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Agenda item 6: IMAP-MPA Project: Progress achieved since the last meeting of the Steering Committee

Bioblitz Activity in Israel

UNEP/MAP
Athens, 2023

Marine Bioblitz

A quantitative Survey of Marine Nature Reserves in the Israeli Mediterranean Sea

Summary report for surveys conducted

in 2015, 2017, 2019, 2021

Chapter 1: Fishing and nature reserves

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Israel Nature and Parks Authority, 2022

ISRAEL NATURE AND PARKS AUTHORITY

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Opening Remarks

Surveys of marine reserves in the Israeli Mediterranean Sea have been carried out since 2015, during two seasons biannually, totaling eight surveys to date. The surveys initially included control sites near the reserves and have since been expanded to include additional sites of interest along the Israeli coastline. This highly comprehensive survey includes fish, invertebrates, and algae.

The main significant result from the report is that marine reserves do indeed offer protection from fishing and influence the composition of fish, invertebrate, and algae communities, or, with some changes, have a real potential to do so. The Rosh Hanikra Marine Reserve, a relatively large reserve where fishing bans have been enforced for many years, has been shown to protect the fish well, as is evident from the biomass of the commercially valuable fish species, especially the dusky grouper, a flagship species in the Eastern Mediterranean. There is an abundance of groupers in the reserve, with a high number of fish that have reached the necessary breeding size. The success of reserves in protecting fish is also evident in other marine reserves, but the differences in the other marine reserves are much less evident, mainly because they are smaller and the edge effect (most of the reserve is "edge)" is significant.

The obvious conclusion is, in my opinion, sharp and clear. The Nature and Parks Authority' master plan for marine reserves, in accordance with the general policies of the Planning Committee, is fundamental to nature conservation in the sea and offers the ideal way to protect nature everywhere, and particularly through the establishment of marine reserves in the Mediterranean Sea.

I would like to thank the very many researchers and students from all the relevant research institutions for their immense efforts invested in consistently carrying out the surveys. I also thank to Eyal Miller, Yigael Ben Ari, and all the marine rangers for their great logistical support and their participation in the survey; Mai Lazarus, Ori Frid Landau1 and Rei Diga for analyzing the data and writing the various chapters of the report; and Ruthy Yahel for contributing to the writing but especially for being the inspiration and driving force of the entire project.

Dr. Yehoshua Shkedy, Chief Scientist, INPA

1 / Summary

Marine Protected Areas (MPAs) play a central role around the world in preserving and restoring ecosystems by protecting habitats and the animals and plants that dwell in them. MPAs are also used as a tool to stabilize fish populations, particularly commercial that provide a source of livelihood and food. The current report examines the impact of four marine reserves (a strict form of MPAs) in the Israeli Mediterranean Sea on commercially valuable fish species. Special emphasis is given to indicator species (bioindicators) belonging to the grouper subfamily, providing a measure of the function of the reserve in protecting the fish populations. Visual surveys of fish were carried out in four marine reserves: Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor, covering rocky substrate habitats, both inside the reserves and outside at nearby control sites with similar characteristics. The surveys were carried out in 2015, 2017, 2019, and 2021, during which there was also an increase in the supervision and enforcement of the marine reserves and of fishing regulations across the entire Israeli marine environment.

The results of the surveys indicate the success of the Rosh Hanikra-Achziv reserve in protecting commercial fish species in general, and groupers in particular. The overall biomass individuals of commercially valuable species of fish was higher inside the reserve compared to the control sites outside it, as was the abundance of large individuals. Individual dusky groupers that had reached the necessary length for breeding (maturation)were observed only inside this reserve, and were rarely observed in the other marine reserves. Individual mottled groupers that reached maturity were also observed mainly within this reserve. The results also indicate a clear increase over the years in the abundance and biomass of grouper species in the Shikmona, Dor-Habonim, and Gdor reserves, due to the proliferation of young individuals. This increase may indicate the beginning of a general improvement in the ability of these reserves to protect fish stock, in coordination with suitable fishing regulations and enforcement outside the reserves as well. In contrast to the general decline in the size of grouper populations worldwide, the success of the Rosh Hanikra-Achziv reserve and the improvement of the grouper populations in the Shikmona, Dor-Habonim, and Gdor reserves are particularly encouraging, and strengthen the recognition that marine reserves offer an important tool for protecting fish stocks. We should continue to oversee the functioning of these marine reserves using ongoing monitoring and enforcement.

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2 / Introduction

The health of the world's seas and oceans is in a continuous decline due to the accumulating effects of human activities and their derivatives such as fishing, physical destruction of habitats, pollution, global atmospheric changes, and the invasion of alien species (He & Silliman 2004, Islam & Tanaka, 2002; Stachowicz et al., 2010; Bruno, & Hoegh-Guldberg, 2019). These processes have devastating effects on the functioning of the marine ecosystems and the services they provide: food supply, oxygen and energy sources, regulation of atmospheric processes, etc. (Worm et al., 2006). These services depend on the existence of healthy ecosystems (Palumbi et al., 2009). Consequently, in order to preserve the natural resources necessary for our existence and at our disposal, we must protect the marine environment.

Among the known tools for protecting the marine environment, protecting representative habitats and large areas offers an effective and important tool for preserving and strengthening the natural ecosystem (Edgare et al., 2014). We can divide nature reserves into two main categories: no-take marine reserves and partially protected areas. Marine reserves are areas with defined borders, in which the physical environment, animals, and plants are protected through the prohibition of detrimental activities such as fishing, aquaculture, digging, mining and drilling, disposal of pollutants, and more; whereas non-harmful activities such as non-motorized boating, swimming, and diving are allowed. MPAs provide protection for all components of the food web, and facilitate the restoration of a healthy ecosystem (Lester et al., 2009), offering a central tool for the protection and restoration of specific species (Giakoumi et al., 2017)

The scientific literature published in the last decade (Guidetti et al., 2017; Giakoumi et al., 2014; Edgar et al., 2014) clearly indicates the benefits that no-take MPAs have in ecological functioning and in achieving conservation goals, compared to only partially protected marine areas (Giakoumi et. al, 2017). The factors that enable the success of a reserve are those of its status as a no-take reserve, high levels of enforcement, a large reserve area, age of the reserve, and distance from sources of human disturbance (Edgar et al., 2014). The level of enforcement in MPAs has been proven to be a key factor in the efficiency and achievement of the reserves' goals, even in older MPAs that have a relatively small area (up to 30 square kilometers; Giakoumi et al., 2017). The success of MPAs in which all exploitation or harming of the natural resources are prohibited, compared to areas that are outside the MPA, manifests itself in a significant increase in general biomass, abundance, individual size, and species richness (Lester et al., 2009).

Fishing is the major agent of habitat destruction and of a significant collapse of fish stocks around the globe (Swartz et al., 2010; Worm et al., 2006; Pauly et al., 2003). Controlling fishing in MPAs allows the populations of the fished species to grow and reach higher abundances than those found outside the MPA. In addition, more fish inside MPAs reach sexual maturity and large sizes. These individuals have higher breeding potential that conduces to the production of more offspring. This allows MPAs to become a dispersal source of larva and juveniles also to the marine environment outside the reserve (Lester et al., 2009).

In addition, when fish populations in a given area grow beyond the carrying capacity of that area, there is a spillover of individuals from the reserve to outside its borders, either as a result of competition for resources, or as part of their natural movement in spawning, breeding, etc. (Abesamis & Russ, 2005). These events show that MPAs, in addition to preserving the diversity of animals and the ecosystem within their borders, also help to increase the fish stock beyond their borders (Lester et al., 2009) and can help to prevent the collapse of fish populations as a result of overfishing (Goñi et al. 2008, Roberts 2008; et al., 2001).

Within fully protected reserves in the Mediterranean Sea, an increase in the density and biomass of fish has been observed, especially of species of high commercial importance and/or relatively limited mobility (Giakoumi et al., 2017). The most significant positive impact of protection was observed for the abundance and biomass of dusky groupers (Epinephelus marginatus), a predatory species present in Israeli waters, and an attractive target for commercial fishing. The biomass of individuals was 10.5-fold higher and the abundance of individuals was 7-fold higher inside MPAs compared to in partially-protected reserves (Giakoumi et al., 2017). Fish are not the only organisms benefitting from the protection provided by MPAs. In the Rosh Hanikra-Achziv reserve, the Mediterranean slipper lobster, Scyllarides latus, is a long-bellied crab with high commercial value and relatively low mobility. In the last few decades this species has become rare in the Mediterranean Sea due to overfishing (Spanier & Lavalli 1998) and is currently defined in Israel as a protected natural asset. In a recent study, it was found that the abundance of the lobster was on average 6-fold higher within the reserve boundaries than in the control area outside it and the body length of individuals inside the reserve was significantly higher, by about 8%, than that of individuals measured in the control area (Miller, 2019).

Among the indicators of ecological performance accepted in the world for MPAs, there are those that are considered the main indicators of success, such as an increase in the general biomass of fish in the reserve and in the abundance of commercial species subject elsewhere to significant fishing pressures, especially predatory species with high commercial value (Edgar et al., 2014) These species constitute important components in maintaining a complete and stable food web (Villamor & Becerro 2012).

This report presents the results of the surveys conducted in the years 2015, 2017, 2019 and 2021 – in four MPAs in the Israeli Mediterranean Sea and in control sites adjacent to them, with reference to the abundance and size of individuals of commercially valuable species of fish, with an emphasis on grouper species and their total biomass. These indicators are accepted indicators for the success of marine reserves in mitigating fishing pressure (Pelletier et al., 2008).

2.1 / Marine reserves in Israel

From the mid-1960s to the beginning of the 2000s, seven small marine reserves were established in Israel, with a total area of 10.4 km2, which constitutes about a quarter of Israel's maritime area in the Mediterranean Sea. Most of the reserves extend from the coastline to a few hundred meters westward into the sea. These reserves protect most of the islets off the coast of Israel and the habitats of the tidal zone and the shallow-water environment but do not represent all the habitats in the marine environment. Due to the increase in the scope of economic activity at sea and the intensity of the threats to the marine environment, there has been increased consensus in both environmental organizations and governmental planning institutions that it is necessary to take additional actions to preserve the marine environment in general and the natural assets and marine habitats in particular (Yahel & Angert, 2012; Ministry of Energy, 2016; Director of Planning, 2020; Technion, 2015.)

The master plan for marine reserves was prepared by the Nature and Parks Authority (INPA) by Yahel and Angert, (2012). The plan is based on the protocol of the Barcelona Convention for the Protection of the Mediterranean Sea and the principles that appear on the subject of "Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, 1995." These protocols include the protection of representative parts of all marine habitats (from the most common to the rare and unique); of marine environments that are in danger of disappearing; of environments vital for the survival, reproduction, and restoration of important species in the system; and of sites of special importance from a scientific or other aspect. In addition to the need to protect representative parts of the marine environment, the master plan also relates to the scope of the protected area. The United Nations CBD (Convention on Biological Diversity) defined the conservation targets in the sea to constitute 10% of the total marine area of each country by the year 2020. The Aichi Biodiversity Targets for the scope of the conservation has since been updated and is now set at 30% of the marine area by the year 2030. This goal was also adopted within the framework of the UN's Sustainable Development Goals (SDGs).

A comprehensive policy for the planning of the territorial water of the Israeli Mediterranean Sea was published in 2020 by the Planning Administration and designated 8.6% of Israel territorial water as target areas for marine reserves (Planning Administration, 2020), in accordance with the master plan and the policy document promoted by the INPA in collaboration with the Society for the Protection of Nature in Israel (SPNI) and other environmental organizations. In 2019, plans for the marine reserve "Yam Rosh Hanikra" were approved, expanding the existing reserve (where the surveys were conducted) to a distance of 15 kilometers from the coastline and an area of 100 km2. In 2021, plans for the "Rosh Carmel" marine reserve were approved, expanding the existing Shikmona reserve to a distance of about 12.5 km from the coastline, over an area of about 50 square kilometers. Today, about 4% of the surface of the Israeli territorial waters are defined as nature reserves. In addition, the Avtach marine reserve between the cities of Ashdod and Ashkelon is in advanced planning stages with the aim of expanding its protection of the shallow sandy habitat on the Mediterranean Sea seabed, to a distance of about 7 km west of the coastline and a maximum bottom depth of 38 m. In addition, plans are being promoted for offshore nature reserves across from the Sharon and Carmel coastlines, which will protect the mesophotic kurkar ridge and the sponge gardens that have developed on it, at 13-17 km off the coastline and a depth of 85-135 meters. These reserves and additional reserves, once approved and established, will protect diverse habitats in the extensive areas suitable for marine organisms.

This report examines the function of the established marine reserves with rocky substrates in protecting the fish community, focusing on species with commercial value. For this, we used bioindicator species, as accepted around the world.

2.2 / Groupers as indicators for the functioning of MPAs

Fish species from the grouper subfamily are considered indicators for the functioning of marine reserves around the world, due to a number of characteristics:

1. These species are considered top predators in the Mediterranean ecosystems and therefore are of great ecological importance to the ecosystem (Heithaus et al., 2008). The groupers shape the structure of the flora and fauna by feeding on herbivorous species and son pecies that feed on small invertebrates. In addition, they eliminate the weak and sick individuals from the system. Groupers have particular ecological importance in the eastern Mediterranean, since their diet consists mainly of species from the family of the rabbitfish (Siganus) – a very common invasive species (Goren & Aronov, 2008). Rabbitfish are mainly herbivorous and contribute to the process of "desertification" of habitats through their intensive grazing on algae (Sala et al., 2011; Vergés et al., 2014). It is possible that groupers regulate the rabbitfish populations as well as the damage caused by their grazing (Yerucham, 2019).

2. Groupers are territorial species that live alone or in small groups and tend to remain in relatively fixed places (Lembo 1999 et al., 1999) making it easier to document them in visual surveys and estimate their population sizes.

3. Groupers are desired target species in diverse fishing methods, including both commercial and recreational fishing. Groupers have high commercial value and are therefore selectively fished.

4. These species are sensitive to fishing. The impact of fishing on their reproduction and the size of their populations is substantial due to a number of reasons:

- Gathering for breeding at fixed sites, in large numbers, and at relatively fixed times offers a focal point of attraction for fishers. If fishing is carried out during such breeding activity, a large number of breeding individuals may be removed from the system simultaneously. In the long term, such fishing can severely damage overall fertility and the ability of the population to reproduce (Hereu et al., 2006).
- Reaching sexual maturity late. Individual fish need to grow over a number of years before they reach the appropriate size for breeding (Aronov & Goren, 2008).
- Grouper change sex over their lifetime. The young hatch from the egg and mature as females, and after maturing some change sex and become males. As a result, all groupers up to a certain size will be female. Large groupers can be either male or female. During the breeding season, the groupers organize in harems of a single male or a limited number of males and many females. A situation in which a large male, even a single one, is fished may create a temporary sex imbalance in the population, meaning that not all sexually mature individuals will be able to reproduce. In addition, overfishing causes a general decrease in the size of the fish in the population, since the large individuals are the ones that are usually caught. As a result, the sex change occurs at a relatively early age, before the females manage to reach their size-

dependent reproductive potential. That is, the number of eggs released by the females before they change to male is less than the potential number of eggs they could have released if they had reached their full size.

- Large individuals of dusky groupers, for example, are territorial males, and therefore easier to fish.

The dusky grouper, a species that characterizes the rocky habitat along the Israeli coasts, is described as particularly sensitive to fishing (Goren, 2020). It reaches sexual maturity at a comparatively late age (3-8 years; Aharonov, 2002) and its large body size makes it an attractive commercial species. The dusky grouper populations in the world, and in the Mediterranean Sea in particular, are decreasing. During only one decade, ending in 2001, a decrease of about 88% was reported in the catch of the dusky grouper in the Mediterranean Sea (Pollard et al.,2018). Studies from Israel have shown that the body size of individual dusky groupers in the fishing catch has become smaller over the years, and these individuals are often below reproductive size (Spanier, 2000; Aharonov, 2002; Belmaker et al., 2018).

It is possible to determine whether MPAs fulfill their role in protecting these species, which are sensitive to fishing, by examining the biomass and abundance of the grouper populations. High biomass and abundance will indicate that the MPAs support a stable ecosystem.

Four species of groupers were observed during the surveys. The white grouper, *Epinephelus aeneus*, was only observed a few times and does not characterize the surveyed habitat and therefore is not included in the data analysis. The other three species, the dusky grouper (*Epinephelus marginatus*), the mottled grouper *(Mycteroperca rubra*), and the golden grouper *(Epinephelus costae),* characterize the rocky habitat and accordingly were frequently observed in surveys and are therefore included in the data analysis. These species are called collectively "groupers."

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2.3 / Changes in fishing in Israel between 2015 and 2019

In 2015, the fish community was surveyed for the first time inside and outside MPAs. Since then, significant changes have taken place in the world of fishing in Israel. In 2016, the Knesset's Economic Committee approved an amendment to the fishing regulations, with reference to commercial and sport fishing (Fishing Regulations, 2016 update, Ministry of Agriculture.) The purpose of the new regulations was to improve the state of the fishing industry in Israel through sustainable management of the fishing resource. The main changes that took place in the fishing regulations included, for example, reduction of the area allowed for trawler fishing; a ban on fishing during the breeding, spawning, and recruitment seasons; the definition of a minimum fish size permitted for fishing for various species of commercial value; the definition of prohibited fishing methods (e.g. seine fishing or the use of artificial air for diving) and a daily catch limit for sport fishing.

In addition, after many years in which fishing regulations were barely enforced, the Ministry of Agriculture authorized the Nature and Parks Authority to enforce the fishing laws in practice. In the summer of 2018, the marine unit of the Nature and Parks Authority was established. Practically, it was only at this point that the new and updated fishing regulations began to be significantly enforced. The updating of the regulations and their enforcement in the field today make it possible to reduce the damage to the fish along Israel's shores. For more on the updated fishing regulations and the marine unit of the Nature and Parks Authority see Appendix 1

3 / Survey objectives

The surveys conducted in 2015, 2017, 2019, and 2021 were designed to examine whether the currently established MPAs protect the flora and fauna within their borders, and to assess whether they contribute to the stabilization of the ecosystem both inside and outside the reserves.

Four general goals were defined for the surveys:

A. Document the species found inside and outside the MPAs.

B. Describe the spatial patterns of marine flora and fauna down to a depth of about 25 m along the Israeli coastline.

C. Compare the animal and plant communities within Mediterranean Sea MPAs to similar nearby control sites with similar substrates.

D. Create a quantitative baseline of the flora and fauna currently found inside MPAs for future comparisons.

This report focuses on the effect of MPAs on commercially valuable fish species, with the following four specific goals:

A. Estimate the effect of reserves on the abundance of commercial species.

B. Estimate the effect of reserves on the abundance of individual large fish.

C. Examine the effectiveness of MPAs in protecting the fish community, using indicator fish species.

D. Assess whether MPAs contribute to increasing the fish stock outside their borders.

4 / Survey sites

The surveys were conducted at four MPAs along the Israeli Mediterranean coast and at adjacent control sites (see map 1): Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor.

Map 1. The survey sampling sites against the background of the master plan for marine reserves in the Mediterranean Sea. The boundaries of the reserves are marked with a dashed orange line. The sampling points inside and outside the reserves are marked in light blue. From north to south: Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor reserves. Note that the maps of each MPA are on different scales.

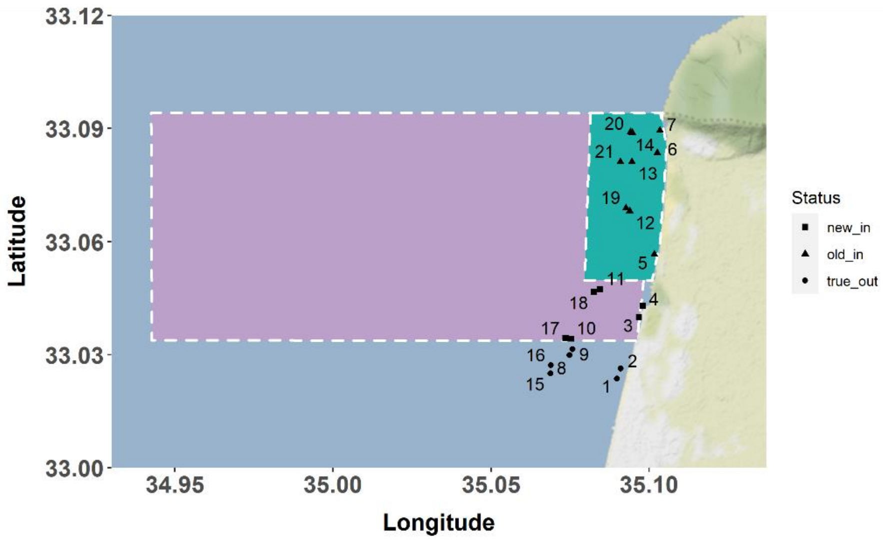
All sampling points, both within the MPAs and at the control sites, were characterized by rocky substrates and no surveys were conducted at sites characterized by sandy substrates. The sampling points at the control sites were ten meters to a few kilometers from the MPA borders, depending on the physical habitat characteristics.

Sampling in each reserve and its control sites was conducted at rocky points with similar substrate complexity, similar distance from the shore, and similar depths. However, there was variation between MPAs in size, maximum bottom depth, distance from the shore, and habitat characteristics. The regulations that determine the permitted and prohibited activities (including fishing activities) also vary from reserve to reserve. Similarly, the length of time during which each MPA has had active monitoring and enforcement also varies, from long-term enforcement (about three decades) to that of only a few years.

4.1/ Rosh Hanikra-Achziv

The surveys were conducted in the "Rosh Hankira-Achziv Reserve" as defined by its 2005 borders, prior to the 2019 expansion. The smaller, original, reserve extends from the Israel-Lebanon border to the ruins of the Port of Achziv, from the coastline out to 2 km west, and including a strip of indented beach about 5 km long. This reserve was, even before its expansion, the largest and most diverse in Israel in terms of habitats and natural assets. The reserve includes abrasion platforms, sandy beaches, caves and burrows in the coastal rocks, an underwater kurkar (limestone) ridge, rocky islands, and an underwater "canyon" (which is actually a steep limestone wall whose bottom reaches the sandy substrate.) The maximum depth of the reserve is 45 m.

In 2019, the Rosh Hanikra Reserve was expanded. The reserve in its new form includes the original reserve, where the surveys were carried out, with a coastline extended 1.8 km southwards towards the northern part of Nahariya, and out to 15 km west of the shore. The total area of the new reserve is 10-fold larger than the area of the original reserve and now covers 100 km^2.



Map 2. The sampling points in Rosh Hanikra-Achziv Reserve and the adjacent control site. The sampling points are marked in black. The MPA area up until 2019 in shown in green and the expanded area in purple. The shape of the sampling points represents the current official protection status as of the expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the area considered “protected” for the surveys is only the green area.

In view of the short period of time from the expansion of the reserve until the 2021 surveys – and the fact that the fishing ban and other protections measures are still not being enforced in the new territory, the area defined as “inside the reserve” has been defined by the same criteria as in the previous surveys.

