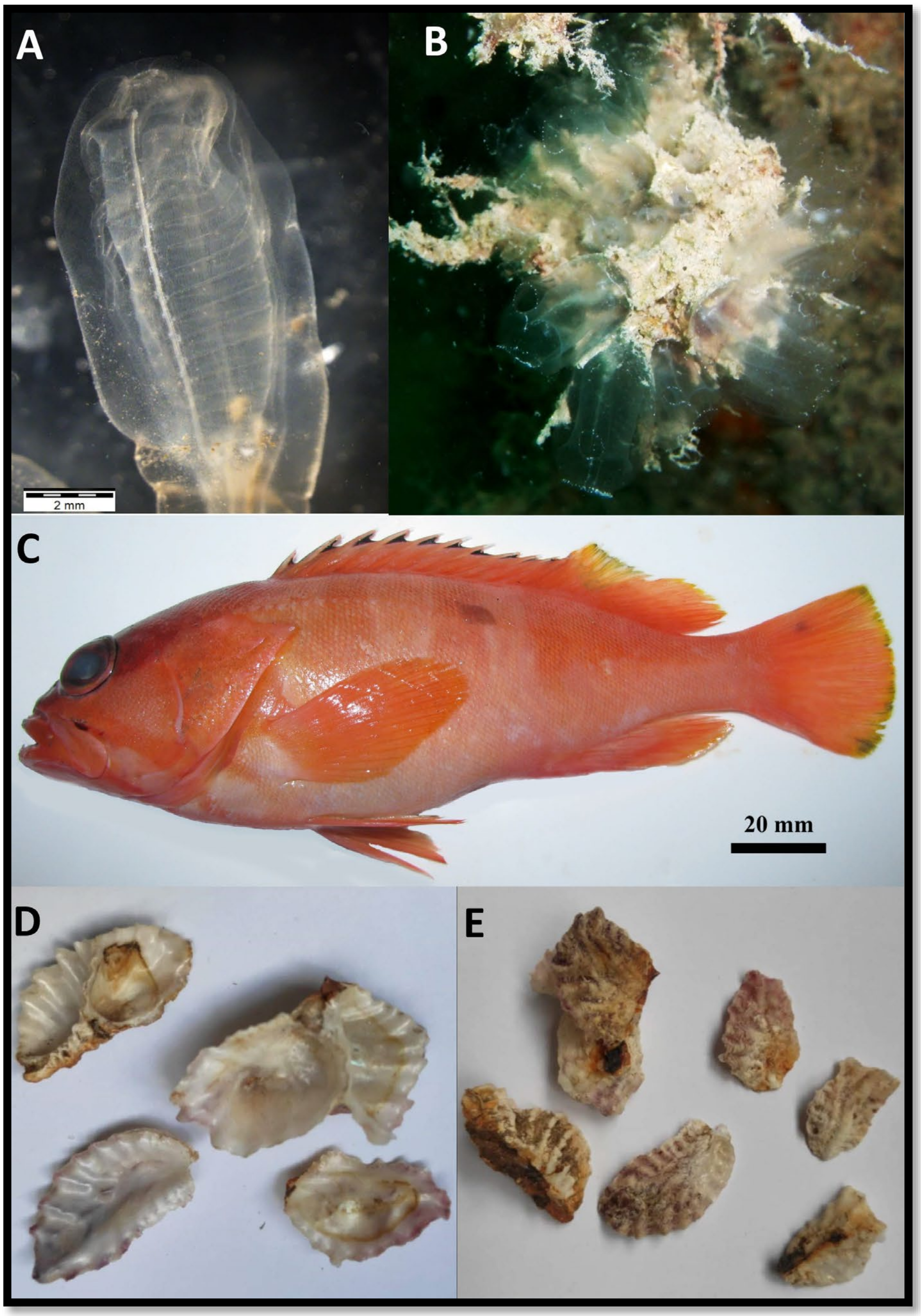
Clavelina oblonga is an ascidian originally described from Bermuda, whose native range is considered the tropical western Atlantic Ocean (Rocha et al. 2012). The species has a long invasion history, at least since 1929 in the Mediterranean, which has led to confusion regarding its biogeographical status (Carlton 2009). Here we report for the first time on the occurrence of *C. oblonga* in Slovenia (45.48778°N; 13.58532°E) and Tunisia (34.30650°N; 10.15590°E) (Figure 4.8A, B). The observations occurred on 3 July 2018 and 31 July 2019, respectively. In Slovenia, most specimens were found within a mussel farm site, while in Tunisia many colonies were observed on artificial structures within Skhira port. The observers reported colonial ascidians united by stolons, forming closed clusters; zooids had thorax and abdomen regions up to 2–3 cm long. The tunic was transparent without the white bands—like Clavelina lepadiformis (Müller, 1776)—around oral and atrial siphons, dorsal and ventral parts, and base of thorax, and only showed fine white dots. Branchial sac had 15–18 rows of stigmata. *Clavelina oblonga* is associated with bivalve mariculture, which is believed to be the original pathway of introduction into the Mediterranean Sea, later expanding its distribution naturally (Ordóñez et al. 2016).

The blacktip grouper *Epinephelus fasciatus*, one of the most common and widespread species of the genus in the tropical Indo-West Pacific (Heemstra and Randall 1993), was first recorded in the Mediterranean Sea in Syria in 2002 (Foulquie and Dupuy de la Grandrive 2003) and then once more in 2011 off the coast of Lebanon (Bariche and Heemstra 2012). Here we report the third occurrence of E. fasciatus in the Mediterranean Sea (Figure 4.8C), which constitutes the first record of this species from Tunisia. On 31 May 2020, a single individual of the blacktip grouper was caught along the Kelibia coast, northern Tunisia (36.8289°N; 11.1357°E). It was entangled in gillnets at a depth of 35 m over a sandy bottom covered by seagrasses. The specimen measured 201 mm in total length and weighed 102 g. The fresh colouration of the body was pale yellowish-red with orangered bars, the margin of inter-spinous dorsal fin membranes black, and the dark reddish-brown dorsal part of the head and nape are characteristic features of the species. The present record in the vicinity of a port suggests that the introduction of the species in Tunisia was via maritime shipping.

Dendostrea cf. folium is a Lessepsian species belonging to the Ostreidae family, found on hard substrata in the infralittoral zone (Zenetos et al. 2011). This species was reported for the first time in the Mediterranean from Greece in 2010 as *Dendrostrea frons* and is expanding its range (Zenetos et al. 2011; Crocetta et al. 2013; Karachle et al. 2016; Ivkić et al. 2019). Based on molecular analysis and although it is a species that exhibits high morphological variability, it seems to be the only representative of its genus in the Mediterranean (Crocetta et al. 2015). Here we report the first record from Syria. Many samples were collected at 0.5 m depth, North of the Latakia port (35.567553°N; 35.739105°E) in April 2019 and near Albassit marina (35.865836°N; 35.866614°E) in August 2021, where they were attached to rock and fishing gear (Figure 4.8D, E). All samples are currently in the High Institute of Marine Research collection (Latakia).

Figure 4.8.

Remarkable new records included in the dataset



Note. (A) *Clavelina oblonga*, a first record from Slovenia reported by Domen Trkov and Ana Fortič; (B) *Clavelina oblonga*, a first record from Tunisia reported by Alfonso Ramos; (C) *Epinephelus fasciatus*, a first record from Tunisia reported by Raouia Ghanem; (D and E) upper and lower valvae of *Dendostrea cf. folium* from Syria, a first record reported by Izdihar Ammar and Alaa Alo.

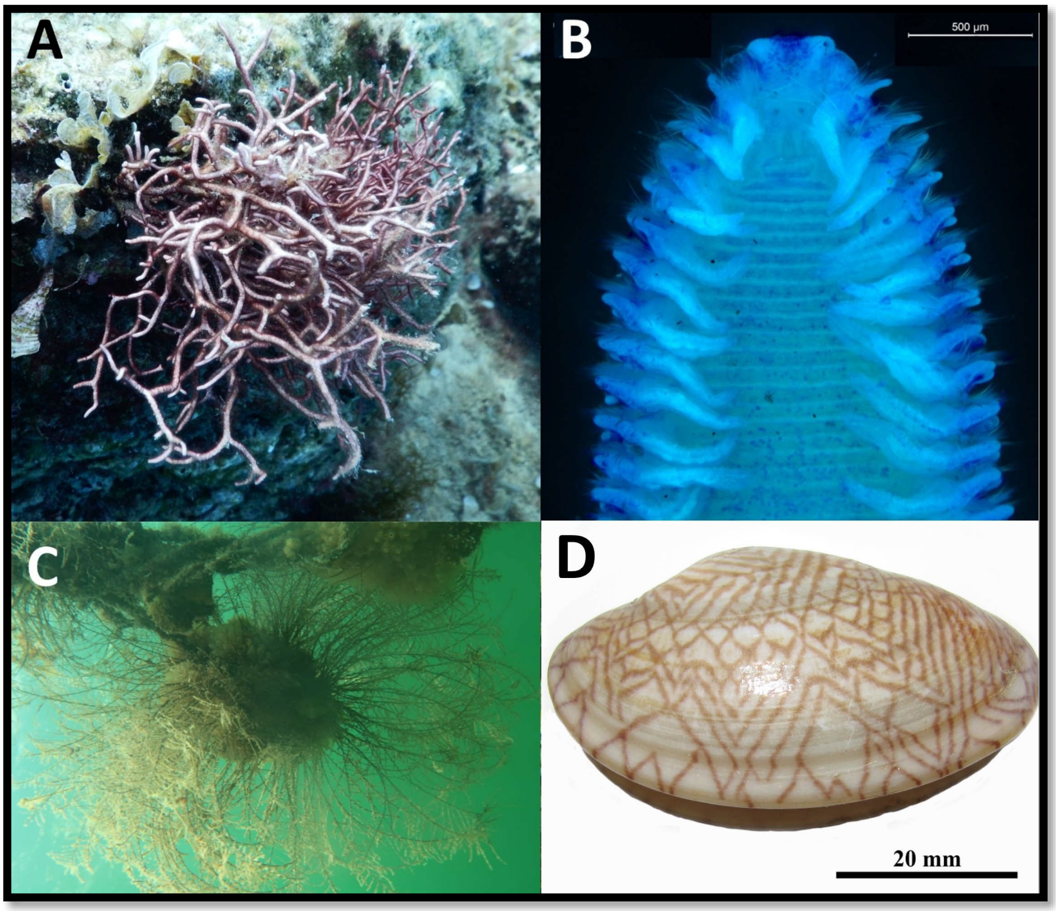
The red alga *Ganonema farinosum* has a heteromorphic life history with alternation of erect gametophyte and filamentous tetrasporophytes. The gametophyte is erect and bushy, light purple to reddish brown, axes cylindrical, subdichotomously branched, moderately calcified, and up to 25 cm high (Lin et al. 2014; Verlaque et al. 2015). The species was described from the Red Sea (Suez) by Lamouroux (1816, as Liagora farinosa), and it is widespread from the Indo-Pacific through western Africa and the eastern Atlantic Ocean. It was recorded for the first time in the Mediterranean Sea from Alexandria (Egypt) in 1808 (Hamel, 1931, as Liagora farinosa) and later mainly in the eastern Mediterranean: Greece (1931), Israel (1964), Syria (1976), Lebanon (2000), Cyprus (2000), Turkey (1978), but also in south Italy (1969), south Spain (1987), Albania (2011), and Malta (Verlaque et al. 2015; Crocetta et al. 2021). Verlaque et al. (2015) suggested the introduction or the co-occurrence of introduced and native populations in the Mediterranean, given that the oldest Mediterranean record dates before the opening of the Suez Canal. Contrary to this, Cormaci et al. (2004) considered this species a Tethyan relict. Hence, the species is treated as cryptogenic due to its uncertain biogeographic status. *Ganonema farinosum* has not been previously reported from the Adriatic Sea except for the Strait of Otranto (Katsanevakis et al. 2011). We may presume that this species could be transported in the form of floating spores by water currents and ballast waters or as fouling of ship hulls, but the northward expansion of this thermophilic species could also be a consequence of climate change. In some tropical waters, *G. farinosum* is utilized for human consumption (Trono 2001), but in the Mediterranean, although well established, it has no importance to humans (Verlaque et al. 2015). Here we report on the first record of *G. farinosum* (Figure 4.9A) from Montenegro (42.09259°N; 19.07768°E), found in October 2018 in the port of Bar area, on an artificial hard substratum, at 7 m depth. This new record is the northernmost record of the species in the Adriatic.

The red gilled mud worm *Marenzelleria neglecta* is an oligohaline polychaete whose invasion history in the Baltic Sea received much attention at the turn of the last millennium (Leppäkoski and Olenin 2000; Zettler et al. 2002). First recorded (as Marenzelleria viridis) in the North Sea in 1983 (Essink and Kleef 1988), the species appeared in the Baltic Sea in 1985 (Bick and Burckhardt 1989).

After only a dozen years, the red gilled mud worm expanded its distribution into almost the whole Baltic Sea. Though the native region of *M. neglecta* is not known with certainty, genetic data suggest that it most likely originates from the Atlantic coast of North America (Bastrop et al. 1998). In the Ponto-Caspian region, the species was reported for the first time in 2014 in the Don River delta and Taganrog Bay of the Sea of Azov and spread rapidly (Syomin et al. 2017; Mikhailova et al. 2021). The first specimens from Romanian waters that we report here (Figure 4.9B) were collected on 27 May 2021 from black detritic mud at 0.5 m depth in the upper reaches of the Mangalia Gulf (43.81180°N; 28.51840°E), at a salinity of 5.9 PSU. In the Sea of Azov, *M. neglecta* is already well established and locally has become a major component of the benthic fauna, reaching high densities (6823 ind. m-2) and large biomass (31.2 g m-2) (Syomin et al. 2017). The most probable vector of its introduction into the Sea of Azov and the Caspian Sea is by ship ballast water through the Volga- Baltic and Volga-Don canals (Syomin et al. 2017; Mikhailova et al. 2021). The secondary spread along the Black Sea shores is probably due to larval dispersal by the quasi-permanent anti-clockwise Main Rim Current. Therefore, the species is expected to occur soon on the Bulgarian Black Sea coast. On 26 May 2022, and while this work was ongoing, Teaca et al. (2022) published their study on “The First record of *M. neglecta* and the Spread of *Laonome xeprovala* in the Danube Delta–Black Sea Ecosystem”. The samples containing *M. neglecta* that we report on were collected less than two weeks prior to the records described in their work, and though far in terms of distance, our results completely agree. Teaca et al. (2022) found *M. neglecta* in the northern part of the Romanian Black Sea coast, where it accounted for 36% of the total density of macrobenthos (50 to 1400 ind m-2). The fact that the species was found in high densities in the northern part of the Romanian coast (Teaca et al. 2021, 2022), while only one specimen was found in the south, indicates that the northern part offers much more suitable habitat conditions for *M. neglecta*.

Figure 4.9.

Remarkable new records included in the dataset



Note. (A) *Ganonema farinosum*, a first record for Montenegro reported by Vesna Mačić; (B) *Marenzelleria neglecta*, a first record from Romania reported by Victor Surugiu; (C) *Macrorhynchia philippina*, a first record for Tunisia reported by Raouia Ghanem; (D) *Paratapes textilis*, a first country record from Tunisia reported by Wafa Rjiba.

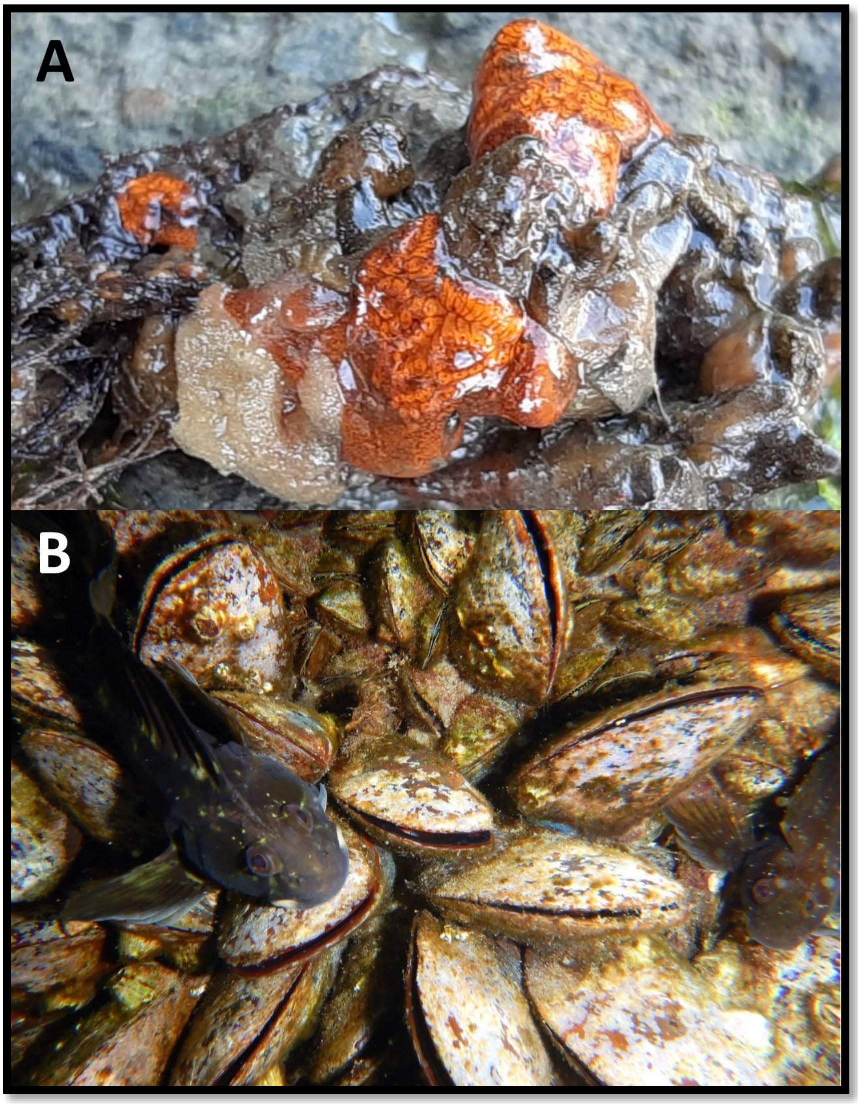
The feathery stinging hydroid *Macrorhynchia philippina* is distributed in tropical and subtropical regions (Rees and Vervoort 1987) and is common in the Red Sea (Vervoort 1993). The species has been observed in the Mediterranean along the coast of Lebanon at 0–40 m depth (Bitar and Bitar-Kouli 1995; Zibrowius and Bitar 2003; Morri et al. 2009) and has since expanded northwards to the Turkish coast (Çinar et al. 2006). About twenty colonies were observed and photographed, for the first time, on southern Tunisian coasts at Bibane lagoon (33.260283°N; 11.236798°E) on a wreck at 2 m depth (Figure 4.9C). This species has probably been introduced via shipping.

Paratapes textilis was first recorded as Tapes undulatus in the Mediterranean in 1939 from Egypt (Moazzo 1939) and then from Palestine Authority in 1935 (Haas 1948). Subsequently, it was reported from Israel (1948), southern Turkey (Niederhöfer et al. 1991), Syria (Kucheruk and Basin 1999), and Cyprus (Zenetos et al. 2009). The first specimen from Tunisia (Figure 4.9D) was caught by trawling off Kelibia coasts in Tunisia (36.82341°N; 11.13739°E) at 50 m depth. The specimen was characterized by the absence of lateral teeth in the hinge, colour externally beige and pale yellow with a characteristic zig-zag pattern in brown, and internally white.

The colonial ascidian *Botrylloides diegensis* is native to the North Pacific but has already colonized several European areas, namely the English Channel, where it was well established in marinas of the United Kingdom, the Atlantic coast of France, and the Italian Adriatic (Viard et al. 2019). In October 2019, colonial ascidians of the genus Botrylloides Milne Edwards, 1841 were observed for the first time in the shallow waters of Bahiret el Bibane lagoon (33.22909°N; 11.172793°E) on a rocky substratum (Figure 4.10A). Subsequently, during surveys carried out at the same location in May 2020, similar colonies were observed on Pinna nobilis Linnaeus, 1758 shells and collected for identification. As morphological identification of botryllid taxa could be deceiving, and several alien species are now spreading in the Mediterranean basin (Rocha et al. 2019; Viard et al. 2019; Della Sala et al. 2022; Virgili et al. 2022), the specimen was identified through DNA barcoding. A 631 base pairs fragment of the cytochrome c oxidase subunit I (COX1) gene was amplified (GenBank accession number: OP802711), yielding a > 98% similarity with sequences of both *B. diegensis* and *B. leachii*. However, the latter species was excluded based on the recent work of Viard et al. (2019), thus the reported ascidians are the first records of *B. diegensis* found in Tunisia.

Figure 4.10.

Remarkable new records included in the dataset



Note. (A) *Botrylloides diegensis*, a first record for Tunisia reported by Raouia Ghanem; (B) *Perna perna* as ecosystem engineer providing shelter and a new habitat for the local fish *Scartella cristata* and barnacle species, and free surface for settlement, establishment and prosperity of the encrusting coralline red alga Hydrolithon sp.; this bivalve's aggregate was observed in 8.10.2020 at 1 m depth in Haifa. The fish is ca. 7 cm in length. Photo by Moti Mendelson.

One last very interesting observation included in the dataset, that does not constitute a first record, belongs to the widely invasive bivalve *Perna perna* (Linnaeus, 1758), initially observed and collected by a citizen scientist during the summer of 2020 in Haifa, located in north Israel (Douek et al. 2021), and spread all along the Levantine Mediterranean shore of Israel like wildfire. At the end of 2020, less than six months since its first record from Israel, this species of western Indian Ocean origin (Gardner et al. 2016; Fofonoff et al. 2018) reached the southernmost beach of Israel in Zikim (31.60630°N; 34.49940°E), by the border with Gaza Strip (Figure 4.10B). Although it is not the first introduction of this invasive mytilid mussel on the Israeli shoreline, the previous introduction (Barash and Danin 1992) was regarded as an ephemeral occurrence, and the species remained cryptic until recently (Douek et al. 2021). Moreover, seven years of steady ongoing seasonal "Bioblitz" surveys of the marine fauna and flora of the shallow and deep subtidal in Haifa, conducted by the Israeli Nature and Parks Authority, proved that the species is indeed a new invader because it was not observed or collected until 2020. The extensive and dense beds observed near Haifa port may point to vessels as the vector of introduction (Douek et al. 2021). In Haifa, Zikim and Tel Aviv, this invasive species is an ecosystem engineer, providing a habitat for marine fauna and epiflora, as depicted in Figure 4.10B. Moreover, although a recently published study reported that a marine heatwave-induced mass mortality event "laid waste to the entire mussel population" in July 2021 and suggests that *P. perna* outbreaks in Israel might be short-lived (Galil et al. 2022), further observation from April 2022 testify that, at least in part, the population seems to be slowly recovering in Zikim.

4.6. Conclusion

Just two years after Katsanevakis et al. (2020a) paper came out, we managed to collect more than double the records of alien, cryptogenic and neonative species, complementing existing data with an additional 12,649 openaccess records. This effort was motivated by the need to demonstrate that a huge amount of valuable information exists, and new data are continuously accumulating that need to be retrieved, harmonized, and openly shared. Despite the requirements of the Barcelona Convention (e.g., UNEP/MAP 2017) and the EU (e.g., for the implementation of the Marine Strategy Framework Directive 2008/56/EC), a state-level monitoring network is still largely missing from the

Mediterranean and Black Seas (Tsiamis et al. 2021). Regional collaboration and networking among scientists can be valuable in partially filling this gap.