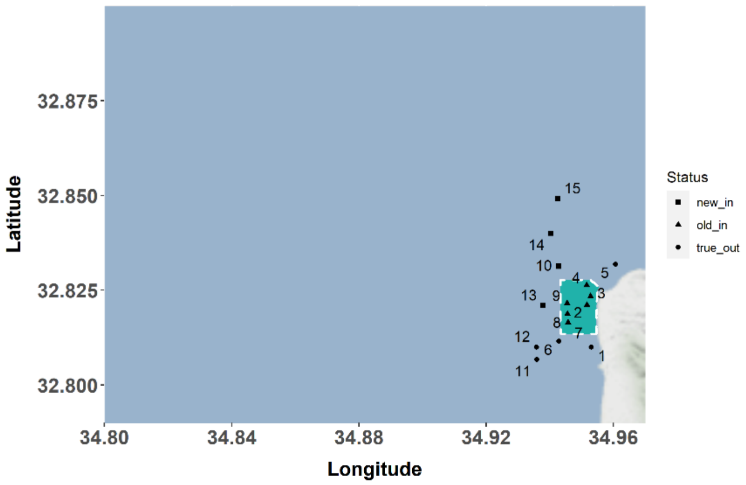
Fishing and enforcement activities in the reserve: The Rosh Hanikra-Achziv reserve is the only reserve which has long-standing monitoring and protection of its natural assets by designated marine rangers. Monitoring inside the MPA began in the 1990s. Up until 2006, the fishing ban was enforced from the shore out to 1 km west, but since 2006 this area has been expanded to include the entire area of the reserve (up to 2 km west of the shore). The only type of fishing ban not enforced inside the reserve over the years was rod fishing from shore, which also started to be enforced in April 2017, with the exclusion of the most southern part of the reserve.

4.2 /Shikmona

This MPA is located off the southern coast of the city of Haifa, from the Israel Oceanographic and Limnological Research institute in the north, to the estuary of the Lotem River (next to the "Maxim" restaurant on the beach) in the south. The MPA extends from the shore 1 km westward. There are abrasion platforms along the shoreline of the Shikmona reserve and. the substrate comprises intermittent rocky and sandy areas. The maximum bottom depth of the reserve is 15 meters.

In 2020, the Shikmona reserve was expanded into the Rosh Carmel Reserve, enlarging the borders to the north and west and increasing the total reserve area to approximately 50 km^2. The maximum depth of the reserve today is 300 m. In view of the short period of time from the expansion to the 2021 survey – and the fact that the fishing ban is still not enforced in the new reserve, the area defined as “inside the reserve” is defined by the same criteria as in the previous surveys.

Fishing activity and enforcement in the reserve: At the time of the first survey in 2015, there was still no enforcement of the fishing ban in the reserve. In 2016, dedicated marine rangers began work in the reserve, and the monitoring and enforcement of the sports fishing ban was increased (with the exception of rod fishing from the shore).

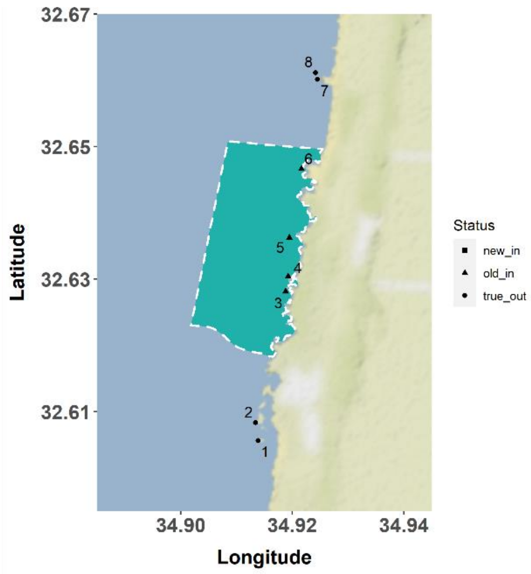


Map 3. The sampling points in the Shikmona Reserve and the adjacent control area. The sampling points are marked in black. The area of the reserve until 2020 is shown in green and the area after the expansion is shown in purple. The shape of the sampling points represents the official protection status as of the MPA expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the area considered "protected" at the time of the surveys is limited to the green area.

4.3 / Dor Habonim

The reserve extends along a 3.5 km coastline between the settlements of Nachsholim and HaBonim and out to 2 km from the shore. The coastline is winding, rugged and rich in unique alcoves, along which stretch well-developed abrasion platforms. The habitat of the rocky substrate in the reserve extends from the abrasion platforms to a maximum depth of 6 m, and further west is a soft substrate (sand and silt) habitat of down to a maximum depth of 21 m.

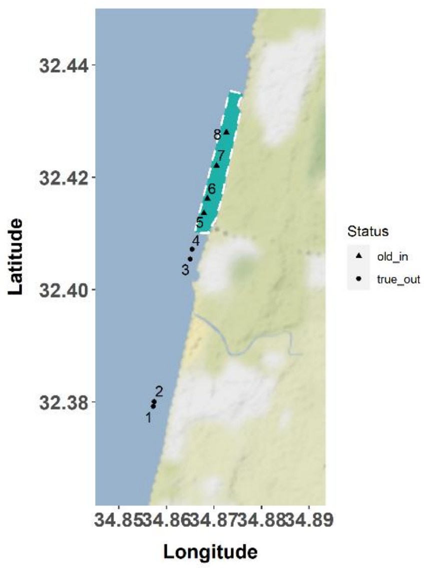
Fishing activity and enforcement in the reserve: at the time of the first survey in 2015, there was still no dedicated marine monitoring inside the reserve and enforcement was carried out by the coastal team. In 2016, dedicated marine rangers began working in the reserve, and supervision and enforcement of the sport fishing ban was increased (with the exception of rod fishing from the shore.) However, there is a group of commercial fishers from the nearby village of Fureidis whose activity predates the reserve, and they were given personal commercial fishing permits inside the reserve during its establishment. Therefore, in practice, this reserve does not function as a no-take reserve.



Map 4. The sampling points in the Dor HaBonim Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve is shown in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.)

4.4 / Gdor

This reserve extends from the south of Givat Olga to Michmoret along a 2.8 km long coastline and out to a distance of 300 meters west of the shore. The disintegration of the limestone cliffs in this coastal strip has created many marine habitats along the shoreline: abrasion platforms and coastal rocks, shallow lagoons, and sandy bays. The maximum depth of the reserve is 5 m.



Map 4. The sampling points in the Gdor Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve appears in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.) In addition to this area, the areas defined as reserve areas and as control sites outside the reserve have remained the same as the areas defined in the previous surveys conducted.

Fishing and enforcement activities in the reserve: with the commencement of work of the marine unit of the Nature and Parks Authority in May 2018, monitoring and enforcement of the fishing ban inside MPAs have been increased (with the exception of rod fishing from the shore).

In the years 2015-2017 there was a large gap between the number of transects sampled inside and outside the reserve (Table number, 2A Appendix.) The reason for this was the paucity of suitable control sites with rocky substrates similar to those of the reserve and located close by. In order to reduce the gap between the number of sampling points inside and outside the reserve, as of 2019 we reduced the number of sampling points within the reserve.

In the Israeli Mediterranean Sea there are two additional MPAs without rocky substrates and therefore no visual surveys were conducted there: the Avtach Marine Reserve and the Shikma Sea Reserve, as well as the Dor Islets of the Maagan Michael Reserve which do not include marine areas and therefore were not surveyed.

5 / Summary of methods

The surveys were conducted in the years 2015, 2017, 2019 and 2021 – during two seasons each year: spring and fall. Comparisons between the MPAs and the control sites outside them were conducted, as well as between the different survey years and between the survey sites. Following an initial examination of the data, no clear and consistent differences between the seasons could be found for the examined indicators. Therefore, for each year of the survey, the results present the average of the data collected for both sampling seasons.

The indicators examined were species abundance (the number of individuals observed), length distribution, and the total biomass of the fish (see Appendix 2). The abundance and biomass were calculated as an average value for each 150 m^2 transect, while the length distribution was based on all the individuals observed and not on the average of the individuals.

In some of the results, commercial and non-commercial fish species were analyzed separately. The commercial species are edible fish that have an economic value, such as species of groupers (dusky grouper, mottled grouper, and golden grouper) and saprosidae species (such as white seabream, zebra seabream, and saddled seabream). A detailed description of the working methods is provided in Appendix 2).

6 / Results

6.1 / Commercially valuable fish species observed in surveys

Table 1. The most common commercial fish species in the bioblitz surveys, in all years, at all sites, inside and outside the reserves. The rating was performed according to the number of transects where fish of these species were observed. In addition, the relative part of the transects in which each species appeared is shown. The total number of transects made in all surveys (1,116)

Species Name (Latin)	Species Name (English)	Transects in which species was observed	Percentage of total transects
Siganus rivulatus	Marbled Spinefoot	752	68
Diplodus sargus	White seabream	655	57
Mycteroperca rubra	Mottled grouper	477	43
Diplodus vulgaris	Two-banded sea bream	454	41
Siganus luridus	Dusky spinefoot	421	38
Oblada melanura	Saddled seabream	335	30
Epinephelus marginatus	Dusky grouper	314	28
Parupeneus forsskali	Red Sea goatfish	275	25
Diplodus cervinus	Zebra seabream	179	16
Epinephelus costea	Golden grouper	142	13

The most common commercial fish species observed in the surveys were the marbled spinefoot (rabbitfish) and white seabream. In addition, fish species from the grouper family – mottled grouper, dusky grouper, and golden grouper – are also included in the ranking of the most common commercial species. It should be noted that while the overall composition of the most common commercial species at each site inside and outside the reserves is very similar to the composition shown here, their abundances differ.

6.2 / Survey results in Rosh Hanikra-Achziv

The surveys carried out in the marine nature reserves starting in 2015 indicate that the Rosh Hanikra-Achziv reserve functions well in protecting fish communities. It functions as a model marine reserve, and this chapter of the results therefore focuses on this reserve only.

6.2.1 Fish biomass from commercial and non-commercial species

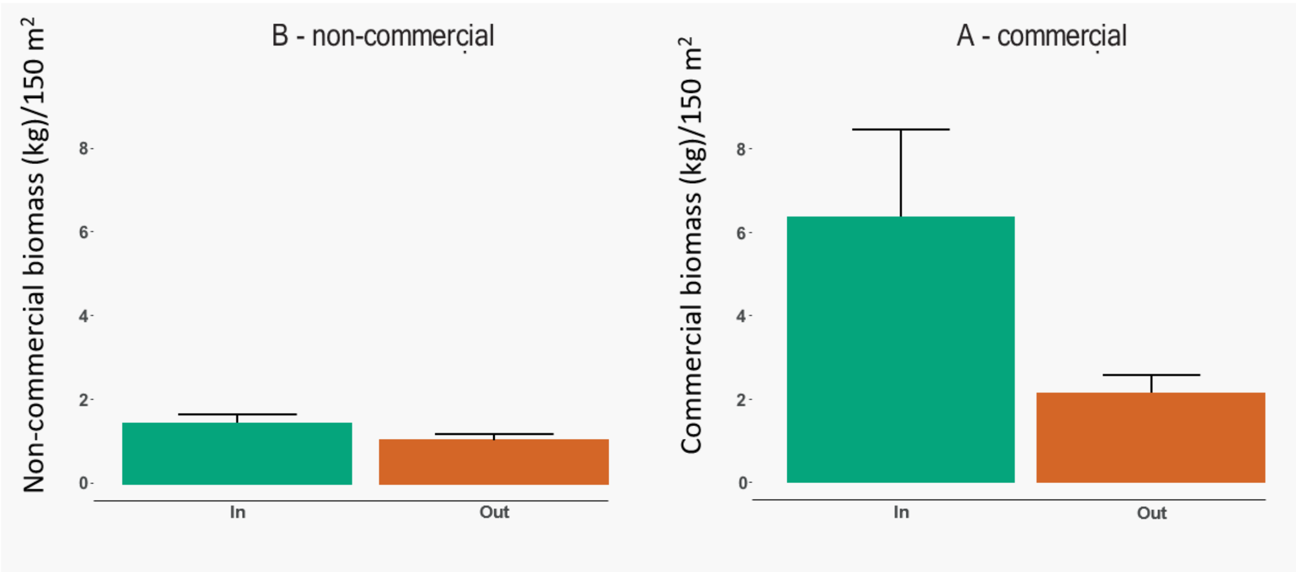


Figure 1. Average biomass for a transect inside and outside the Rosh Hanikra-Achziv reserve across all surveys. (a) biomass of commercial species (b) biomass of non-commercial species. The X axis indicates whether the sampling was conducted inside the reserve (green) or outside it (orange), and the Y axis shows the average biomass in kilograms per 150 m2 transect. 95% confidence intervals are shown above the columns.

The average biomass of the commercial fish species per unit area inside the Rosh Hanikra-Achziv reserve is 3-fold higher than their biomass outside the reserve. About half of the biomass of commercial fish outside the reserve is from the Siganus family (rabbitfish) – an invasive fish of relatively low commercial value. Within the reserve, they constitute less than a third of the biomass of all commercially valuable species of fish, even though their biomass is higher inside than outside the reserve.

6.2.2 Abundance of large individuals of all species

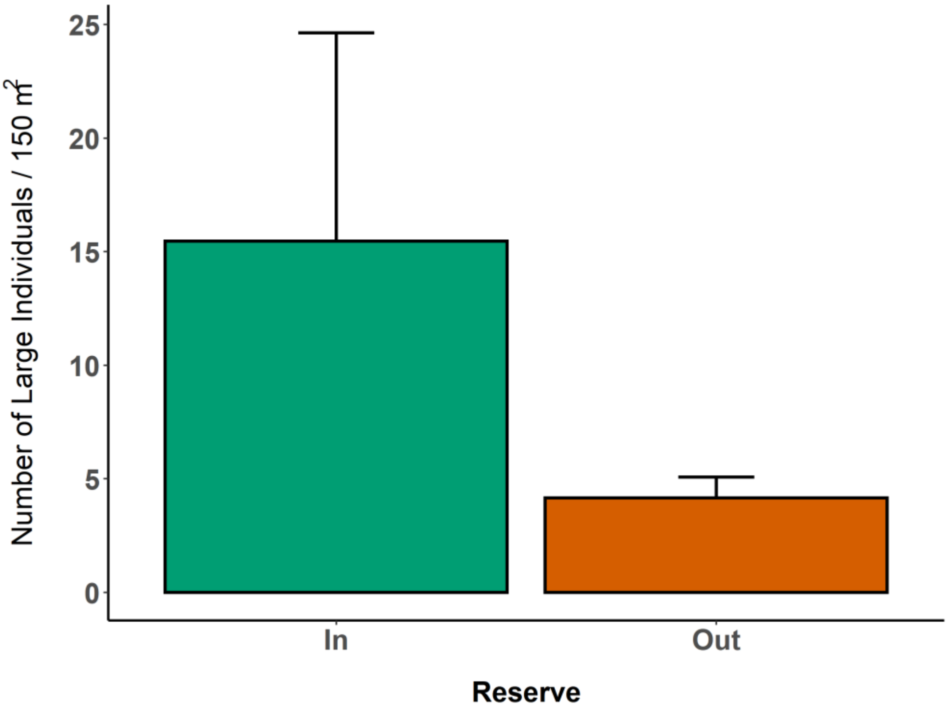


Figure 2. Average abundance per transect of large individuals of all fish species inside and outside the Rosh Hanikra-Achziv reserve in all the surveys. Large fish are defined as having a body length > 20 cm. The X axis indicates whether the sampling was conducted inside the reserve (green) or outside (orange) and the Y axis shows average abundance values over a 150 m^2 transect. A 95% confidence interval is shown above the columns.

The abundance of large individuals is almost 4-fold higher (3.7) within the Rosh Hanikra-Achziv reserve than outside it. Most of the large species are of commercial value (small species generally have no commercial value.)

6.2.3 Biomass and abundance of groupers

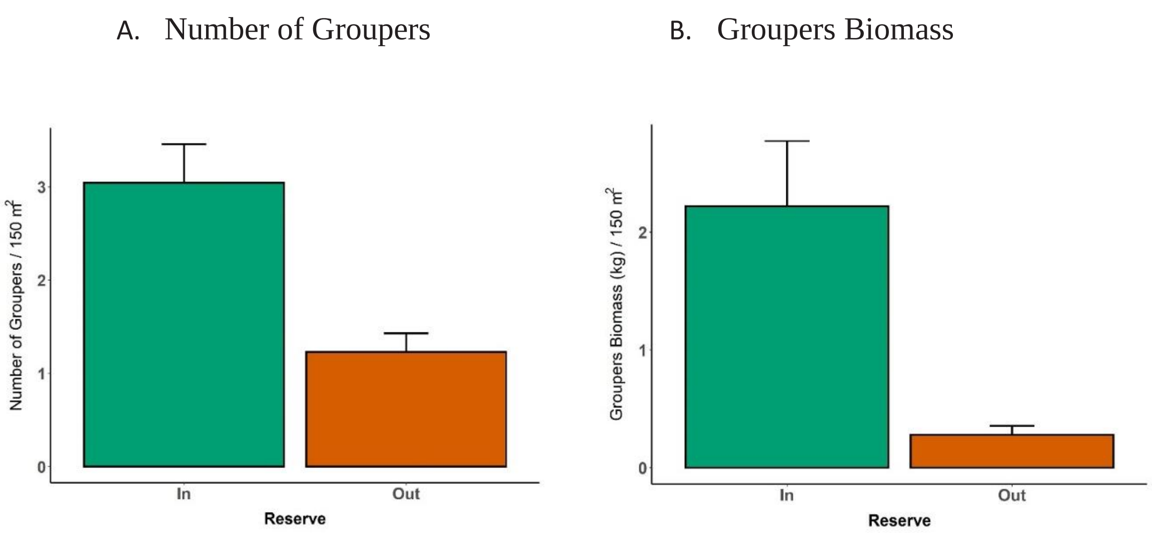


Figure 3. Biomass and average abundance per transect of groupers inside and outside the Rosh Hanikra-Achziv reserve in all surveys. The Y axis shows the average biomass (a) and the average abundance (b) of all grouper species for a 150 m^2 transect. The X axis indicates whether the sampling was conducted inside the reserve (green) or outside it (orange). A 95% confidence interval is shown above the columns.

The average grouper abundance (the number of individuals per unit area) inside the reserve is 2.5-fold higher than their abundance outside the reserve. The average biomass of all groupers per unit area inside the reserve is 8-fold higher than their biomass outside the reserve. The source of the high biomass inside the reserve is mainly from large individuals.

6.2.4 Length distribution of dusky groupers and mottled groupers

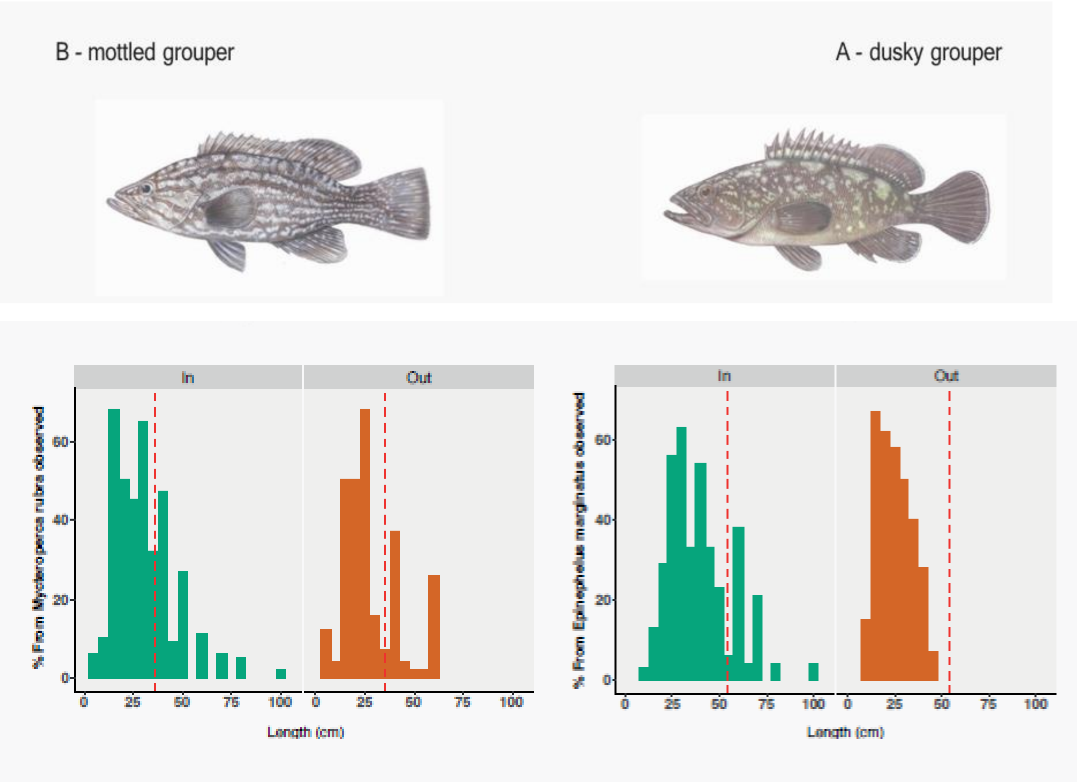


Figure 4. Length distribution of individuals of the species *Epinephelus marginatus* (a) and *Mycteroperca rubra* (b) inside and outside the Rosh Hanikra -Achziv reserve in all surveys. The X-axis shows the observed fish length and the Y-axis shows the percentage of the observed fish. The different lengths observed were grouped into 5 cm size categories. The graph shows the percentage of individuals observed in each size category out of the total number of individuals observed inside/outside the reserve. The dashed red line indicates the breeding size of the species (Stergiou, & Tsikliras 2008; Goren & Aronov, 2014). On the left of each graph, in green, is the distribution of lengths inside the reserve and on the right, in orange, the distribution outside the reserve.

The range of sizes of the dusky grouper observed inside the reserve is wider than outside the reserve, and individuals that reached breeding size were only observed inside the reserve throughout all the surveys. A few individuals of the mottled grouper that reached breeding size were also observed outside the reserve, and the percentage of the population that reached breeding size is higher inside the reserve than outside it (31% vs 8% respectively).

6.2.5 Summary of results - Rosh Hanikra-Achziv

In Rosh Hanikra-Achziv, clear and consistent differences are visible between fish populations of commercially valuable species found inside the reserve and those outside it:

- The general biomass of commercially valuable fish species is much higher (approximately 3-fold) within the reserve than the biomass outside of it.
  - The abundance of large individuals, most of which belong to commercially valuable species, is almost 4-fold higher (3.7) within the reserve than outside it.
- The abundance of groupers is 2.5-fold higher inside the reserve than outside it.
- The total biomass of the groupers inside the reserve is 8-fold higher than their biomass outside it. This difference is due to the presence of larger groupers inside the reserve.
- Individuals of the dusky grouper species that had reached breeding size are only found inside the reserve. The fish found outside the reserve are smaller and none have reached breeding size.
- A higher percentage of mottled groupers reached breeding size inside the reserve compared to outside of it (31% compared to 8% respectively)

These findings indicate that the grouper community within the boundaries of the reserve is thriving and has a higher concentration of breeding individuals. The groupers within the reserve have the potential to produce more offspring for future generations. In the nearby fished areas, no breeding-sized individuals of the dusky grouper species were observed at all, and the percentage of breeding-sized mottled groupers was low compared to that in the area inside the reserve. Apparently, these much sought-after fishing areas depend on the populations breeding within the reserve to provide young fish of commercially valuable species.

6.3 Comparison between the reserves

6.3.1 Grouper abundance in all surveys, at all sites, inside and outside the reserves

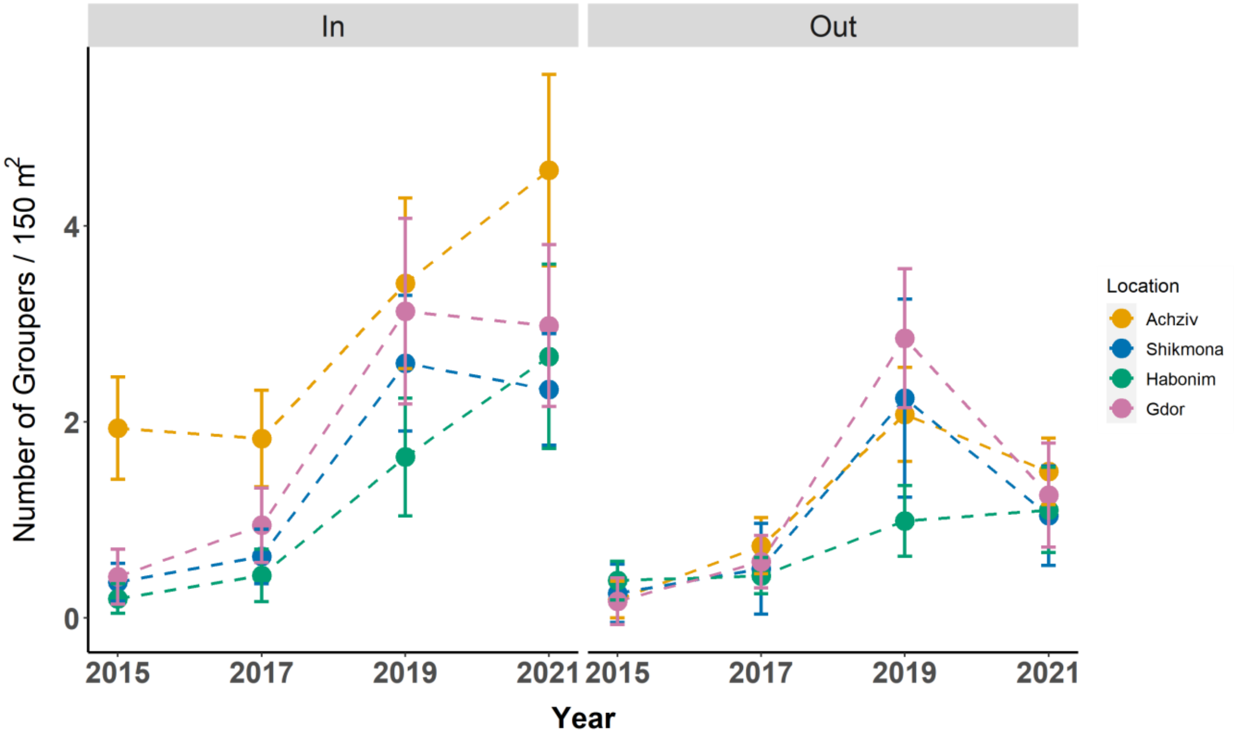


Figure 5. Average grouper abundance per transect inside and outside the reserves. The Y axis shows the average abundance per 150 m2 transect for all the grouper species The X axis shows the year of the survey. The colors represent the survey locations. On the left is shown the average grouper abundance inside the reserve and on the right their abundance outside the reserve. A 95% confidence interval is shown for each site in each survey year.

6.3.2 Grouper biomass in all surveys, at all sites, inside and outside the reserves

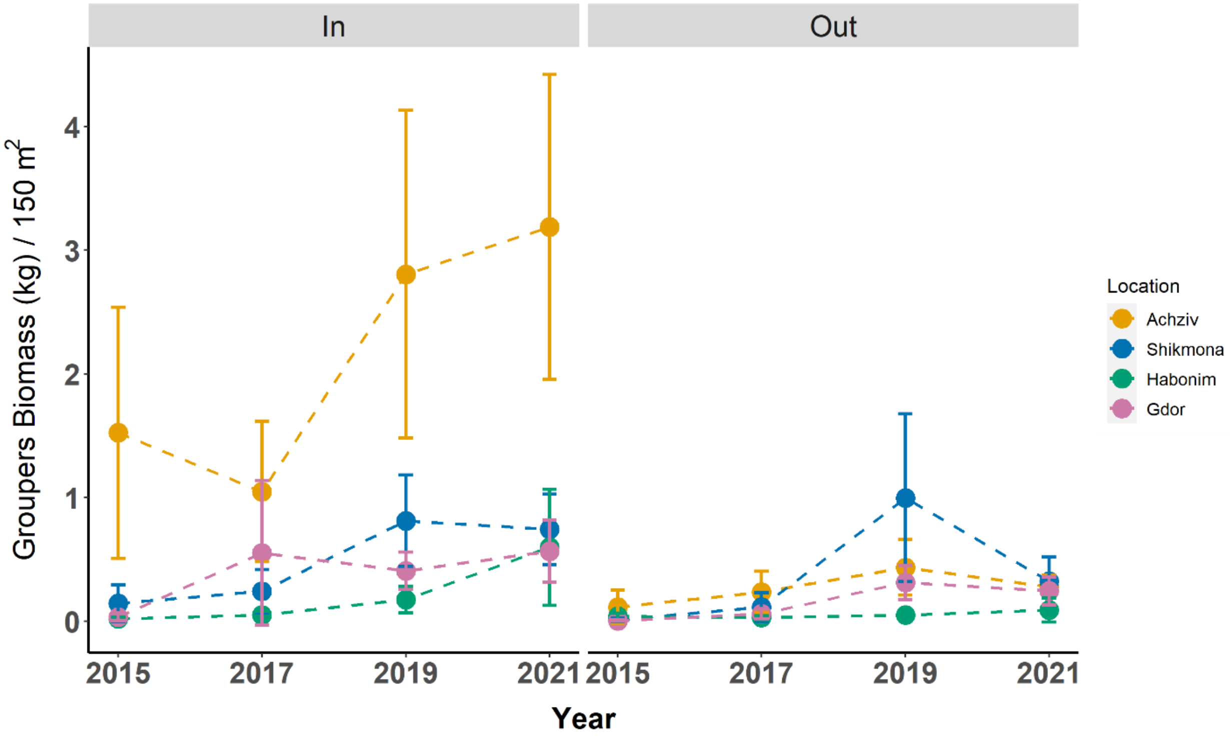


Figure 6. Average grouper biomass per transect inside and outside the reserves. The Y-axis - shows the average biomass for a 150 (m^2) section of all the individuals of the species. The X-axis - shows the year of the survey. The colors represent the survey locations. On the left is shown the average grouper biomass inside the reserve and on the right the biomass outside the reserve. A 95% confidence interval is shown for each site and each survey year.

Between the years 2015 and 2021 there was a small increase in the grouper biomass, mainly within the reserves. At this stage the larger increase in the number of individuals is reflected in a smaller increase in biomass. If this is the beginning of a trend, we expect over time to observe a continued increase in biomass within the boundaries of the reserve while the biomass outside the reserve will remain low. Throughout all the years of the survey, the grouper biomass within the Rosh Hanikra-Achziv reserve was significantly higher than that within the other reserves.

6.3.3 The ratio between the abundance of adult and young groupers in all surveys, at all sites, inside and outside the reserves

Mycteroperca rubra, mottled grouper

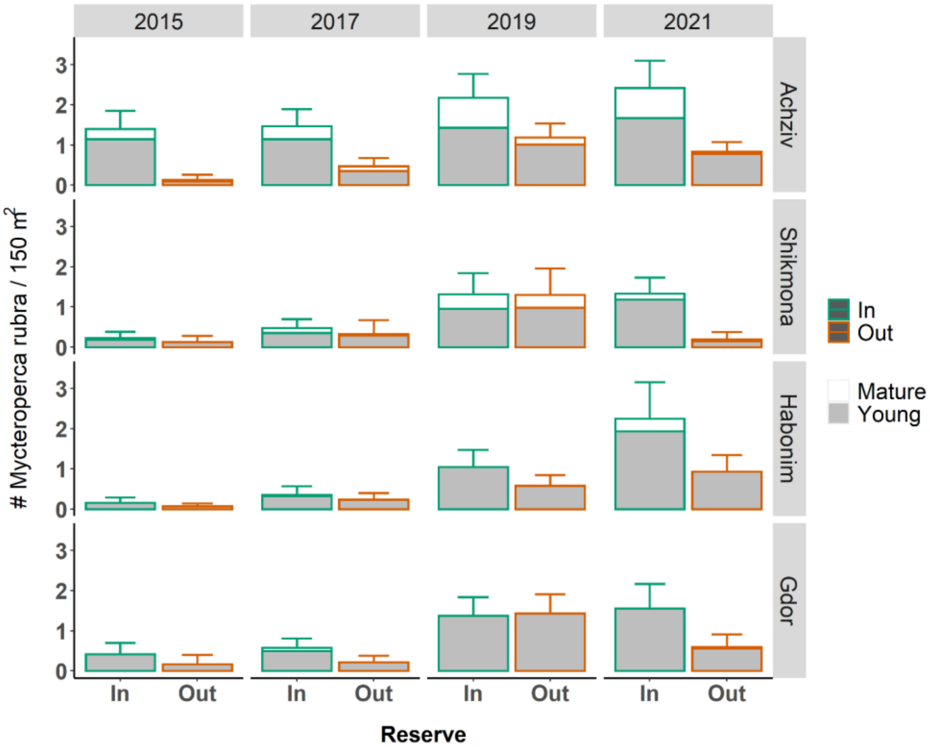


Figure 7. Average abundance of *Mycteroperca rubra* (mottled groupers) per transect inside and outside the reserves, over the years, separated into mature and young individuals. The Y-axis shows the average abundance of individuals for a 150 m^2 transect. The relative proportion of mature individuals (over a length of 35.5 cm, Goren, & Aronov, 2008) is shown in white. The X-axis indicates whether the survey was inside the reserve (green) or outside it (orange). A 95% confidence interval is shown above each column.

Individuals that had reached breeding size were found mainly within the Rosh Hanikra-Achziv reserve, and their abundance increased over the years. In the Shikmona reserve, an increase in the general abundance is also seen over the years, as well as in the abundance of individuals that had reached breeding size, especially within the reserve.

In Gdor and Dor-HaBonim, there was a marked increase in the abundance of young individuals both within the reserves and outside them between 2015 and 2021; and in 2021 mature groupers were observed within the the Gdor reserve borders; no individuals were observed to have reached breeding size.

Epinephelus marginatus, dusky grouper

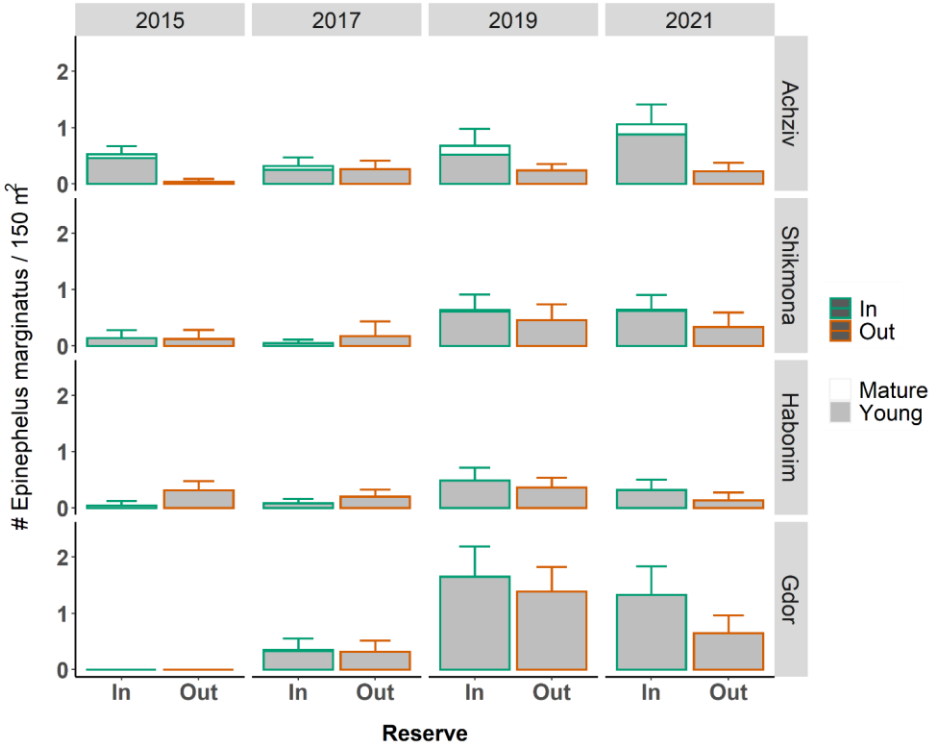


Figure 8. Average abundance of *Epinephelus marginatus* (dusky groupers) per transect inside and outside the reserves, over the years, separated into mature and young individuals. The Y-axis shows the average abundance of individuals for a 150 m^2 transect. The relative proportion of mature individuals (over a length of 35.5 cm, Goren, & Aronov, 2008) is shown in white. The X-axis indicates whether the survey was inside the reserve (green) or outside it (orange). A 95% confidence interval is shown above each column.

Individual dusky groupers that had reached breeding size were observed almost exclusively within the Rosh Hanikra-Achziv reserve (apart from two isolated observations in the Shikmona Reserve in 2019 and in the Gdor Reserve in 2017). The increase in the abundance of juveniles between the years 2015-2021 is prominent in all reserves.

Epinephelus costae, golden grouper

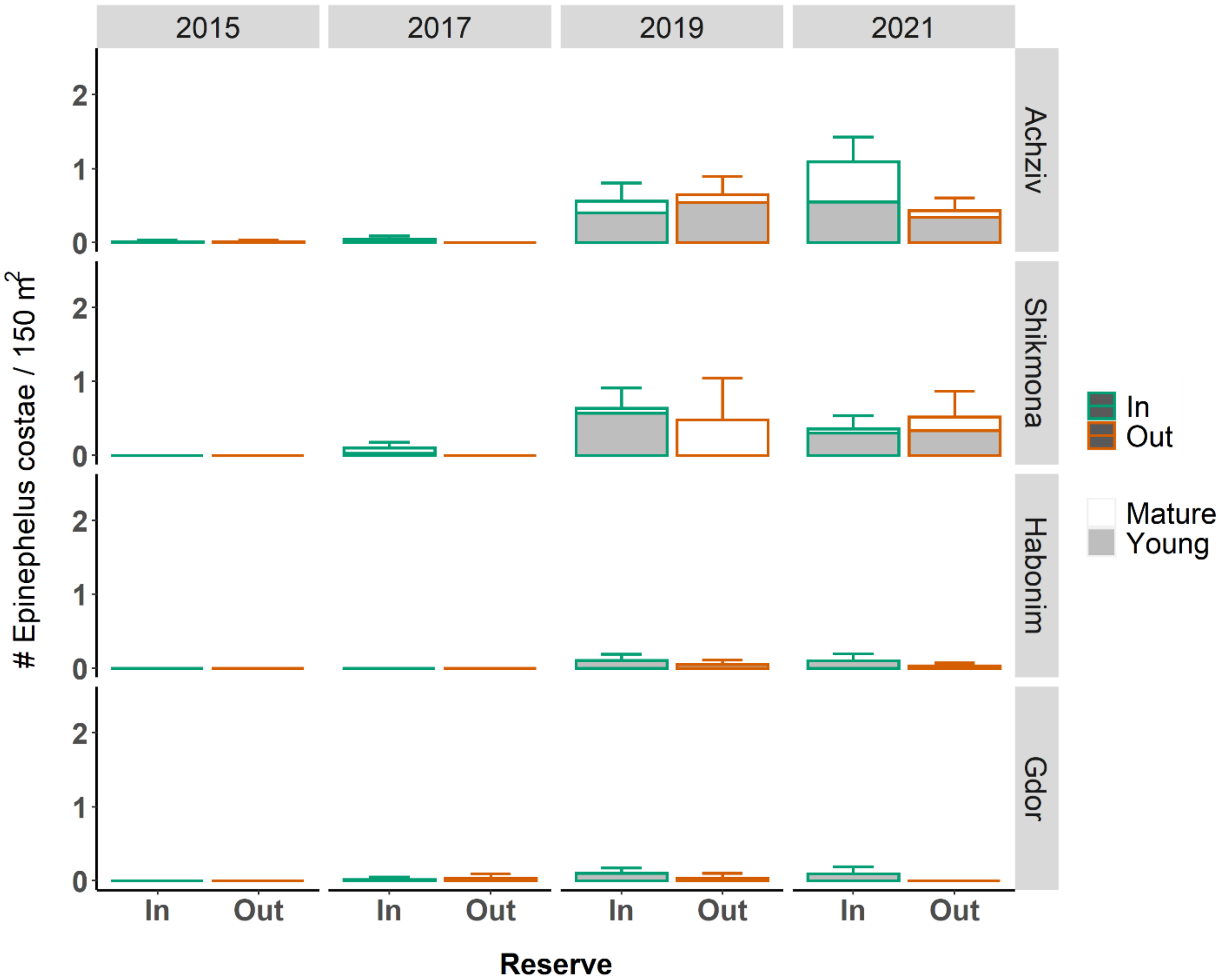


Figure 9. Average abundance of *Epinephelus costae* (golden grouper) per transect inside and outside the reserves, over the years, separated into mature and young individuals. The Y-axis shows the average abundance of individuals for a 150 m^2 transect. The relative proportion of mature individuals (above a length of 35.5 cm, Goren, & Aronov, 2008) is shown in white. The X-axis indicates whether the survey was inside the reserve (green) or outside it (orange). A 95% confidence interval is shown above each column

Young and adult golden groupers were observed both inside and outside the Rosh Hanikra-Achziv and Shikmona reserves starting in 2019.

6.3.4 Summary of the results for all the surveyed reserves

Grouper abundance

- The grouper abundance was consistently higher within the Rosh Hanikra-Achziv reserve compared to the areas outside it over all years.
- An increase in the grouper abundance in all reserves was observed between the surveys carried out in 2017 and those carried out in 2019 and 2021. This increase was visible at all the surveyed sites, but the abundance was higher within the reserves.

Overall grouper biomass

- Similar to the grouper abundance, there was an increase in their general biomass between the years 2017 and 2021 in all reserves.
- Notable differences between reserve borders and control sites were only visible in Rosh Hanikra-Achziv.
- The general biomass values of the groupers within the Rosh Hanikra-Achziv reserve were significantly higher than those within the other reserves (sometimes 10-fold).
- In the other reserves, the increase in the number of individuals manifests itself as a small increase in biomass due to an increase in the abundance of young individuals. Over time we expect to see a continued increase in biomass within the boundaries of the reserve while the biomass outside the reserve will probably remain low.

Mottled groupers that reached breeding size

- Individuals mottled groupers that reached breeding size were seen mainly in the Rosh Hanikra-Achziv and Shikmona reserves, but were also seen outside the reserves albeit in lower numbers. In 2021 individuals above breeding size were also observed in Dor Habonim.
- In the Gdor reserves, individuals of this species that had reached breeding size were seldom seen, but there was a marked increase in juvenile abundance over the years; observed for the first time in 2019, both inside and outside the reserves.

Dusky groupers that reached breeding size

- Individual dusky groupers that had reached breeding size were seen only within the Rosh

Hanikra-Achziv reserve (except for two observations –within the Shikmona and Gdor reserves).

- Similar to the mottled grouper species, in the Shikmona , Dor-Habonim, and Gdor reserves, there was a marked increase in the abundance of young dusky groupers, especially during the surveys carried out in 2017 and 2019

Golden groupers that reached breeding size

- Golden groupers that had reached breeding size were observed in Rosh Hanikra-Achziv and Shikmona, both inside the reserves and in the control sites as of 2019. An increase was also observed in the abundance of young individuals of this species in both reserves.

7 / Discussion and conclusions

- The current report summarizes eight surveys that were carried out within four MPAs in the Israeli Mediterranean Sea and at adjacent control sites, during the years 2015-2021. This chapter of the report focuses on the fish surveys and the effect of reserves on commercially valuable fish species.
- During the years of the survey a significant change in the fishing regulations and monitoring in the Israeli Mediterranean took place, with the establishment of the Marine Unit of the Israel Nature and Parks Authority in 2018.
- As of 2018, monitoring efforts were expanded to include the Shikmona, Dor-Habonim, and Gdor marine reserves, in addition to Rosh Hanikra-Achziv where enforcement activities were already in place. The report presents the changes in size and abundance of commercial fish species, especially groupers, inside and outside the reserves.
- The data collected over the years indicate the clear success of the Rosh Hanikra-Achziv reserve in protecting the commercial species inhabiting it.
- In all the reserves, an increase in the abundance and size of groupers was observed, with a similar increase also observed at the control sites.
- As of 2017, there was an increase in the abundance of golden groupers in both Rosh Hanikra-Achziv and Shikmona and their control sites. In 2021, the species was

declared a protected natural asset, which may further increase the numbers in the coming years.

- A total of 79 species of fish was observed during the surveys (as well as fish identified to the family level only: sardines, silversides, and mullets.)

The functioning of the Rosh Hanikra-Achziv reserve is reflected in all the indicators examined.

MPA effects can be expresses in an increase in the abundance and biomass of individuals of commercial species within the reserve's boundaries (Cote et al., 2001; Edgar et al., 2014). The present survey reveals this to have been the case in the Rosh Hanikra-Achziv reserve: the biomass of commercial species was higher there compared to in the control area outside the reserve, which is similar in terms of the substrate, depth, distance from the shore, and other characteristics, except that of all types fishing are permitted there (Figure 1a.) In contrast, the difference in the non-commercial species biomass between the reserve and the control sites outside it was smaller (Fig. 1b.) The success of MPAs can also be expressed in the increased presence of large individual fish within the boundaries of the reserve compared to at the control sites (Fig. 2) Commercially valuable fish are protected from fishing within the limits of the reserve and are therefore able to reach a larger body size.

The high biomass and abundance of the grouper species observed in the surveys within the Rosh Hanikra-Achziv reserve also indirectly indicate an increase in the reproductive capacity (i.e. the ability to produce more offspring) of these species (Venturelli et. al., 2009). This increase is also directly expressed in the abundance of individuals that have reached breeding size. Adult dusky groupers that had reached breeding size (Fig. 4a) were observed only within the boundaries of the reserve and not outside it. Out of all the mottled grouper individuals observed, the relative portion that reached breeding size was higher within the boundaries of the reserve (Fig. 4b.). Similar findings were obtained for all the survey years (Appendix. 3).

The condition of the groupers in the Shikmona, Dor-Habonim, and Gdor as indicators of functional improvement

The condition of the groupers in these three reserves improved throughout the years of the survey and is an indication of improvement in their functioning. The most noticeable increase is expressed in the grouper abundance between the years 2017-2021 (Fig. 5) The main contributors to this increase in abundance were small young individuals rather than large mature individuals, as seen from the change in the abundance of the two common grouper species - the mottled grouper and the dusky grouper (Figs. 7 and 8) – here, too, the most noticeable change occurred between the years 2017 to 2021 – but it was not accompanied by a large increase in the total biomass of the groupers due to the small size of the individuals.

Between the years 2017-2021, there was increased enforcement of the fishing regulations, updated in 2016, some of which are extremely significant for groupers. The new regulations include the definition of a minimum catch size (set at 40 cm total length for all grouper species), a daily catch limit for sport fishing, and a ban on fishing with guns or diving tanks. In addition, a ban on grouper fishing during the breeding season began to be enforced. Although the breeding season takes place between the months of April and July, the ban itself applies to only a limited period during these months and not to the entire duration. It is possible that these changes allowed the groupers to produce a new generation of offspring and more effectively establish themselves.

In addition to the possible effect of the changes in the fishing regulations and their enforcement in regard to the groupers, it is also possible that during the years 2017-2021 conditions in the sea prevailed that were especially suitable for the recruitment of young individuals into the system. The importance of environmental conditions such as temperatures, nutrient concentrations, timing of the algal bloom, etc. (Beaugrand et al., 2003) is known to be a key factor in the success of the recruitment of young fish into the population (Platt et al., 2003).

However, the ability of a population to thrive is measured by the proportion of individuals that reproduce in it, and not by the number of young individuals. Therefore, despite the increase in the abundance of young groupers, it will take several more years in order to determine whether this increase also reflects the abundance of adult individuals and indicates a stable population.