This extensive and large-scale cooperation, aiming to collect data from a large geographic area, facilitates networking among colleagues in the biological invasions field, promoting future cooperation. Scientists have been very positive in sharing their data and working together despite regional geopolitical issues for the benefit of science and society. By continuing this effort regularly, we believe we will further promote invasion science in the region and increase opportunities for further research and analyses that will improve our understanding of ecosystem change and the impacts of biological invasions in the Mediterranean and the Black Sea.

As expected, our dataset is not unbiased in the spatial and taxonomic representation of biological invasions in the Mediterranean and the Black Sea. Species size and habitat distribution, the feasibility of visual identification, the location of participating scientists, varying sampling effort and methodology among countries, the uneven distribution of citizen science initiatives, socioeconomic differences, and field methods used to obtain data may have introduced biases in our dataset. Still, the emerged patterns can highlight the invasive potential of certain species (e.g., *Caulerpa cylindracea*, *Charybdis (Archias) longicollis*, *Upeneus moluccensis*, *Pterois miles*, *Saurida lessepsianus*, *Siganus rivulatus*, *Siganus luridus*) that appear abundant and widespread. Moreover, the ever-growing use of advanced machine learning and artificial intelligence technology for big-data analysis can help overcome biases and produce novel applications to spatially and temporally map alien species advances in our seas using large datasets such as the one collated in the present study.

Chapter V

Assisted Recovery of Mediterranean Native Fish Species by Removal of Two Established Invasive Alien Species, *Pterois miles* and *Diadema setosum*

5.1. Introduction

Calamitous biodiversity reductions with more than 90 percent loss occurred at various geohistorical times, but life recovered and flourished with prosperity every time. Current research suggests that the present historical era is also one of these devastating periods of biodiversity loss at all levels (Ghaly, 2022). Introductions of invasive alien species (IAS) have been suggested as the second most common cause of species extinctions, surpassed only by habitat fragmentation and loss (Bellard et al., 2016). The Mediterranean Sea is a global biodiversity hotspot (Coll et al., 2010) and highly impacted by IAS (Edelist et al., 2013; Giakoumi et al., 2019b; Katsanevakis et al., 2014; Tsirintanis et al., 2022). Therefore, in this region, the threat posed to world marine biodiversity by IAS is particularly concerning. The Suez Canal is mostly to blame for the exorbitant number of IAS, while vectors such as active swimming or transportation in ballast waters of commercial ships, on hulls or even on plastic litter can be held particularly responsible (Flagella and Abdulla, 2005; Zenetos et al., 2020). In most situations, complete eradication of a successfully established marine invasive alien species, with currently available tools and technology is almost impossible (Côté et al.). While in terrestrial habitats, specifically in limited areas such as islands, success stories are present (Burbidge and D., 2002; Caut et al., 2008; Robertson et al., 2017), within the highly connected nature of the marine environment, controlling biological invasions are generally more challenging (Williams and Grosholz, 2008). However, there are rare cases in which the IAS were eradicated early in the invasion curve (Anderson, 2005; Willan et al., 2000).

Approximately 650 km from the Suez Canal, Cyprus has been heavily impacted by alien species from the Indo-Pacific and is among sites where IAS become established early in Mediterranean invasions from this route (Giovos et al., 2019; Iglésias and Frotté, 2015; Peyton et al., 2020). Coastal Cyprus is under intense pressure by invasive alien fish, such as the rabbitfish species, dusky spinefoot *Siganus luridus* and marbled spinefoot *Siganus rivulatus* accounting for 32-54% of the seasonal total catch (Kletou et al., 2016; Moutopoulos and Stergiou, 2002). Other invasive alien fish species are the redcoat *Sargocentron rubrum*, pufferfish such as the orange-spotted toadfish *Torquigener hypselogeneion* and silver-cheeked toadfish *Lagocephalus sceleratus*, the Red Sea goatfish *Parupeneus forsskali,* common lionfish *Pterois miles.* There is a continuous process of establishment, for instance, with striped eel catfish *Plotosus lineatus*, recently recorded (Tiralongo et al., 2022). Considering the combined and cumulative impacts of heavy overfishing, sea warming and the presence of alien fauna and flora in the eastern Mediterranean, modelled data for the period between 2015 and 2017 suggests that 29% of the total fish production in Cyprus are alien (Michailidis et al., 2019). Similar results of unfavorable future scenarios have been obtained for the Israeli coastal shelf (Corrales et al., 2018).

To assist native biodiversity, frequent removals of IAS from certain critical marine habitats are one of the methods applied to tackle the problem, particularly if targeted IAS are detected early in the invasion process and subsequent management activities are implemented fast enough (Giakoumi et al., 2019a). It is well documented that the shallow rocky habitats of coastal Cyprus are invaded by *P. miles* and *D. setosum* (Bronstein et al., 2017; Jimenez et al., 2016; Kletou et al., 2016; Langeneck et al., 2022; Mytilineou et al., 2016; Savva et al., 2020; Stern et al., 2019). Crevices, ledges, overhangs, and sheltered areas in general, are filled with venomous spines of these two species, possibly interfering with the occupancy of suitable habitat of native fish species, such as the cardinal fish *Apogon imberbis*, *Serranus* spp., *Diplodus* spp., young *Epinephelus* spp. and various Labriform fish. Such a displacement has been exemplified by the alien goldband goatfish *Upeneus moluccensis*, replacing the natives, red mullet *Mullus barbatus* and striped, red mullet *Mullus surmuletus* (Galil, 2008).

In consequence, it can be assumed, that periodic removal of these two IAS may allow native fish to be able to recolonize the rocky habitats and increase their abundance. To test this hypothesis, we assessed the abundance of fish before and after removals of all at *D. setosum* and *P. miles* from two submerged rocky reefs in order to evaluate the effects on the native and other established alien fish ichthyofauna.

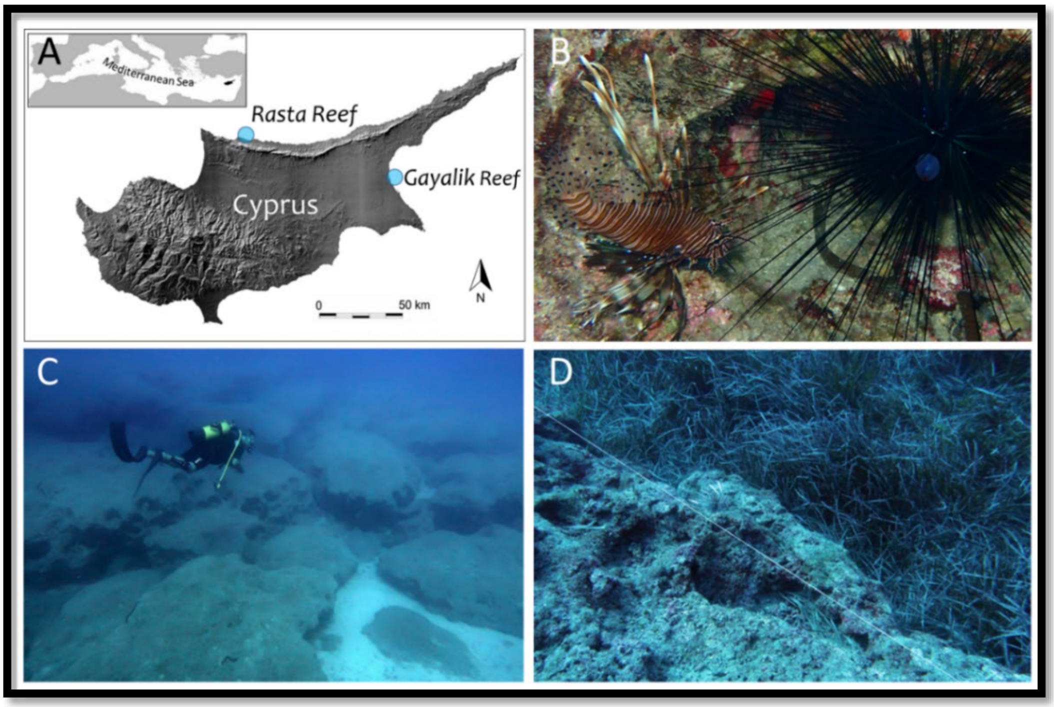
5.2. Methods

5.2.1. Study area

Two rocky reefs in Cyprus (Levantine Sea) were selected because human activities, such as fishing, are limited due having an unofficial protection status for recreational scuba diving and because they have significant populations of lionfish and the long-spined sea urchin (Figure 5). Rasta Reef (35°22'05", 33°09'42") (Figure 5), is an irregular but cylindrical-shaped (12m x 60m x 2m) rocky platform with boulders, crevices and ledges surrounded by extensive and dense *Posidonia oceanica* seagrass meadows at 28m depth. The meadows isolate the reef from nearby rocky systems by tens of meters. Gayalik Reef (35°11.62', 033°55.18') (Figure 5) is the end section of a long rocky reef system spanning approximately two hundred meters between 16 m and 21 m depth. The reef system is highly heterogenous with large boulders, crevices, small caves, overhangs, and the reef’s scarp is delimited by a sandy bottom.

Figure 5.

General Views of The Studied Areas



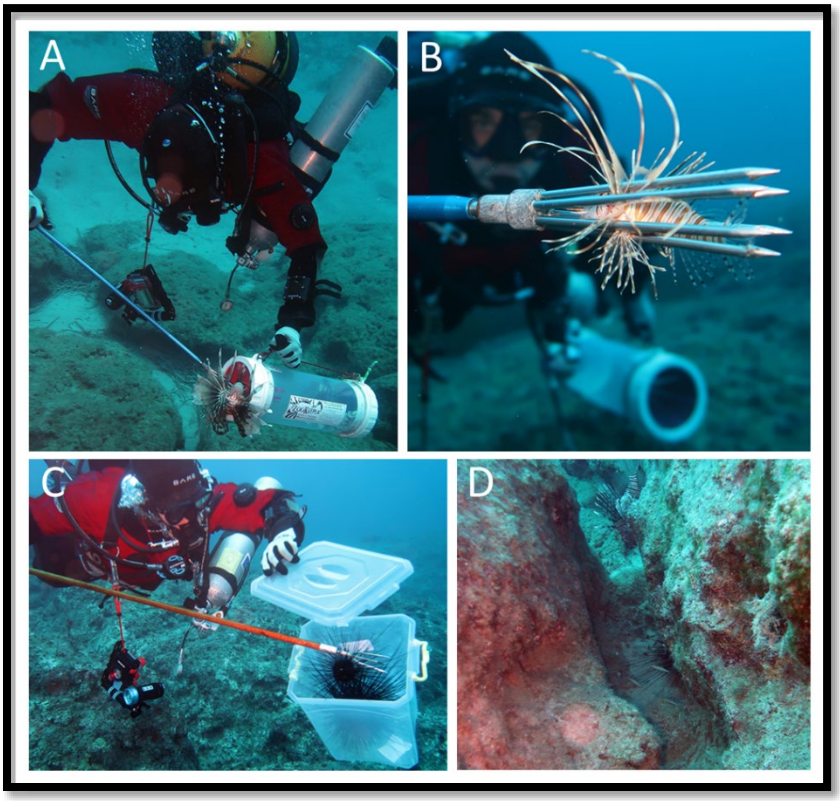
Note. (A) Locations of Cyprus in the Mediterranean Sea and the two rocky reefs studied in Cyprus. (B) *P. miles* and *D. setosum* found typically close to each other (Rasta Reef, 17.12.2021). (C) General view of Gayalik Reef (21m depth). (D) Transect line in Rasta Reef (28m depth) along the scarp bordered by extensive *P. oceanica* meadows.

5.2.2. Sampling

At each reef, 10 surveys were performed within 12 months (September 2021-September 2022). First three surveys were dedicated to performing visual census (Colvocoresses and Acosta, 2007; Murphy and Jenkins, 2010) of the ichthyofauna associated to the rocky reefs. Succinctly, the visual census consisted of counts along a fix distance of a 50m x 4m x 2m long transects and keeping approximately a constant speed to avoid over-sampling. The transects at both reefs were of similar rugosity (heterogeneity). The visual census was repeated three times (months 1-3), and the situation was evaluated. After this first stage of the initial assessment of the ichthyofauna, removals of all lionfish and long-spined sea urchins along the transects and on the reefs in general (Rasta Reef, 12m x 60m = 720m^2 approx.; Gayalik Reef, 12m x 50m = 600m^2 approx.) were performed by decompression diving on four occasions (months 4-7) utilizing pole spears and containers (Figure 5.1). Four divers crossed checked the culled areas verifying that no individuals were left. Live individuals of *D. setosum* were removed for further analysis (Huseyinoglu, unpublished data). The third stage involved three surveys (months 8-10) to reassess the ichthyofauna, *P. miles* and *D. setosum*, after the removals.

Figure 5.1.

Examples of Removal Activities



Note. Examples of removal activities. (A) Adult *P. miles* at the Gayalik Reef. (B) Juvenile *P. miles* at the Rasta Reef. (C) Sampling live adult *D. setosum*. (D) Removals included crevices where individuals are usually difficult to reach. Gayalik Reef= A, D. Rasta Reef= B, C.

5.2.3. Computational Details

In this study, Pearson correlation coefficients were used to detect and discover positive or negative linear relations between the number of each fish species and the number of *D. setosum* and

P. miles through time (Hinkle et al., 2003). The aim was to determine any possible increase or decrease of each particular species due to the removal of *D. setosum* and *P. miles*. A high negative Pearson correlation coefficient should be interpreted in such a way that the removal of these two species provided an increase in the number of that particular fish. A high positive correlation value, on the other hand, suggests that the removal resulted in a drop in the fish.

The change in the number of *D. setosum* and *P. miles* in the removal period was modeled by exponential regression in the form of Equation 1, where *y* refers to the number of fish and *t* is the time while *A* and *B* are constants (Calixto, 2016). The models were built by taking t as zero on the first day of the removal occasion. The accuracies of the models were measured by evaluating their coefficient of determination (R^2) values.

$$y = A \cdot e^{B \cdot t} \tag{1}$$

5.3. Results and Discussion

5.3.1. Ichthyofauna

A total of 25 and 22 fish species were recorded at Rasta Reef and at Gayalik Reef, respectively, where 18 species were common at both reefs. Of the recorded species, 16 and 13 fish species were recorded on every dive at Rasta and Gayalik Reefs, respectively (see Supplementary Table 6). Two species were recorded outside of the transects only once: the common stingray *Dasyatis pastinaca* at Rasta Reef (4 November 2021) and the common guitarfish *Rhinobatos rhinobatos* at Gayalik Reef (30 August 2022). The most abundant species at Rasta Reef was the native damselfish *Chromis chromis* while at Gayalik Reef, it was the alien species, Indian Ocean two spot cardinalfish *Cheilodipterus novemstriatus*. The latter was observed almost exclusively sheltered between the long spines of *D. setosum* utilizing the sea urchin as a microhabitat. At both reefs, small to medium sized fish, such as the bogue *Boobs boobs,* Mediterranean rainbow wrasse *Coris julis,* common two-banded seabream *Diplodus vulgaris,* parrotfish *Sparisoma cretense,* ornate wrasse *Thalassoma pavo, P. forsskali*, and *T.*

hypselogeneion were also present in high abundance; the last two species are successfully established Lessepsian migrants in Cyprus.

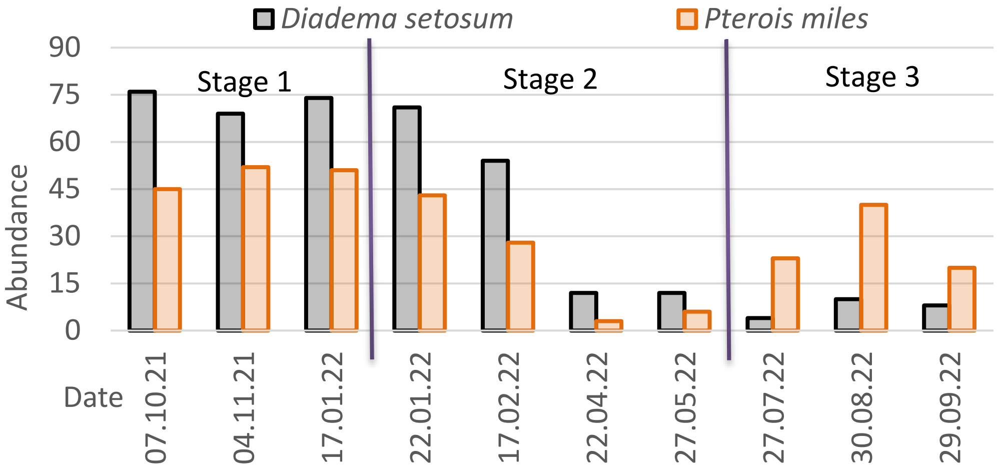
5.3.2. Long-spined sea urchin and lionfish

The average number ± standard deviation of *P. miles* and *D. setosum* per visit during the baseline survey at Rasta and Gayalik Reefs were 49.3 ± 3.8, 73.0 ± 3.6 and 67.7 ± 22.2, 41.7 ± 14.7 individuals respectively. In the second stage, during the removals, the total numbers of *P. miles* culled from Rasta and Gayalik Reefs were 80 and 154, and the average number culled per visit was 20.0 ± 19.0 and 38.5±26.8 individuals respectively. Likewise, for *D. setosum* at each location, the total numbers for eradication were 149 and 102 at Rasta and Gayalik Reefs respectively, while average numbers either eradicated per visit were 37.3 ± 30.0 and 25.5 ± 24.2 respectively. The average density of total lionfish culled at each location was 0.1 individuals/m^2 Gayalik and 0.3 individuals/m^2 Rasta Reef. The total number of *D. setosum* removed at each site was 0.21 individuals/m^2 and 0.17 individuals/m^2 from Gayalik and Rasta Reefs, respectively (see Supplementary Table 5).

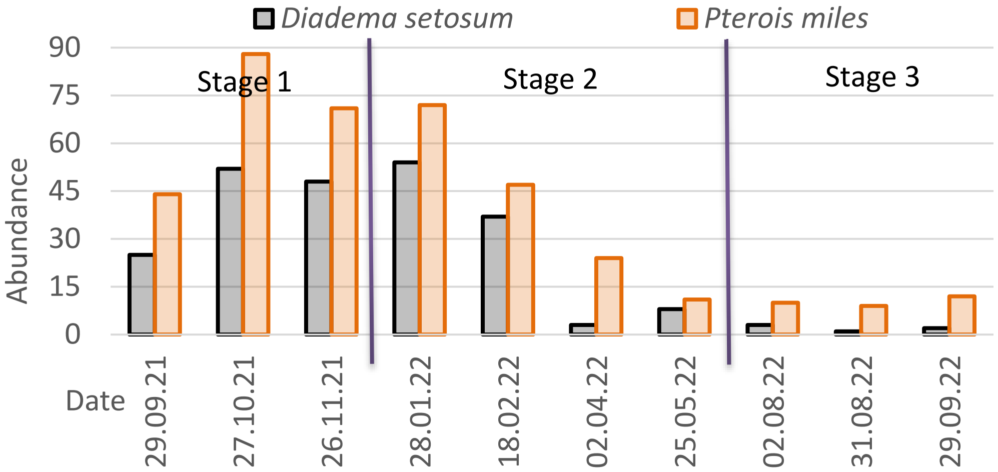
Figure 5.2.

Abundance (Number of Individuals) at Rasta (a) and Gayalik (b) Reefs

a) Rasta Reef



b) Gayalik Reef



Note. Abundance (number of individuals) of *D. setosum* and *P. miles* before (stage 1), during (stage 2) and after (stage 3) removals for the reefs Rasta (a) and Gayalik (b).

The changes in the abundance of *D. setosum* and *P. miles* during the three stages of the study at the two reefs (Figure 5.2) show the abrupt decline of the baseline population of *D. setosum* at Rasta Reef. Even after four months since the eradication stage ended, *D. setosum* abundance was as low as four individuals at the entire reef. *P. miles* abundance dropped from as high as 52 to only three individuals during cullings. But when the removals during the stage 2 were over, a higher recruitment rate was observed and the numbers of *P. miles* at Rasta Reef climbed to between 20 and 40 individuals.

On the other hand, the situation at Gayalik Reef was different Initially, the numbers for *D. setosum* and *P. miles* were as high as 52 and 88 individuals at Rasta and Gayalik Reefs, respectively, but dropped to between 1-3 and 9-12 individuals, respectively. While at Rasta, the numbers of lionfish recovered to more than half of its initial population in four months, it stayed at as low as 16% of its initial numbers at Gayalik Reef (Figure 5.2).

5.3.3. Correlation Analysis

The calculated Pearson correlation coefficients between the number of each species and the number of *D. setosum* and *P. miles* in the Rasta region are given in Table 5.1. The color green indicates a positive correlation, while orange indicates a negative correlation, with shades showing intensity, such that darker green boxes correspond to stronger positive correlations, while darker orange boxes correspond to stronger negative correlations. The analyses show that *S. rubrum* has a very high positive correlation with *D. setosum* and high positive correlation with *P. miles*, while *P. forsskali*, the black seabream *Spondyliosoma cantharus, T. hypselogeneion,* and *S. scriba* have different degrees of positive correlation between *D. setosum* and *P. miles*, indicating that with removals, these fish also decreased in abundance. On the other hand, other species which are under various levels of higher negative correlation are the axillary wrasse *Symphodus mediterraneus, D. vulgaris,* grey triggerfish *Balistes capriscus, S. rivulatus,* dusky grouper *Epinephelus marginatus, S. cretense,* goldblotch grouper *Epinephelus costae* and *C. chromis,* indicating that the decrease in the number of *D. setosum* and *P. miles* provide an increase in their number. Further analysis for selected significant fish is presented in Figure 5.3.

Table 5.1.

Pearson correlation matrix for the species counted in Rasta Reef.

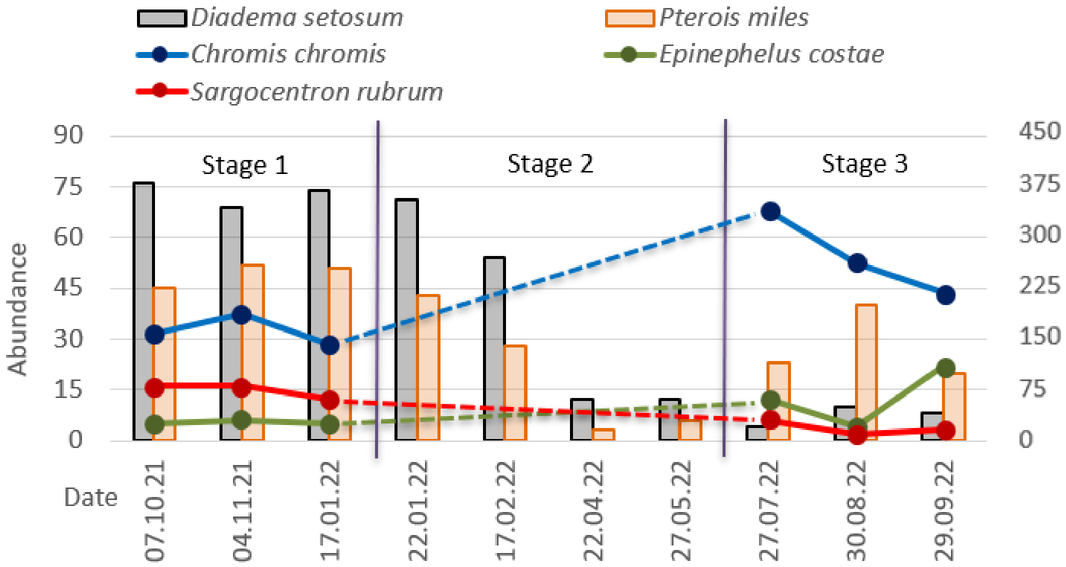
	Diadema setosum	***Pterois miles***
Diadema setosum	1.00	0.86
Pterois miles	0.86	1.00
Sargocentron rubrum	0.93	0.74
Symphodus tinca	0.81	0.59
Parupeneus forskalii	0.74	0.45
Spondyliosoma cantharus	0.49	0.23
Muraena helena	0.46	0.44
Mycteroperca rubra	0.44	0.28
Torquigener hypselogeneion	0.36	0.33
Serranus scriba	0.31	0.11
Symphodus rostratus	0.18	0.49
Boobs boops	0.15	0.08
Dosyatis pastinaca	-0.01	0.42
Serranus cabrilla	-0.03	-0.08
Siganus luridus	-0.04	-0.18
Thalassoma pavo	-0.06	-0.06
Coris julis	-0.28	0.05
Spicara smaris	-0.29	0.02
Diplodus vulgaris	-0.35	-0.56
Balistes capriscus	-0.44	-0.65
Epinephelus marginatus	-0.49	-0.69
Symphodus mediterraneus	-0.50	-0.40
Siganus rivulatus	-0.51	-0.68
Epinephelus costae	-0.59	-0.85
Sparisoma cretense	-0.69	-0.54
Chromis chromis	-0.85	-0.70

Note: The color green indicates a positive correlation, while orange indicates a negative correlation, with shades showing intensity, such that darker green boxes correspond to stronger positive correlations, while darker orange boxes correspond to stronger negative correlations.