MPAs are designed to preserve a wide variety of habitats in order to protect all the species of animals and plants found within them. An additional benefit of MPAs lies in their conservation of a commercial fishing resource. Since the fish inside MPAs are protected from fishing, the existence of the reserves enables more individuals to reach a large body size, sexual maturity, and reproduction. The spillover of some fish and the dispersal of juveniles from inside to outside the reserves help to maintain their populations outside the reserves.

Throughout the years of the survey, the success of the Rosh Hanikra-Achziv reserve in protecting commercial species of fish that inhabit it, including groupers, was evident. An increase in the number of groupers, but not in the size of the individuals, was also found at the other survey sites. This increase is likely due to a combination of enforcement of the new fishing regulations and suitable environmental conditions at sea. However, the stability of the populations should be measured according to the abundance of large and breeding individuals, which have rarely been observed outside the Rosh Hanikra-Achziv reserve. Several more years of follow-up will be required in order to determine whether the current increase in abundance will also be reflected in an increase in body size and the ability of these fish to reach breeding size.

Against the background of the general decrease worldwide in the population sizes of commercial target species such as groupers, and particularly in the Mediterranean Sea, the successful functioning of the Rosh Hanikra-Achziv reserve and the first signs of recovery that have also been observed in the other reserves since increased enforcement began, are particularly encouraging and reinforce the need for large no-take MPAs as a means of protecting the world’s fishing resources.

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Appendix 1

Changes in the world of fishing in Israel during the years 2015-2021:

In 2015, the effects of marine reserves on fish communities in the Israeli Mediterranean Sea were examined for the first time. Since then, significant changes have occurred in the world of fishing in Israel.

Appendix 1.1 Update of fishing regulations

In 2016, the finance committee of the Knesset approved a revision of the fishing regulations with respect to commercial and sport fishing (fishing regulations, 2016 update, Ministry of Agriculture). The purpose of the new regulations is to improve the state of the fishing industry in Israel through the sustainable management of the fishery resources. The key changes in commercial fishing regulations include, for example:

Restrictions on trawler fishing: the new fishing regulations strictly prohibit fishing from trawlers in the northern part of Israel – from the Lebanese border in the north to Nahsholim in the south. This method of fishing has also been prohibited in rocky areas in all territorial (sovereign) waters of Israel. Trawler fishing is also prohibited annually during the fish recruitment season (when juveniles join the adult fish populations) for up to 90 consecutive days between May 1 and August 31, based on the determination of the chief fishing official.

Prohibition of shore fishing during the breeding season: fishing is prohibited annually for 60 to 90 consecutive days during the period of March 1 to July 1, based on the determination of the chief fishing official. In practice, this prohibition is in effect for shorter periods. During the transitional period (the first three years 2017-2019) up until the time of full implementation of the regulations, the maximum duration of the ban was set at 45 days. In practice, however, during those years and even in 2020, the duration of the complete ban on fishing during the breeding season did not exceed 30 days in any year. During those years there was also a fishing ban on groupers during part of their specific breeding season, in addition to the general fish breeding season. This prohibition applied to all methods of fishing, including rod fishing from shore, based on the determination of the chief fishing official.

In addition, the fishing regulations include minimum catch sizes with the aim of allowing individual fish to reach breeding size; the prohibition of certain fishing methods (e.g. dragnet fishing); increasing the minimum mesh sizes for fishing nets; and denoting the distance from the shore required for the various fishing methods.

With regard to sport fishing, whose extent is increasing and now comprises a significant component of the fish haul in Israel (Frid and Gavrieli, 2019), there have been a number of significant changes, including a complete ban on fishing using artificial breathing equipment for diving and applying daily catch limits. In addition, fishing bans on all species in general, and groupers in particular, during the different fish breeding seasons, are now also valid for sport fishing.

In practice, the enforcement of the new regulations began in the summer of 2018 with the introduction into operation of the Marine Unit of the Israel Nature and Parks Authority. The regulations have been summarized in an information booklet to make them accessible to the fisher community (Israel Nature and Parks Authority, 2018).

Updates of the protected natural assets: In 2021, the golden grouper was declared a protected species and fishing it is banned.

Appendix 1.2 The establishment of the Marine Unit of the Israel Nature and Parks Authority

After many years in which the fishing regulations were rarely enforced, the Israel Nature and Parks Authority was authorized in 2018 by the Ministry of Agriculture to enforce the regulations for which the fishery department is responsible. Intensive monitoring and enforcement work pertaining to the fishing regulations (including the new regulations of 2016) began in the summer of 2018, following the recruitment and training of suitable personnel. In addition to the unit's activities in the Mediterranean, the monitoring work is also carried out in Lake Kinneret (Sea of Galilee) by professional personnel with specialized equipment.

Up until the establishment of the Marine Unit of the Nature and Parks Authority, the supervision of marine reserves comprised a designated ranger for the Rosh Hanikra reserve (from the 1990s), a marine ranger for the Carmel Coast, Shikmona, and Dor-Habonim reserves (from 2016), and a part-time ranger for the southern Mediterranean reserves - Avtach and Shikma.

As of May 2018, the monitoring system comprises 12 marine rangers and 4 enforcement boats in the Mediterranean. Under the agreement to enforce the fishing regulations, marine rangers engage in a variety of activities, including educating the fishers, monitoring fishing licenses on land and at sea, fishing licenses for boating, fishing equipment and haul (including in stores and markets), and enforcement of regulations pertaining to prohibited fishing methods and seasons. In addition, the rangers help to administer the established Mediterranean marine reserves, monitor reserve activity (including enforcing the specific fishing bans of each reserve that define what kind of fishing is permitted or prohibited), and enforce nature conservation laws (such as those that protect natural assets) also outside the reserves.

Annex 1.3 Fishing bans for rod-fishing from shore in the Rosh Hanikra-Achziv reserve

As of April 2017, rod-fishing from shore has been prohibited in the Rosh Hanikra-Achziv reserve, with the exception of the southern stretch of the reserve from the monument to clandestine immigration in front of the Achziv resort village, along 500 m of the coastline, to the southern border of the reserve area surveyed (the Rosh Hanikra-Achziv reserve with its southern border at the archeological ruins). In this area, rod fishing from shore is allowed only for fishers using the "buss" fishing rod – a pole, line, and hook that extend to no further than 20 meters from the fisher.

This ban on fishing rods, which has been enforced along most of the reserve's coastline, was due to a significant increase in the number of fishers using rods in the reserve, and to the other elaborate fishing gear used that increased the overall fishing haul and effectiveness. In addition, there was an increase in the total biomass fished from the waters of the reserve, an increase in the number of turtles and additional protected natural assets caught in the areas of the reserve (such as rays and sharks that were accidentally caught by coastal fishers), as well as in the number of large fish from species that play an important role in the marine food web, such as groupers. When the reserve was expanded to the northern borders of the city Nahariya, rod fishing on the southern end was allowed.

Appendix 2 - Methods

Appendix 2.1 Survey participants

The sampling, documentation, species definition, compilation of the survey database, and analysis of the findings were collaboratively carried out by researchers and students from several institutions: The School of Zoology - Tel Aviv University, The Steinhardt Nature Museum - Tel Aviv University, The Maurice Kahn Sea Research Station, The School of Marine Science - Haifa University, The School of Marine Science - Ruppin Academic Center, The Israel Oceanographic and Limnological Research, and the INPA.

Appendix 2.2 Survey description

Surveys were conducted in 2015, 2017, 2019, and 2021 during two seasons annually: spring and autumn. In total, 8 surveys were conducted using the "BioBlitz" approach (Table A1, Appendix 2): namely, intensive and simultaneous sampling and documentation of various taxonomic groups (fish, invertebrates, and algae in the benthic zone), inside the reserves and outside at control sites featuring similar substrate characteristics in terms of depth, type (rocky), and complexity. The sampling points at the control sites were within several meters to a few kilometers from the reserve borders, depending on the physical characteristics of the habitats. Each marine reserve (including its control sites) was allocated one working day per season. Sampling in the various reserves was conducted as far as possible on successive days.

Table A1 Survey dates in 2015, 2017, 2019, and 2021 by season

Reserve	Spring	Autumn	Year
Dor-Habonim	April 27	November 2	2015
Shikmona	April 28	November 3	2015
Rosh Hanikra-Achziv	April 29	November 5	2015
Gdor	April 30	November 12	2015
Dor-Habonim	June 4	October 15	2017
Shikmona	June 5	October 19	2017
Rosh Hanikra-Achziv	June 6	October 18	2017
Gdor	June 7	November 7	2017
Dor-Habonim	April 8	October 27	2019
Shikmona	April 29	October 28 November 27	2019
Rosh Hanikra-Achziv	April 30	October 31	2019
Gdor	April 7	October 30	2019
Dor-Habonim	May 2	October 10	2021
Shikmona	May 3	October 25	2021
Rosh Hanikra-Achziv	May 4	October 26	2021
Gdor	April 25	September 29	

Appendix 2.3 Survey work methods

The fish surveys were conducted using visual assays (observation and documentation only) in belt transects 25 m long and 6 m wide (3 m from each side of the tape measure). The location of the transects was determined by advance planning (deliberate sampling) with the goal of achieving a representative survey of the rocky terrain within both the reserve and the control sites. The substrate of the control sites was similar to that of the reserve in terms of physical characteristics (rocky substrate), distance from the coastline, and separation from other rocky areas.

The transects were carried out at three different depths, as detailed below, where possible (given the maximum depth of the surveyed reserve). At each depth, three sites were surveyed inside the reserve and two in the control area outside the reserve.

Appendix 2.4 Site location and depth

The transects were made parallel to the shore (to maintain a uniform depth along the transect). The number of transects per site was limited by the dive limitations of the surveyors and ranged from 2-4 transects per site.

Sampling was conducted, where possible, in three depth categories:

Shallow: 0-9 m.

Medium: 9.1-17.4 m, if the reserve possessed this depth range.

Deep: 17.5-26.4 m, if the reserve possessed this depth range.

In the Rosh Hanikra-Achziv reserve, all three depths were surveyed. In 2015 and 2017, two depths were surveyed (shallow and medium) and in 2019 and 2021 a deeper area was also surveyed, which is now outside the borders of the reserve (west of it). In the Dor-Habonim reserve, only shallow depths were surveyed. In Gdor, the shallow depth was surveyed and, in 2015 only, the medium depth outside the reserve was also surveyed.

Appendix 2.5 Sampling protocol

The survey points in and out of the reserve were marked on the morning of the survey by buoys and their locations were accurately documented. With the descent of the divers into the water, a maximum visibility distance test was carried out to ascertain the distance at which individual fish could be seen and identified. The test was conducted by two surveyors, one of whom held a page showing two black rectangles. The second surveyor swam away from the first one holding a rolling measuring tape. When the two rectangles appeared to merge into one, the surveyor stopped and recorded the distance. This distance was defined as the visibility measure in the water.

The range of visibility in all the surveys ranged from 3-30 m. In a survey conducted in the spring of 2019 in the Dor-Habonim and Gor reserves, the sea conditions made it difficult to carry out the survey, and visibility in the water was extremely low compared to the survey in the spring of 2017. The average visibility in Gdor in the spring of 2017 was 12.2±1.9 m compared to 4.6±0.9 m in the spring of 2019 . In Dor-Habonim, the average visibility in the spring of 2017 was 12.8±2 m compared to 6.5±1.7 m in the spring of 2019.

After testing the visibility range, the tape measure was rolled up and reused to measure a 25 m transect in the opposite direction, while recording all the fish found in the field, including identifying the species of the fish, assessing the number of individuals of the same species, the size of the fish, and their distance from the center of the transect. To analyze the data, we included all fish recorded at a distance of up to 3 meters in each direction from the center of the transect.

Documentation was carried out on waterproof forms. In the event that the survey was conducted by two experienced surveyors, two repetitions were obtained for the same transect, and the average value between the two surveyors was used in the data for analysis. In the event that one of the surveyors was less experienced, only the data of the senior surveyor were included.

After the surveyors finished the first transect, they continued to make another transect in the opposite direction (north or south). If the surveyors had sufficient dive time, they continued to make two more transects to the east or west of the starting point, thereby avoiding repetition of the same transect area.

Table A1 Survey efforts in 2015, 2017, 2019, and 2021 by site and depth

Site	Depth	Spring		Autumn		Total transects in the site
		Inside the reserve	Outside the reserve	Inside the reserve	Outside the reserve	
Rosh Hanikra-Achziv	Shallow	28	29	48	35	374
	Medium	31	30	44	46	
	Deep	16	19	22	26	
	Total	75	78	114	107	
Shikmona	Shallow	37	33	42	30	240
	Medium	26	17	38	17	
	Deep					
	Total	63	50	80	47	
Dor-Habonim	Shallow	63	60	66	66	256
	Medium		1			
	Deep					
	Total	63	61	66	66	
Gdor	Shallow	73	41	77	55	246
	Medium					
	Deep					
	Total	73	41	77	55	
Total all transects						1116

Appendix 2.6 Data analysis

All data analysis was carried out using R software, which is both a programming language and a work environment for analyzing statistics and creating graphics.

The data were analyzed for each survey separately, and a comparison was made between the survey sites, the different seasons, the year of the survey, and between the reserves for the outside control sites. The seasons in which surveys were carried out - spring and autumn - differ in the characteristics of fish communities (species composition and abundance) due to various environmental conditions (such as water temperature). However, a preliminary examination of the data revealed no clear and consistent differences between the seasons with reference to the indicators examined. Consequently, the results for each year include the average of all data collected during the two survey seasons.

The examined indicators are: the abundance of fish (the number of individuals found), the fish biomass, and the distribution of the fish lengths. The abundance and biomass were calculated as an average value by transect (150 m^2) while the distribution of lengths was based on all the lengths found

Appendix 2.7 Abundance and biomass

An examination of the overall biomass of fish inside and outside the reserves was carried out using the sizes estimated by the surveyors and the conversion from length to weight. Since a constant ratio of length to weight is maintained in individuals of the same species, it is possible, based on the species of fish, to convert its length into weight using the following formula:

$$W = aL^b$$

where W equals the weight of the fish, L equals the length of the fish, and the parameters a and b-are constants specific to the species. For the current survey, values a and b are from Fishbase (Froese and Pauly).

In some data analyses, there was a separation of commercial fish species and non-commercial species. Commercial species are edible fish that have economic value, such as species from the grouper subfamily (dusky grouper *Epinephelus marginatus*, mottled grouper *Myycteroperca rubra*, and golden grouper *Epinephulus costae*), all called "groupers" in this report, and the Sparidae family (such as the white seabream, zebra seabream, and saddled seabream).

Within commercial species, a further distinction was made between all species and Siganus (rabbitfish) species – *Signaus Rivulatis* and *Siganus Luridus* - which are of low-to-medium commercial value. These latter species are invasive species that have been very successful in the Israeli Mediterranean and, as herbivores that feed on algae and plant matter, they have caused a significant change in rocky substrate habitats. Since the habitat that characterizes rabbitfish is that of the rocky shallows, surveys such as BioBlitz offer a good opportunity to examine their relative status in the fish community.

Non-commercial species are not considered edible due to their taste, toxicity and, sometimes, because of body size, and therefore are not a target for fishing. These include, for example, species from the family of wrasses (the ornate wrasse, East Atlantic peacock wrasse, five spotted wrasse, etc.). The complete list of species, divided according to commercial and non-commercial species, is provided in Table A3 in Appendix 3.

Appendix 3 - Detailed results

Table 3A. The names of fish species found in the surveys, divided according to commercial species (for food purposes) and non-commercial species

Latin name	Commercial / non commercial	Common name
Oblada melanura	*Commercial*	*Saddled seabream*
Sciaena umbra	*Commercial*	*Brown meagre*
Upeneus pori	*Commercial*	
Serranus hepatus	*Non-commercial*	*Brown comber*
Serranus scriba	*Non-commercial*	*Painted comber*
Serranus cabrilla	*Non-commercial*	*Comber*
Sphyraena chrysotaenia	*Commercial*	*Yellowstripe barracuda*
Apogon imberbis	*Non-commercial*	*Mediterranean cardinalfish*
Apogonichthyoides pharaonis	*Non-commercial*	*Pharaoh cardinalfish*
Parupeneus forsskali	*Commercial*	*Red Sea goatfish*
Sargocentron rubrum	*Non-commercial*	*Redcoat*
Boops boops	*Commercial*	*Bogue*
Pomadasys incisus	*Commercial*	*Bastard grunt*
Pempheris rhomboidea	*Non-commercial*	
Abudefduf saxatilis	*Non-commercial*	*Sergeant major*
Epinephelus costae	*Commercial*	*Golden grouper*
Epinephelus aeneus	*Commercial*	*White grouper*
Epinephelus marginatus	*Commercial*	*Dusky grouper*
Fistularia commersonii	*Non-commercial*	*Smooth flutemouth*
Mycteroperca rubra	*Commercial*	*Mottled grouper*

Pagellus acarne	*Commercial*	*Axillary seabream*
Pterois miles	*Non-commercial*	*Common lionfish*
Stephanolepis diaspros	*Non-commercial*	*Reticulated filefish*
Diplodus puntazzo	*Commercial*	*Sharpsnout seabream*
Torquigener flavimaculosus	*Non-commercial*	*Yellow spotted pufferfish*
Thalassoma pavo	*Non-commercial*	*Ornate wrasse*
Trachurus mediterraneus	*Commercial*	*Mediterranean horse mackerel*
Dasyatis pastinaca	*Non-commercial*	*Common stingray*
Himantura uarnak	*Non-commercial*	*Honeycomb stingray*
Coris julis	*Non-commercial*	*Mediterranean rainbow wrasse*
Trichonatos ovatos	*Commercial*	*Pompano*
Cheilodipterus novemstriatus	*Non-commercial*	*Indian Ocean twospot cardinalfish*
Chromis chromis	Non-commercial	Mediterranean chromis (damselfish)
Pteragogus trispilus	Non-commercial	??
Lagocephalus sceleratus	Non-commercial	Silver-cheeked toadfish
Xyrichtys novacula	Non-commercial	Cleaver wrasse
Mullus surmuletus	Commercial	Striped red mullet
Muraena helena	Non-commercial	Mediterranean moray
Taeniurops grabatus	Non-commercial	Round stingray
Spicara maena	Non-commercial	Blotched picarel
Spicara smaris	Non-commercial	Picarel
Atherinidae	Commercial	Silverside family
Clupeidae	Commercial	Sardine family
Gobiidae	Non-commercial	Goby family
Mugilidae	Commercial	Mullet family

Blenniidae	Non-commercial	Blenny family
Labridae	Non-commercial	Wrasses
Balistes capriscus	Commercial	Grey triggerfish
Siganus luridus	Commercial	Dusky spinefoot (rabbitfish)
Siganus rivulatus	Commercial	Marbled spinefoot (rabbitfish)
Sarpa salpa	Commercial	Salafit yellow-striped
Pagrus auriga	Commercial	Redbanded seabream
Sparus aurata	Commercial	Gilt-head bream
Pagrus coeruleostrictus	Commercial	Blue-spotted seabream
Scomberromorus commerson	Commercial	Narrow-barred Spanish mackerel
Diplodus annularis	Commercial	Annular seabream
Diplodus cervinus	Commercial	Zebra seabream
Diplodus vulgaris	Commercial	Two-banded sea bream
Diplodus sargus	Commercial	White seabream
Sardina pilchardus	Commercial	European pilchard
Herklotsichthys punctatus	Commercial	Spotted herring
Cryptocentrus caeruleopunctatus	Non-commercial	Harlequin prawn-goby
Seriola dumerili	Commercial	Greater amberjack
Scorpaena maderensis	Non-commercial	Madeira rockfish
Scorpaena porcus	Non-commercial	Black scorpionfish
Caranx crysos	Commercial	Blue runner
Pseudocaranx dentex	Commercial	White trevally
Gobius bucchichi	Non-commercial	Bucchich's goby
Parablennius gattorugine	Non-commercial	Tompot blenny
Parablennius incognitus	Non-commercial	Mystery blenny

Parablennius zvonimiri	Non-commercial	Zvonimir's blenny
Parablennius rouxi	Non-commercial	Longstriped blenny
Dentex dentex	Commercial	Common dentex
Belone belone	Commercial	Garfish
Lithognathus mormyrus	Commercial	Striped seabream
Plotosus lineatus	Non-commercial	Striped eel catfish
Symphodus roissali	Non-commercial	Five spotted wrasse
Symphodus tinca	Non-commercial	East Atlantic peacock wrasse
Symphodus mediterraneus	Non-commercial	Axillary wrasse
Sparisoma cretense	Commercial	Mediterranean parrotfish
Scarus ghobban	Non-commercial	Blue-barred parrotfish
Tripterygion delaisi	Non-commercial	Black-faced blenny
Tripterygion melanurus	Non-commercial	Threefin blenny
Tripterygion tripteronotum	Non-commercial	Red-black triplefin
Pagrus pagrus	Commercial	Common seabream
Parablennius pilicornis	Non-commercial	-
Symphodus cinereus	Non-commercial	-

Overall average biomass

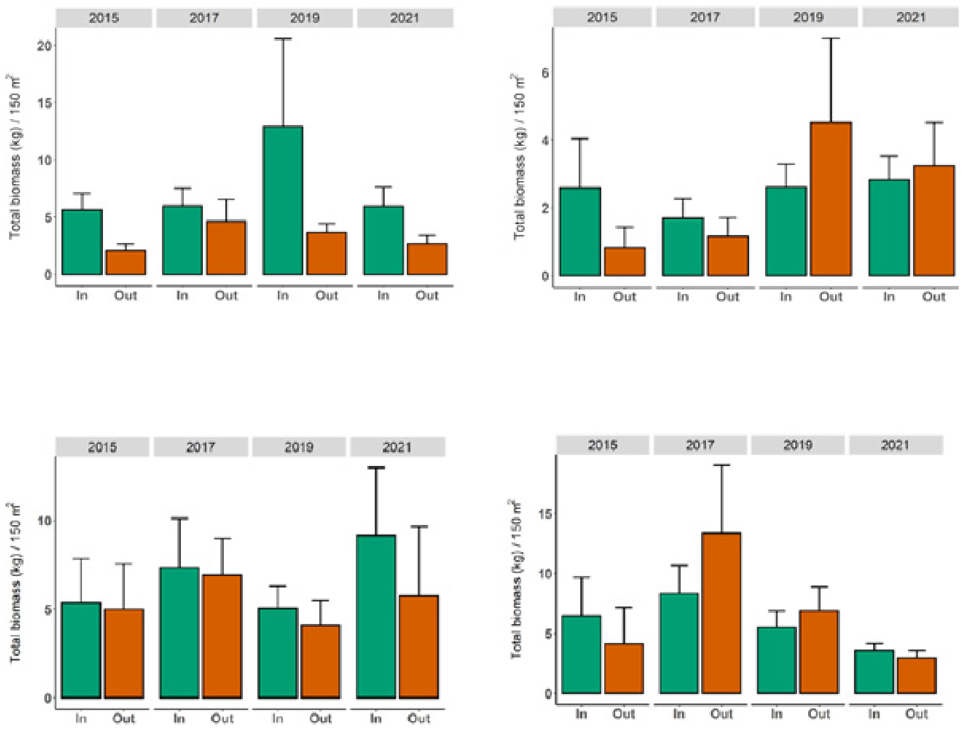

Figure 1A. Overall average biomass inside and outside the reserves, over the years. The Y-axis shows the average biomass values per transect (150 m^2) of all the fish species found. The X-axis indicates whether the survey was conducted inside the reserve (green) or outside it (orange). Upper left panel-Rosh Hanikra-Achziv; upper right panel-Shikmona; lower left panel-Dor-Habonim; lower right panel-Gdor. A 95% confidence interval is shown above the columns for each survey year.