Three fish species having high to very high negative or positive correlation with the abundance of *D. setosum* and *P. miles* at Rasta Reef are presented in Figure 5.3. The most common native fish in the eastern Mediterranean rocky reefs is possibly the damselfish *C. chromis*, which is also one of the top prey items of *P. miles* (Savva et al., 2020). Its population apparently grew after the four consecutive removal events. However, it must be noted that *C. chromis*, at all stages of its life cycle, may use *D. setosum* spines for protection (Bilecenoğlu et al., 2019; Çiçek et al., 2020). The increase in the number of *C. chromis* may be due to data collection during the season when young damselfish are not inside sheltered areas but actively swimming around the reef and so continuous year-round observations should be conducted. Another fish which seems to be affected by the removals is the Lessepsian Redcoat squirrelfish, *S. rubrum*. Its numbers dropped from 15 to 1-2 through stage 1 to stage 3. *D. setosum* and *P. miles* mostly occupy large cracks, caves or any type of three-dimensional structures. However, *S. rubrum* occupies smaller cracks unobstructed by the former two species. It can be speculated that the two spined species protected the access to smaller cracks against predators such as *Epinephelus costae* and the mottled grouper *Mycteroperca rubra*. As such protection was lifted with the removals, very low numbers of *S. rubrum* could be a result. Adult *E. costae* is a potential predator of *P. miles*, however, at Rasta Reef, the sizes of *E. costae* individuals were usually around the same size with an adult *P. miles* at stages 1 and 2, disallowing them to be a potential prey item for *P. miles*. The numbers of *E. costae* increased at stage 3, with the final observation of two large males displaying and competing for a harem of 20 other females.

Figure 5.3.

Abundance (Number of Individuals) At Rasta Reef.



Note. Abundance (number of individuals) of *C. chromis*, *E. costae* and *S. rubrum* before (stage 1), during (stage 2; modeled) and after (stage 3) removals at Rasta Reef. To maintain y-axis at the same scale for all species, the vertical number axis for the abundance of *C. chromis* is on the right, while the rest of the fish number scale is on the left. Moreover, in Figures 5.2-5.5, the dashed lines are used to represent estimations, due to the planning that underwater visual census was not held during stage 2.

The Pearson correlation coefficients calculated between the number of each species and the number of *D. setosum* and *P. miles* in the Gayalik region are given in Table 5.2. It is recently documented that the small Indo-Pacific cardinal fish *C. novemstriatus* lives among or around the spines of *D. setosum* individuals or clusters in the Mediterranean (Bilecenoğlu et al., 2019; Çiçek et al., 2020), moreover, it was the most common fish at Gayalik Reef at the first stage. Analyzed coefficient is 1.0 positive correlation, so it is completely absent at stage 3. *S. tinca* and *T. hypselogeneion* have a very high positive correlation between *D. setosum* and high positive correlation between *P. miles*, indicating that these two fish seem to be disadvantaged by the decrease of the two target species. Sample size for *S. tinca* was very low so *T. hypselogeneion* was further analyzed. On the other hand, *S. cretense, E. costae, C. julis* and *D. vulgaris* have comparably high negative correlation coefficient suggesting that they increased in number when *P. miles* and *D. setosum* were removed. *S. cretense* and *C. julis* had the highest negative coefficients, thus they were further analyzed.

Table 5.2.

Pearson correlation matrix for the species counted in Gayalik Reef

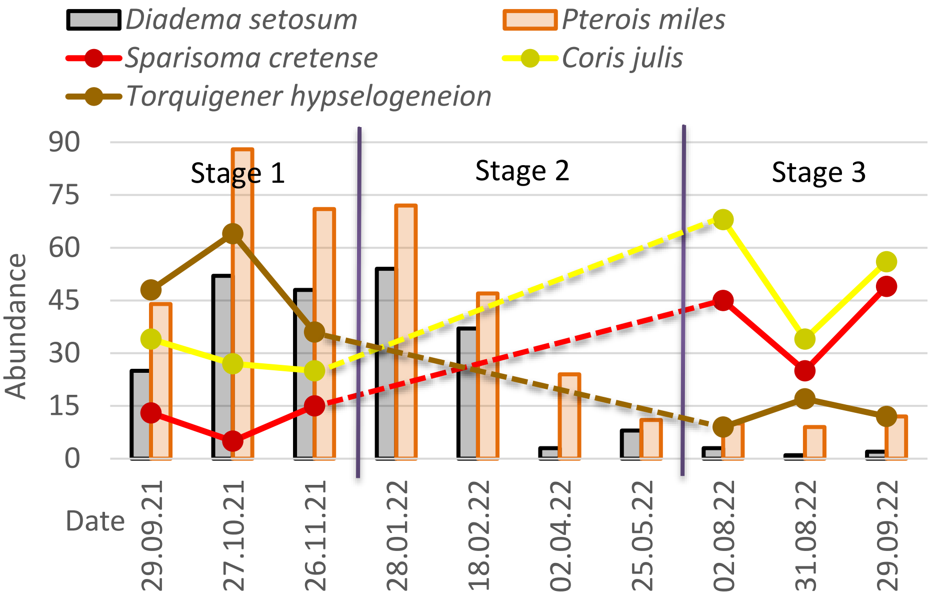
	Diadema setosum	***Pterois miles***
Diadema setosum	1.00	0.99
Pterois miles	0.99	1.00
Cheilodipterus novemstriatus	1.00	1.00
Symphodus tinca	0.92	0.91
Torquigener hypselogeneion	0.87	0.90
Boobs boops	0.63	0.70
Parupeneus forskalii	0.61	0.53
Epinephelus marginatus	0.54	0.46
Spicara smaris	0.54	0.46
Mycteroperca rubra	0.54	0.46
Symphodus mediterraneus	0.54	0.46
Sargocentron rubrum	0.26	0.24
Muraena helena	0.07	0.07
Serranus scriba	0.01	-0.05
Chromis chromis	0.01	0.00
Dasyatis pastinaca	0.00	0.00
Serranus cabrilla	0.00	0.00
Spondyliosoma cantharus	0.00	0.00
Symphodus rostratus	0.00	0.00
Thalassoma pavo	-0.35	-0.37
Centracanthus cirrus	-0.39	-0.41
Siganus luridus	-0.43	-0.43
Siganus rivulatus	-0.46	-0.45
Diplodus vulgaris	-0.66	-0.68
Coris julis	-0.74	-0.74
Epinephelus costae	-0.80	-0.83
Sparisoma cretense	-0.83	-0.84

Note: The color green indicates a positive correlation, while orange indicates a negative correlation, with shades showing intensity, such that darker green boxes correspond to stronger positive correlations, while darker orange boxes correspond to stronger negative correlations.

S. cretense and *C. julis* are native fish in the Mediterranean while *T. hypselogeneion* is a Lessepsian pufferfish. These two native fish increased in numbers while the alien species decreased through stage 1 to 3 of the study. This increase in the regular denizens of the rocky reefs of Cyprus, such as *S. cretense* and *C. julis* could be a response to removal of the pressure of another predator which it is naïve to (D’Agostino et al., 2020), and also the increased availability of crevices previously obstructed by the mildly venomous spines of *D. setosum*. Seasonal bias in our data collection may be another explanation. On the other hand, *T. hypselogeneion* numbers decreased from the maximum of 64 to as low as nine individuals. The small pufferfish is not a preferred prey of *P. miles* (Savva et al., 2020), moreover, hungry lionfish in control tanks regurgitate pufferfish immediately (Huseyinoglu, pers. obs). Possibly *T. hypselogeneion* somehow benefited from the presence of *D. setosum* and *P. miles* (Figure 5.4).

Figure 5.4.

Abundance (Number of Individuals) At Gayalik Reef

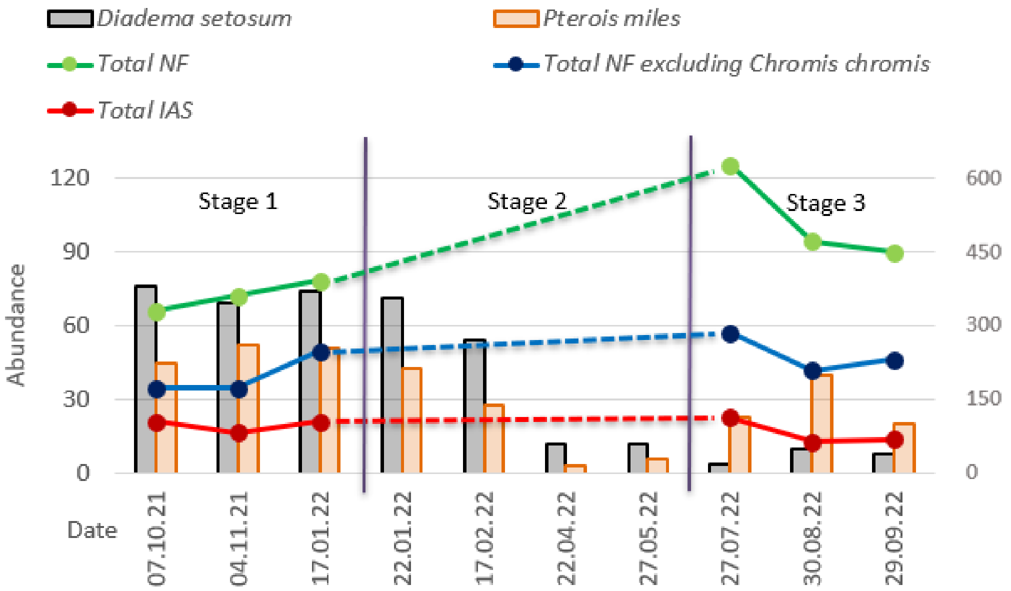


Note. Abundance of *S. cretense*, *C. julis* and *T. hypselogeneion* before (stage 1), during (stage 2; modeled) and after (stage 3) removals at Gayalik Reef. Dashed lines correspond to modeled data.

The analysis of total averaged numbers of native fish versus IAS, suggests that in general, native fauna increased in numbers while IAS decreased; The total numbers of native fish will be denoted as (NF) through the rest of the text and in Figures 5.5 and 5.6. The abundance of individuals of two fish species were dominant (higher number of individuals). At Rasta Reef, *C. chromis* was the most common fish, at stage 1, the average number of fish per visit was 162,66 and the abundance has highest at the beginning of stage 3 with 340 fish. Meanwhile, at Gayalik Reef, the invasive alien *C. novemstriatus* was numerically dominant during stage 1, with an average of 232,33 fish per visit surpassing *C. chromis* which had an average number of 135,66 fish per visit. However, after the removals of *D. setosum*, it was completely absent in stage 3.

Figure 5.5.

Abundance (Number of Individuals) At Rasta Reef

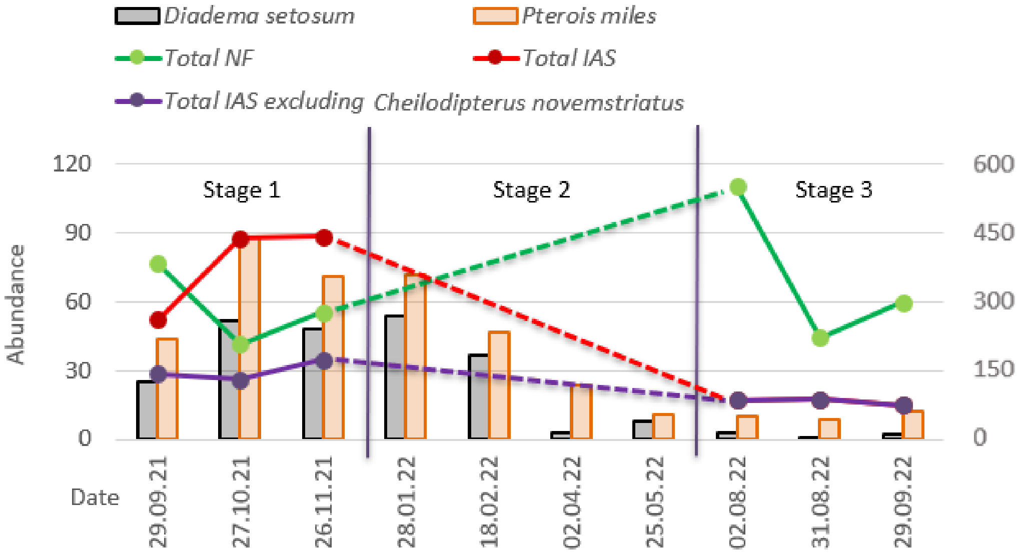


Note. Abundance of *D. setosum, P. miles* and selected fish and fish groups present before (stage 1), during (stage 2; modeled) and after (stage 3) removals at Rasta Reef. It must be noted that the numbers of NF and IAS are represented by the vertical number scale on the right, while for *D. setosum* and *P. miles*, the number scale is demonstrated on the left. Dashed lines correspond to modeled data.

Figure 5.5 shows the change in the abundances of total IAS, total native fish (NF) and total NF excluding *C. chromis*, while Figure 5.6 shows the similar situation at Rasta Reef. It was explained earlier that *C. chromis* was the most common species, therefore NF was analyzed twice, with blue and green lines, including and excluding *C. chromis* to better demonstrate the increase separately. It can be observed that there is a slight decrease in the total number of the IAS group. Concurrently, there is also a slight projected increase in the total number of native fish (NF) excluding *C. chromis* at the end of stage 2 (dashed lines). The first counts of NF on stage 3 are the highest, but it drops possibly with the recolonization of the reef by lionfish (Figure 5.5).

Figure 5.6.

Gayalik Reef Abundance (Individuals) comparisons



Note. The situation at Gayalik Reef regarding the change in Abundance of *D. setosum,* P. *miles* and selected fish and fish groups present before (stage 1), during (stage 2; modeled) and after (stage 3) removals at Gayalik Reef. It must be noted that the numbers of NF and IAS are represented by the vertical number scale on the right, while for *D. setosum* and *P. miles*, the number scale is demonstrated on the left. Dashed lines correspond to modeled data.

Figure 5.6 shows the change in the abundances of total IAS, total native fish (NF) and total NF excluding *C. novemstriatus*, at Gayalik Reef. The abundance of *C. novemstriatus* at Gayalik Reef was initially very high, so as per NF and *C. chromis* at Rasta Reef (Figure 5.5), the analysis has two curves related with IAS: Total IAS and Total IAS excluding *C. novemstriatus*. The total number of IAS during the initial stage before the removals, greatly dropped compared to stage 3, but this is partially due to the absence of *C. novemstriatus*. When *C. novemstriatus* is subtracted, there is a smaller decline of 50.9 % compared to 80.8 % if *C. novemstriatus* is included. Regarding native fish, the highest numbers are at the beginning of stage 3 (after removals), when the reef has been culled during four consecutive months. However, it must also be noted that this is the time of the high summer, and these increased numbers could also have been a seasonal effect. Moreover, although Rasta Reef is surrounded by very wide *Posidonia* meadows which may possibly be a problem for recolonization, Gayalik Reef is a fraction of a large strip of reef of hundreds of meters long, with much higher connectivity with nearby rocky reefs, *P. miles* recruitment at Gayalik Reef was lower compared to Rasta Reef.

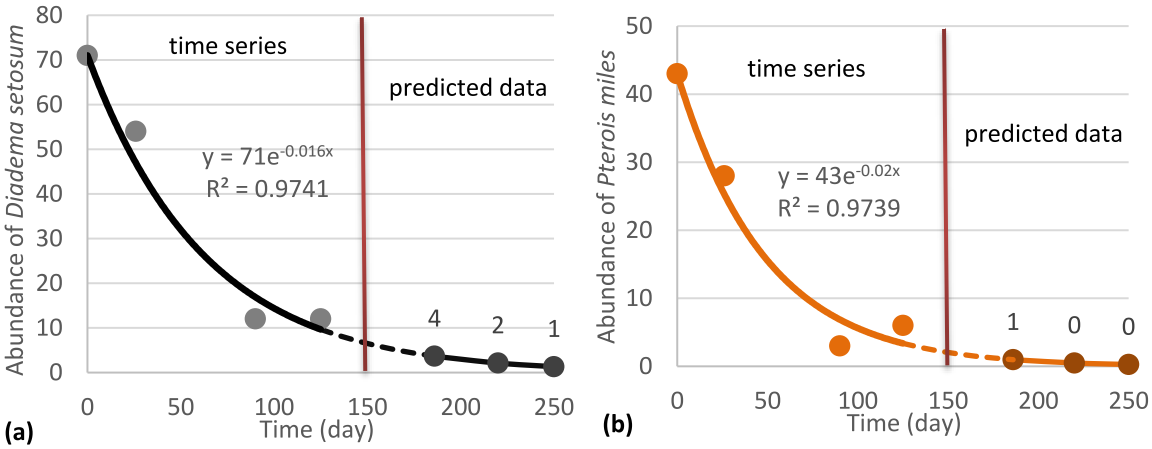
At both reefs, different levels of increase in native ichthyofauna and conversely decrease in the number of invasive alien fish species were observed. Comparisons of numbers before and after the removals show that at Rasta Reef, the average total number of IAS dropped 25.1% while average total number of native fish increased 13.5%. Similarly, at Gayalik Reef, average total number of IAS dropped 32% while the average total number of native fish increased by 28.8% when Stage 1 and Stage 3 counts are compared. These results suggest that regular removals of these two established species help native ichthyofauna to flourish, while other alien species are affected negatively.

5.3.4. Forecasting removal efficiency

The removals of *D. setosum* and *P. miles* were performed exclusively on four different occasions during stage 2. After that period, the number of these two invasive species did not drop to zero as anticipated. However, it was possible to model and evaluate the impact of the continual removal of these two IAS by fitting exponential equations modeling their populations in relation to time. Setting the date of the first removal time as zero, it was possible to model both species with coefficient of determination (R^2) values of 0.9741 and 0.9739 for *D. setosum* and *P. miles,* respectively, both of which indicate quite high accuracies (Figure 5.7). Over a period of time of 250 days, the model shows that it was possible to reduce the number of *D. setosum* to only one (value at end) after three more culling occasions and completely remove *P. miles* in 225 days if two more cullings took place.

Figure 5.7.

Abundance (Number of Individuals) Simulated by Exponential Models at Rasta Reef

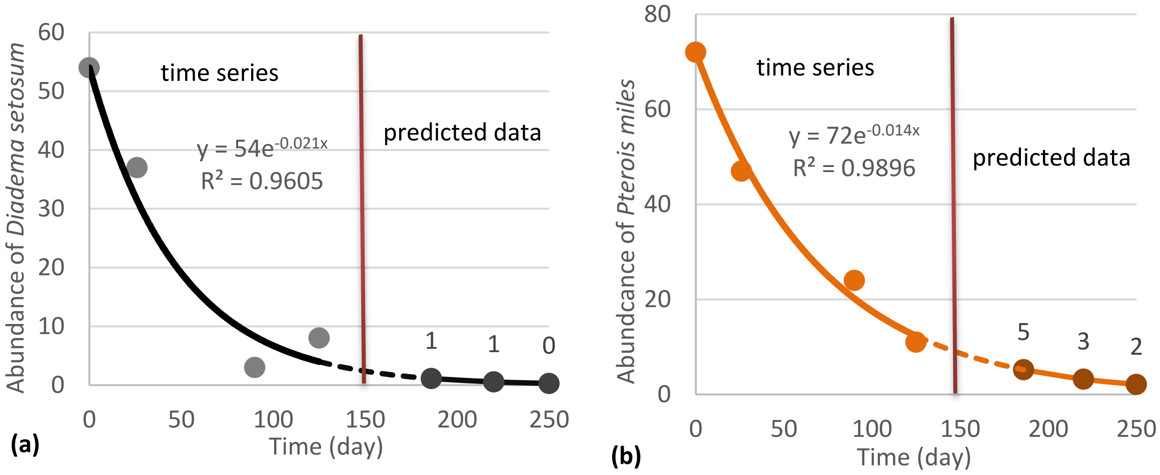


Note. Abundance (number of individuals) simulated by exponential models of *D. setosum* (a) and *P. miles* (b) at Rasta Reef.

Likewise, a similar approach was applied for the Gayalik Reef and the exponential models yielded very high R^2 values (0.9605 and 0.9896 for *D. setosum* and *P. miles,* respectively) as shown in Figure 5.7. The exponential models revealed that it was possible to completely remove *D. setosum* in 250 days while it was likely to decrease the number of *P. miles* to only two individuals at the same time.

Figure 5.8.

Abundance (Number of Individuals) Simulated by Exponential Models at Gayalik Reef



Note. Abundance (number of individuals) simulated by exponential models of *D. setosum* (a) and *P. miles* (b) at Gayalik Reef.

Despite rocky reefs on the shores of Cyprus being extensively spearfished (with the main target species, such as *E. marginatus*, *E. costae*, *E. aeneus*, *M. rubra*, common dentex *Dentex dentex*, *Diplodus* spp., and the greater amberjack *Seriola dumerlii* (Michailidis et al., 2020), *P. miles* is abundant, easy to hunt and has tasty meat, so it is also a target fish now in Cyprus and the numbers on frequently culled reefs are declining. However, understudied deeper reefs (>40m) cannot be easily accessed by every spearfisher, and the populations present in deeper waters can always be considered as a pool for recruitment (Andradi-Brown, 2019; Jimenez et al., 2019). Meanwhile, commercial set net and trammel net fisheries began to sell lionfish catches in recent years and are even beginning to target lionfish commercially, with individual boats landing hundreds of kg lionfish annually. This constant extraction will likely have a far greater regulating role on this species population and its impacts, than could be achieved by spearfishing. Onboard observation studies in these fisheries may allow us to understand the status of the species colonization and the impacts of its targeted extraction on other catches.

Time-limitation is a major caveat of this study. The study was far too short to assess the effects of seasonality of the fish species, such as *B. boops*, the curled picarel *Centracanthus cirrus*, *Siganus* spp. etc. on the efficiency of removals. Although not with a regular trend, Rasta Reef is still being quantitatively monitored with removals of *D. setosum* and *P. mile*s.

5.4. Conclusion

When prevention and early detection are ineffective, removal and eradication may be the best choice for managing established species and perpetual control (Wittenberg and Cock, 2001). If a critical species is recognized at an early stage of colonization and has a limited spatial distribution, eradication of these species may be achieved. In this case, an initial expenditure in eradication may result in a highly cost-effective long-term result. However, for the case of *P. miles* and *D. setosum*, results suggest otherwise (Bronstein et al., 2017; Huseyinoglu et al., 2021) because these two species colonized the eastern Mediterranean far too quickly and in great numbers. Moreover, our results suggest that regular removals can be used as a method to weaken or eradicate the IAS populations of established species at least in protected areas to assist native biodiversity.