Average biomass of commercial species

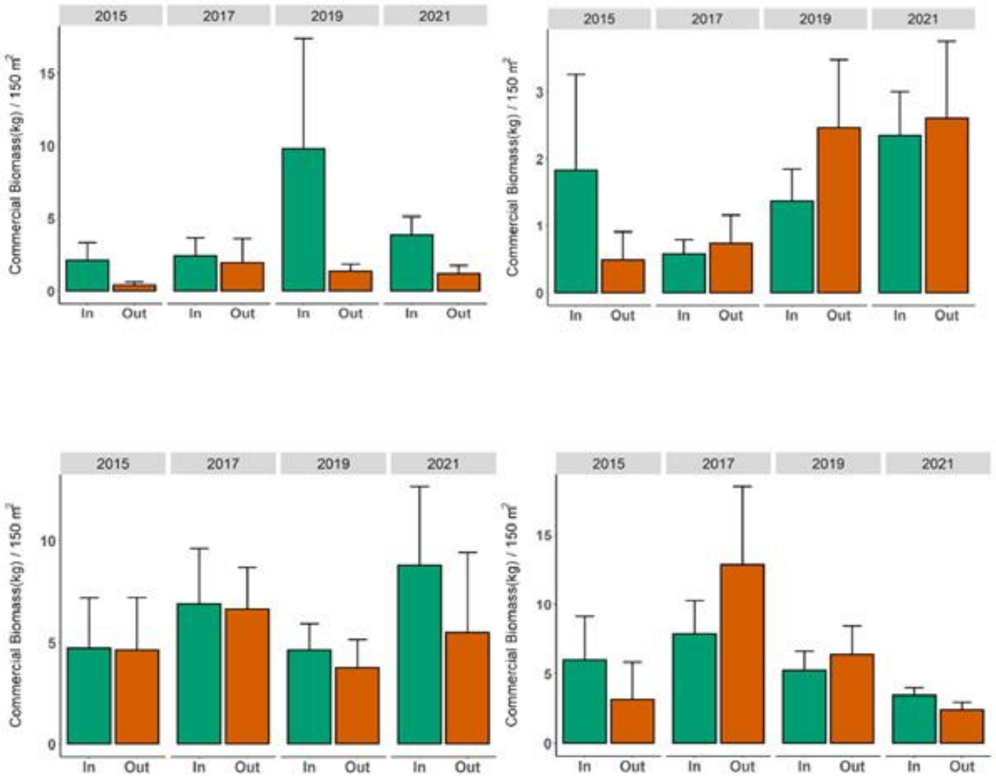

Figure 2A. Average biomass of commercial species inside and outside the reserves, over the years. The Y-axis shows the average biomass values per transect (150 m^2) of all the fish species found. The X-axis indicates whether the survey was conducted inside the reserve (green) or outside it (orange). Upper left panel-Rosh Hanikra-Achziv; upper right panel-Shikmona; lower left panel-Dor-Habonim; lower right panel-Gdor.A 95% confidence interval is shown above the columns for each survey year.

Average abundance of commercial species

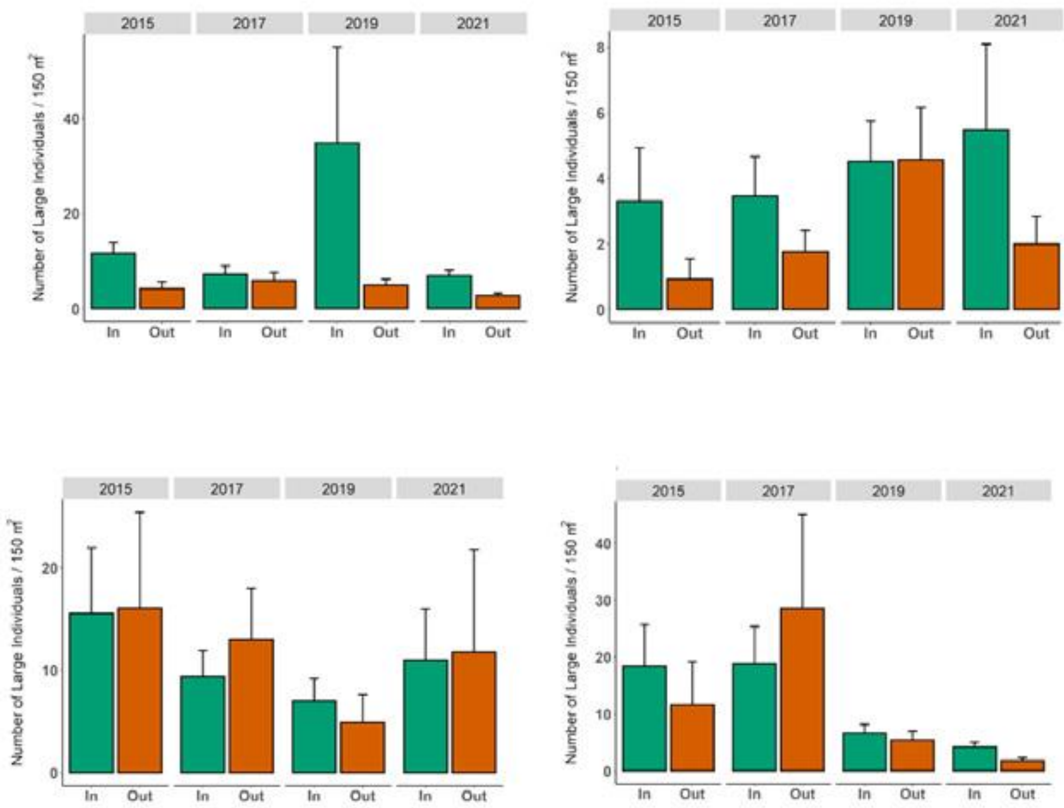

Figure 3A. Average abundance of commercial species inside and outside the reserves, over the years, divided according to all species and species from the rabbitfish family (shown in gray). The Y-axis shows the average abundance values per transect (150 m^2) of commercial fish species. The X-axis indicates whether the survey was conducted inside the reserve (green) or outside it (orange). Upper left panel-Rosh Hanikra-Achziv; upper right panel-Shikmona; lower left panel-Dor-Habonim; lower right panel-Gdor.A 95% confidence interval is shown above the columns for each survey year.

Distribution of mottled grouper lengths

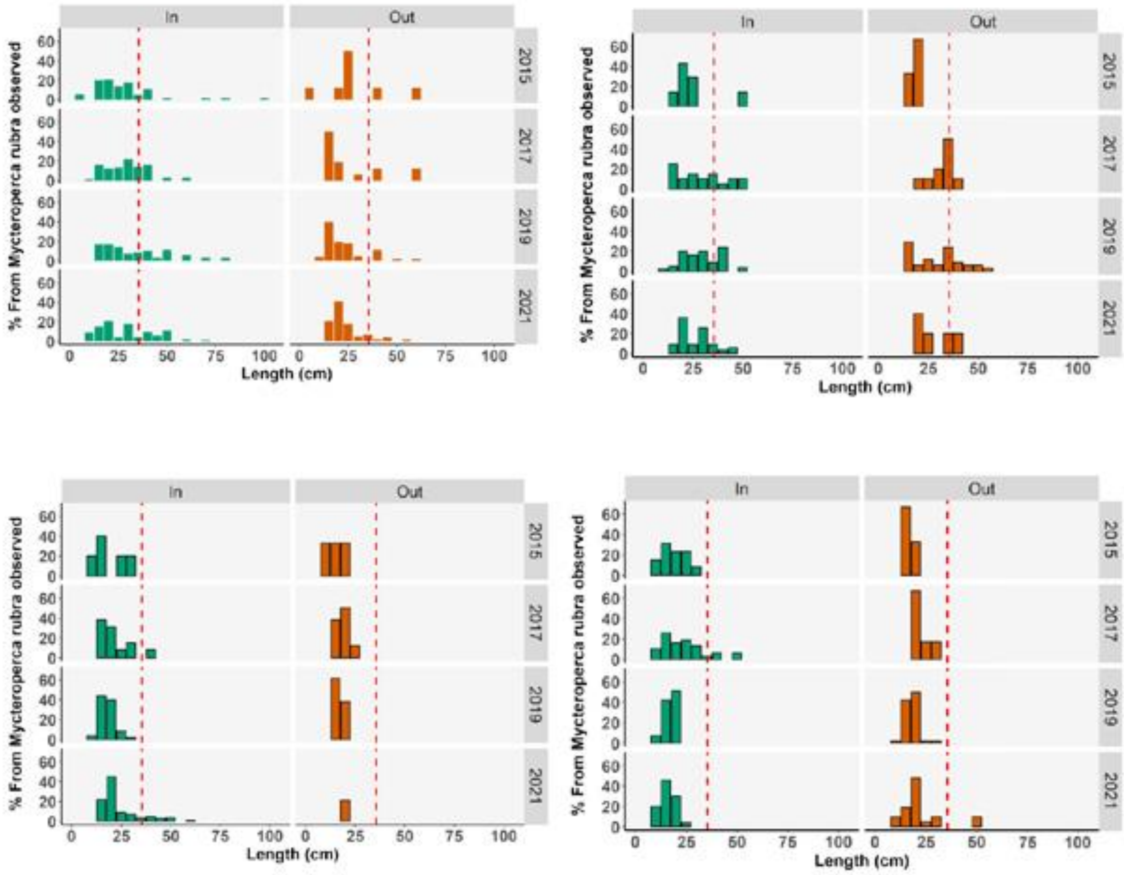

Figure 4A. The distribution of lengths of mottled groupers (*Mycteroperca rubra*) inside and outside the reserves, over the years. The Y-axis shows the number of found individuals and the X-axis the length of the individuals in bins of 5 cm. The dotted red line indicates the breeding size of the species (Aronov & Goren, 2008). Upper left panel-Rosh Hanikra-Achziv; upper right panel-Shikmona; lower left panel-Dor-Habonim; lower right panel-Gdor.Ber

Distribution of dusky grouper lengths

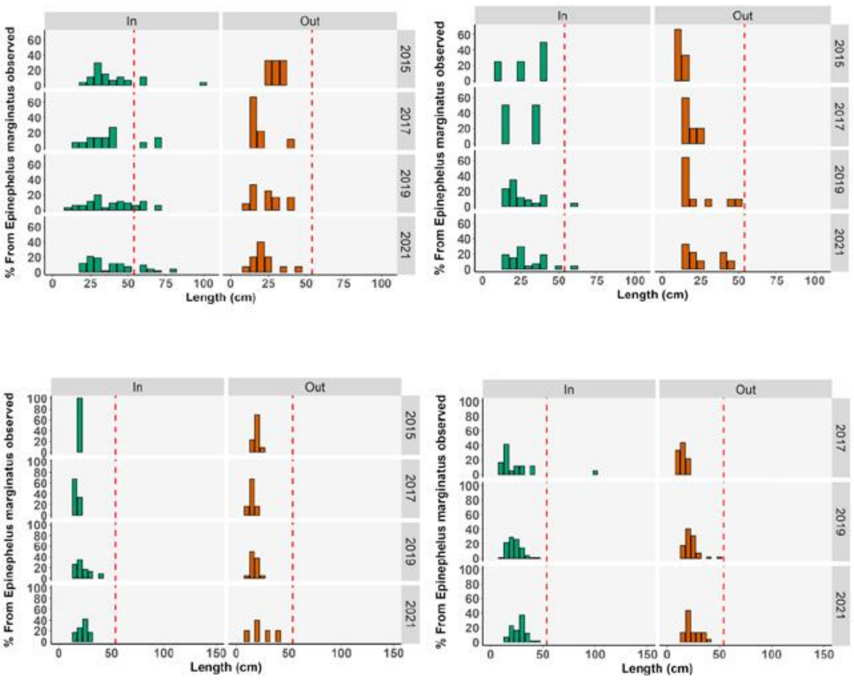

Figure 5A. Longitudinal distribution of dusky groupers (*Epinephelus marginatus)* inside and outside the reserves, over the years. The Y-axis shows the number of found individuals and the X-axis the length of the individuals in bins of 5 cm. Upper left panel-Rosh Hanikra-Achziv; upper right panel-Shikmona; lower left panel-Dor-Habonim; lower right panel-Gdor. The dotted red line indicates the breeding size of the species (Tsikliras & Stergiou, 2014).

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For any clarification questions or comments, please contact Dr. Ruthy Yahal, Marine Ecologist, Science Division, Nature and Parks Authority - Ruthy@npa.org.il

Marine Bioblitz

A quantitative Survey of Marine Nature Reserves in the Israeli Mediterranean Sea

Summary report for surveys conducted

in 2015, 2017, 2019, 2021

Chapter 2: Fish Community Structure

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Opening Remarks

Surveys of marine reserves in the Israeli Mediterranean Sea have been carried out since 2015, during two seasons biannually, totaling eight surveys to date. The surveys initially included control sites near the reserves and have since been expanded to include additional sites of interest along the Israeli coastline. This highly comprehensive survey includes fish, invertebrates, and algae.

The main significant result from the report is that marine reserves do indeed offer protection from fishing and influence the composition of fish, invertebrate, and algae communities, or, with some changes, have a real potential to do so. The Rosh Hanikra Marine Reserve, a relatively large reserve where fishing bans have been enforced for many years, has been shown to protect the fish well, as is evident from the biomass of the commercially valuable fish species, especially the dusky grouper, a flagship species in the Eastern Mediterranean. There is an abundance of groupers in the reserve, with a high number of fish that have reached the necessary breeding size. The success of reserves in protecting fish is also evident in other marine reserves, but the differences in the other marine reserves are much less evident, mainly because they are smaller and the edge effect (most of the reserve is "edge)" is significant.

The obvious conclusion is, in my opinion, sharp and clear. The Nature and Parks Authority' master plan for marine reserves, in accordance with the general policies of the Planning Committee, is fundamental to nature conservation in the sea and offers the ideal way to protect nature everywhere, and particularly through the establishment of marine reserves in the Mediterranean Sea.

I would like to thank the very many researchers and students from all the relevant research institutions for their immense efforts invested in consistently carrying out the surveys. I also thank to Eyal Miller, Yigael Ben Ari, and all the marine rangers for their great logistical support and their participation in the survey; Mai Lazarus, Ori Frid Landau1 and Rei Diga for analyzing the data and writing the various chapters of the report; and Ruthy Yahel for contributing to the writing but especially for being the inspiration and driving force of the entire project.

Dr. Yehoshua Shkedy, Chief Scientist, INPA

Summary

Global ecosystems, including those in the marine environment, are subject to many ongoing and increasing human pressures. As a result, the importance of marine protected areas (MPAs) around the world is increasing. The MPAs' main function is to preserve and restore ecosystems through the protection of habitats and of the flora and fauna that inhabit them. The current report examines the effect of four MPAs in the Israeli Mediterranean Sea on the fish communities that characterize the rocky habitat. Visual fish surveys were carried out at four sites: the Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor reserves, and the control sites adjacent to them. Each surveyed site comprised the reserve itself and its control site. The surveys were carried out in 2015, 2017, 2019, and 2021.

Many changes are occurring along the coasts of the Israeli Mediterranean, including on the one hand pressures such as the warming of the seawater and the arrival and establishment of many invasive species, and on the other hand an increasing awareness of environmental issues, updated fishing regulations (aimed at promoting sustainable fishing), better supervision and enforcement of the regulations, and action against illegal fishing. It is thus necessary to determine how the fish communities are being impacted by these changes, and to act to protect them accordingly.

The results indicate differences in the structure of the fish communities between the various sites, and especially between the northern sites of Shikmona and Rosh Hanikra-Achziv and the southern sites of Dor-Habonim and Gdor. The highest richness and diversity of species were observed at Rosh Hanikra-Achziv, and it seems that a major factor in these differences lies in the wide range of depths at this site compared to the other sites, which are shallower. Even between the different depths at the Rosh Hanikra-Achziv site, clear differences in the structure of the fish community are visible. The shallow zone is characterized, for example, by the Sparidae family (Porgies), while the deep zone is characterized by grouper species, such as the golden grouper, and by the painted comber of the subfamily Serraninae. Differences in the structure of the fish community, the richness and diversity of species, and in the general biomass were also

observed between the two survey seasons, spring and fall, mainly at the Shikmona, Dor-Habonim, and Gdor sites. Biomass, richness, and species diversity were all found to be higher in the fall at these sites.

The structure of the fish communities differs between the reserves and the adjacent control sites. Accordingly, there are certain species that characterize the reserves (their biomass is higher inside the reserves). In addition, a higher species richness was observed inside the reserves consistently throughout the years of the survey, except at the Rosh Hanikra-Achziv reserve. However, it seems that even here the depth had a great effect: in some years for the shallow and medium depths, where species richness and diversity were higher outside the reserve compared to the reserve itself, while at the deeper depth they were consistently higher inside the reserve throughout all the years of the survey. Other measures indicate that the Rosh Hanikra-Achziv reserve is functioning well: e.g., the general biomass inside the reserve was consistently higher than that at the control sites throughout all the years of the survey.

Twenty-five percent of the species observed in the surveys are invasive species, accounting for a total of 44% of the general abundance and 47% of the general biomass. Of the invasive species, the invasive Signaus (rabbitfish) species stand out in their high abundance: the marbled spinefoot and the dusky spinefoot, whose populations are already well established along the shores of the Israeli Mediterranean Sea. Throughout the years of the survey changes were observed in the abundance of these species as well as a clear increase in the prevalence of the Red Sea goatfish, an invasive species that was first recorded along the Israeli coast in 2013. Its increased abundance was observed at all the sites, but most noticeably at Rosh Hanikra-Achziv.

The differences in the community structure among the measured parameters – protection status, geographical location along the coast, depths, and seasons – indicate that the fish communities differ among the rocky habitats of the Israeli Mediterranean coastline as characterized by different seasons, sites, and depths. Consequently, in order to conserve them effectively, certain areas must be protected along the entire coastline, at a wide range of depths, and throughout the year. The higher richness observed inside the reserves compared to that of the control sites indicates the capacity of the reserves to protect biological diversity and emphasizes their importance as an effective tool for preserving the marine natural environment.

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1 / Introduction

The world's seas and oceans are in decline due to the increasing impact of human activities and their derivatives, such as fishing, physical destruction of habitats, pollution, global atmospheric changes, and the invasion of alien species (He & Silliman 2004; Islam & Tanaka, 2002; Stachowicz et al., 2010; Hoegh-Guldberg & Bruno, 2010). In addition to the obvious damage to the marine ecosystem and all its components, the services it provides to humans are also impacted – food supply, oxygen and energy sources, regulation of atmospheric processes, etc. (Worm et al., 2006). These services depend on the existence of healthy ecosystems (Palumbi et al., 2009). In order to preserve the natural resources necessary to our existence and at our disposal, we must therefore protect the marine environment.

Among the known tools for protecting the marine environment, protecting representative habitats and large areas offers an effective and important means to preserving and strengthening the natural ecosystem (Edgar et al., 2014). We can divide marine protected areas (MPAs) into two main categories: no-take protected areas and partially protected areas. No-take MPAs are areas with defined borders, in which the entire physical environment, its animals and plants, are protected through laws prohibiting detrimental activities such as fishing, aquaculture, digging, mining and drilling, disposal of pollutants, and more. In contrast, activities such as non-motorized boating, swimming, and diving are allowed in MPAs. Specifically, no-take MPAs make it possible to preserve and restore the habitats of all the components of the food web that dwell in them, as well as to maintain the overall ecological functioning of the area (Lester et al., 2009), and constitute a central tool for the protection and restoration of specific species (Giakoumi et al., 2017).

The scientific literature published in the last decade (Guidetti et al., 2017; Giakoumi et al., 2014; Edgar et al., 2014) clearly indicates the benefits that no-take MPAs have for healthy ecological functioning and achieving the conservation goals, compared to the partially protected marine areas (Giakoumi et. al, 2017). The factors that enable the success of a reserve are those of its status as a no-take reserve, high levels of enforcement, a large reserve area, age of the reserve, and distance from sources of human disturbance (Edgar et al., 2014). The level of enforcement in MPAs has been proven to be a key factor in the efficiency and achievement of the reserves' goals, even in older MPAs with a relatively small area (up to 30 km2; Giakoumi et al., 2017). The success of MPAs in which any exploitation or harming of natural resources is prohibited, compared to areas that are outside the MPA, manifests itself in a significant increase in general biomass, abundance, individual size, and species richness (Lester et al., 2009).

Among the ecological performance indicators accepted in the world for MPAs, there are those that are considered the main markers of success, such as an increase in the general biomass of fish in the reserve and in the abundance of commercial species subject to significant fishing pressures, especially predatory species with high commercial value (Edgar et al., 2014) These species constitute important components in maintaining a complete and stable food web (Villamor & Becerro 2012). The effects of the MPAs surveyed as part of the Bioblitz program on species of commercial value were seen mainly in the Rosh Hanikra-Achziv reserve, the most enforced and oldest reserve in Israel, although the possible beginnings of positive trends were also seen in the other reserves surveyed (Lazaros et al, 2020). In addition, in previous surveys that were carried out in the islets of the Rosh Hanikra-Achziv Reserve and islets outside the reserve, it was found that the abundance of commercially valuable fish species was higher in the shallow habitat inside the reserve (Rilov, 2015; 2018, Rilov et al).

At the same time, it is necessary to understand the effects of marine reserves on the fish community as a whole (a fish community is defined by the composition of its species and their relative abundance in a certain place and at a certain time). Species react to nature reserves in a variety of ways: because MPAs often improve the population status of commercially valuable species, especially predators, prey species are often indirectly affected by the reserve (Micheli et al 2004). In addition, in order to understand how fish communities can be effectively protected, it is necessary to examine how they are affected by the different environmental conditions.

Therefore, we examined the effects of the marine reserves and key environmental conditions (depth, geographic location, and season) on the fish communities using several indicators: structure of the fish community, indicator species, richness and diversity of species, general biomass, and abundance of prominent invasive species. This chapter of the report presents the results of the surveys conducted in 2015, 2017, 2019, and 2021 in four MPAs in the Israeli Mediterranean Sea and at control sites adjacent to them, with a focus on the characteristics of the fish community structure.

1.1 / Marine reserves in Israel

From the mid-1960s to the beginning of the 2000s, seven small marine reserves were established in Israel, encompassing a total area of 10.4 km2, which constitutes about a quarter of Israel's maritime area in the Mediterranean Sea. Most of the reserves extend from the coastline to a few hundred meters westward into the sea. These reserves protect most of the islets off the coast of Israel and the habitats of the tidal zone and the shallow-water environment but do not represent all the habitats in the marine environment. Due to the increase in the scope of economic activity at sea and the intensity of the threats to the marine environment, there has been increased consensus in both environmental organizations and governmental planning institutions that it is necessary to take additional actions to preserve the marine environment in general and the natural assets and marine habitats in particular (Yahel & Angert, 2012; Ministry of Energy, 2016; Director of Planning, 2020; Technion, 2015.)

The master plan for marine reserves was prepared by the Nature and Parks Authority (INPA), by Yahel and Angert, (2012). The plan is based on the protocol of the Barcelona Convention for the Protection of the Mediterranean Sea and the principles that appear on the subject of "Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, 1995." These protocols include the protection of representative parts of all marine habitats (from the most common to the rare and unique); of marine environments that are in danger of disappearing; of environments vital for the survival, reproduction, and restoration of important species in the system; and of sites of special importance from a scientific or other aspect. In addition to the need to protect representative parts of the marine environment, the master plan also relates to the scope of the protected area. The United Nations CBD (Convention on Biological Diversity) defined the conservation targets in the sea to constitute 10% of the total marine area of each country by the year 2020. The Aichi Biodiversity Targets for the scope of the conservation has since been updated and is now set at 30% of the marine area by the year 2030. This goal was also adopted within the framework of the UN's Sustainable Development Goals (SDGs).