While developing and implementing mitigation measures for IAS, it is critical to develop risk analysis, environmental impact assessments and to evaluate relevant policies, legislations and institutions in order to reinforce and adopt effective national management measures. 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.

As observed in many cases in the Atlantic, Caribbean (Albins and Hixon, 2008) and recently in the Mediterranean seas, lionfish and long-spined sea urchin have severe impact on the native fish assemblages as well as benthic communities causing significant reductions in the populations (Bradley et al., 2019; D’Agostino et al., 2020). Intensive and continual efforts to reduce densities of these species at key locations, such as dispersal points and vulnerable or valuable areas, may help to mitigate their negative ecological impacts and help to recover the native communities (Albins and Hixon, 2008).

Maintaining and monitoring healthy populations of potential native predators of these species may also help reduce the harmful effects of these avid invasive predators (Vafidis et al., 2021). Given that resources for instance funds, time and technical staff can be limited, authorities and managers need tools to effectively plan and allocate resources to achieve lionfish and long-spined sea urchin control objectives. Within which should be training fishing communities as sentinels to provide an early-warning system for key species. The methods applied in this study are generally applicable as an upfront way for to estimate the efforts needed to achieve the national conservation targets for IAS. These efforts can easily be replicated to other key locations within the vicinity of the geographical area to enhance the connectivity and increase the resilience of the ecosystems under invasion. Local control is effective at minimizing invasive species impacts at local scales and should be applied where possible.

The control of venomous IAS can generate socio-economic advantages that are for the public good, it necessitates the involvement of public in certain stages of the management efforts (Shine et al., 2010). As an example, tasting events can contribute to the conservation of our seas. During the summer of 2022, within the frame of this study, a tasting event open to public was organized with the support of experts and local stakeholders. With the slogan "Eat it to beat it!" an opportunity was created for local people to taste the two species that they were unfamiliar, aiming to encourage people to buy or order these species with the aim to increase their consumption by creating a demand.

Figure 5.9.

Photos from the tasting event

Note. Photo credits: Olkan Ergüler

Chapter VI

Investigations on the Erosional Platforms of the Tidal Zone in the Northern Coasts of Cyprus

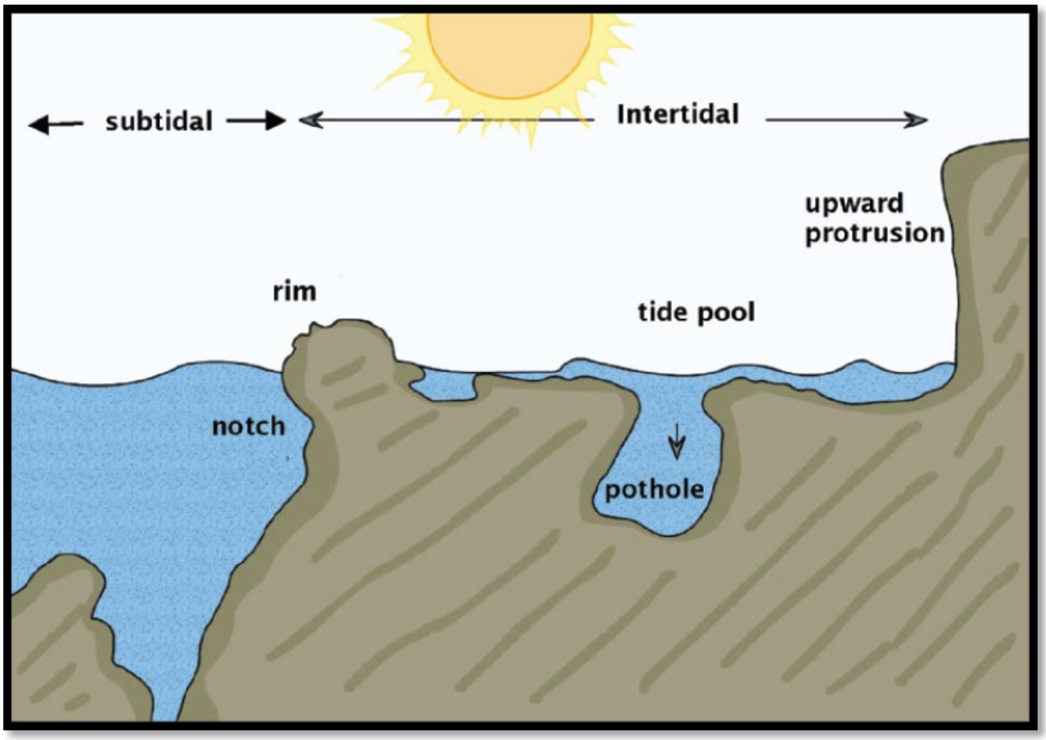
6.1. Introduction

The adaptive strategies and physiological needs of marine macroalgae (seaweeds) to survive in the harsh conditions of the intertidal zone. Seaweeds have remained within this narrow and restricted niche for millions of years, despite several episodes of environmental change. Today, there are around 20,000 species of seaweeds, and they are divided into three major categories: green (Chlorophyta), brown (Phaeophyta), and red (Rhodophyta). The Mediterranean flora has a history of around five million years, and the climate changes in the late Pliocene and Pleistocene may have promoted the speciation and origin of endemic species. Despite losing its coral reefs and tropical character, the Mediterranean coasts remain home to a rich seaweed flora, including endemic, tropical, warm and cold-temperate species (Lunning, 1990; Hoek and Breeman, 1990; Orfanidis, 1992).

The rocky shores of the eastern Mediterranean, which are unique abrasion platforms made of calcareous sandstones and limestones (Zahavi, 2006). These surfaces are influenced by tidal fluctuations and can range from a few to about 30 meters wide. The edges of the platforms are higher than the rest of the surface and enclose shallow tidal pools and potholes (Figure 6). Marine worms and snails such as *Vermetus triquetrus* and *Dendropoma petraeum* help reinforce the platforms with their calcified skeletons. The tidal fluctuations in the region are modest but play a significant role in the dynamics of the seaweed community on the platforms. During calm seas and low tides, seaweeds may remain exposed for many hours, which can damage dominant and opportunistic species like *Ulva spp.* and *Jania rubens* for weeks. Low sea levels occur during winter and early spring, particularly when low humidity winds blow from the east, called 'Hamsin' locally (Einav and Israel, 2007).

Figure 6.

A vertical profile of an intertidal platform



Note: vertical profile of an intertidal platform in the eastern Mediterranean showing the typical niches created in which seaweeds can be found (Einav and Israel, 2007).

The availability of substrate can be limited, as rocky surfaces in the intertidal zone can be scarce and competition among algae for space can be intense. This competition can result in vertical zonation of algal communities, with certain species dominating specific vertical zones based on their ability to tolerate different environmental conditions, such as desiccation, wave exposure, and competition for light and nutrients. The dominant species in the uppermost intertidal zone are typically small, tough, and resistant to desiccation, while those in the lower intertidal zone are generally larger and more reliant on water for support. Human activities, such as coastal development, fishing, and pollution, can also have significant impacts on intertidal algal communities, leading to declines in species richness and changes in community composition. Therefore, it is important to protect and conserve intertidal zones and their diverse algal communities (Einav and Israel, 2007).

Rocky beaches are more conducive to the growth of algal species due to their stable substrate, whereas sandy beaches are less suitable for algal attachment due to the unstable nature of the substrate. However, rocky shores are less common in the eastern Mediterranean due to the presence of sand runoff from the Nile River. Seaweeds play a significant role in the composition and abundance of marine communities, and their growth can hinder the development of other marine organisms. In the eastern Mediterranean, most macroalgae are relatively small in size, and this trend extends to other marine organisms such as fish and shellfish. This phenomenon is believed to be an adaptation to the oligotrophic conditions commonly found in the area, as higher water temperatures can prompt earlier sexual maturity in marine organisms before they reach their full size. While there is ongoing research in this area, a comprehensive study into this matter has not yet been carried out (Sonin et al., 1996; Einav, 2004).

Our study in the Alsancak and Esentepe regions of Cyprus examines the effects of wave motion, air, light, temperature, salinity, nitrogen, and phosphorus, and grazing on changes in the coastal area platforms (Figure 6.1). In addition, our research area in the Esentepe region also includes unique flysch formations and organisms (Figure 6.2). Cyprus coasts host many different lithological formations, one of which is flysch formations. Flysch is a sedimentary rock formed by repeatedly stacking rock layers with opposite characteristics. Flysch formations can have various forms, especially due to earthquake and tectonic activity. Flysch formations in Cyprus have a twisted, warped, and layered structure due to these activities. Flysch formations have also been eroded and shaped by environmental factors during the historical process. Flysch formations in Cyprus are considered as an important resource both geologically and touristically.

Figure 6.1.

Platforms Workspaces

Note: Alsancak (35°21'30.27"N - 33°11'52.40"E) and Esentepe (35°21'31.93"N - 33°38'4.91"E)

The flysch formations on the Cyprus coasts are located on the north coast of Cyprus, which is part of the Mediterranean. Along this coastline, there is the Levant Flysch zone, which is a large geological formation that extends from the west of the Anatolian Peninsula of Turkey to Syria. Flysch is a type of sedimentary rock formed by the accumulation of interlinked thin layers of rock. The flysch formations on the Cyprus coasts are located mainly in the northwest part of the Cyprus Fold Belt, under the Kyrenia Mountains, and were formed approximately 80 million years ago during the Cretaceous Period (Shaanan et al., 2021).

6.2. Materials and Methods

The research methodology involves creating a grid pattern on a 50 x 50 square platform, with divisions at every 5 cm interval. To facilitate detailed analysis, the areas are demarcated using fishing lines. Random numbers are assigned to determine the 50-meter strip-shaped regions. Initially, general information such as data collection date and time is recorded, followed by indicating the percentages of different parameters (e.g., sand, rocks, or holes) and noting the coverage. Subsequently, the algae present in each region (red, brown, and green) are grouped by observers under subheadings within the main categories. Any unknown species or those not listed are separately noted and recorded for further analysis. The records are documented based on photographs, collected samples, and direct examination by at least 2 observers. Additionally, the selection of study days and time intervals for each region is based on tidal conditions.

Figure 6.2.

Esentepe Research Area

The effect of waves on algal communities is not uniform throughout the intertidal zone. In the lower intertidal zone, where seaweeds are submerged for longer periods, waves play a more direct role in providing minerals and dissolved CO2 for photosynthesis (Figure 6.3). In contrast, in the upper intertidal zone, where seaweeds are exposed to air for longer periods, the effect of waves is more indirect, as they erode the substrates and provide nutrients for the growth of new algae. The size of waves also affects algal communities. Larger waves have a more pronounced effect on the lower intertidal zone, where they can cause damage to algae and dislodge them from the substrate. In contrast, smaller waves have a greater effect on the upper intertidal zone, where they can dislodge sand particles and create new substrate for algae to colonize. The interplay between waves, substrate, and algal communities is complex and dynamic, and is influenced by a range of environmental factors such as temperature, light, and nutrient availability (Einav et al., 1996, 1998).

Figure 6.3.

Alsancak Research Area

The exposure of seaweeds to air can cause water loss and dehydration due to the lack of mechanisms or anatomical features that prevent water loss from their tissues. Seaweeds lose water rapidly when exposed to air, which can lead to increasing solute concentration. Environmental conditions such as temperature, relative air humidity, wind velocity, and topography affect the rate of water loss. Seaweeds are vulnerable to desiccation, but some morphology and features may delay dehydration. Air exposure affects the algal ability to absorb Ci from the air or from the thin seawater film on the thallus surface and impairs many intracellular enzymatic processes. Seaweeds that are exposed to prolonged desiccation during low tides in spring may experience massive bleaching and partial destruction of the communities. Some species of algae can maintain positive photosynthetic levels even after losing 90% of their water content, indicating high tolerance to air. Examples of high tolerance to air are found in *Gelidiella pannosa* or leaf-like Porphyra and Ulva that grow in dense communities in the upper intertidal zone. These species have survival strategies that involve a combination of re-sorting of the layers with wave action and tide change and/or shielding of the main bulk of the plant by the upper layers (Sonin et al., 1996; Einav, 2004). The adaptability of intertidal algae to air exposure is composed of two strategies: the ability to maintain positive photosynthesis during exposure and the ability to recover quickly upon immersion in seawater (Figure 6.4). Some seaweeds can use air-born CO2 directly, conferring a clear advantage over those unable to do so. Seaweeds' rates of photosynthesis measured in the air may be 3–5 fold higher than rates measured when submerged, as long as environmental parameters such as increased temperature, salinity, or dehydration do not significantly harm the photosynthetic capabilities of exposed algae (Einav and Beer, 1993; Einav et al., 1995).

Figure 6.4.

A Rocky shore in Mare Monte Beach (Alsancak)

The role of light in sustaining photosynthesis and growth is critical for marine photosynthetic organisms, as seaweeds transform light into chemical energy that is needed for metabolic processes. However, light penetration into seawater is limited, and therefore light may be a limiting resource for many marine organisms. Algae that develop on abrasion platforms are an exception to this limitation, as they are not limited by sunlight. In fact, many Mediterranean species can reach maximum photosynthesis at intensities of only 1-10% of full sunlight. Further increases in irradiance can lead to photochemical inhibition of photosynthesis and growth (Einav and Beer, 1993).

As the depth in the subtidal zone increases, the irradiance decreases, and so does the algal community. This decrease in irradiance is even more pronounced due to water turbulence and sediment agitation, which create littoral waters with relatively high turbidity. Calcifying algae, such as Corallina elongata and Alsidium corallinum, prevail as the lower limit of the photic zone is approached (not accurately measured but believed to be at approximately 100 meters). In even more shaded areas, Lobophora variegata, Peyssonnelia squamaria, and Bryopsis plumosa dominate (Goldsmith and Sofer, 1983).

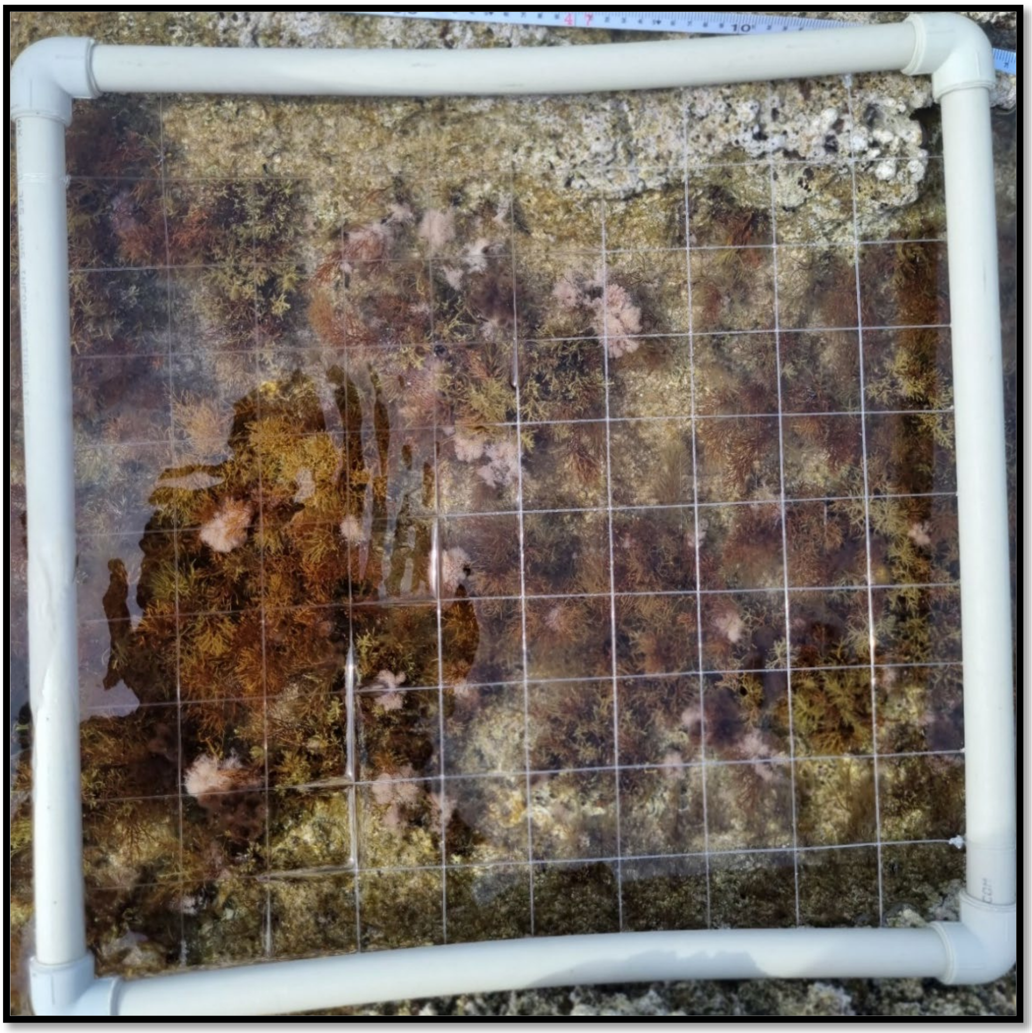
In addition to depth, lack of sunlight in intertidal cavities is a significant limiting factor for algae development. The darkest areas are populated by mostly sponges, colonial hydras, and bryozoa, which displace the algae. Therefore, while light intensity is a controlling factor in seaweed community development in cavities and at increasing depths, it is not a limiting factor in the intertidal zone, where algae are already saturated with light (Einav and Israel, 2007).

Light is not the only environmental factor that affects algal growth and community development. Temperature also plays a critical role in sustaining photosynthesis and respiration processes in seaweeds. Seawater temperature is a key factor that determines variations in algal communities throughout the year. During winter, several species disappear from the coast and are visibly replaced by species of the order Ulvales that dominate large parts of the intertidal zone (Figure 6.5). Generally, with decreasing temperature, both photosynthetic and respiratory levels drop, directly inhibiting growth, enabling winter species or other opportunistic species to invade the area and take over (Lobban and Harrison, 1994).

Air temperature can also have a significant impact on algal communities, as it can shift swiftly over a 10-15°C range during a 24-hour period. Temperature changes in potholes are apparent during low tide or as a result of low wave activity. In some isolated potholes and rocky pools, increasing temperature lowers gas solubility, resulting in low CO2 and O2 contents. This is in contrast to the higher demand for CO2 as the temperature rises. Several species are distinguished according to their ability to withstand high temperatures for extended periods of time. Thus, temperature is another key factor that affects algal growth and community development (Einav and Beer, 1993).

Figure 6.5.

Quadrat Sampling Area (Esentepe Flysch)



In addition to temperature and salinity, the nutrient content of seawater is also an important factor in algal growth and community structure. Nutrient availability varies widely in the Mediterranean Sea, and there are several areas where nutrient concentrations are particularly high. One of these is the eastern Mediterranean, where the influx of nutrient-rich waters from the Nile and other rivers results in high productivity and biomass of phytoplankton and seaweeds (Shaltout and Omstedt, 2014). In contrast, the western Mediterranean is relatively oligotrophic, with lower nutrient concentrations and lower primary productivity (Béthoux and Morin, 2002). However, even in areas of high nutrient availability, excess nutrients can lead to eutrophication and harmful algal blooms, which can have negative impacts on the marine ecosystem and human health (Hallegraeff, 1993). Therefore, nutrient management and monitoring are important for maintaining a healthy and productive marine environment.

In summary, the oligotrophic nature of the Mediterranean Sea limits algal growth due to low concentrations of key nutrients such as nitrogen and phosphorous, which originate mainly from rivers and continental runoff. However, sufficient levels of light and carbon dioxide (Ci) are still necessary for positive photosynthesis and growth of marine macroalgae. Seaweeds in the Mediterranean, including those in the intertidal zone, can efficiently utilize the abundant HCO3 (Barak et al., 2005).

In seawater through carbon concentrating mechanisms, and do not suffer from carbon limitations. Nevertheless, the unstirred boundary layer at the thallus surface creates constraints on carbon acquisition, and the rather low concentrations of CO2 and slow diffusion rates in seawater can limit photosynthetic activity. Species-specific and environmental factors such as temperature, irradiance, and nutrient status also affect the preferred mechanism of HCO3 − utilization by marine macroalgae (Axelsson et al., 1995).

The text explains that grazing activity is more active in the subtidal zone than in the intertidal zone, and that the lower boundaries of algal species in the intertidal zone are determined by herbivory. Fish, snails, and shellfish are common grazers in the subtidal zone, and certain fish species, such as Siganus rivulatus and *Siganus luridus*, feed mainly on species like *Ulva compressa* and *Ulva olivascens*. These fish may be responsible for the disappearance of certain algal species from the intertidal zone, while other species, such as calcified species, may thrive in the subtidal zone due to less grazing pressure on softer algae (Lundberg, 1989).

The potential effects of global changes on marine macroalgae in the eastern Mediterranean. The global changes include a continuous rise in atmospheric CO2 leading to higher total carbon concentrations in seawater, a greenhouse effect caused by specific gases such as CO2 trapping heat, and an increase in solar flux of UV radiation. These changes could lead to more acidic, richer inorganic carbon, and slightly warmer oceans and seas in the future (Crutzen, 1992).

Benthic macroalgae play an important role in marine primary production and serve as a food source for herbivores and detrivores. They also act as nursery areas for juvenile fish and crustaceans and produce natural products for humans. However, the effects of rising carbon concentrations in seawater and UV radiation in nutrient-rich areas on marine macroalgae are not well understood (Franklin and Forster, 1997; Israel and Hophy, 2002).

Studies have shown that macroalgae exposed to deleterious UV radiation may suffer damage to their photosynthetic apparatus and DNA, and even under normal conditions, solar UVB has inhibitory effects on photosynthetic performance and nutrient uptake. However, many organisms have evolved strategies such as photo repair or the presence of screening compounds to cope with the harmful effects of UV radiation (Gröniger et al., 1999; Sinha et al., 2000).

The passage also notes that global warming due to increasing levels of atmospheric CO2 and other greenhouse gases is causing rising sea levels, which could lead to permanent submergence of intertidal zones. This would have significant implications for the dynamics and composition of algal communities.

6.3. Conclusion

That's an interesting observation about the intertidal algal communities in the eastern Mediterranean. The fact that high standing stocks develop on abrasion platforms during high growth seasons and that these platforms are periodically exposed to air during low tides suggests that these communities have adapted to the harsh conditions of the intertidal zone.

The limited tidal fluctuations in the area may also play a role in shaping the community structure and species composition of these algal communities. The severe conditions of temperature, irradiance, and dehydration during low tide create a challenging environment for seaweeds, but they also provide opportunities for the growth of many species that are not found in the deeper waters of the benthic zone.

Overall, it's fascinating to see how different species have adapted to survive and thrive in the intertidal zone, and it highlights the importance of studying these unique ecosystems to better understand the diversity of life on our planet.

Chapter VII

Analysis of Shallow Coastal Habitats in the Northern Coasts of Cyprus

7.1. Introduction

Coastal habitats are ecosystems located in the transitional zone between land and sea. These habitats can exhibit different characteristics in different regions of the coastline. Coastal habitats serve as a connection point between marine and terrestrial ecosystems. They also provide habitat for both marine and terrestrial species. Coastal habitats can be found in various types. These include beaches, sand dunes, rocky shorelines, mangrove forests, seagrass beds, salt marshes, and reefs. Each habitat type has different physical and chemical properties, which support the life of different species. For example, beaches typically have sandy substrates and serve as nesting areas for species like sea turtles. Rocky shorelines provide protection against wave erosion and serve as shelter for species such as marine mammals, fish, and corals (Barbier et al., 2011).

The analysis and study of coastal habitats are conducted to understand their structure, functions, and diversity. These analyses may involve various data collection methods. Factors such as measuring physical characteristics, analyzing water quality, inventorying plant and animal species, and monitoring population dynamics are important in these analyses. The ecosystem functions of coastal habitats are also an important research topic. Food web analyses are used to understand how the food chain operates and how energy is transferred. Additionally, studies that determine the impacts of habitat diversity, biodiversity, and ecosystem health are crucial (Elliott et al., 2007).

The analysis and study of coastal habitats are essential for the development of long-term monitoring programs and conservation strategies. These studies provide fundamental data for the conservation, restoration, and sustainable management of habitats. Furthermore, these analyses are used to understand and mitigate threats to coastal habitats, such as human impacts, climate change, and sea-level rise.

Cyprus is an island located in the eastern region of the Mediterranean Sea and it has various coastal habitats. The coastline of Cyprus encompasses different areas such as beaches, sand dunes, rocky shores, and seagrass meadows. The beaches of Cyprus play a significant role in tourism. These beaches usually have beautiful sandy shores, offering visitors the enjoyment of the sea, sun, and sand. They can also serve as nesting areas for rare species like sea turtles.

Sand dunes are important habitats found along the coasts of Cyprus. These natural formations are sand mounds formed by wind and wave action. Sand dunes provide habitat for specific plant and animal species and help prevent coastal erosion. The rocky shores of Cyprus are coastal structures formed by wave action. These areas provide protection against high waves and erosion. Rocky shores can serve as shelter and food sources for marine life such as fish, crustaceans, and corals.

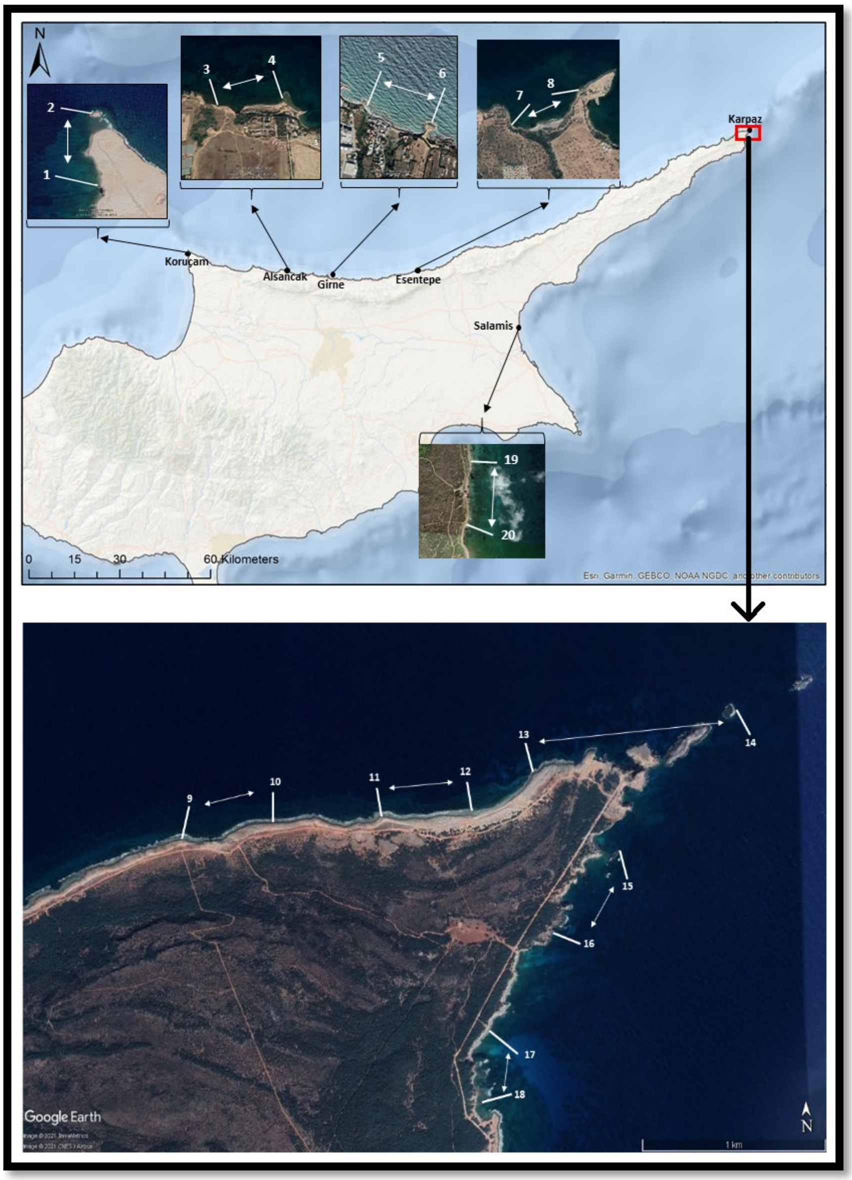
Seagrass meadows are another important ecosystem in Cyprus' coastal habitats. These meadows consist of underwater plant communities spreading in shallow marine areas. Seagrass meadows play a crucial role in the food chain, maintain water quality, and can help reduce coastal erosion. The coastal areas of Cyprus offer natural beauty and various recreational opportunities for both locals and tourists. However, these areas need to be protected from environmental threats. Factors such as pollution, excessive tourism activities, and coastal development can pose risks to coastal habitats. Therefore, sustainable management and conservation strategies are crucial for the future of Cyprus' coastal areas.

7.2. Materials and Methods

Six sites representing the major shallow coastal habitat types observed on the north coast of Cyprus were chosen for this study (Figure 7). Diverse habitat expectance, intensity of recreational use, fishing pressure, oceanographic conditions, and remarkable landmarks such as vermetid reef formations were taken into consideration while determining the exact locations.

Figure 7.

Locations of the transects



At each site 200 m long transects were set 500 m apart from each other and perpendicular to the shore. The beginning of each transect was fixed on the high tide line and its end was fixed on the sea bottom with an anchor, which was marked with a buoy. Each transect was made of 2 cm thick sinking rope, tagged at every 5 meters, showing the distance from the starting point. The coordinates of the transects were taken by GPS instrument (Garmin eTrex 10, USA). At each site transects were set in parallel, 500 m apart from each other. A total of 20 transects were set in six sites (Table 7).

Table 7.

Coordinates of the transects

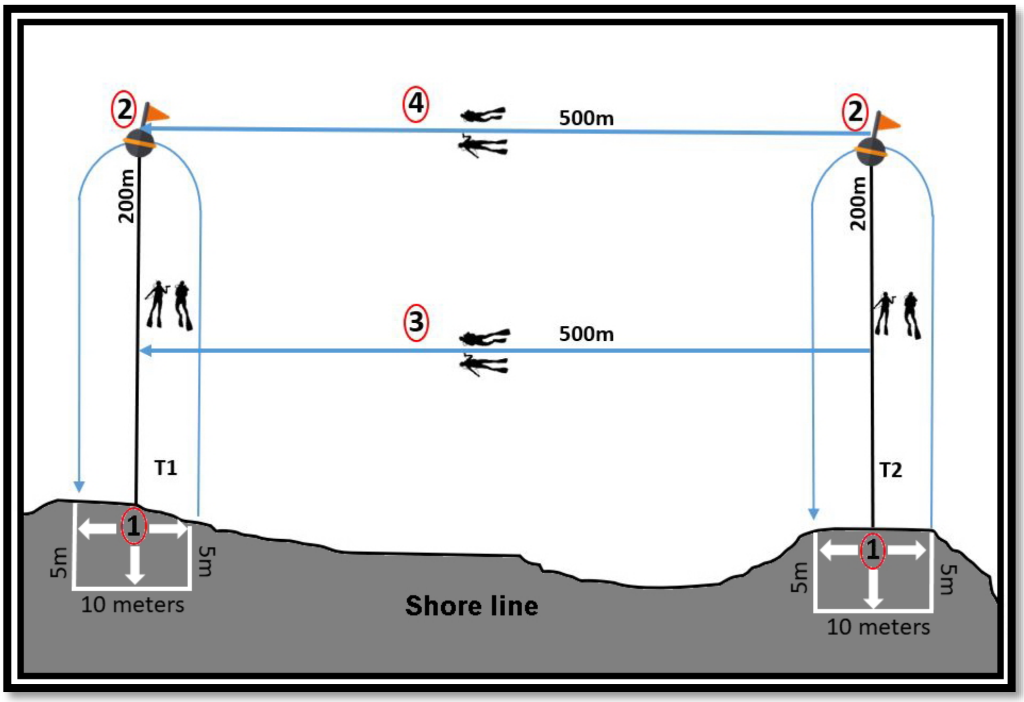
Transect	Start		End	
	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)
1	5°24'03.64"	32°55'13.99"	35°24'04.95"	32°55'06.20"
2	35°24'18.23"	32°55'11.88"	35°24'19.18"	32°55'04.26"
3	35°21'26.93"	33°11'58.70"	35°21'32.97"	33°11'56.63"
4	35°21'30.46"	33°12'15.71"	35°21'35.75"	33°12'12.36"
5	35°20'13.68"	33°20'29.42"	35°20'19.36"	33°20'33.05"
6	35°20'10.31"	33°20'46.20"	35°20'16.10"	33°20'48.82"
7	35°21'21.51"	33°36'04.58"	35°21'27.19"	33°36'08.16"
8	35°21'32.95"	33°36'21.23"	35°21'30.52"	33°36'13.85"
9	35°41'31.46"	34°33'34.28"	35°41'38.19"	34°33'36.22"
10	35°41'33.77"	34°33'53.98"	35°41'40.11"	34°33'53.93"
11	35°41'34.28"	34°34'17.78"	35°41'40.65"	34°34'16.48"
12	35°41'34.26"	34°34'38.95"	35°41'40.68"	34°34'36.59"
13	35°41'40.87"	34°34'51.81"	35°41'46.86"	34°34'49.34"
14	35°41'50.07"	34°35'35.29"	35°41'44.49"	34°35'38.64"
15	35°41'27.83"	34°35'09.49"	35°41'22.31"	34°35'11.42"
16	35°41'14.61"	34°34'54.87"	35°41'12.28"	34°35'01.43"
17	35°40'59.17"	34°34'39.76"	35°40'55.82"	34°34'46.58"
18	35°40'47.49"	34°34'38.96"	35°40'48.36"	34°34'46.08"
19	35°13'35.40"	33°54'13.36"	35°13'35.24"	33°54'21.26"
20	35°13'19.29"	33°54'13.30"	35°13'17.07"	33°54'20.71"

Standard scuba equipped two-diver team started diving from the starting point of the transects on the shore and swam towards the end point (Figure 7.1). While taking notes on the habitat characteristics and depths, the divers took the videos of the benthic structure, covering 5 m from the right side and 5 m from the left side of the transect. Therefore, an area of 10m x 200 m were recorded along each transect. Divers also collected sediment, dominant invertebrate, and algae samples along the transects. Collected samples were stored in appropriate fixatives such as ethanol or formaldehyde until laboratory analysis.

The area between two transects were investigated by two scuba diving teams started diving at the 100 m and 200 m marks of the transects and swam towards the neighboring transect. The aim of these examinations was to evaluate the continuity and variance of the habitats recorded alongside the transect lines (Figure 7.1).

Figure 7.1.

Methodology of examinations. 200 m long transects were set perpendicular to the shore, starting from the high tide zone. SCUBA divers



Supralittoral surveys were carried out in a total area of 50 m^2, 5 meters to the right, 5 meters to the left and 5 meters towards inland from the beginning of each transect with thorough observations, and samples were obtained.

Observed habitat types were classified according to updated EUNIS (EUNIS, 2022), SPA/RAC (SPA/RAC-UN Environment/MAP, 2019) and IUCN (IUCN, 2012) habitat classification systems.

7.3. Results

Transect mapping revealed the presence of 22 coastal habitats, 11 littoral and 11 infralittoral (Table 7.1). The maximum depth recorded during the survey is 17.4 m. Therefore, lower limits of the infralittoral zone and circalittoral habitats were excluded from the research.

Table 7.1.

Codes of the observed habitats according to EUNIS (2022), SPA/RAC (2019) and IUCN (2012) habitat classification systems

	Habitat type	**EUNIS**	**RAC/SPA**	**IUCN**
Supralittoral	Inorganic sand	MA5511	MA5.51	13.3?
	Foraminiferal sand	MA5511	MA5.51	13.3?
	Mixed sediment	MA351	MA4.51a	-
	Rock	MA151	MA1.513	13.1
Mediolittoral	Sand	MA55	MA5.52	12.2
	Mixed sediment	MA452	MA4.52	12.3
	Upper mediolittoral rock facies with gastropods	MA153	MA1.534	12.1
	Lower mediolittoral rock facies with gastropods	MA154	MA1.547	12.1
	Lower mediolittoral communities associated with *Cystoseira amantacea*	MB1513	MA1.542	12.1
	Rockpools	MA153	MA1.54a	12.6
	Mediolittoral abrasion platforms	MA154A	MA2.513	12.1
Infralittoral	Fine sand	MB551	MB5.51	9.4
	Mixed sediment	MB45	MB4.5	9.3
	Communities associated with canopy forming algae other than *Cystosiera* spp.	MB151	MB1.511a	9.7
	Communities dominated by *Jania rubens*	MB151	MB1.51a	9.7
	Communities dominated by *Dictyota fasciola*	MB151	MB1.512a	9.7
	Communities dominated with *Stypopodium schimperi* or *Padina pavonina*	MB151	MB1.512a	9.7
	Cystoseira spp. communities on bedrock	MB151	MB1.511a	9.7
	Cystoseira spp. communities on sand	-	M5.523	9.7
	Calcerous algae reefs	MB251	MB1.51a	9.2
	Posidonia oceanica beds	MB2521	MB5.521	9.9
	Barren rocks	MB15	MB1.5	9.2

It was observed that the supralittoral zone did not show much variation in the stations examined within the scope of the study. The biodiversity in the supralittoral zone is found to be quite low due to the homogeneous ground structure and high temperature. In addition, the fact that a narrow part of the supralittoral zone was investigated is one of the reasons for the lack of habitat diversity.

The mediolittoral zone observed during the study covered a belt of approximately 40 cm. For this reason, it can be said that the wave effect on biodiversity is more than the tidal effect in open areas. In sheltered areas, habitats are exposed to excessive sunlight and high temperature during low tide, while habitats in wave-exposed areas are constantly wet. Therefore, there is a habitat difference between open and closed environments. In addition, *Dendropoma patraeum* and *Neogoniolithon brassica-florida* deposits growing on abrasion platforms significantly increase local biodiversity. On the other hand, it was observed that the invasive alien foraminifera species, *Amphistegina lobifera*, has drastic effects on the supralittoral and infralittroal zones enough to completely change the habitat structure (Table 7.2 – 7.6).

Table Abbreviations (7.2 – 7.6)

SIS: Supralittoral inorganic sand, **SFS:** Supralittoral foraminiferal sand, **SMS:** Supralittoral mixed sediment, **SR:** Supralittoral rock, **MS:** Mediolittoral sand, **MMS:** Mediolittoral mixed sediment, **MUG:** Upper mediolittoral rock with gastropods, **MLG:** Lower mediolittoral with gastropods; **MCa:** Lower mediolittoral communities with Cystoseira amantacea, **MRP:** Mediolittoral rockpools, **MAP:** Mediolittoral abrasion platforms**,** **IFS:** Infralittoral fine sand, **IMS:** Infralittoral mixed sediment, **IC:** Infralittoral algae community dominated by canopy forming algae other than Cystoseira spp. **IJr:** Infralittoral algae community dominated by Jania rubens, **IDf:** Infralittoral algae community dominated by Dictyota fasciola, **ISP:** Infralittoral Stypopodium schimperi and Padina pavonina, **ICB:** Cystoseira spp. on bedrock, **ICS:** Infralittoral Cystoseira spp. on sand, **ICA:** Infralittoral calcerous algae reefs, **IPo:** Posidonia oceanica, **IBR:** Infralittoral barren rock.

Table 7.2.

Depth and distribution of habitat types along the transects (Station 1 - 4)

Transect distance (m)	Station 1 (Koruçam)			Station 2 (Koruçam)			Station 3 (Alsancak)			Station 4 (Alsancak)		
	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left
Supralittoral		SIS	SIS		SR	SR		SMS	SMS		SIS	SIS
0	0	MUG	MUG	0	MUG	MUG	0	MMS	MMS	0	MRP	MRP
5	0.1	MLG	MLG	3.7	ISP	ISP	0.2	MMS	MMS	0.2	MCa	MCa
10	0.1	MLG	MLG	5	IFS	ISP	0.2	MMS	MMS	1.8	IC	IC
15	0.2	ICS	ICS	4.9	IFS	ISP	0.5	ICA	ICA	3.1	ISP	ISP
20	0.5	ICS	ICS	4.6	IBR	ISP	0.6	ICA	ICA	4	ISP	ISP
25	0.6	ICS	ICS	4.3	IBR	ISP	0.7	ICA	ICA	4.4	ISP	ISP
30	0.7	ICS	ICS	5.8	IBR	IBR	0.7	ICA	ICA	4.7	ISP	ISP
35	0.8	ICS	ICS	6.8	ISP	ICA	0.8	ICA	ICA	5	ISP	ISP
40	0.9	ICS	ICS	6.7	ISP	ICA	1	ICA	ICA	5.2	ISP	ISP
45	1	ICS	ICS	7.6	ICA	ICA	1.1	ICA	ICA	5.8	ISP	ISP
50	1.1	ICS	ICS	7.8	IPO	ICA	1.1	ICA	ICA	5.9	ISP	ISP
55	1.2	ICS	ICS	9.1	IPO	ICA	1.2	ICA	ICA	7	ISP	ISP
60	1.3	IFS	IFS	9.6	IPO	ICA	1.2	ICA	ICA	7.6	ISP	ISP
65	1.4	IFS	IFS	10	IFS	ICA	1.3	ICA	ICA	8.4	ISP	ISP
70	1.4	IFS	IFS	11.6	IFS	ICA	1.3	ICA	ICA	8.7	ISP	ISP
75	1.6	IFS	IFS	12	IPO	IFS	1.4	ICA	ICA	9.4	ISP	ISP
80	1.7	IFS	IBR	12.5	IFS	IFS	1.4	ISP	ISP	9.5	ISP	ISP
85	1.8	IFS	IFS	13.3	IFS	ICA	1.5	ISP	ISP	9.8	ISP	ISP
90	1.9	IFS	IFS	13.7	IFS	IPO	1.5	ISP	ISP	10	ICB	ICB
95	1.9	ICS	IFS	14.2	IFS	ISP	1.6	ISP	ISP	10.8	ICB	ICB
100	2	IFS	IBR	14.6	IPO	IFS	1.6	ISP	ISP	11.3	ICB	ICB
105	2	IFS	IFS	14.4	IFS	IFS	1.7	ISP	ISP	11.5	ICB	ICB
110	2.1	IFS	IFS	15	IFS	IFS	1.7	ISP	ISP	11.7	ICB	ICB
115	2.1	IFS	IFS	15.4	IPO	IPO	1.8	ISP	ISP	12.4	ICB	ICB
120	2.2	IFS	IFS	15.9	IPO	IPO	1.8	ISP	ISP	12.5	ICB	ICB
125	2.2	IFS	IFS	16	IPO	IPO	1.9	ISP	ISP	12.7	ISP	ISP
130	2.2	IFS	IFS	16.1	IPO	IPO	1.9	ISP	ISP	12.8	ISP	ISP
135	2.3	IFS	IFS	16.4	IPO	IPO	1.8	ISP	ISP	12.9	ISP	ISP
140	2.3	IFS	IFS	16.7	IPO	IPO	2	ISP	ISP	13.7	ISP	ISP
145	2.4	IFS	IFS	16.9	IPO	IPO	2.1	ISP	ISP	13.8	ISP	ISP
150	2.5	IFS	IFS	17.2	IPO	IPO	2.2	ISP	ISP	14	IPO	IPO
155	2.6	IFS	IFS	17.6	IPO	IPO	2.2	IPO	IPO	14.2	IPO	IPO
160	2.7	IFS	IFS	17.8	IPO	IPO	2.3	IPO	IPO	14.3	IPO	IPO
165	2.7	IFS	IFS	18	IPO	IPO	2.3	IPO	IPO	15.1	IPO	IPO
170	2.8	IBR	IBR	18	IPO	IPO	2.4	IPO	IPO	15.7	IPO	IPO
175	2.8	IBR	ICB	18.2	IPO	IPO	2.4	IPO	IPO	16.3	IPO	IPO
180	2.8	IBR	ICB	18.5	IPO	IPO	2.4	IPO	IPO	16.7	IPO	IPO
185	2.9	IBR	ICB	18.8	IPO	IPO	2.5	IPO	IPO	16.7	IPO	IPO
190	2.9	ICB	ICB	19.3	IPO	IPO	2.5	IPO	IPO	17	ICA	ICA
195	3	ICB	ICB	19.2	IPO	IPO	2.4	ICA	ICA	17.4	ICA	ICA
200	3	ICB	ICB	19.4	IPO	IPO	2.4	ICA	ICA	17.4	ICA	ICA

Table 7.3.

Depth and distribution of habitat types along the transects (Station 5 - 8)

Transect distance (m)	Station 5 (Kyrenia)			Station 6 (Kyrenia)			Station 7 (Esentepe)			Station 8 (Esentepe)		
	Depth (m)	**Right**	**Left**	**Depth (m)**	**Right**	**Left**	**Depth (m)**	**Right**	**Left**	**Depth (m)**	**Right**	**Left**
Supralittoral		SR	SR		SR	SR		SR	SR		SR	SR
0	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG
5	0.3	MCa	MCa	3.2	ISP	ISP	0.8	IC	IC	0.5	IC	IC
10	2.4	ISP	ISP	3.8	ISP	ISP	1.4	IMS	IMS	0.8	IJr	IJr
15	2.7	ISP	ISP	3.4	ISP	ISP	1.5	IMS	IMS	1.2	IJr	IJr
20	2.7	ISP	ISP	1.9	ISP	ISP	1.8	ICA	ICA	1.5	IJr	IJr
25	2.8	IFS	IFS	2.7	ISP	ISP	1.9	ICA	ICA	1.8	IDf	IDf
30	2.9	IFS	IFS	4.5	ISP	ISP	1.6	ICA	ICA	2.1	IDf	IDf
35	3	IFS	IFS	5	IFS	IFS	1.9	ICA	ICA	2.2	IDf	IDf
40	3.1	IFS	IFS	5.5	IFS	IFS	1.9	IFS	IFS	2.3	IDf	IDf
45	3.3	IFS	IFS	6	IFS	IFS	2	IFS	IFS	2.4	IDf	IDf
50	3.4	IFS	IFS	6.2	ICA	ICA	2.6	IFS	IFS	2.5	IFS	IDf
55	3.6	IFS	IFS	6.5	ICA	ICA	2.6	ICS	ICS	2.5	IDf	IDf
60	3.7	IFS	IFS	5.7	ICA	ICA	2.8	ICS	ICS	2.6	IDf	IDf
65	3.9	IFS	IFS	6.2	ICA	ICA	2.9	ICS	ICS	2.6	IDf	IDf
70	4	IFS	IFS	6.5	ICA	ICA	3.2	ICS	ICS	2.7	IDf	IFS
75	4.1	IFS	IFS	6.9	ICA	ICA	3.2	IMS	ICA	2.7	IDf	IDf
80	4.2	IFS	IFS	7.3	IFS	IFS	3.6	ICA	ICA	2.8	IDf	IDf
85	4.3	IFS	IFS	7.7	IFS	IFS	3.6	ICA	ICA	2.9	IDf	IDf
90	4.3	IFS	IFS	8.1	ICB	ICB	3.6	ICA	IFS	2.9	IPo	IPo
95	4.4	IFS	IFS	8.5	IFS	IFS	3.7	ICA	ICA	3	IPo	IPo
100	4.4	IFS	IFS	8.8	IFS	IFS	3.9	ICA	ICA	3	IPo	IPo
105	4.5	IFS	IFS	9.3	IFS	IFS	3.8	IFS	IFS	3.1	IMS	IMS
110	4.6	IFS	IFS	9.9	IFS	IFS	3.9	IFS	ICA	3.1	IPo	IPo
115	4.7	IFS	IFS	10.3	IFS	IFS	4.2	IFS	ICA	3.2	IPo	IPo
120	4.9	IFS	IFS	10.8	IFS	IFS	4.6	IFS	ICA	3.2	IPo	IPo
125	5.1	IFS	IFS	11.2	IFS	IFS	4.7	IFS	IFS	3.3	IFS	IPo
130	5.2	IFS	IFS	11.7	IFS	IFS	4.9	IFS	IFS	3.5	IMS	ICA
135	5.3	IFS	IFS	12	IFS	IFS	5.3	IFS	IFS	3.6	ICA	ICA
140	5.4	IFS	IFS	12.3	IFS	IFS	5.1	IFS	IFS	3.6	ICA	ICA
145	5.5	IFS	IFS	12.6	IFS	IFS	5.6	IMS	IMS	3.8	ICA	ICA
150	5.6	IFS	IFS	13.8	IFS	IFS	5.7	IMS	IMS	3.9	ICA	ICA
155	5.8	IFS	IFS	14	IFS	IFS	5.9	IMS	IMS	4.1	ICA	ICA
160	6	IFS	IFS	14.2	IFS	IFS	5.9	IMS	IMS	4.3	ICA	ICA
165	6.1	IFS	IFS	14.4	IFS	IFS	6.2	IMS	IMS	4.4	ICA	ICA
170	6.3	IFS	IFS	14.7	IFS	IFS	6.4	IMS	IMS	4.5	IPo	IPo
175	6.4	IFS	IFS	14.9	IFS	IFS	6.3	ICA	ICA	4.6	ICA	ICA
180	6.5	IFS	IFS	15.1	IFS	IFS	6.4	ICA	ICA	4.7	ICA	ICA
185	6.7	IFS	IFS	15.7	IFS	IFS	6.5	ICA	ICA	4.8	ICA	ICA
190	6.9	IFS	IFS	15.9	IFS	IFS	6.3	ICA	ICA	4.9	ICA	ICA
195	7.1	IFS	IFS	16.3	IFS	IFS	6.7	IPo	IPo	5.1	ICA	ICA
200	7.3	IFS	IFS	16.9	IFS	IFS	6.8	IMS	IMS	5.2	ICA	ICA

Table 7.4.