A comprehensive policy for the planning of the territorial waters of the Israeli Mediterranean Sea was published in 2020 by the Planning Administration and designated 8.6% of Israel territorial water as target areas for marine reserves (Planning Administration, 2020), in accordance with the master plan and the policy document promoted by the INPA in collaboration with the Society for the Protection of Nature in Israel (SPNI) and other environmental organizations. In 2019, plans for the marine reserve "Yam Rosh Hanikra" were approved, expanding the existing reserve (where the surveys were conducted) to a distance of 15 km from the coastline and an area of 100 km2. In 2021, plans for the "Rosh Carmel" marine reserve were approved, expanding the existing Shikmona reserve to a distance of about 12.5 km from the coastline, over an area of about 50 km2. Today, about 4% of the surface of the Israeli territorial waters are defined as nature reserves. In addition, the Avtach marine reserve between the cities of Ashdod and Ashkelon is in advanced planning stages, with the aim of expanding its protection of the shallow sandy habitat on the Mediterranean Sea seabed, to a distance of about 7 km west of the coastline and a maximum bottom depth of 38 m. In addition, plans are being promoted for offshore nature reserves across from the Sharon and Carmel coastlines, which will protect the mesophotic kurkar ridge and the sponge gardens that have developed on it, at 13-17 km off the coastline and at a depth of 85-135 meters. These reserves and additional reserves, once approved and established, will protect diverse habitats in the extensive areas suitable for marine organisms.

This report examines the function of the established marine reserves featuring rocky substrates in protecting the fish community, focusing on species with commercial value. For this, we used bioindicator species, as accepted for such surveys around the world.

2 / Survey objectives

The surveys conducted in 2015, 2017, 2019, and 2021 were designed to examine whether the currently established MPAs protect the flora and fauna within their borders, and to assess whether they contribute to the stabilization of the ecosystem both inside and outside the reserves.

Four general goals were defined for the surveys:

A. Document the species found inside and outside the MPAs.

B. Describe the spatial patterns of marine flora and fauna down to a depth of about 25 m along the Israeli coastline.

C. Compare the animal and plant communities within Mediterranean Sea MPAs to similar nearby control sites with similar substrates.

D. Create a quantitative baseline of the flora and fauna currently found inside MPAs for future comparisons.

This report focuses on the effect of MPAs on commercially valuable fish species, with the following four specific goals:

A. Estimate the effect of reserves on the abundance of commercial species.

B. Estimate the effect of reserves on the abundance of individual large fish.

C. Examine the effectiveness of MPAs in protecting the fish community, using indicator fish species.

D. Assess whether MPAs contribute to increasing the fish stock outside their borders.

3 / Survey sites

The surveys were conducted at four MPAs along the Israeli Mediterranean coast and at adjacent control sites (see map 1): Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor.

Map 1. The survey sampling sites against the background of the master plan for marine reserves in the Mediterranean Sea. The boundaries of the reserves are marked with a dashed orange line. The sampling points inside and outside the reserves are marked in light blue. From north to south: Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor reserves. Note that the maps of each MPA are on different scales.

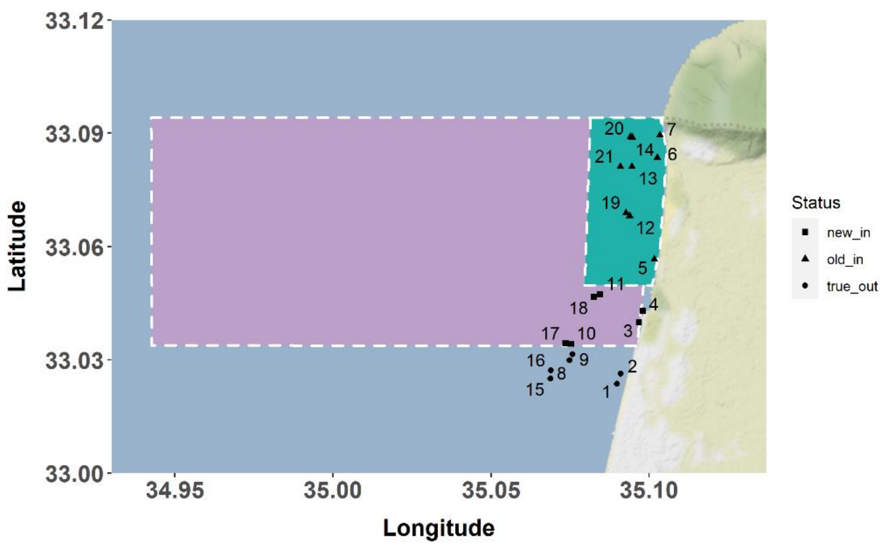
All sampling points, both within the MPAs and at the control sites, were characterized by rocky substrates and no surveys were conducted at sites characterized by sandy substrates. The sampling points at the control sites were ten meters to a few kilometers from the MPA borders, depending on the physical habitat characteristics.

Sampling in each reserve and its control sites was conducted at rocky points with similar substrate complexity, similar distance from the shore, and similar depths. However, there was variation between MPAs in size, maximum bottom depth, distance from the shore, and habitat characteristics. The regulations that determine the permitted and prohibited activities (including fishing activities) also vary from reserve to reserve. Similarly, the length of time during which each MPA has had active monitoring and enforcement also varies, from long-term enforcement (about three decades) to that of only a few years.

3.1/ Rosh Hanikra-Achziv

The surveys were conducted in the "Rosh Hankira-Achziv Reserve" as defined by its 2005 borders, prior to the 2019 expansion. The smaller, original, reserve extends from the Israel-Lebanon border to the ruins of the Port of Achziv, from the coastline out to 2 km west, and including a strip of indented beach about 5 km long. This reserve was, even before its expansion, the largest and most diverse in Israel in terms of habitats and natural assets. The reserve includes abrasion platforms, sandy beaches, caves and burrows in the coastal rocks, an underwater kurkar (limestone) ridge, rocky islands, and an underwater "canyon" (which is actually a steep limestone wall whose bottom reaches the sandy substrate.) The maximum depth of the reserve is 45 m.

In 2019, the Rosh Hanikra Reserve was expanded. The reserve in its new form includes the original reserve, where the surveys were carried out, with a coastline extended 1.8 km southwards towards the northern part of Nahariya, and out to 15 km west of the shore. The total area of the new reserve is 10-fold larger than the area of the original reserve and now covers 100 km^2.



Map 2. The sampling points in Rosh Hanikra-Achziv Reserve and the adjacent control site. The sampling points are marked in black. The MPA area up until 2019 in shown in green and the expanded area in purple. The shape of the sampling points represents the current official protection status as of the expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the area considered “protected” for the surveys is only the green area.

In view of the short period of time from the expansion of the reserve until the 2021 surveys – and the fact that the fishing ban and other protections measures are still not being enforced in the new territory, the area defined as “inside the reserve” has been defined by the same criteria as in the previous surveys.

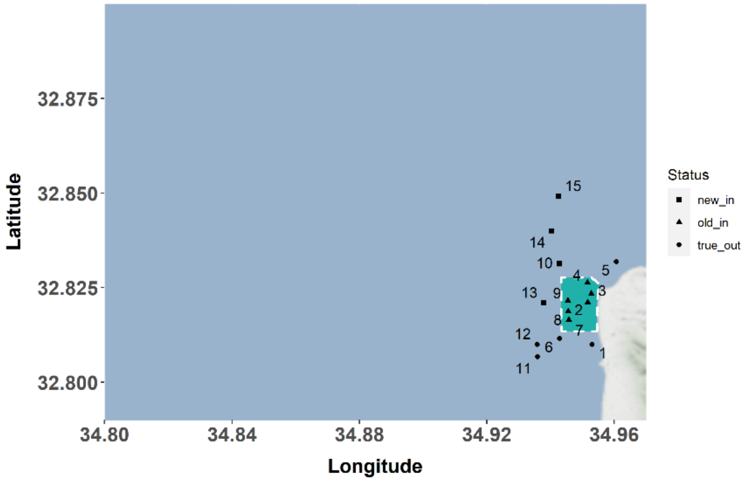
Fishing and enforcement activities in the reserve: The Rosh Hanikra-Achziv reserve is the only reserve which has long-standing monitoring and protection of its natural assets by designated marine rangers. Monitoring inside the MPA began in the 1990s. Up until 2006, the fishing ban was enforced from the shore out to 1 km west, but since 2006 this area has been expanded to include the entire area of the reserve (up to 2 km west of the shore). The only type of fishing ban not enforced inside the reserve over the years was rod fishing from shore, which also started to be enforced in April 2017, with the exclusion of the most southern part of the reserve.

3.2 /Shikmona

This MPA is located off the southern coast of the city of Haifa, from the Israel Oceanographic and Limnological Research institute in the north, to the estuary of the Lotem River (next to the "Maxim" restaurant on the beach) in the south. The MPA extends from the shore 1 km westward. There are abrasion platforms along the shoreline of the Shikmona reserve and. the substrate comprises intermittent rocky and sandy areas. The maximum bottom depth of the reserve is 15 meters.

In 2020, the Shikmona reserve was expanded into the Rosh Carmel Reserve, enlarging the borders to the north and west and increasing the total reserve area to approximately 50 km^2. The maximum depth of the reserve today is 300 m. In view of the short period of time from the expansion to the 2021 survey – and the fact that the fishing ban is still not enforced in the new reserve, the area defined as “inside the reserve” is defined by the same criteria as in the previous surveys.

Fishing activity and enforcement in the reserve: At the time of the first survey in 2015, there was still no enforcement of the fishing ban in the reserve. In 2016, dedicated marine rangers began work in the reserve, and the monitoring and enforcement of the sports fishing ban was increased (with the exception of rod fishing from the shore).

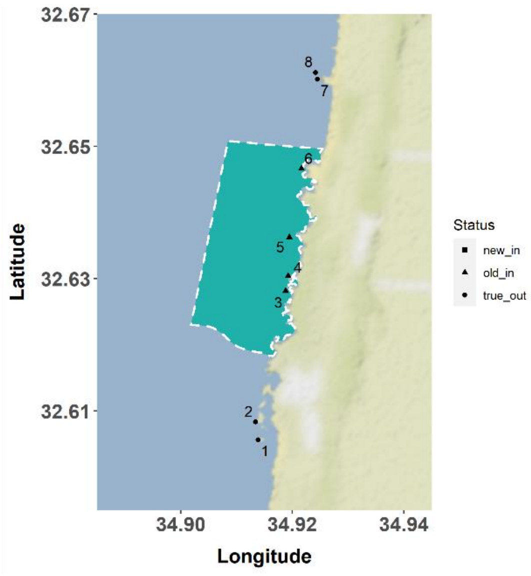


Map 3. The sampling points in the Shikmona Reserve and the adjacent control area. The sampling points are marked in black. The area of the reserve until 2020 is shown in green and the area after the expansion is shown in purple. The shape of the sampling points represents the official protection status as of the MPA expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the area considered "protected" at the time of the surveys is limited to the green area.

3.3 / Dor Habonim

The reserve extends along a 3.5 km coastline between the settlements of Nachsholim and HaBonim and out to 2 km from the shore. The coastline is winding, rugged and rich in unique alcoves, along which stretch well-developed abrasion platforms. The habitat of the rocky substrate in the reserve extends from the abrasion platforms to a maximum depth of 6 m, and further west is a soft substrate (sand and silt) habitat of down to a maximum depth of 21 m.

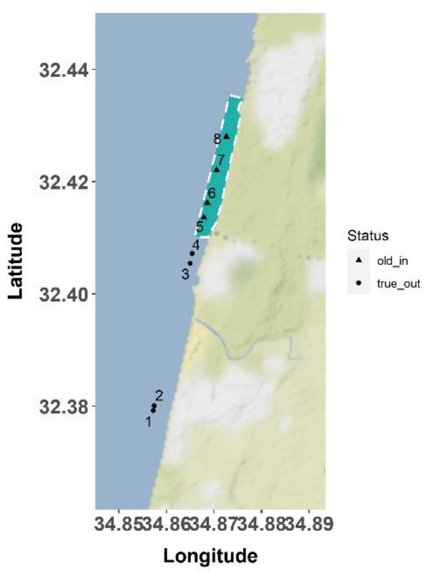
<u>Fishing activity and enforcement in the reserve</u>: at the time of the first survey in 2015, there was still no dedicated marine monitoring inside the reserve and enforcement was carried out by the coastal team. In 2016, dedicated marine rangers began working in the reserve, and supervision and enforcement of the sport fishing ban was increased (with the exception of rod fishing from the shore.) However, there is a group of commercial fishers from the nearby village of Fureidis whose activity predates the reserve, and they were given personal commercial fishing permits inside the reserve during its establishment. Therefore, in practice, this reserve does not function as a no-take reserve.



Map 4. The sampling points in the Dor HaBonim Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve is shown in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.)

3.4 / Gdor

This reserve extends from the south of Givat Olga to Michmoret along a 2.8 km long coastline and out to a distance of 300 meters west of the shore. The disintegration of the limestone cliffs in this coastal strip has created many marine habitats along the shoreline: abrasion platforms and coastal rocks, shallow lagoons, and sandy bays. The maximum depth of the reserve is 5 m.



Map 4. The sampling points in the Gdor Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve appears in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.) In addition to this area, the areas defined as reserve areas and as control sites outside the reserve have remained the same as the areas defined in the previous surveys conducted.

<u>Fishing and enforcement activities in the reserve:</u> with the commencement of work of the marine unit of the Nature and Parks Authority in May 2018, monitoring and enforcement of the fishing ban inside MPAs have been increased (with the exception of

rod fishing from the shore).

In the years 2015-2017 there was a large gap between the number of transects sampled inside and outside the reserve (Table number, 2A Appendix.) The reason for this was the paucity of suitable control sites with rocky substrates similar to those of the reserve and located close by. In order to reduce the gap between the number of sampling points inside and outside the reserve, as of 2019 we reduced the number of sampling points within the reserve.

In the Israeli Mediterranean Sea there are two additional MPAs without rocky substrates and therefore no visual surveys were conducted there: the Avtach Marine Reserve and the Shikma Sea Reserve, as well as the Dor Islets of the Maagan Michael Reserve which do not include marine areas and therefore were not surveyed.

4 / Summary of methods

The surveys were conducted in the years 2015, 2017, 2019, and 2021 – during two seasons each year: spring and fall. Comparisons between the MPAs and the control sites outside them were conducted, as well as between the different survey years and between the survey sites. Following an initial examination of the data, no clear and consistent differences between the seasons could be found for the examined indicators. Therefore, for each year of the survey, the results present the average of the data collected for both sampling seasons.

The species composition, species diversity, and general abundance were measured. In addition, we measured the abundance of key invasive species – particularly those of the Siganus family, Siganus rivulatus (marbled spinefoot) and Signaus luridus (dusky spinefoot), as well as the Red Sea goatfish (Parupeneus forsskali), compared to the abundance of groupers, apex predators in the Mediterranean marine ecosystem. All values (other than community composition) were measured as the average for each 150 m2 transect.

A detailed description of the working methods can be found in Appendix 2.

5 / Data analysis

5.1 / Fish community structure along the Israeli coast

A fish community constitutes all those fish species that share a specific habitat and interact with each other. The community structure can vary both spatially (with varying habitat characters and depths) and temporally (according to the seasons or over time). Migratory species, i.e. species that are transient and have a wide habitat range, become part of a given community only temporarily, while local species, which have a more specific spatial distribution, comprise part of the community throughout the year.

The fish community at a given site can change drastically as a result of exploitation by overfishing, as this systematically reduces the abundance of targeted species. In the Mediterranean Sea, and particularly in its eastern basin, the establishment of invasive species of Indo-Pacific origin (Lessepsian migrants through the Suez Canal) is considered another main modifier of the local fish community (Galil, 2007; Edelist et al., 2013, Goren et al., 2016). In order to examine the variation in fish communities between MPAs and their adjacent control sites, as well as between the different MPA sites along the Israeli coast, at the different depths and during the different seasons, an analysis was conducted to study the species' composition and their relative abundance.

Community structures were assessed using multivariate analyses, which consider multiple species combined. One example of such analysis is that of non-metric multidimensional scaling (nMDS). This is a non-parametric analysis used for visualization of the variations among different samples (here, transects) (Kruskal, 1964). It is based on the Bray-Curtis dissimilarity index (Faith el al., 1987), which distinguishes transects from one another in terms of species composition and their abundance. The distinction between transects is represented by distance, and the nMDS analysis uses the Bray-Curtis dissimilarity index to visually present the dispersion of data in theoretical (non-metric) space. This analysis enables a visual demonstration of which transects are more similar to one another, based on the underlying fish communities that comprise them. Transects that differ more from one another will be located further away from each other in theoretical space.

To understand the extent of differences between communities, and how well such differences are represented in the visualization, a “stress value” is calculated. A lower stress value means the visual representation better describes the real differences. Stress values between 0.05-0.1 show excellent representation; values between 0.1-0.2 show very good representation; values between 0.2-0.3 show good representation; and values higher than 0.3 show poor representation (for the present analysis the data were log-transformed for more even distribution).

5.2. / Biodiversity

Biodiversity reflects the number of species per given area and their relative abundance. It can be calculated using several indices that differ one from the other by the weight of rare species in the community. The biodiversity Renyi profile (Renyi Jost, 2006) used for the present analysis considers several community metrics. The difference between the indices is obtained by changing the α component of the following equation:

$$H_{\alpha} = \frac{(log \sum_{i=l}^{s} P_i^{\alpha})}{(1-\alpha)}$$

For detailed information on the above equation see Tothmeresz, 1995.

When α=0 the value of H will be the species richness, meaning the number of species in a given area, with all species contributing evenly to the community diversity, regardless of the number of individuals of the same species. As the α value grows, the contribution of rare species to the diversity index diminishes. For instance, a value of α=1 represents Shannon diversity (Shannon & Weaver, 1949). The maximum value of α (infinity) represents the diversity of only the main species in the community. One site can be said to be more diverse than another only when the biodiversity values (H) remain high for each α value (Tothmeresz, 1995).

Here we present two indices for biodiversity:

Species richness (number of species), in which common species have the same contribution as rare species.

Shannon diversity, where common species have a higher contribution than rare species.

We note that cases in which the trend of the above-noted indices did not match other indices are not presented here. If the results of other indices were similar to those of the indices provided here, no notes have been added.

The effects of fishing pressure (inside and outside of MPAs), sampling sites, and seasons on biodiversity were examined using ANOVA (Analyses of Variance) and post-hoc tests (Tukey's Honest Significance Test).

Biodiversity was also calculated for each of the sampling sites, inside and outside the MPA, for each sampling season and depth category. Biodiversity is very sensitive to sampling effort intensity – sites with higher sampling effort tend to reveal higher biodiversity. Rarefaction offers a data analysis method that allows the examination of species richness at a given site, while avoiding possible bias caused by sampling effort (Gotelli & Colwell, 2001). In practice, this method samples transects randomly to create an accumulated species richness curve. Sites can thereby be compared across the same number of samples (transects), preventing the richness from being biased by the sampling effort.

5.3 / Representative species

To determine which species are representative of the different depths and seasons, and which characterize the marine reserves and the control sites, we used the log transformation of the ratio of each species' mean biomass between two categories, using the SingleCaseES R package (Swan & Pustejovsky, 2018). Confidence in the significance of the results is considered high when the error bars do not cross the 0 mark. The effect size corresponds to the absolute values of the ratio; a higher absolute value of the ratio indicates a higher effect size.

To assess which species characterized the different sampled sites, we calculated the percentage of transects in which each species was present out of the total number of transects surveyed at each site.

5.4 / Biomass

The total fish biomass and the biomass of each species were calculated based on fish length as estimated by the surveyors. Since the ratio between length and weight is constant for individuals of the same species, it is possible to convert the length of an individual to its weight using the following formula:

$$w = aL^b$$

where W represents the fish weight, L represents the fish length, and the parameters a and b are constant and species-specific. In this survey we used the a and b constant values from the FishBase database (Froese & Pauly).

Cryptic species (e.g. blennies) were not included in this analysis as they are difficult to detect and their abundance is therefore prone to underestimation. The recorded abundance of cryptic species is however presented in Table 4A, Appendix 2.

6 / Results

6.1 / Fish community differences inside and outside the MPAs

MPAs are generally protected from various human activities, such as fishing, infrastructure establishment, wastewater discharge, and motorized vessels. There are two exceptions in our surveyed MPAs: Dor-Habonim, where some commercial fishing activity is allowed (see Introduction, Section 3.3), and Rosh Hanikra-Achziv, where motorized boats are allowed for tourism and for national security requirements. To examine the impact of protection on fish communities, we compared the community structure and biodiversity inside and outside the MPAs. Since survey depths varied, depending on the maximum depth included at an MPA, analyses in this chapter present data from shallow depths only, which could be sampled at all the MPAs.

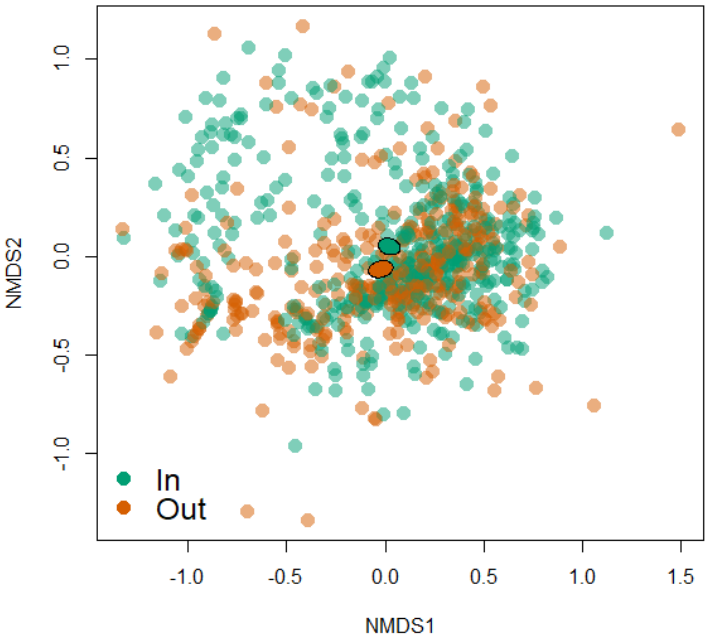


Figure 1.1 nMDS ordination presenting the distances between fish communities inside and outside the MPAs at shallow depths only, at each site, from all surveys, and for both sampling seasons. Distances were calculated using the Bray-Curtis dissimilarity index. Each point in space represents a transect and is graphed according to the log-transformed abundance value of each species. The colors indicate whether the transect was located inside (green, n = 434) or outside (brown, n = 356) an MPA. Ellipses, color-coded in the same way, represent the separation between fish communities inside and outside the MPAs. Stress = 0.2

There was a strong and significant difference (Table 5A, Appendix 3) in the fish community structure between MPAs and their corresponding control sides outside of the protected areas. This pattern was also found for each MPA separately (Fig. 9A, Appendix 3). Protection status, however, only explains a small part of this variance in community structure (Table 5A, Appendix 3).