Depth and distribution of habitat types along the transects (Station 9 - 12)

Transect distance (m)	Station 9 (Rizokarpaso)			Station 10 (Rizokarpaso)			Station 11 (Rizokarpaso)			Station 12 (Rizokarpaso)		
	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left
Supralittoral		SR	SR		SR	SR		SR	SR		SFS	SFS
0	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG
5	0.2	MLG	MLG	0.2	MLG	MLG	0.2	MLG	MLG	0.2	MLG	MLG
10	0.2	MAP	MAP	0.3	MAP	MAP	0.2	MAP	MAP	0.2	MAP	MAP
15	0.3	MAP	MAP	0.4	MAP	MAP	0.3	MAP	MAP	0.3	MAP	MAP
20	1.9	IC	IC	2.2	ISP	ISP	0.4	IC	IC	0.6	IC	IC
25	2.1	IBR	IBR	2.4	ISP	ISP	0.6	IC	IC	1.5	IC	IC
30	2.4	IBR	IBR	2.7	ICB	ICB	2.6	ICB	ICB	1.8	ICB	ICB
35	2.7	IBR	IBR	3.5	ICB	ICB	2.9	ICB	ICB	2.2	ICB	ICB
40	3.2	IBR	IBR	3.9	ICB	ICB	3.4	ICB	ICB	2.4	ICB	ICB
45	3.6	ICB	ICB	4.3	ICB	ICB	3.9	ISP	ISP	2.6	ICB	ICB
50	3.8	ICB	ICB	4.6	ICB	ICB	4.6	ISP	ISP	2.9	ICB	ICB
55	3.9	ICB	ICB	4.8	ICB	ICB	4.9	ISP	ISP	3.3	ICB	ICB
60	4.1	ICB	ICB	5	ICB	ICB	5.8	ISP	ISP	3.5	ICS	ICS
65	4.3	ICB	ICB	5	ICB	ICB	6.4	ISP	ISP	3.6	ICS	ICS
70	4.8	ICB	ICB	5.1	ICB	ICB	6.9	ICB	ICB	3.8	ICS	ICS
75	5	ICB	ICB	5.6	ICB	ICB	7	ICB	ICB	4	ICS	ICS
80	5.3	ICB	ICB	5.7	ICB	ICB	7.2	IBR	IBR	4.2	ICS	ICS
85	5.9	ICB	ICB	6.2	ICB	ICB	7.3	IBR	IBR	4.4	ICS	ICS
90	6.1	ICB	ICB	6.4	IBR	IBR	7.6	IPo	IPo	4.5	ICS	ICS
95	6.4	ICB	ICB	6.8	IBR	IBR	7.9	IPo	IPo	4.6	ICS	ICS
100	6.7	ICB	ICB	7.4	IPo	IPo	8.1	IPo	IPo	5.1	ICS	ICS
105	7	ICB	ICB	7.8	IPo	IPo	8.6	IPo	IPo	5.8	ICS	ICS
110	7.2	ICB	ICB	8.4	IPo	IPo	8.8	IPo	IPo	6.3	ICS	ICS
115	7.5	ICB	ICB	8.9	IPo	IPo	9.6	IPo	IPo	6.8	ICB	ICB
120	7.8	ICB	ICB	9.2	IPo	IPo	9.9	IPo	IPo	7.1	IBR	IBR
125	8.2	ICB	ICB	9.6	IPo	IPo	10	IPo	IPo	8.5	IFS	IFS
130	8.4	ICB	ICB	9.8	IPo	IPo	10.3	IPo	IPo	8.8	IFS	IFS
135	8.5	ICB	ICB	10.2	IPo	IPo	10.6	IPo	IPo	9.1	IPo	IPo
140	8.8	ICB	ICB	10.6	IPo	IPo	11.3	IPo	IPo	9.2	IPo	IPo
145	9	ICB	ICB	10.7	IPo	IPo	11.7	IPo	IPo	9.4	IPo	IPo
150	9.4	ICB	ICB	10.9	IPo	IFS	11.7	IPo	IPo	9.5	IPo	IPo
155	9.6	ICB	ICB	11.6	IPo	IFS	11.9	IPo	IPo	9.6	IFS	IFS
160	9.9	ICB	ICB	11.8	IFS	IFS	12.4	IPo	IPo	9.8	IPo	IFS
165	10.2	ICB	ICB	12.4	IFS	IPo	12.7	IPo	IPo	9.9	IPo	IFS
170	10.6	ICB	ICB	12.6	IFS	IFS	12.8	IPo	IPo	10.1	IPo	IFS
175	10.8	ICB	ICB	12.7	IFS	IFS	12.9	IPo	IPo	10.4	IFS	IFS
180	11	IBR	IBR	12.9	IPo	IFS	12.9	IPo	IPo	10.6	IFS	IFS
185	11.3	IBR	IBR	13.3	IPo	IFS	13.2	IPo	IPo	10.7	IFS	IFS
190	11.5	IPo	IPo	13.4	IPo	IFS	13.4	IPo	IPo	10.9	IFS	IFS
195	11.9	IPo	IPo	13.6	IPo	IFS	13.5	IPo	IPo	11	IFS	IFS
200	12.2	IPo	IPo	13.7	IPo	IFS	13.6	IPo	IPo	11.3	IFS	IPo

Table 7.5.

Depth and distribution of habitat types along the transects (Station 13 - 16)

Transect distance (m)	Station 13 (Rizokarpaso)			Station 14 (Rizokarpaso)			Station 15 (Rizokarpaso)			Station 16 (Rizokarpaso)		
	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left
Supralittoral		SR	SR		SR	SR		SR	SR		SR	SR
0	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG	0	MUG	MUG
5	0.2	MLG	MLG	3.2	ISP	ISP	2	ISP	ISP	3.2	ISP	ISP
10	0.2	MAP	MAP	3.7	ISP	ISP	3.2	ISP	ISP	3.4	ISP	ISP
15	0.3	MAP	MAP	4.2	ISP	ISP	1.5	ISP	ISP	3.6	ISP	ISP
20	0.5	IC	IC	4.7	ISP	ISP	1.8	ISP	ISP	3.4	ISP	ISP
25	2.9	ISP	ISP	5.1	ISP	ISP	2.1	ISP	ISP	3.8	ISP	ISP
30	3.7	ISP	ISP	5.3	ISP	ISP	4.2	ISP	ISP	3.8	ISP	ISP
35	4	ISP	ISP	4.9	IFS	IFS	4.3	ISP	ISP	4.1	ISP	ISP
40	4.7	ISP	ISP	4.9	IFS	IFS	4.3	ISP	ISP	4.5	ISP	ISP
45	4.9	ISP	ISP	4.8	ISP	ISP	4.4	ISP	ISP	4.7	ISP	ISP
50	5.4	ISP	ISP	4.4	ISP	ISP	4.7	ISP	ISP	4.9	ISP	ISP
55	5.7	ISP	ISP	5.7	ISP	ISP	5	ISP	ISP	5.2	ISP	ISP
60	6.4	ISP	ISP	5.9	ISP	ISP	5.2	IPo	IPo	5.6	ISP	ISP
65	6.7	ISP	ISP	6.4	ISP	ISP	5.6	IPo	IPo	5.8	ISP	ISP
70	7.2	ISP	ISP	6.7	ISP	ISP	5.7	IPo	IPo	6.2	IFS	ISP
75	7.6	ISP	ISP	6.3	ISP	ISP	5.8	IPo	IPo	6.5	IFS	ISP
80	7.8	ISP	ISP	6.8	ISP	ISP	6.2	IPo	IPo	6.9	IFS	IFS
85	8.4	IFS	IFS	6.9	ISP	ISP	6.5	IPo	IPo	7	IFS	IFS
90	8.6	IPo	IPo	7.1	IFS	ISP	6.8	IPo	IPo	7.4	ISP	ISP
95	9	IPo	IPo	7.2	IFS	ISP	7.3	IPo	IPo	8.2	ISP	ISP
100	9.6	IPo	IPo	7.4	ISP	ISP	7.4	IPo	IPo	8.5	ISP	ISP
105	10.1	IPo	IPo	7.6	ISP	ISP	7.6	IPo	IPo	8.9	ISP	ISP
110	10.4	IPo	IPo	7.7	IFS	ISP	7.8	IPo	IPo	9.4	IFS	ISP
115	10.6	IPo	IPo	7.8	IFS	IFS	7.9	IPo	IPo	9.7	IFS	ISP
120	10.9	IPo	IPo	8.4	IPo	IPo	8.1	ISP	ISP	9.9	ISP	ISP
125	11.3	IPo	IPo	8.6	IPo	IPo	8.1	ISP	ISP	10.1	ISP	ISP
130	11.6	IPo	IPo	8.9	IPo	IPo	8.3	ISP	ISP	10.3	ISP	ISP
135	11.9	IPo	IPo	8.7	IFS	IPo	8.4	IFS	IFS	10.4	ISP	ISP
140	12.4	IPo	IPo	8.9	IFS	IPo	8.8	IFS	IFS	10.6	ISP	ISP
145	12.9	IPo	IPo	9	IPo	IPo	8.5	ISP	ISP	10.8	ISP	ISP
150	13.3	IPo	IPo	9.2	IPo	IPo	8.7	ISP	ISP	11.1	ISP	ISP
155	13.7	IPo	IPo	9.6	IFS	IPo	8.9	ISP	ISP	11.2	IFS	IFS
160	13.9	IPo	IPo	9.8	IFS	IPo	9.3	ISP	ISP	11.3	IFS	IFS
165	14.3	IPo	IPo	10.2	IPo	IPo	9.6	ISP	ISP	11.3	IFS	IPo
170	14.6	IPo	IPo	10.6	IPo	IPo	9.7	ISP	ISP	11.4	IFS	IPo
175	14.8	IPo	IPo	10.7	IPo	IPo	10.1	ISP	ISP	11.6	IFS	IPo
180	15.4	IPo	IPo	10.7	IPo	IPo	10.4	ISP	ISP	11.7	IFS	IPo
185	15.9	IPo	IPo	10.9	IPo	IPo	10.8	ISP	ISP	11.8	IFS	IPo
190	16.2	IPo	IPo	10.9	IPo	IPo	11.6	ISP	ISP	12	IFS	IFS
195	16.5	IPo	IPo	11	IPo	IPo	12.1	ISP	ISP	12.2	IFS	IFS
200	16.6	IPo	IPo	11	IPo	IPo	12.7	ISP	ISP	12.4	IFS	IFS

Table 7.6.

Depth and distribution of habitat types along the transects (Station 17 - 20)

Transect distance (m)	Station 17 (Rizokarpaso)			Station 18 (Rizokarpaso)			Station 19 (Salamis)			Station 20 (Salamis)		
	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left	Depth (m)	Right	Left
Supralittoral		SMS	SMS		SMS	SMS		SIS	SIS		SIS	SIS
0	0	MMS	MMS	0	MMS	MMS	0	MS	MS	0	MS	MS
5	1.5	IC	IC	1.2	IC	IC	0.2	MS	MS	0.2	MS	MS
10	1.7	ISP	ISP	1.5	ISP	ISP	0.3	MS	MS	0.2	MS	MS
15	1.7	ISP	ISP	1.6	IMS	IMS	0.4	IFS	IFS	0.3	MS	MS
20	1.8	ISP	ISP	1.7	IMS	IMS	0.6	IBR	IBR	0.4	IFS	IFS
25	2	ISP	ISP	1.8	IMS	IMS	0.8	ICB	ICB	0.6	ICB	ICB
30	2.3	ISP	ISP	2.2	IMS	IMS	1	ICB	ICB	0.8	ICB	ICB
35	2.4	ISP	ISP	2.3	IMS	IMS	1.1	ICB	ICB	0.9	ICB	ICB
40	2.6	ISP	ISP	2.5	IMS	IMS	1.2	ICB	ICB	0.9	ISP	IFS
45	2.7	ISP	ISP	2.6	IMS	IMS	1.3	ICB	ICB	1	ISP	ISP
50	2.8	ISP	ISP	2.8	IMS	IMS	1.3	ICB	ICB	1.1	ISP	ISP
55	2.9	ISP	ISP	2.9	IMS	IMS	1.4	IFS	IFS	1.1	ISP	ISP
60	3	ISP	ISP	3.4	IMS	IMS	1.4	IFS	IFS	1.3	ISP	ISP
65	3.1	ISP	ISP	3.5	ISP	ISP	1.5	IFS	IFS	1.3	ISP	ISP
70	3.2	ISP	ISP	3.7	ISP	ISP	1.5	IFS	IFS	1.4	ISP	ISP
75	3.3	ISP	ISP	3.9	ISP	ISP	1.5	IFS	IFS	1.4	ISP	ISP
80	3.6	ISP	ISP	3.6	ISP	ISP	1.6	IFS	IFS	1.2	ISP	ISP
85	3.8	ISP	ISP	3.4	ISP	ISP	1.6	IFS	IFS	1.2	ISP	ISP
90	4	ISP	ISP	3.8	ISP	ISP	1.7	IFS	IFS	1.3	ISP	ISP
95	4.2	ISP	ISP	4.1	ISP	ISP	1.7	IFS	IFS	1.3	ISP	ISP
100	4.4	ISP	ISP	4.6	ISP	ISP	1.8	IFS	IFS	1.4	ISP	ISP
105	4.7	ISP	IFS	4.7	ISP	ISP	1.9	IFS	IFS	1.5	ISP	ISP
110	4.9	ISP	IFS	4.9	ISP	ISP	2.1	ICA	IFS	1.6	ISP	ISP
115	5.1	ISP	IFS	5.2	ISP	ISP	1.9	ICA	IFS	1.7	ISP	ISP
120	5.3	ISP	IFS	5.3	ISP	ISP	1.6	ICA	IFS	1.9	ISP	ISP
125	5.5	ISP	IFS	5.6	ISP	ISP	1.8	ICA	ICA	2.1	ISP	ISP
130	5.7	IFS	IFS	5.7	ISP	ISP	2.5	ICA	ICA	2.2	ICA	IFS
135	6	IFS	IFS	5.9	ISP	ISP	2.6	ICA	ICA	2.2	ICA	IFS
140	6.3	IFS	IFS	5.9	ISP	ISP	2.7	ICA	ICA	2.3	IFS	IFS
145	6.5	IFS	IFS	5.9	ISP	ISP	2.9	ICA	ICA	2.4	IFS	IFS
150	6.6	IFS	IFS	6	ISP	ISP	3.1	ICA	ICA	2.5	IFS	IFS
155	6.8	IFS	IFS	6	ISP	ISP	3.2	ICA	ICA	2.5	IFS	IFS
160	7.1	IFS	IFS	6.1	ISP	ISP	3.3	ICA	ICA	2.6	ICA	IFS
165	7.4	IFS	IFS	6.4	ISP	ISP	3.5	ICA	ICA	2.6	ICA	ICA
170	7.6	IFS	IFS	6.5	ISP	ISP	3.7	ICA	ICA	2.6	IFS	IFS
175	7.7	IFS	IFS	6.7	ISP	ISP	3.8	ICA	ICA	2.7	IFS	IFS
180	7.8	IFS	IFS	6.7	ISP	ISP	3.9	ICA	ICA	2.7	IFS	IFS
185	7.8	IFS	IFS	6.8	ISP	ISP	4.1	ICA	ICA	2.8	IFS	IFS
190	7.9	IFS	IFS	6.8	ISP	ISP	4.3	ICA	ICA	2.8	IFS	IFS
195	7.9	IFS	IFS	6.9	ISP	ISP	4.5	ICA	ICA	2.9	IFS	IFS
200	7.9	IFS	IFS	6.9	ISP	ISP	4.6	ICA	ICA	2.9	ICA	ICA

7.3.1. Supralittoral habitats

7.3.1.1. Supralittoral inorganic sand

The investigated part is the lowest level of the supralittoral, 5 m away the high tide limit, but not reaching the drift line (Figure 7.2). Very sparsely dispersed dead phanerogam leaves may be found, but they do not form wracks. This section of the supralittoral zone is unvegetated. Most of the sandy beaches found along the coasts of the island, the sand particles are of rocky origin and fine sized. The top 5-10 cm of the sand may get dry due to extreme temperatures during summer, but the deeper part is always damp because of sea water table beneath. Talitrid amphipods can be found around the organic or anthropogenic debris. *Ocypode cursor* burrows are common in this supralittoral section. The shore is not steep, and the beach smoothly extends to infralittoral zone. Besides the phanerogams, shells of bivalves and gastropods are also sparsely found in the organic debris. The habitat is used for nesting by loggerhead turtle, *Caretta caretta* and green turtle, *Chelonia mydas*.

Figure 7.2.

*Supralittoral inorganic sand beach. Ghost crab (*Ocypode cursor*) burrowing (right)*

7.3.1.2. Supralittoral foraminiferal sand

The second type of supralittoral sand is composed of the alien foraminifera *Amphistegina lobifera* tests (Figure 7.3). This type of sandy beaches is observed on the northeastern coast of Rizokaspaso. The main structure of the coast is made of bedrock and the foraminiferal tests are washed up to the shore during storms and accumulated on the bedrock. The thickness of the sand layer can exceed 30-40 cm. Since the upper sandy part of the beach is not connected to the sea because of the bedrock beneath, all the sand layers may get dry during summer season. The test size ranges between 0.2-2.2 mm, forming a coarse sediment. This type of beaches is found above the abrassion platforms, which include diverse mollusk fauna, especially gastropods. Thus, on the lower limits of this region dense shell grits are found over the *Amphistegina lobifera* test layer.

Figure 7.3.

Supralittoral foraminiferal sand beach. Close-up photo of sand composed of abundant Amphistegina lobifera *tests*

7.3.1.3. Supralittoral mixed sediment

The habitat is composed of pebles, cobles and limited amount of sand (Figure 7.4). Washed up algae (mainly *Jania rubens*) and phanerogams during storms can sometimes form wracks. Decaying organic materials enable the formation of amphipod and insect communities. However, in summer, excessive sun rays and heat cause the top layer to dry completely. No vegetation is observed. In the upper supralittoral zone, this habitat belt is usually followed by a rocky elevation, which may reach 2-3 meters in height, creating a barrier and causing extensive accumulation of marine litter, as well as petroleum waste in this limited zone.

Figure 7.4.

Supralittoral mixed sediment. Washed up marine litter and Jania rubens

7.3.1.4. Supralittoral rock

This is the habitat type that is formed by steep rocky walls or very large boulders along the coastline and surrounding islets located off the coast (Figure 7.5). The supralittoral protrusions of the abrasion platforms also extend inland, forming supralittoral bedrocks with rough and perforated surfaces. The habitat is in the spray zone above the high tide level, and it is highly exposed to wave action. *Echinolittorina punctata* and *Melarhaphe neritoides* are commonly found in the first meter above intertidal zone. *Ligia italica*, which is seen in dense populations, has a wider range of distribution within this habitat zone.

Figure 7.5.

Supralittoral rock made of rocky clifs and boulders. Melarhaphe neritoides *is abundant in the splash zone*

7.3.2. Mediolittoral habitats

7.3.2.1. Mediolittoral sands

This habitat type is a transition zone between dry supralittoral sand and permanently submerged infralittoral sand habitats (Figure 7.6). A major part of the sediment is fine inorganic sand, mixed with foraminiferal tests and shell grits. *Talitrid amphipods* are characteristic species. Bivalves *Donax semistriatus* and *Donax trunculus* are rarely found in the lower part of the zone. The habitat is also vital for the endangered *Ocypode cursor*.

Figure 7.6.

Talitrid amphipod *burrowings on mediolittoral sands*

7.3.2.2. Mediolittoral mixed sediment

This habitat includes shores of mobile pebbles and gravel with small amounts of coarse sand (Figure 7.7). The sediment in the upper parts is subject to high degrees of drying between tides during calm days. There are no characteristic macrofaunal elements associated with this habitat, but in the low tide limits, gastropods *Phorcus richardi* and *Steromphala adansonii* are rarely observed on the less mobile pebles and the bivalve *Donacilla cornea* is occasionally found in coarse sand. Very few amphipods and isopods may be found washed to the shore.

Figure 7.7.

Mediolittoral mixed sediment

7.3.2.3. Upper mediolittoral rock facies with gastropods

The habitat is made of bedrock, boulders and stones, highly exposed to wave action, as well as extreme sunlight (Figure 7.8). The species living in this habitat are resistant to high temperatures and desiccation. No macrophytes were observed. *Rivularia atra* can be found at sheltered places. Dominant faunal species are composed of molluscs, such as *Patella caerulea*, *Patella rustica*, *Patella ulyssiponensis*, *Phorcus articulatus* and *Phorcus turbinatus*. *Echinolittorina punctata* and *Melarhaphe neritoides* are rarely observed in this zone. The crustacean decapod *Pachygrapsus marmoratus* can also be locally abundant. During the low tide dense colonies of *Ligia italica* can be observed above the water level.

Figure 7.8.

Upper mediolittoral rock facies with gastropods

7.3.2.4. Lower mediolittoral rock facies with gastropods

This habitat type is a continuation of the habitat type described above. Besides the *Patella* spp. and *Phorcus* spp., *Cerithium lividulum* and *Cerithium scabridum* are dominant gastropod species found in the pits filled with sand on the rocky substrate (Figure 7.9). The habitat does not include *Echinolittorina punctata* and *Melarhaphe neritoides*. It is also poor in terms of macrophytes. Very rarely, small clusters of *Cystoseira* spp., *Cladophora* sp. and *Cladophoropsis membranacea* are found.

Figure 7.9.

Lower mediolittoral rock facies with gastropods. Cerithium spp. are commonly found on accumulated sand over the rocky surface

7.3.2.5. Lower mediolittoral communities associated with *Cystoseira amantacea*

The habitat is found in the intertidal zone on big boulders and bedrock, higly exposed to wave action (Figure 7.10). It is exposed to air during wavy days and at low tide. *Cystoseira amantacea* forms very dense mat on the rocky surface, together with *Palisada perforata* and *Laurencia obtusa* and. At the lower limits of the mediolittoral zone the coverage of *Cystoseira amantacea* decrases and *Laurencia* spp. are rarely found, where *Centroceras clavulatum*, *Polysiphonia spp.*, *Spyridia filamentosa*, *Cladophora* spp., *Cladophoropsis membranacea*, *Valonia utricularis*, *Ectocarpus* spp., *Jania rubens* and *Halopteris scoparia* become more abundant.

Figure 7.10.

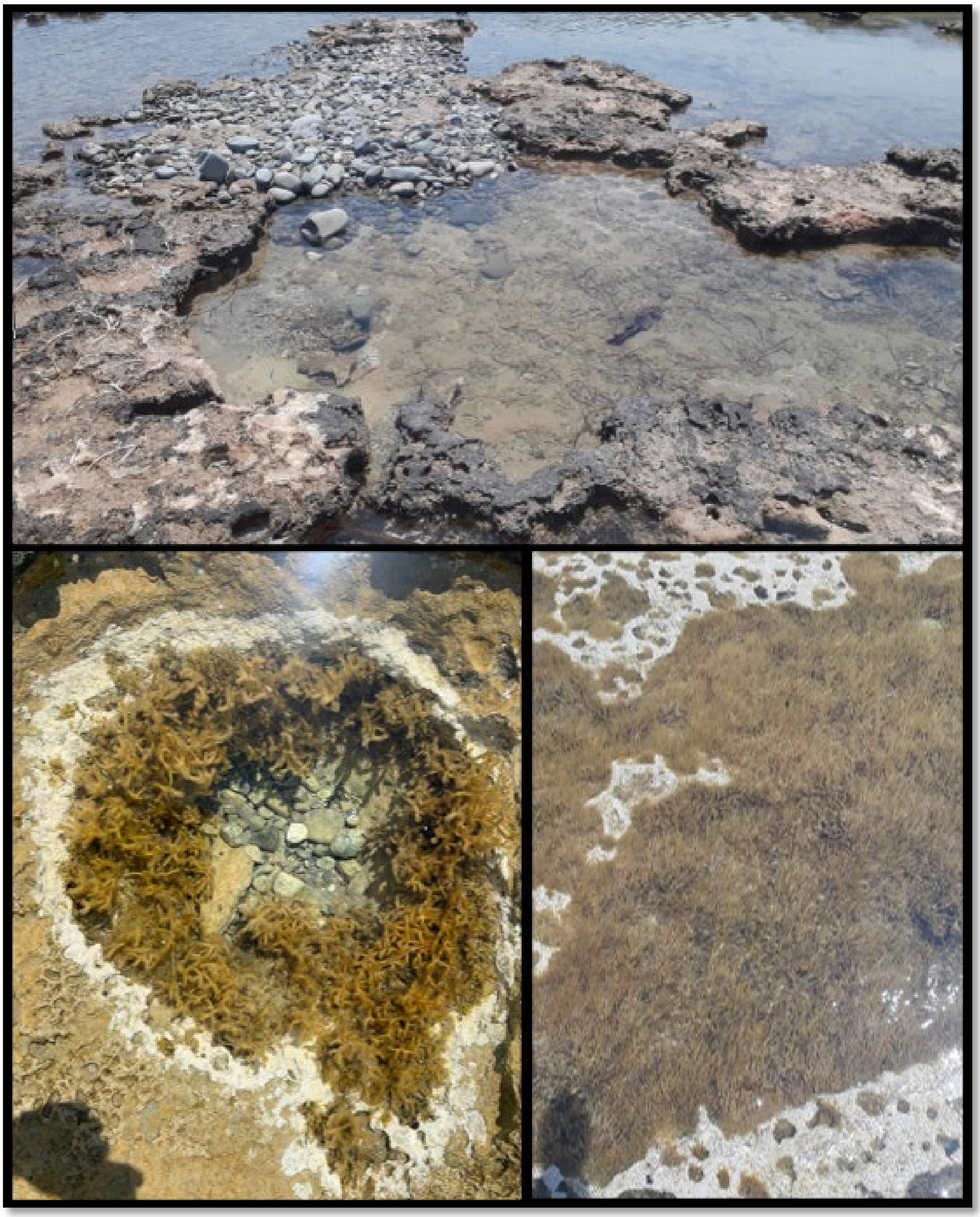
Lower mediolittoral communities associated with Cystoseira amantacea

7.3.2.6. Mediolittoral rockpools

A large rockpool area was found at the Station 4 (Figure 7.11). Majority of the area is under the influence of high tide. But there are also closed parts which are not washed during calm days. The most abundant algae species is found to be *Digenea simplex*. The other common species observed within the rockpools are; Algae: *Acanthophora nayadiformis, Palisada perforata, Jania rubens, Padina pavonina, Digenea simplex, Ulva* spp.; Invertebrates: *Actinia equina, Palaemon elegans, Palaemon serratus, Porcellana platycheles, Pachygrapsus marmoratus, Eriphia verrucosa, Xantho poressa, Gonioinfradens paucidentatus, Ampelisca spp., Caprella spp., Chiton olivaceus, Phorcus turbinatus, Phorcus articulatus, Steromphala adansonii, Steromphala divaricata, Bittium latreillii, Rissoa splendida, Rissoa variabilis, Cerithium scabridum, Ergalatax junionae;* Fish species: *Atherina boyeri, Parablennius gattorugine, Liza aurata, Gobius bucchichi, Gobius cobitis.*

Figure 7.11.

*Mediolittoral rockpools include mixed sediment type. Digenea simplex is the dominant algae species with high coverage. Snakelocks anemone (*Anemonia sulcata*) usually forms dense colonies*



7.3.2.7. Abrasion platforms

Mediterranean abrasion platforms are made of calcareous sandstones and limestones (Zahavi, 2006). The rims of the platforms, which are higher than the platform surface, are formed by the vermetid gastropods *Dendropoma petraeum* and the algae *Neogoniolithon brassica-florida*, creating the vermetid reefs (Figure 7.12). The top of the platforms is intertidal and usually exposed during low tide. The outer parts of the platforms are surrounded by walls that go straight down to 1-3 m of depth. The platforms surrounding the coast can be hundreds of meters long and their width can reach 40 meters, especially on the north coast of Rizokarpaso. Besides the calcerous biogenic part of the platforms, substantial amount of sand is carried by waves and accumulates on the intertidal section, creating a diverse benthic sturcture and enhancing a diverse biota.

Figure 7.12.

Abrasion platforms are intertidal and usually exposed during low tide

Note: However, the pits, which are always submerged in water, contribute to the development of the *Cystoseira* mat, providing shelter for many vertebrate and invertebrate species during low tide. The rims of the platforms are formed by the vermetid gastropods *Dendropoma petraeum* and the algae *Neogoniolithon brassica-florida.*

During low tide, a considerable part of the platform is usually exposed, but there are many potholes found in the intertidal part, which are usually deeper than a meter. A diverse floral and faunal elements can be found in these potholes and other intertidal parts of the platforms remained submerged during low tide, including Algae: *Acetabularia acetabulum, Cystoseira* spp., *Dictyota spp., Acanthophora nayadiformis, Palisada perforata, Jania rubens, Digenea simplex*; Cnidaria: *Actinia equina, Actinia viridis, Aiptasia diaphana, Cereus pedunculatus, Balanophyllia europea*; Polychaeta: *Hermodice carunculata, Serpula* spp., *Protula* spp.; crustacea: *Palaemon elegans, Palaemon serratus, Pachygrapsus marmoratus, Pachygrapsus transversus, Eriphia verrucosa, Portunus segnis, Xantho poressa*; fish species: *Atherina boyeri, Scorpaena maderensis, Serranus hepatus, Serranus cabrilla, Epinephelus marginatus* (juveniles)*, Liza aurata, Symphodus roissali, Aidablennius sphynx, Parablennius gattorugine, Gobius bucchichi, Gobius cobitis.*

The outer margin of the reef is the active part, growing outwards and upwards, forming the rim of the platform, where floral diversity is high. Besides the algae species found in the intertidal part, *Titanoderma trochanter* and *Tenarea tortuosa* are also very common on the rims. Very few alive *Dendropoma petraeum* and *Vermetus triquetrus* individuals were observed, suggesting that, today, calcerous algae species play a major role in the formation of these reefs. The outer walls of the platforms are often overshadowed by the protruding upper edge, allowing the growth of coralligenous algae (such as *Lithothamnion philippii, Mesophyllum lichenoides Lithophyllum spp., Peyssonnelia spp.*) and bryozoans (*Calpensia nobilis, Celleporina spp., Schizoporella spp., Schizomavella spp., Smittina cervicornis, Hornera frondiculata*). Decapod crustaceans: *Maja crispata*, *Dromia personata*, *Palaemon serratus*; echinoderms: *Diadema setosum*, *Arbacia lixula*, *Echinaster sepisotus*, *Coscinasterias tenuispina*; tunicates: *Halocynthia papillosa*, *Microcosmus* sp., *Herdmania momus* are the invertebrates commonly observed on the outer walls of the platforms. A total of 74 Mollusks species were either identified from the alive individulas or from the shell grits collected on the transcets that were set on the abrasion platforms (unpublished data). The most abundant alive collected species were *Phorcus* spp.*, Steromphala* spp.*, Bittium latreillii, Rissoa variabilis, Alvania cimex, Cerithium* *lividulum, Cerithium scabridum, Ergalatax junionae, Vexillum* spp.*, Columbella rustica, Striarca lactea, Brachidontes pharaonis, Septifer bilocularis, Ctena decussata,* and *Chama pacifica*.

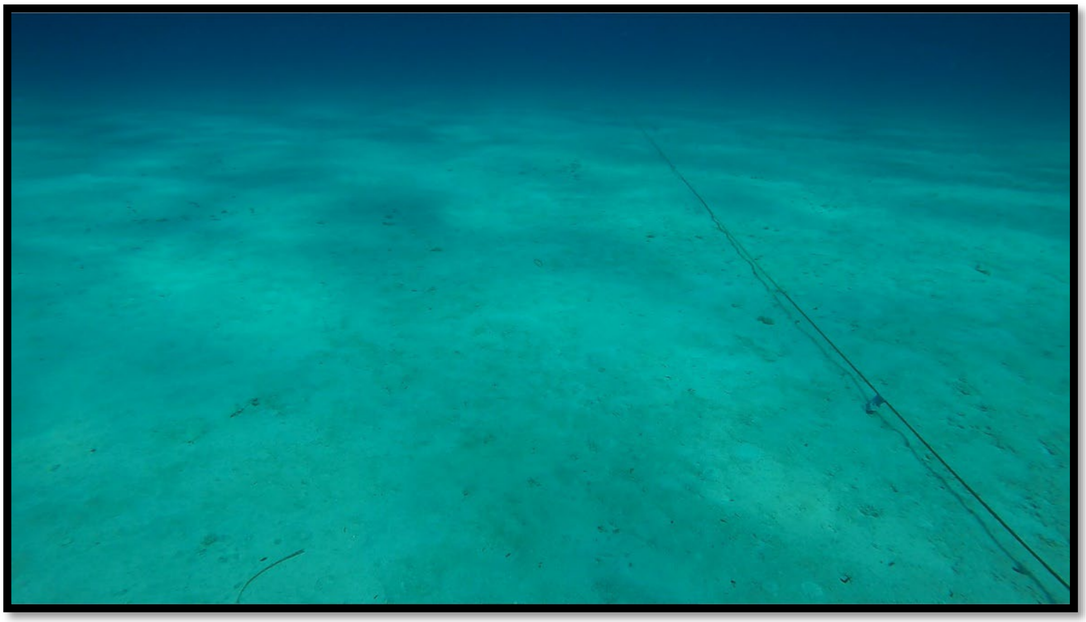
7.3.3. Infralittoral habitats

7.3.3.1. Infralittoral fine sand

This habitat is formed by clean fine sands between 1 and 18 m depth in the studied stations (Figure 7.13). Most of the mediolittoral sandy beaches have this type of infralittoral extensions. But the presence of this kind of habitat is not always limited to sandy beaches, it can also be observed off the rocky coasts or in empty spaces between *Posidonia* meadows. Faunal community is dominated by the mollucs; Loripes *lucinalis, Ctena decussata, Mactra stultorum, Spisula spp., Pecten jacobeus, Donax semistriatus, Glycymeris glycymeris, Chamelea gallina, Neverita josephina, Tonna galea, Bolinus brandaris, Naticarius hebraeus, Nassarius circumcinctus, Tritia pellucida* and *Tritia gibbosula* are the most abundant ones. The decapod crustaceans: *Diogenes pugilator, Coleusia signata, Liocarcinus* spp.*, Portunus segnis, Thalamita poissoni;* Echinoderms*: Astropecten* spp.*, Synaptula reciprocans, Echinocardium mediterraneum;* fishes: *Gobius bucchichi, Gobius niger, Gobius geniporus, Bothus podas, Trachinus draco, Bothus podas* and *Xyrichtys novacula* are also commonly observed.

Figure 7.13.

Infralittoral fine sand



7.3.3.2. Infralittoral mixed sediment

The habitat is a mixture of sand, pebbeles and cobbles (Figure 7.14). It is below low tide and extends from 1.5 m to 3.5 m of depth. The size of the sediment decreases with increasing depth. The algae composition is very limited, *Acetabularia acetabulum*, *Amphiroa rigida and Jania rubens* are sparsely found on shallow rocks. Fauna is not very rich. *Anemonia viridis* and *Balanophyllia europea* are common at the upper boundary and *Condylactis aurantiaca* is seldomly observed where coarse sand is abundant. The dominant mollusks are *Cerithium scabridum, Tritia pellucida, Hexaplex trunculus, Pisania striata, Ctena decussata, Striarca lactea, Pinctada imbricata radiata* and *Chama pacifica*. *Maja crispata* and *Xantho poressa* are are commonly observed crustacean decapods.

Figure 7.14.

Infralittoral mixed sediment

7.3.4. Algal-dominated infralittoral rock

A large percentage of algae species detected in rocky areas in the infralittoral zone show a wide depth distribution. However, it was observed that the dominant algae species in the environment changed depending on the depth, forming different belts of algal associations.

7.3.4.1. Infralittoral algae community dominated by canopy forming algae other than Cystoseira spp.

The habitat is usually a continuation of the lower mediolittoral communities associated with *Cystoseira amantacea* in the infralittoral zone. However, *Cystoseira amantacea* is mostly replaced with other *Cystoseira* spp., such as *C. compressa, C. barbata, C. foeniculacea* but none of them is dominant in the habitat. *Jania rubens, Laurencia spp., Dictyota spp., Palisada perforata, Digenea simplex, Chondracanthus acicularis*, *Anadyomene stellata*, *Ceramium* spp., and *Polysphonia* spp. are common algae species and collectively form a dense mat on the rocky surfaces. The habitat is subtidal and observed at 0.3-1.5 m depth range, but it can be exposed to strong wave action, usually during storms. (Figure 7.15). The habitat is also rich in gastopods and crustaceans. The invasive alien bivalve species *Chama pacifica and Pinctada imbricata radiata* are common*. Eripihia verrucosa, Pachygrapsus marmoratus* and *Pachygrapsus transversus* are observed in the upper part.

Figure 7.15.

Infralittoral algae community dominated by canopy forming algae other than Cystoseira spp.

7.3.4.2. Infralittoral algae community dominated by *Jania rubens*

Jania rubens shows a wide distribution of depth in the infralittoral region investigated within the scope of this study. However, it has been observed that the most intense depth range is 0-3 m (Figure 7.16). Although it is found together with other algae species such as *Cystoseira* spp., *Laurencia* spp., *Palisada perforata*, *Dictyota* spp., *Acanthophora nayadiformis* in the uppermost layer of the infralittoral zone, it has been observed that it can form a dominant cover alone in the 0.5-1.5 m depth range, with upto 23% coverage on the hard surfaces. *Amphiroa rigida* and encrusting corallinales are also observed on the boulders, with a total coverage less than 1%.

Figure 7.16.

Infralittoral algae community dominated by Jania rubens

7.3.4.3. Infralittoral algae community dominated by *Dictyota fasciola*

Dictyota fasciola is found in the mediolittoral pools and on the abrasion platforms. It also shows a wide distribution range in the infralittoral zone. But it becomes the dominant species at 1.5-2.5m depth range, below *Jania rubens* belt (Figure 7.17). Encrusting corallinales and other erect, but not canopy forming algae species, such as *Padina pavonina*, *Stypopodium schimperii* and *Ganonema farinosum* may be found in very small percentages, but *Dictyota fasciola* may have a 6-18 % coverage on the well illuminated surfaces of the boulders and the rocks.

Figure 7.17.

Infralittoral algae community dominated by Dictyota Fasciola

7.3.4.4. Infralittoral algae community dominated by *Stypopodium schimperi* and *Padina pavonina*

The bedrock and boulders covered by dense mat of the alien algae, *Stypopodium schimperi* and/or native *Padina pavonina* (Figure 7.18). Turf forming algae species, mainly *Sphacelaria* spp are also abundant. The dense turf captures fine sand on the rocky surface, creating a mixed microenvironment on the rocks, where infaunal organisms can survive. The alien forminifera *Amphistegina lobifera* and *Amphisorus hemprichii* groving on the turf enhance the sand accumulation.

Figure 7.18.

Infralittoral algae community dominated by Stypopodium schimperi *and* Padina pavonine

7.3.4.5. Infralittoral Cystoseira spp. communities on bedrock

This habitat occurs at 1-12 m depth range and is characterised by dense *Cystoseira* facies. *Cystoseira* spp., are the only canopy forming algae species, turf forming algae is also not observed (Figure 7.19). The rocky bottom is ususally the flat bedrock, without any sheltered caverns and crevices. Thus, the habitat is poor in invertebrates other than gastropods. *Tricolia pullus pullus, Jujubinus* spp.*, Calliostoma laugieri laugieri, Bittium* spp.*, Alvania spp., Rissoa spp., Cerithium scabridum, Conomurex persicus, Muricopsis cristata, Ergalatax junionae, Engina leucozona, Vexillum spp., Conus mediterraneus* are commonly observed in this habitat. *Palaemon spp., Hippolyte spp., Thoralus cranchii* and *Pagurus anachoretus* are the dominant decapod crustacean species. The echinoderms *Arbacia lixula* and *Diadema setosum* are sparsely found.

Figure 7.19.

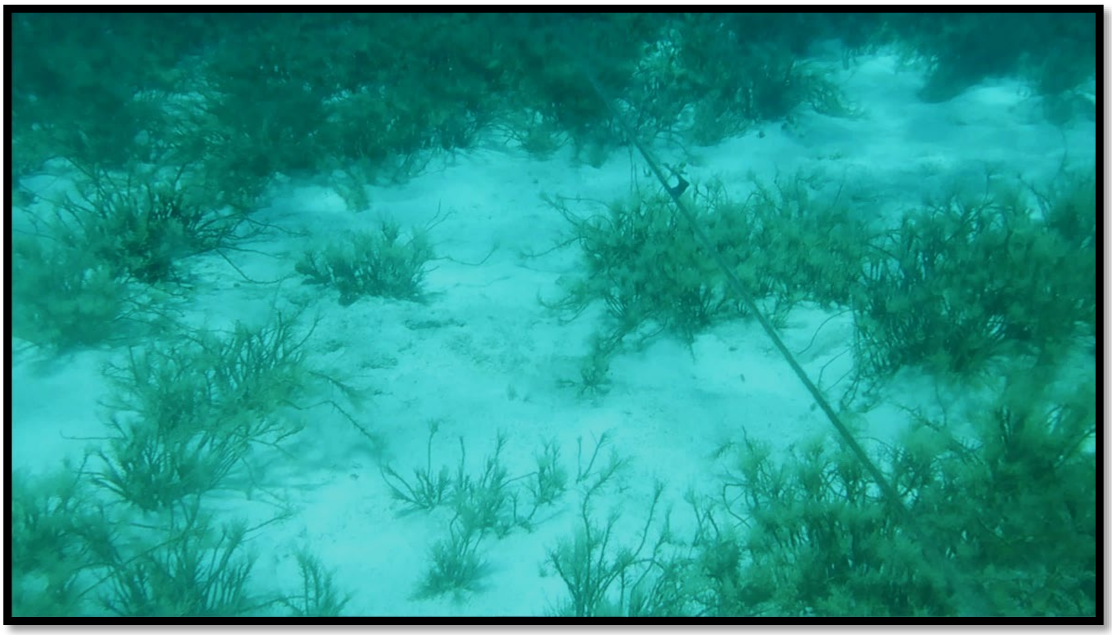
Infralittoral Cystoseira spp. communities on bedrock.

7.3.4.6. Infralittoral Cystoseira spp. communities on sand

In the present study extensively accumulated *A. lobifera* tests were observed in some stations on the north coast of Rizokarpaso, making up to 80-95 % of the infralittoral sediment, totally covering bedrock on the sea bottom. Because of the test size (0.2-2.2 mm), foraminiferal sand forms loose and coarse sediment and its thickness on the bedrock may reach 5-10 cm, enabling the *Cystoseira* spp. hold on the rocky surface and grow over the sand (Figure 7.20). Besides the foraminiferal sand, similar habitat has also been observed over inorganic fine sand at Station 1 at shallow depths between 0.4m-1.2m. Sand dwelling invertebrates and fish species are commonly observed in this habitat. But, since it allows the growth of *Cystoseira* spp. fields, faunal charactersitics are more diverse compared to sandy habitats that lack vergetation. Besides the species observed in the *Cystoseira* communities on the rocky benthos, some sand dwelling species are also common in this habitat, such as, Polychaeta: *Hermodice carunculata*, Crustacea: *Coleusia signata*, *Liocarcinus* spp., *Portunus segnis*, *Diogenes pugilator,* Gastropoda: *Conomurex persicus, Neverita josephina*, *Tritia pellucida*, *Retusa* spp., *Bulla striata*.; Bivalvia: *Loripes lucinalis*, *Tellina pulchella*, *Chamelea gallina* and *Ctena decussata*.

Figure 7.20.

Infralittoral Cystoseira spp. communities on sand



Note: The main axis is acually attached to the bedrock covered with foraminiferal sand, mainly composed of *Amphistegina lobifera* tests. The loose and coarse sediment of 5-10 cm thickness enables the sand dwelling organisms inhabit the *Cystoseira* field.

7.3.4.7. Infralittoral calcerous algae reefs

Bedrocks and boulders covered by various species of encrusting algae species, which is the main characteristic of the habitat (Figure 7.21). The thickness of the calcerous deposits may reach several centimeters. The soft deposit is easily carved by the boring sponge *Cliona viridis*, creating a rough and porous appearance. There aren’t any canopy forming algae except very limited amount of *Laurencia* spp. concentrated on the shaded areas. Turf forming *Sphacelaria* spp. are abundant, *Dasycladus vermicularis* is rarely found at shallow depths. Due to the algal mat and porous surface, the habitat contains substantial number of amphipods and polychaetes. *Bittium* spp. and *Cerithium scabridum* are the dominant gastropod species.

Figure 7.21.