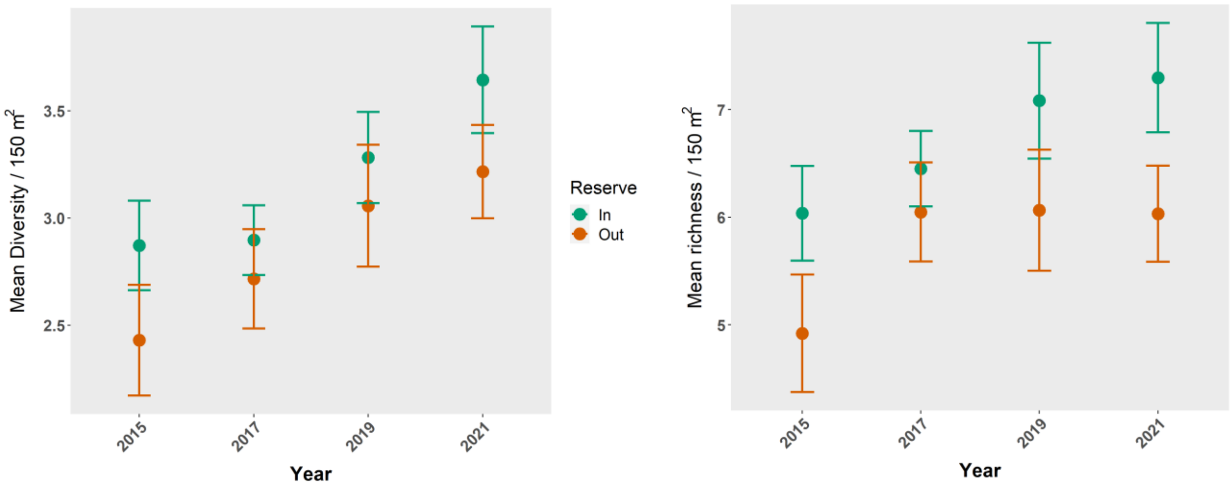


Figure 1.2 Mean species richness (A) and biodiversity (B) per transect inside and outside the MPAs during each surveyed year, at shallow depths, at all sites. The x-axis shows the survey year, and the y-axis shows the mean value. The colors indicate whether the transect was located inside (green) or outside (brown) an MPA (see Table 2A, Appendix 2 for sampling sizes). The error bars show 95% confidence intervals.

Mean species richness and biodiversity per transect were higher inside the MPAs compared to the control sites throughout all the surveyed years. Note, however, the overlap on the error bars between MPAs and control sites in some years for species richness and across all years for biodiversity. This overlap may indicate that the differences in species diversity between samples inside or outside MPAs are not statistically significant. Furthermore, species richness increased inside the MPAs over the years. Biodiversity similarly increased both inside and outside the MPAs (these results are supported by a statistical model, Tables 6A and 7A, Appendix 3).

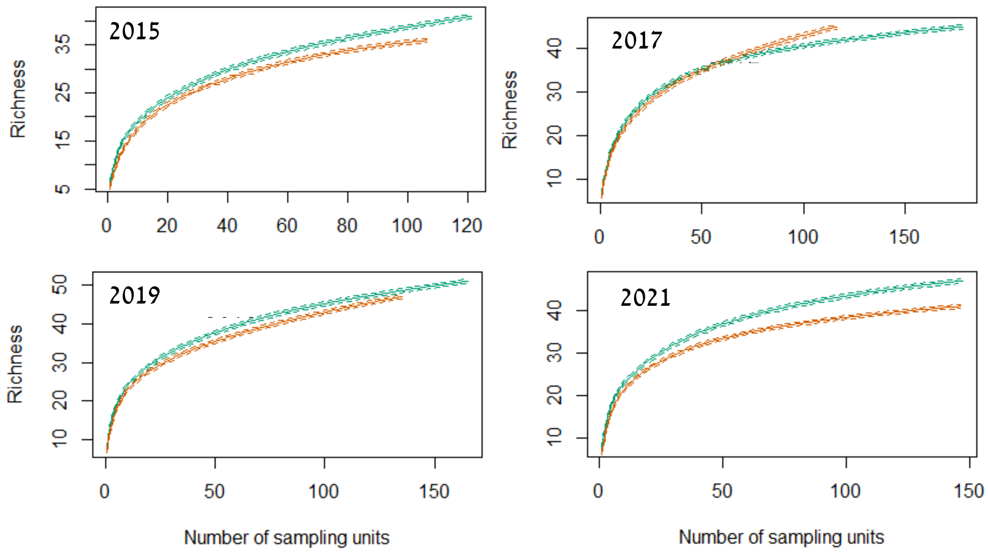


Figure 1.3 Total species richness inside and outside the MPAs for each sampling year (2015, 2017, 2019, 2021) in the shallow transects only, and at all sites. The x-axis shows the number of transects (sampling effort) and the y-axis shows the number of species. The colors indicate whether the transect was located inside (green) or outside (brown) an MPA. The reference point for comparison between sites is the shortest maximum point of any of the curves in each panel (marked by a dashed vertical line). The dashed lines along the curve show standard errors.

The total species richness and biodiversity were higher inside the MPAs than outside them, except in 2017. The overlap between inside and outside MPAs when examining the mean species richness per transect, despite the distinction in the overall mean species richness, indicates that the species composition varies between different transects, and the species pool is higher inside than outside MPAs.

Some species consistently characterized MPAs (meaning their biomass was typically higher inside MPAs than outside them), such as the mottled grouper, a species of very high ecological and commercial value (see BioBlitz Chapter A: Fishing and Nature Reserves). Moreover, some species characterized specific MPAs, such as the Mediterranean parrotfish and the common stingray at the Rosh Hanikra-Achziv reserve (Fig. 14A, Appendix 3).

There was a difference in fish community structure between MPAs and control sites. Both species richness and biodiversity were consistently higher inside the MPAs and these have increased over the years.

6.2 / Variation in fish communities among survey sites

Four sites were sampled during the surveys: Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor. Each site included areas inside the MPA and adjacent control sites outside it. The sampling sites differed from one another in a number of ways: geographic location, depth range, topographic complexity, substrate type, etc. In this chapter we focus on the variations in community structure, biodiversity, and representative species between the different sites.

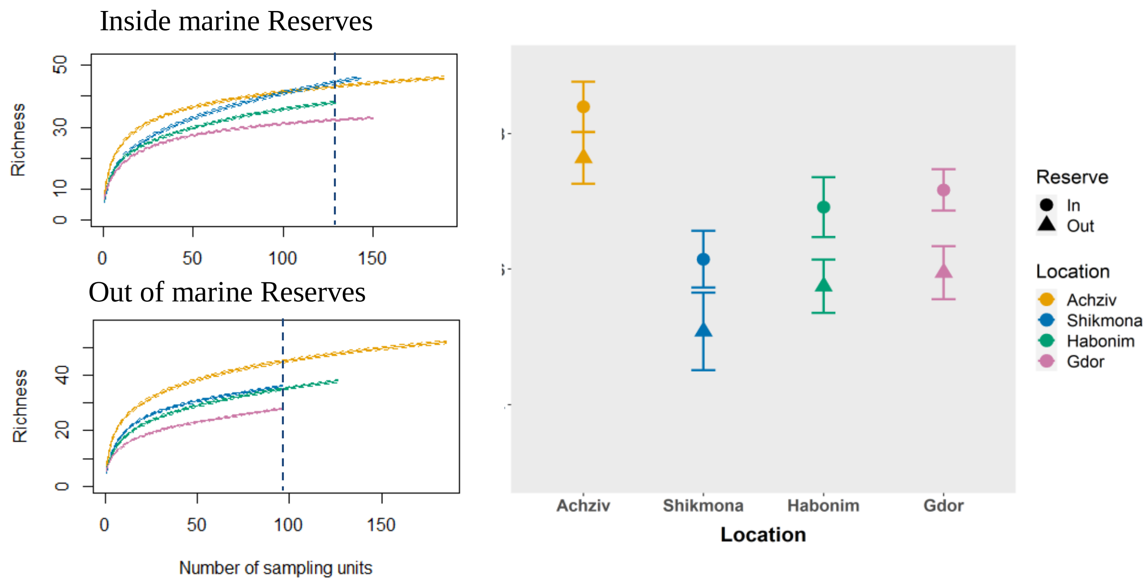


Figure 2.1 Species richness (number of species) at the different sites for all surveys, all depths, and the two sampling seasons. Colors correspond to sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink). Mean species richness per transect, left panel: the x-axis shows the sampling site, and the y-axis shows mean species richness per transect. Shapes indicate whether the transect was located inside (circle) or outside (triangle) an MPA. The error bars show 95% confidence interval. Species richness per site, right panel: inside (top) and outside (bottom) MPAs. The x-axis shows the number of transects (sampling effort) and the y-axis shows the number of species. The reference point for comparison between sites is the shortest maximum point of any of the curves in each panel (marked by a dashed vertical line). The dashed lines along the curve show standard errors.

Species richness (number of species) per transect in an area of 150 m2 was found to be between a minimum of 5 species per transect and a maximum of 8 species (the values in the figure are not whole numbers because they give the mean value). At all four sampling sites the species richness observed inside the MPAs was higher than outside them.

Species richness varied between sites: at Rosh Hanikra-Achziv the mean species richness per transect was the highest, both inside and outside the MPA. This pattern was found across all depth categories (shallow, medium, and deep) as well as when assessing the shallow depths only (Fig. 1A, Appendix 3). Shikmona presented the lowest values of mean species richness per transect among all the MPAs. However, the highest mean species richness per transect, per site, within an MPA was observed at Shikmona (also when accounting for shallow depths only, see Fig. 1A, Appendix 3). Thus, although the mean species richness per transect in Shikmona was the lowest of all sites, the variance in species composition between transects was very high, with different species being observed in different transects. In sum, the overall number of representative fish species in Shikmona was the highest of all the MPAs. The lowest species richness per site (inside and outside MPAs) was observed in Gdor.

Similar patterns were also observed when we examined mean biodiversity per transect: biodiversity in Rosh Hanikra-Achziv was the highest, both inside and outside the MPA (Fig. 2A, Appendix 3). Additionally, the highest biodiversity per site was observed at Rosh Hanikra-Achziv, both inside and outside the MPA, while the lowest biodiversity per site was observed at Gdor, both inside and outside the MPA (Fig. 3A, Appendix 3).

Variance in species richness and in biodiversity between depth categories was found in Rosh Hanikra-Achziv. When species richness was calculated for all depth categories together, the values were higher inside the MPA (Fig. 2.1); whereas when calculating the shallow depth only, species richness was similar both inside and outside the MPA (Fig. 1A, Appendix 3). There were also differences in biodiversity regarding depth categories. Biodiversity was equal, both inside and outside the MPA, for all depths together, while for the shallow depth only, biodiversity was higher inside the MPA (Fig. 2A, Appendix 3).

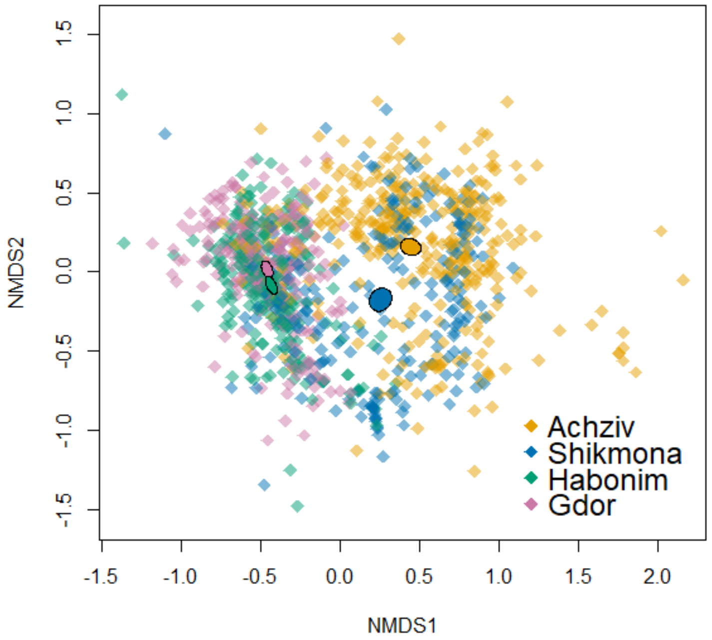


Figure 2.2 Species richness presented in an nMDS ordination, revealing the distances between fish communities across the different sites for all surveys and for the two sampling seasons, both inside and outside the MPAs, for all depth categories. Distances were calculated using the Bray-Curtis dissimilarity index. Each point in space represents a transect and is graphed according to the log-transformed abundance values of each species. The colors correspond to the sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink). Ellipses, color-coded in correspondence to sites, represent the separation between fish communities at the different sites. Stress = 0.17.

The fish species in Gdor and Dor-Habonim were very similar and differed from those in the northern sites, Shikmona and Rosh Hanikra-Achziv. While there was also a difference in community structure between Shikmona and Rosh Hanikra-Achziv, they were more similar to one another than to the southern sites.

A differentiation between the fish communities at the northern sites (Rosh Hanikra-Achziv and Shikmona) and southern sites (Dor-Habonim and Gdor) is also prominent when examining only the shallow depths (Fig. 4A, Appendix 3). Similar results were found when examining each surveyed year separately (both for all depths and for the shallow depth alone), indicating that the distinction between sites had remained consistent across the years. These differences are statistically significant, and for the shallow depths 15% of the variance in community structure is explained by the site location (Table 5A, Appendix 3).

To determine which fish species characterized each site, we examined the percentage of transects in which common species were recorded at each site, out of all the transects at this site. In these analyses we included observations from all depths.

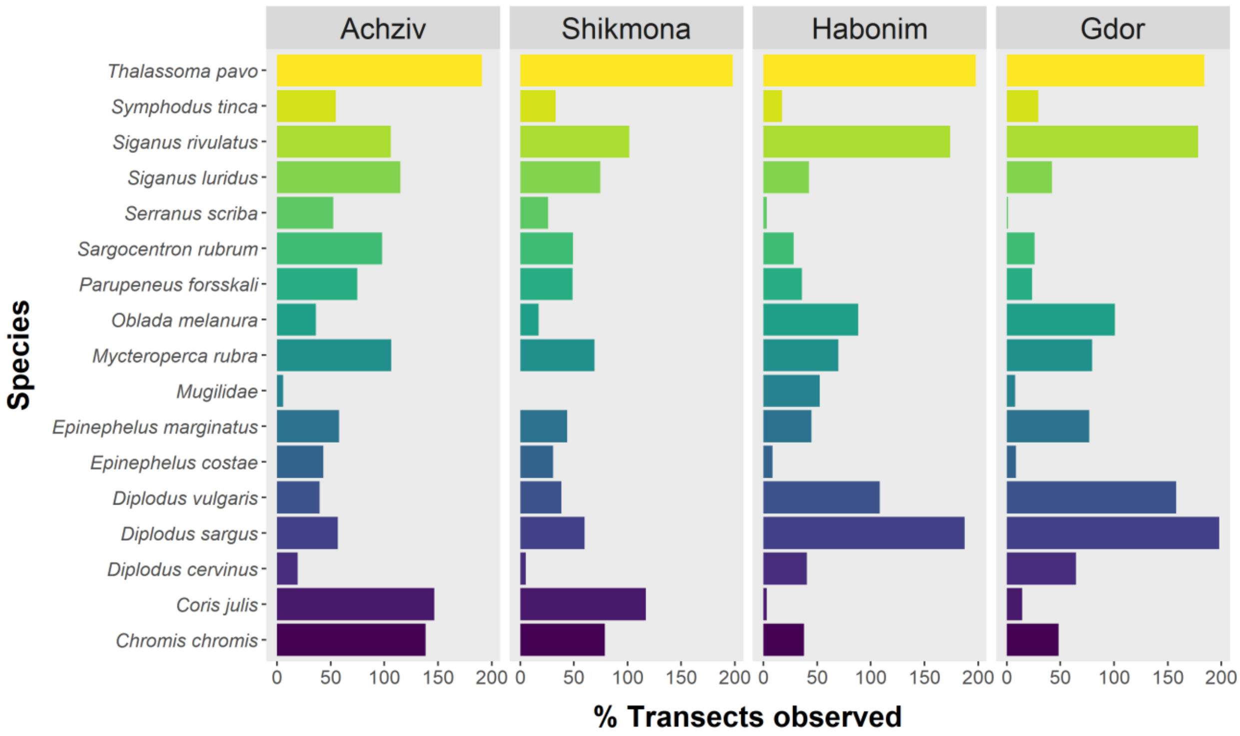


Figure 2.3 Percentage of transects where common species were observed at each site, in all surveys, both inside and outside the MPAs. Common species are defined as the ten most observed species by transect at each site. The percentage of observations of the species per site was calculated as the proportion of the number of transects where the species was observed out of the total number of transects at that site (regardless of the number of observed individuals). The x-axis shows the percentage of transects where the species was observed out of the total number of transects at that site. The y-axis present species' names.

- The ornate wrasse characterized all the surveyed sites.
- The northern sites (Rosh Hanikra-Achziv and Shikmona) were characterized mostly by the dusky spinefoot, redcoat, Mediterranean rainbow wrasse, and Mediterranean chromis.
- Apart from the dusky spinefoot, the other three above-noted species characterized the deep-water surveys at Rosh Hanikra-Achziv, at depths that were not sampled at the other sites (Ch. 6.3, Fig. 3.2). These species may therefore not necessarily characterize the northern sites, but rather the deeper surveyed areas (note that in Shikmona the depth range was wider than at Dor-Habonim and Gdor, and transects were carried out at depths down to 17 m).
- Certain species were observed more in Dor-Habonim and Gdor than in Rosh Hanikra-Achziv and Shikmona, despite the overlap in shallow depths at all sites. It is possible that the geographical location plays an important role in the distribution of these species, which

belong to the porgy family (such as seabream) and the marbled spinefoot. Mullets mainly characterized Dor-Habonim.

- The impact of geographical location was even more pronounced in the community structure differences at shallow depths only, at the different sites (Fig. 4A, Appendix 3).
- The two local grouper species – the dusky grouper and mottled grouper – were observed at similar frequencies at all sites.
- All the common species were found at all four sites, except for mullets. The most common species along the Israeli Mediterranean coastline were present in varying abundances throughout the entire surveyed area.
- The proportion of transects in which the common species were present was similar both inside and outside the MPAs (Fig. 5A, Appendix 3).
- The full species list for all surveys is provided in Table 4A, Appendix 2.

Fish community structure, biodiversity measures, and the representative species differed between sites. Some of this difference is due to varying sampling depth (see Ch. 6.3), and some due to the sites' specific geographical location along the Israeli Mediterranean coast.

6.3 / Depth effect on the fish community

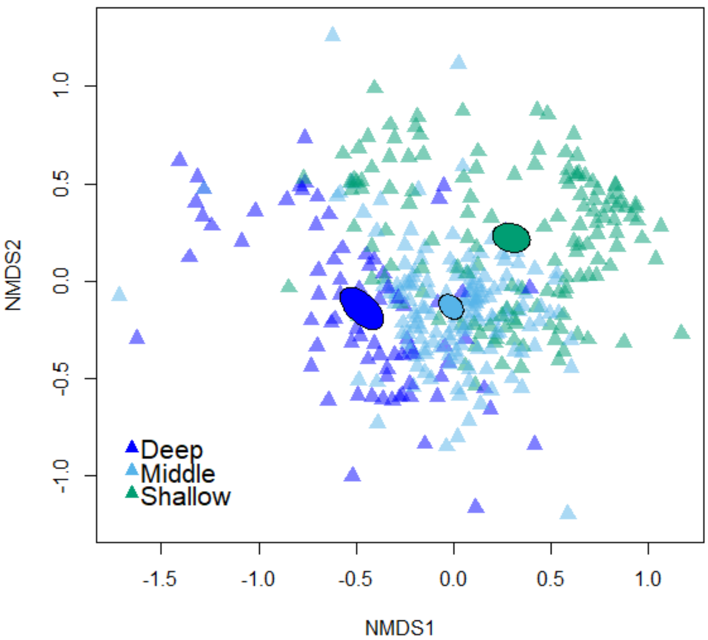


Figure 3.1 nMDS ordination plot presenting the distances between fish communities in the different depth categories at Rosh Hanikra-Achziv, in all surveys, both inside and outside the MPA. Distances were calculated using the Bray-Curtis dissimilarity index. Each point in space represents a transect and is graphed according to the log-transformed abundance values of each species. The colors correspond to the depth category (shallow – green, n = 140; middle – light blue, n =151; deep – blue, n = 83). Ellipses, color-coded in correspondence to depth categories, represent the separation between fish communities at the different sites. Stress = 0.21.

The effect of bottom depth is well reflected in the fish community structure at Rosh Hanikra-Achziv. Fish communities in the three depth categories significantly differed from each other, and 16% of the variance in community structure is explained by the depth category (Table 5A, Appendix 3). This pattern was also observed both inside and outside the MPA, when each area was examined separately (Table 6A, Appendix 3).

In order to determine which species characterized the shallow and the deep depth categories, we examined the ratio between each species' biomass in shallow water and in deep water.

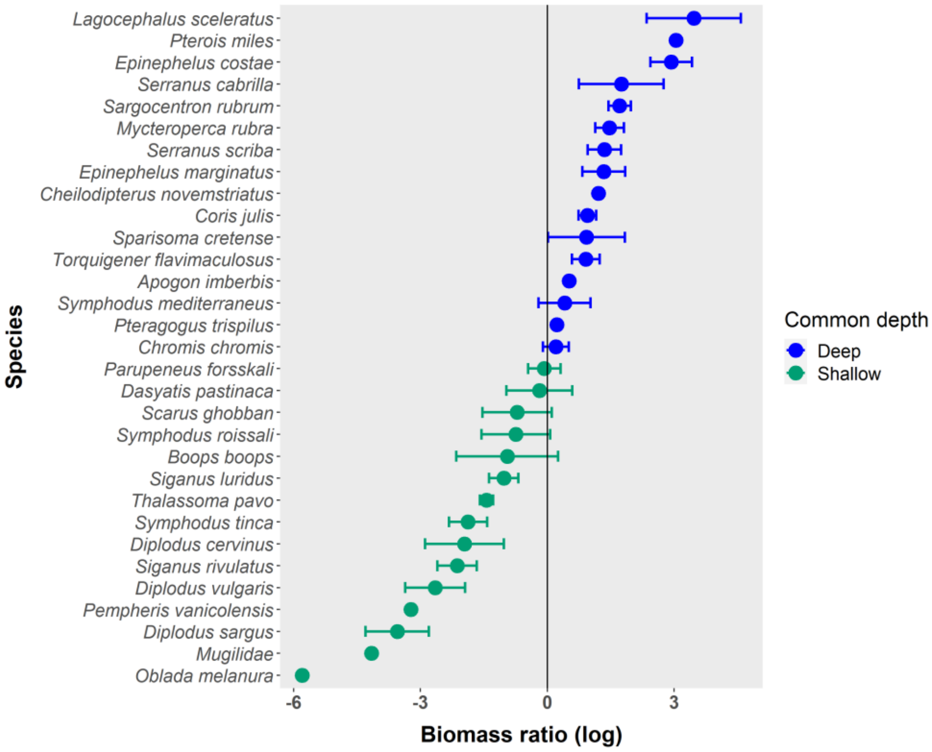


Figure 3.2 Species biomass distribution in shallow and in deep water at Rosh Hanikra-Achziv, in all surveys. For each species, we calculated the ratio between the mean biomass per transect in shallow water and in deep water. The ratio values underwent a log-transformation. Negative ratios indicate that the species had greater biomass in shallow water (green), and positive ratios indicated greater biomass in deep water (blue). Species that were observed in fewer than 10 transects are not included in this analysis. Error bars show standard error. Species without error bars are species that were observed in only one of the two depth categories.

When considering biomass, the species that characterized the shallow water (down to 9 m) at Rosh Hanikra-Achziv MPA were mainly porgies (species of seabream) and spinefoot species. The deep water (~20 m) was characterized by groupers and combers, puffers, and cardinalfishes. Some species were observed only at a specific depth: the newly invasive lionfish, Indian Ocean two-spot cardinalfish, Mediterranean cardinalfish, and Pteragogus trispilus were not observed in shallow water, while Pempheris rhomboidea, some mullets, and the saddles seabream were not observed in deep water.