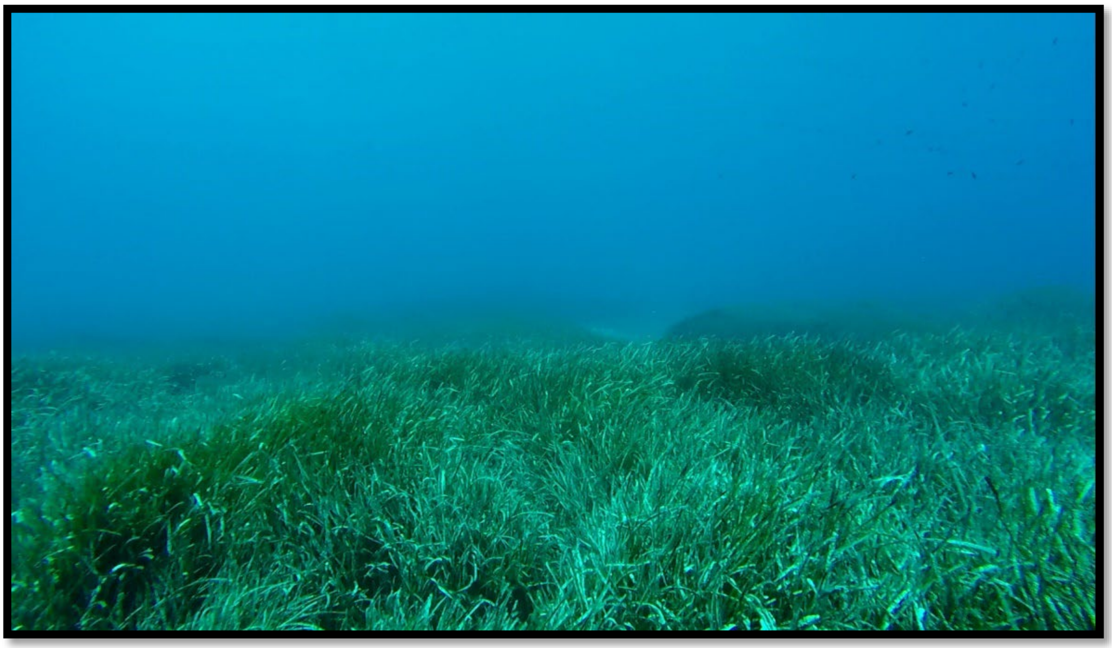
Infralittoral calcerous algae *reefs*

7.3.4.8. *Posidonia oceanica* beds

The habitat is created by the Mediterranean endemic *Posidonia oceanica* (Figure 7.22). It can grow on silt, sand and coarse material, as well as on rock. It was observed from 2 m to 20 m of depth, which was the maxiumu depth of this study, the meadows are extending much deeper. In 13 out of 20 stations *Poisdonia oceanica* was found as large meadows with 90-100% coverage, or just few small patches.

Figure 7.22.

Posidonia oceanica *beds*



7.3.4.9. Infralittoral barren rocks

This habitat is found at 6-10 m depth range, between the *Cystoseira* spp. facies and infralittoral sands or *Posidonia* beds (Figure 7.23). The habitat is made of solid barren rock, without any algae on it. The faunal community is very poor, dominated by the alien gastropod species, *Conomurex persicus* and *Cerithium scabridum*. The only fish species observed in this habitat is the alien Yellow spotted puffer *Torquigener hypselogeneion*.

Figure 7.23.

Infralittoral barren rocks

H. Conclusion

The limited and insufficient nature of protected areas in Cyprus makes it challenging to support and preserve natural habitats. Species such as *Posidonia oceanica* and vermetid reefs, which require protection, are found within human-inhabited areas, further emphasizing the need for conservation. Despite the increasing human activities in these areas, it is important to highlight the lack of concrete steps taken for coastal zone management.

In the field of marine sciences, for approximately 7 years, our research and investigations have been conducted in parallel with the insufficient importance and support given to scientific studies in Cyprus. The number of such studies is directly proportional to the inadequate focus on preserving natural life. It is undeniable that these studies not only benefit the natural environment but also have advantages for the local community. As a result of our research and work, it has become evident that there hasn't been significant progress in the conservation and sustainability of marine life in Cyprus. Furthermore, the lack of enforceable measures, regulations, or legislations regarding coastal management has resulted in an ongoing increase in the degradation of coastal areas.

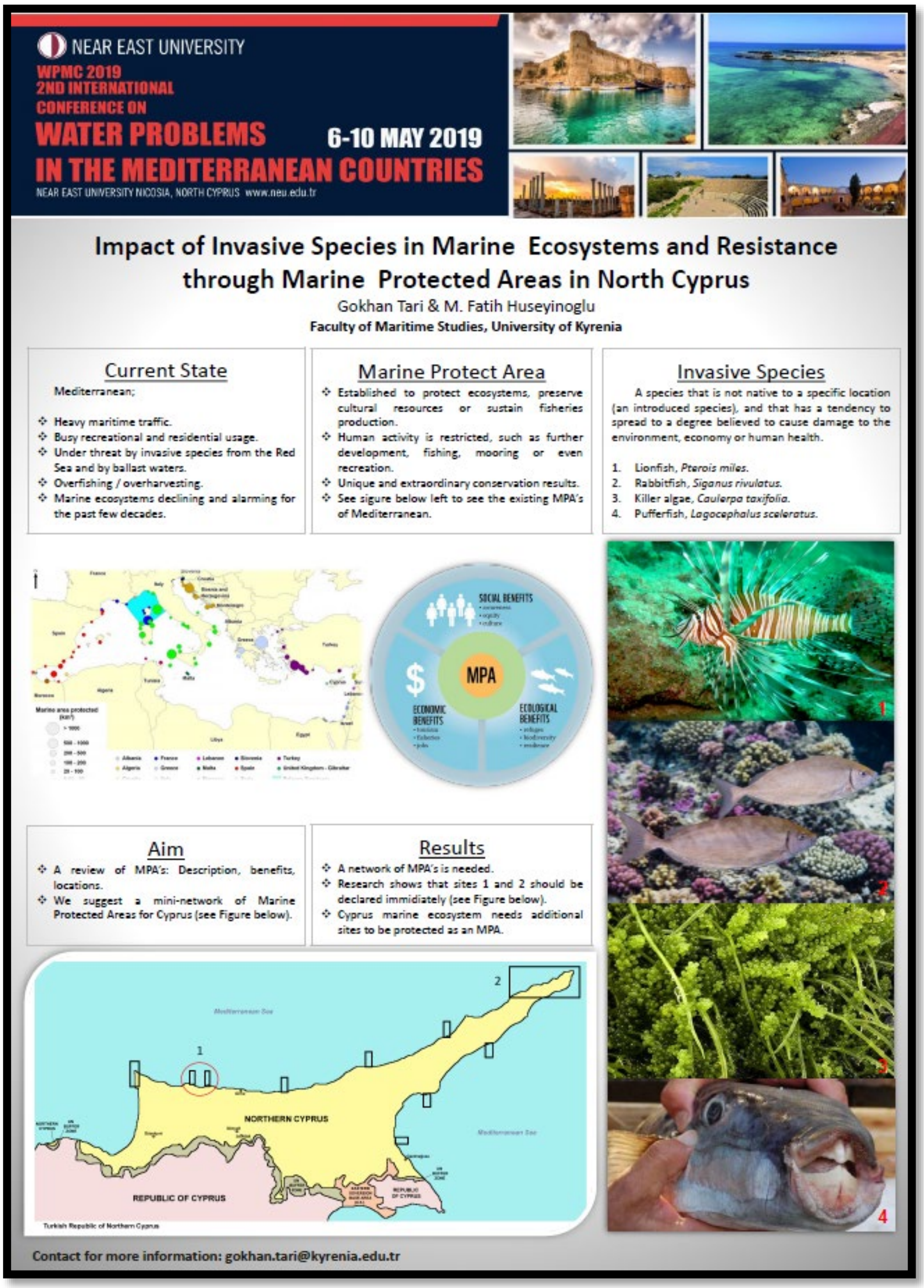
During our species-related records, we have been engaging the local community through various activities to raise awareness and encourage their sensitivity in this regard. We are collaborating with official and local individuals to work on necessary procedures, regulations, and measures. We are currently continuing our efforts to establish official marine conservation areas through ongoing contacts.

Throughout these processes, despite their informal nature, we have contributed to the protection of natural life by establishing conservation areas in collaboration with the local community. Awareness has been raised through events such as competitions and promotions related to invasive species. Examples of these are P*terois miles* (Lionfish) and *Diedema Setosum* (Sea Urchin). As a result, fishermen have prioritized lionfish hunting, and lionfish has started to appear more frequently in fish markets and kitchens.

Within the scope of these studies, our research and findings were presented at the "WPMC 2019 2nd International Conference on Water Problems in the Mediterranean Countries" as both a conference presentation and a poster (Figure 8.1). In this conference, recommendations were made for establishing a conservation status and designating marine protected areas for the northern coasts of Cyprus, marking the first concrete steps in this regard.

Figure 8.1.

The Poster Presented at WPMC Conference



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Impact of Invasive Species in Marine Ecosystems and Resistance through Marine Protected Areas in North Cyprus

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Current State

Mediterranean;

- Heavy maritime traffic.
- Busy recreational and residential usage.
- Under threat by invasive species from the Red Sea and by ballast waters.
- Overfishing / overharvesting.
- Marine ecosystems declining and alarming for the past few decades.

Marine Protect Area

- Established to protect ecosystems, preserve cultural resources or sustain fisheries production.
- Human activity is restricted, such as further development, fishing, mooring or even recreation.
- Unique and extraordinary conservation results.
- See sigure below left to see the existing MPA's of Mediterranean.

Invasive Species

A species that is not native to a specific location (an introduced species), and that has a tendency to spread to a degree believed to cause damage to the environment, economy or human health.

1. Lionfish, *Pterois miles*.
2. Rabbitfish, *Siganus rivulatus*.
3. Killer algae, *Caulerpa taxifolia*.
4. Pufferfish, *Lagocephalus sceleratus*.

Aim

- A review of MPA's: Description, benefits, locations.
- We suggest a mini-network of Marine Protected Areas for Cyprus (see Figure below).

Results

- A network of MPA's is needed.
- Research shows that sites 1 and 2 should be declared immidiately (see Figure below).
- Cyprus marine ecosystem needs additional sites to be protected as an MPA.

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Our collaboration with the local community and official institutions has progressed in parallel throughout all of our work, and it has been increasing. In this context, as a result of our studies, our participation was requested in discussions for the planning of marine protected areas to be established by the authorities. These participations involved extensive exchanges of information and lengthy discussions, ultimately leading to the official designation of specific areas as marine protected areas (MPA) in the first half of 2023 (Figure 8.2). This achievement can be regarded as the collective outcome of all our efforts.

Figure 8.2.

Officially Declared Conservation Areas

The progress and development of these efforts and research require collaboration and organization. The shared goal, duty, and responsibility of scientists is to protect, sustain, and pass on the natural life of Cyprus to future generations.

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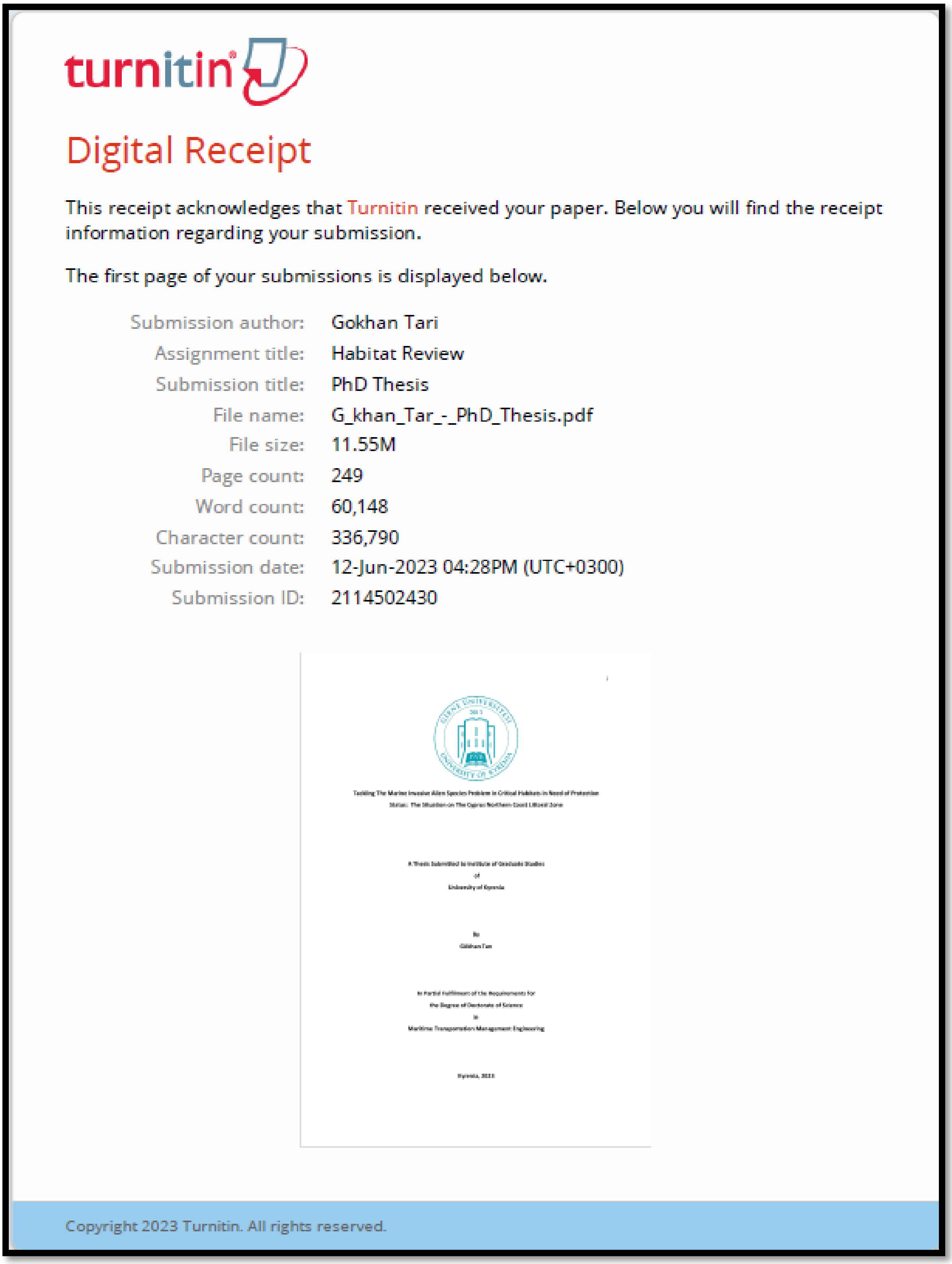
J. Appendices

Appendix 1: Turnitin Report



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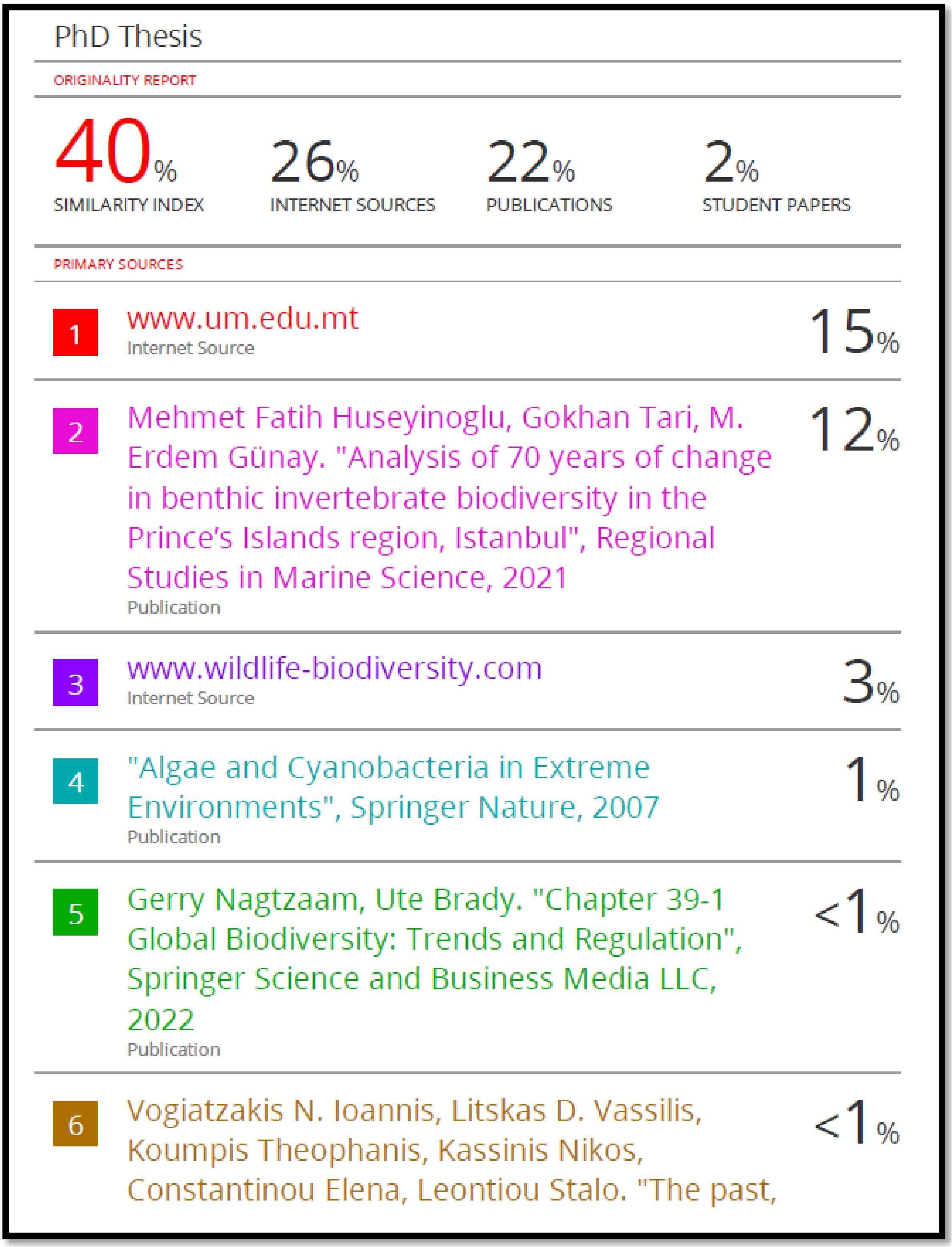

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Appendix 2: Curriculum Vitae

1. **Name Surname** : Gökhan Tarı
2. **Date of Birth** : 06/05/1990
3. **Title** : Lecturer
4. **Education** : Postgraduate
5. **Institution** : University of Kyrenia

Degree	Field	University	Year
Bachelor	Maritime Management	Near East University	2014
Master	Maritime Transportation Management Engineering	University of Kyrenia	2020
Doctorate	Maritime Transportation Management Engineering	University of Kyrenia	2023

6. **Academic Titles**

PhD.

7. **Graduate Theses Supervised**

7.1. Master Theses

- Institute of Science and Technology, University of Kyrenia, Kyrenia, North Cyprus ʼʼClassification of The Marine Habitats of Northern Coasts in Cyprusʼʼ Tari G., and Huseyinoglu M. F., 2020.

7.2. Doctorate Theses

- Institute of Graduate Studies, University of Kyrenia, Kyrenia, North Cyprus ʼʼTackling the Marine Invasive Alien Species Problem in Critical Habitats in Need of Protection Status: The Situation on The Cyprus Northern Coast Littoral Zoneʼʼ Tari G., and Huseyinoglu M. F., 2023.

8. Publications

8.1. Articles published in peer reviewed international journals (SCI, SSCI Arts and Humanities)

- Ragkousis, M., Zenetos, A., Souissi, J. B., Hoffman, R., Ghanem, R., Taşkın, E., ... & Kousteni, V. (2023). Unpublished Mediterranean and Black Sea records of marine alien, cryptogenic, and neonative species.
- Huseyinoglu, M. F., Tari, G., & Günay, M. E. (2021). Analysis of 70 years of change in benthic invertebrate biodiversity in the Prince's Islands region, Istanbul. *Regional Studies in Marine Science*, *48*, 102003. https://doi.org/10.1016/j.rsma.2021.102003
- Hüseyinoğlu, M. F., Tari, G., Demir, V., Yaprak, A., & Yokeş, M. B. (2020). Distribution of vermetid reefs on the northern shores of Cyprus Island. *Journal of Wildlife and Biodiversity*, 6-12. https://doi.org/10.22120/jwb.2020.127523.1139

8.2. Articles published in other peer reviewed international journals

8.3. Papers delivered in international conferences and printed as proceedings

- WPMC 2019 2nd International Conference on Water Problems in the Mediterranean Countries, Near East University, North Cyprus. "Impact of Invasive Species in Marine Ecosystems and Resistance through Marine Protected Areas in North Cyprus" Tari G., and Huseyinoglu M. F., 2019.

8.4. Books and sections in books published internationally

8.5. Articles published in peer reviewed national journals

8.6. Papers delivered at national conferences and printed as proceedings

8.7. Other publications Patents

9. Projects directed and participated

- **2023 -** Faculty of Maritime Studies, University of Kyrenia, North Cyprus, ʻʻPhysical and chemical oceanographical investigation, bathymetrical mapping, and alien species invasion modelling in relation with maritime traffic in two ports in Cyprus (PACOBAM)ʼʼ, International Association of Maritime Universities (IAMU), Project Coordinator.
- **2020 -** Faculty of Maritime Studies, University of Kyrenia, Cyprus, Pan-Mediterranean Larval Collectors' Network ʻʻ Mediterranean Noble Pen Shell Crisis (*Pinna nobilis*)ʼʼ Researcher.
- **2019 – 2020** Institute of Science and Technology, University of Kyrenia, North Cyprus, ʻʻ Mapping the Coasts of Northern Cyprus Within the Framework of the European Union EUNIS Habitat Classification Protocol ʻʻ Project Coordinator, BAP / GRN-2019-1-004.

10. Administrative designations

2023,03 -	Lecturer of Faculty of Maritime Studies, University of Kyrenia
2023,03 -	Faculty Coordinator of Faculty of Maritime Studies, University of Kyrenia
2023,03 -	Member of the Faculty Board of Directors of Faculty of Maritime Studies, University of Kyrenia
2023,03 -	Head of Department of Vocational School of Technical Sciences, University of Kyrenia
2020,02 – 08,2022	Remote Education Unit Coordinator, University of Kyrenia
2018,09 – 08,2022	Vice Coordinator of Faculty of Maritime Studies, University of Kyrenia
2017,10 – 08,2022	Research Assistant of Faculty of Maritime Studies, University of Kyrenia.

11. Membership in scholarly institutions

12. Awards and grants

13. Courses taught over the last two academic years

Academic Year	Term	Course Name	Hours/week	
			Theoretical	**Applied**
2022 / 2023	**Summer**	Cargo Handling and Operations I	2	2
		Ship Handling and Maneuvering I	1	1
		Introduction to Law and Maritime Law	3	0
2022 / 2023	**Spring**	Environmental Effects of Transportation	2	2
		Environmental Chemistry	2	2
		Environmental Laboratory I	2	2
		Environmental Microbiology	3	2
		Environmental Health	3	0
		Urban And Environment Planning	2	0
		Maritime Law and International Conventions II	2	2
2021 / 2022	**Spring**	Graduation Project	0	6
		Environmental Law	3	0
		Environmental Technologies	3	0
		Water Pollution and Control Techniques	3	0
		Electronic and Hazardous Waste Recycling	3	0
		Noise and Dust Pollution Control Techniques	3	0
		Waste Recovery Techniques	3	0
2021 / 2022	**Fall**	Solid Waste Management	2	2
		Environmental Laboratory II	2	2
		Environmental İmpact Assessment	3	0
		Soil Pollution and Control	2	2
		Renewable Energy Sources	3	0
		Quality and Environmental Management Systems	3	0
		Water Quality and Control	2	2
2021 / 2022	**Summer**	Introduction to Law and Maritime Law	3	0
		Maritime Law and International Conventions I	3	0
		Maritime Law and International Conventions II	2	2