Regarding abundance, the division of species according to depth category has generally remained the same (Fig. 8A, Appendix 3). Two of the most common grouper species, however, the mottled grouper and the dusky grouper, which prominently characterized the deep water in terms of biomass, do not exhibit depth-specific characteristics in terms of abundance. Despite having higher mean biomass in deep water, their abundance was similar in both deep and shallow water. These two species were observed at all the surveyed depths, but larger individuals were observed in the deeper waters.

In terms of species richness and biodiversity, we found different patterns between inside and outside the MPA for the varying depths (Fig. 7A, Appendix 3). Inside the MPA, the highest species richness per transect was found in the middle depth category as well as the highest total species richness, while outside the MPA the highest total species richness was in the shallow depth category.

The highest biodiversity inside the MPA, both in total and per transect, was observed in deep water, while outside the MPA the highest biodiversity (both in total and per transect) was in shallow water.

The fish community structure at Rosh Hanikra-Achziv varied across depths. The different depths were characterized by different species, which were present in varying numbers and sizes (as their biomass differed at different depths). The species richness and biodiversity also varied across depth categories. The protection that the MPA provides to fish species was more apparent in deeper water (middle and deep categories).

6.4 / Seasonal variation in fish communities

The BioBlitz surveys were conducted over two seasons –spring and fall, defined by their different physical conditions, such as seawater temperature and nutrient availability, which affect the fauna and flora. This chapter describes the changes in fish community structure, biodiversity, and representative species between the two sampling seasons. We examined the total fish biomass in both seasons and between sampling sites.

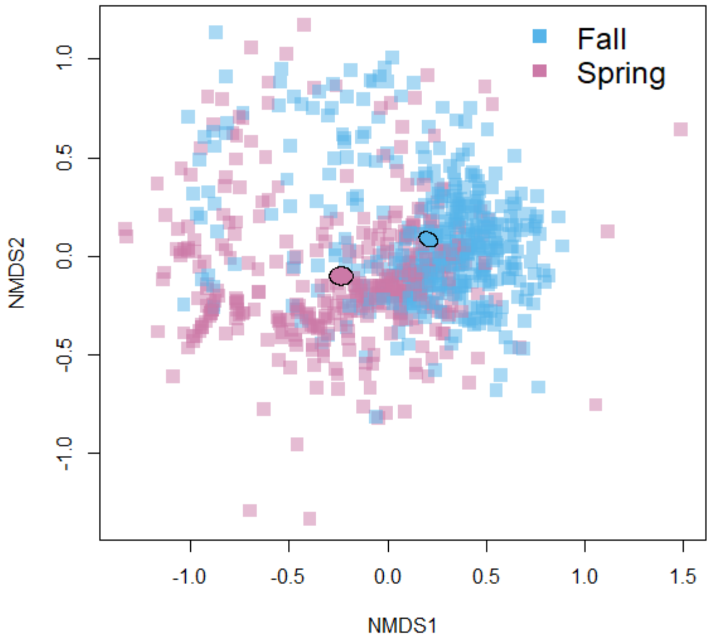


Figure 4.1 nMDS ordination plot presenting the distances between fish communities in shallow water only, for both sampling seasons, for all years and at all sites, inside and outside the MPA. Distances were calculated using the Bray-Curtis dissimilarity index. Each point in space represents a transect and is graphed according to the log-transformed abundance values of each species. The colors correspond to the season (spring – purple, n = 362; fall – light blue, n = 419). Ellipses, also color-coded in correspondence to seasons, represent the separation between fish communities in different seasons. Stress = 0.2.

The community structure varied between spring and fall. There was a clear and significant distinction in fish communities between these seasons, with 11% of the variance in community structure being explained by the season (Table 5A, Appendix 3).

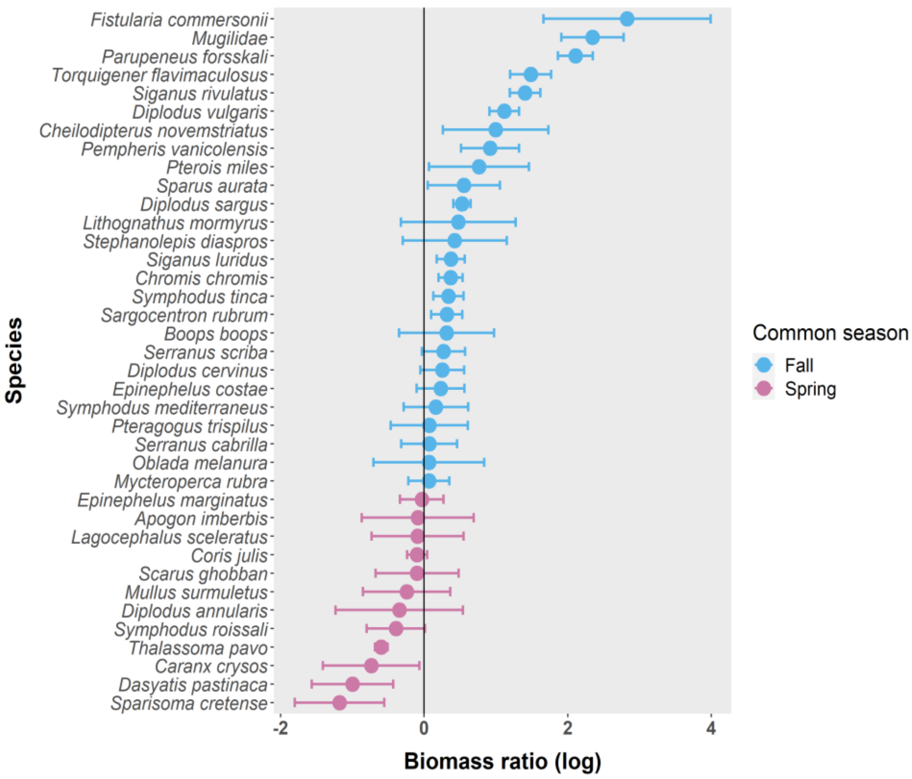


Figure 4.2

Species biomass distribution in spring and fall, for all surveyed years, sites, and depths, inside and outside the MPAs. All depth categories were included in order to examine the effect of season on the common species. For each species, we calculated the ratio between the mean biomass per transect in fall and in spring. The ratio values then underwent log-transformation. Negative ratios indicate that the species had greater biomass in spring (purple), and positive ratios indicate greater biomass in fall (light blue). Species that were observed in fewer than 10 transects are not included in this analysis. Error bars show standard error. Species without error bars were observed in only one of the two seasons.

The fall, when water temperature is higher, had more characteristic species than the spring. More invasive species characterized the fall.

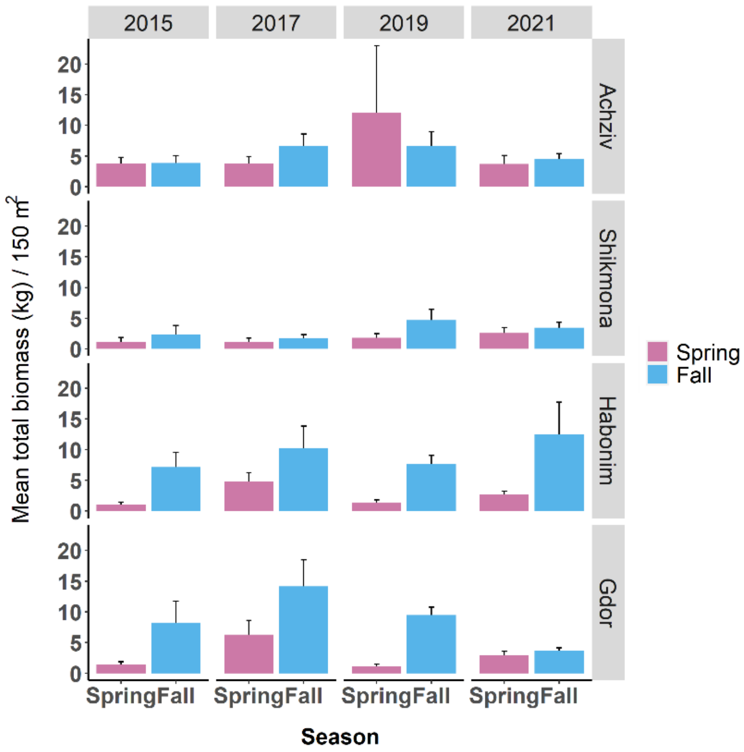


Figure 4.3 Total biomass per transect in spring and fall throughout the survey years and sites, at all depths, inside and outside the MPAs. The x-axis indicates the survey season: spring (purple columns) or fall (light blue columns) (for sampling sizes see Table 2A, Appendix 2). The y-axis shows the total mean biomass per transect. Error bars display 95% confidence intervals.

Throughout the years the total biomass was higher in fall than in spring at all sites except Rosh Hanikra-Achziv, where the pattern was not clear (partially due to schools of large fish seen in spring 2019 as well as only small differences between seasons in 2015 and 2021).

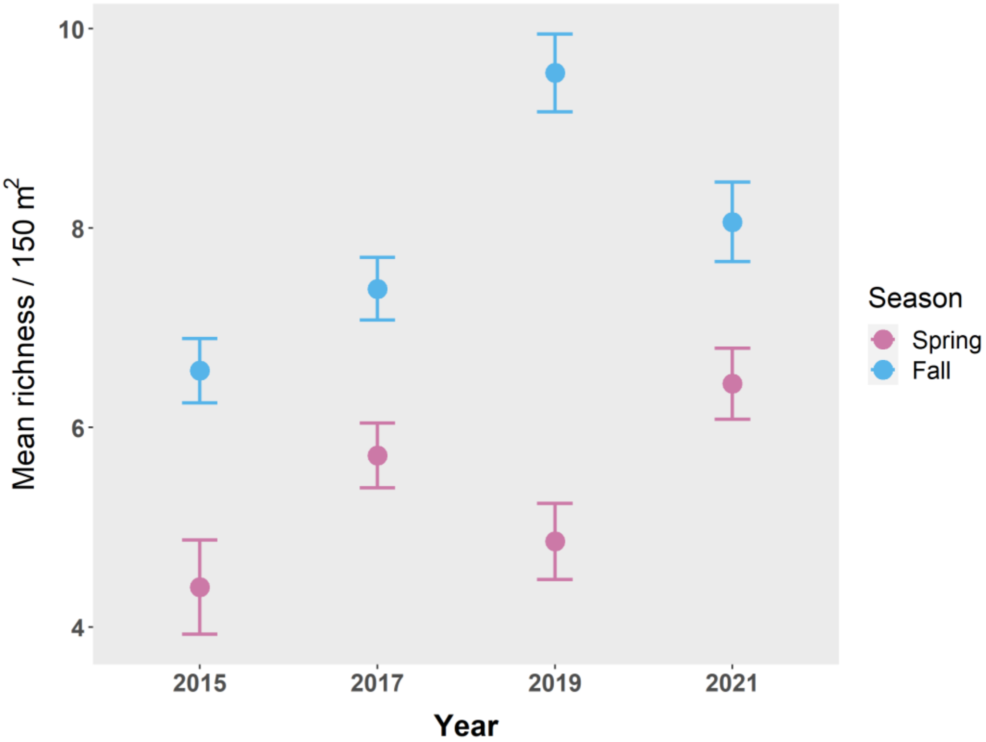


Figure 4.4 Mean species richness per transect in spring and fall in shallow water only, at all sites, inside and outside the MPAs. The x-axis shows the survey year and the y-axis shows mean species richness per transect. The colors indicate the season (spring – purple; fall – light blue; sample size provided in Table A2, Appendix 2). Data reflect shallow water surveys only for a more equal comparison among sites, as this is the only depth surveyed at all sites. Error bars show 95% confidence intervals.

The mean species richness per transect was higher overall for all sites in the fall than in the spring, throughout all the survey years. The same pattern was also found for each site separately. For all years except 2017, species biodiversity displayed the same pattern (Fig. 19A, Appendix 3). Both species richness and biodiversity increased by year for both seasons in total (Fig. 1.2, Section 6.1). Similar species richness patterns were found for each season separately (after accounting for sampling effort, Figs. 17A and 18A, Appendix 3), with the exception of 2021, which did not differ between seasons.

The fish community structure exhibited a variation between spring and fall at all sites. In the fall both biomass and biodiversity were higher than in the spring.

6.5 / Invasive species

Since the opening of the Suez Canal in 1869 linking between the Red Sea and the Mediterranean Sea, the Eastern Mediterranean has experienced a continuous invasion of dozens of fish species of Indo-Pacific origin. This invasion has extensive ecological consequences caused by, but not limited to, the establishment of grazing species that alter the structure of the algal community on the seabed (Vergés et al., 2014); predatory species whose populations are not controlled by their own natural predators (EastMed, 2010; Côté et al., 2013); and species feeding on invertebrates living on the seabed that alter the properties of the substrate (Yahel et al., 2002). Long-term invaders, such as rabbitfish (Siganus), were observed throughout the survey years. Due to the abundance of sampling points, we were also able to detect new invasive species, such as the Red Sea goatfish. In this chapter we examine the relationship between the indigenous fish biomass and the invasive fish biomass, the abundance of invasive species throughout the survey timespan, and the changes in biodiversity of both invasive and indigenous species throughout the years. The data provided in this chapter cover all the surveyed depth.

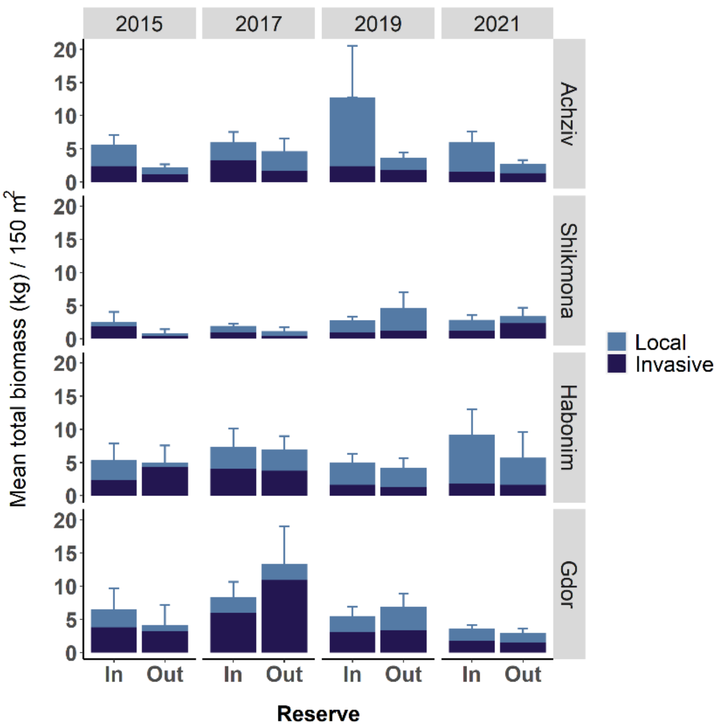


Figure 5.1 Total mean biomass per transect of indigenous and invasive species throughout the survey years, inside and outside each MPA, at all depths. The x-axis indicates whether the sampling was inside or outside the MPA. The y-axis shows total mean biomass per transect, separated by indigenous (light blue) and invasive (dark blue) species. Error bars show 95% confidence interval.

The proportion of invasive species was lower throughout the years at Rosh Hanikra-Achziv (inside and outside the MPA), compared to the proportion of invasive species elsewhere. The proportion of invasive species at Dor-Habonim and Gdor derives from the high abundance of rabbitfishes at both sites (see BioBlitz Chapter A).

In 2019 we observed a decline in the proportion of invasive species in the total biomass at all sites inside the MPAs, and at most of the control sites. In 2021 a similar decline was found only in Dor-Habonim, both inside and outside the MPA.

Rabbitfish (Siganus family)

Two species of rabbitfish are known to have invaded the Mediterranean Sea from the Red Sea – the marbled spinefoot (*Siganus rivulatus*) and the dusky spinefoot (*Siganus luridus*). These two species are now very abundant in the Israeli Mediterranean Sea (the marbled spinefoot is the more abundant) and the impact of their invasion is considered harmful, mainly due to their mostly herbivorous diet (Sala et al., 2011; Vergés et al., 2014, Yeruham et al., 2020).

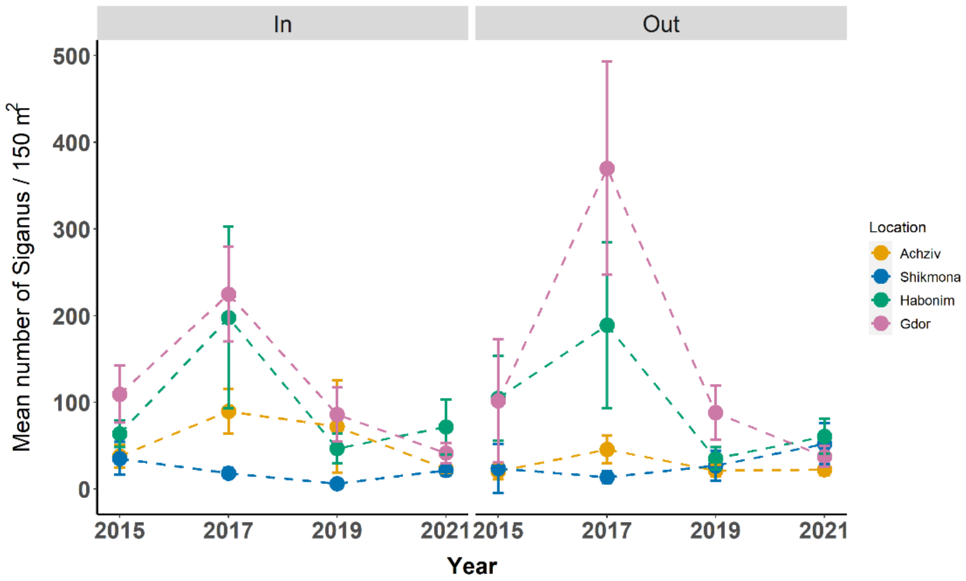


Figure 5.2 Mean rabbitfish abundance per transect throughout the survey years inside and outside each MPA, at all depths. The x-axis shows mean abundance per transect of rabbitfish species (marbled spinefoot and dusky spinefoot). The left and right panels provide data for inside and outside the MPAs respectively. The colors correspond to sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink).

Rabbitfish abundance was higher at Dor-Habonim and Gdor than at Rosh Hanikra-Achziv and Shikmona in 2015-2017, both inside and outside the MPAs. Between 2017 and 2019 their abundance at Dor-Habonim and Gdor declined drastically, possibly due to an increase in grouper abundance during those years (See Ch. A of this report); groupers are important predators of rabbitfish (Aharonov, 2002). In 2021, Gdor exhibited a similar, though subtler, negative trend (inside and outside the MPA), while in Dor-Habonim, the trend seems to have changed to a moderate increase in rabbitfish (inside and outside the MPA).

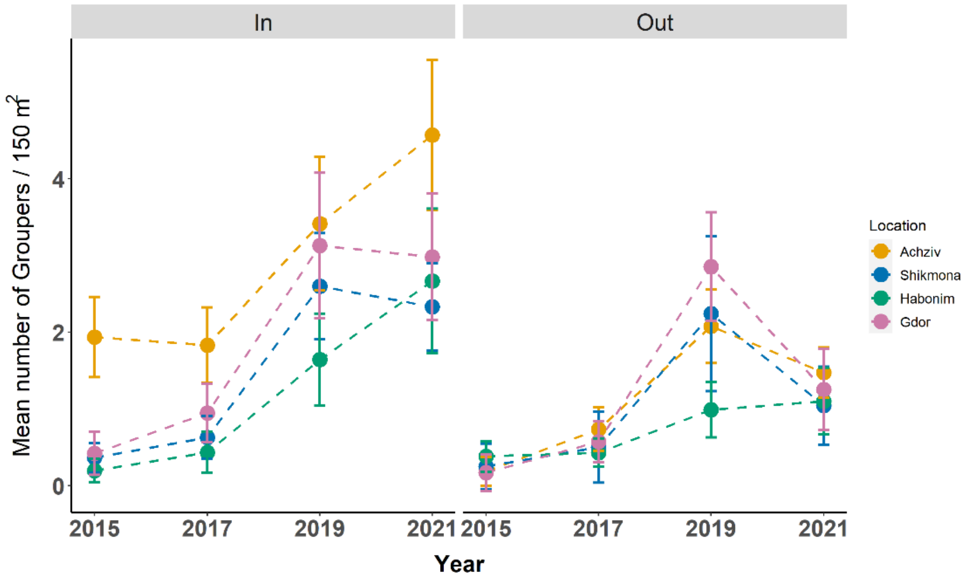


Figure 5.2.1 Mean grouper abundance per transect throughout the survey years inside and outside each MPA, for all depth categories. The x-axis shows mean abundance per transect of grouper species (dusky grouper, mottled grouper, and golden grouper). The left and right panels provide data for inside and outside the MPAs, respectively. The colors correspond to sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink).

Parupeneus forsskali

Parupeneus forsskali, a Red Sea goatfish, was first observed along the Israeli coast in 2013 (Sonin et al., 2013). These fish feed by burrowing in the sediment, searching for infauna (invertebrates dwelling in the soft sediment), and cause sediment resuspension (Yahel et al., 2002). Therefore, their establishment can lead to the alteration of soft substrate habitats. This species was mostly found in sandy areas near rocky reefs.

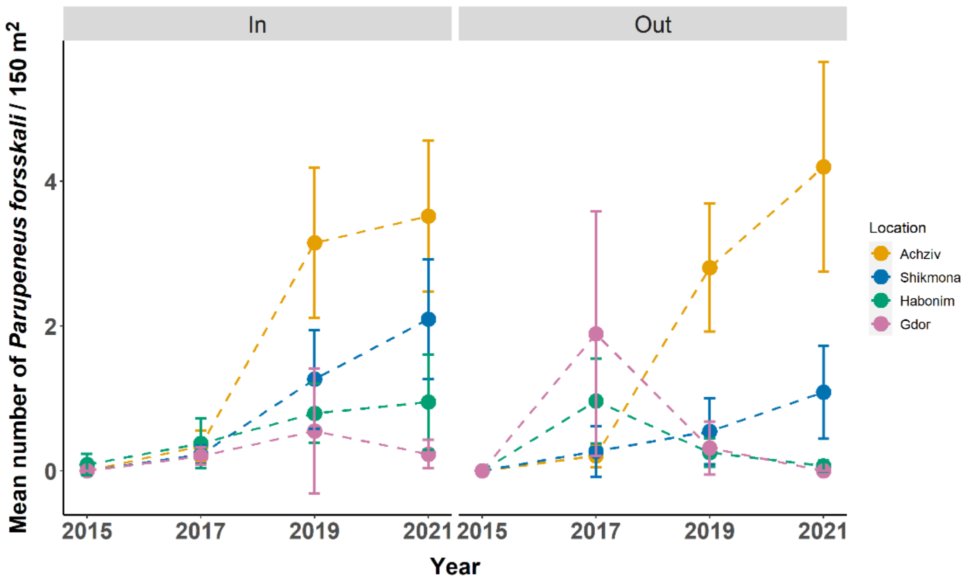


Figure 5.3 Mean *Parupeneus forsskali* abundance per transect throughout the survey years inside and outside of each MPA, at all depths. The x-axis shows mean abundance per transect of Red Sea goatfish. The left and right panels provide data for inside and outside the MPAs, respectively. The colors correspond to sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink).

Parupeneus forsskali abundance increased dramatically between 2015-2021. The patterns differed between the sites, with the most prominent increase in Rosh Hanikra-Achziv, inside and outside the MPA. Outside the MPAs, while their abundance increased in Rosh Hanikra-Achziv and Shikmona throughout the years, in Gdor and Shikmona it decreased between 2015-2017 with the decrease becoming more moderate between 2019-2021 (in Dor-Habonim the decrease was even more subtle).

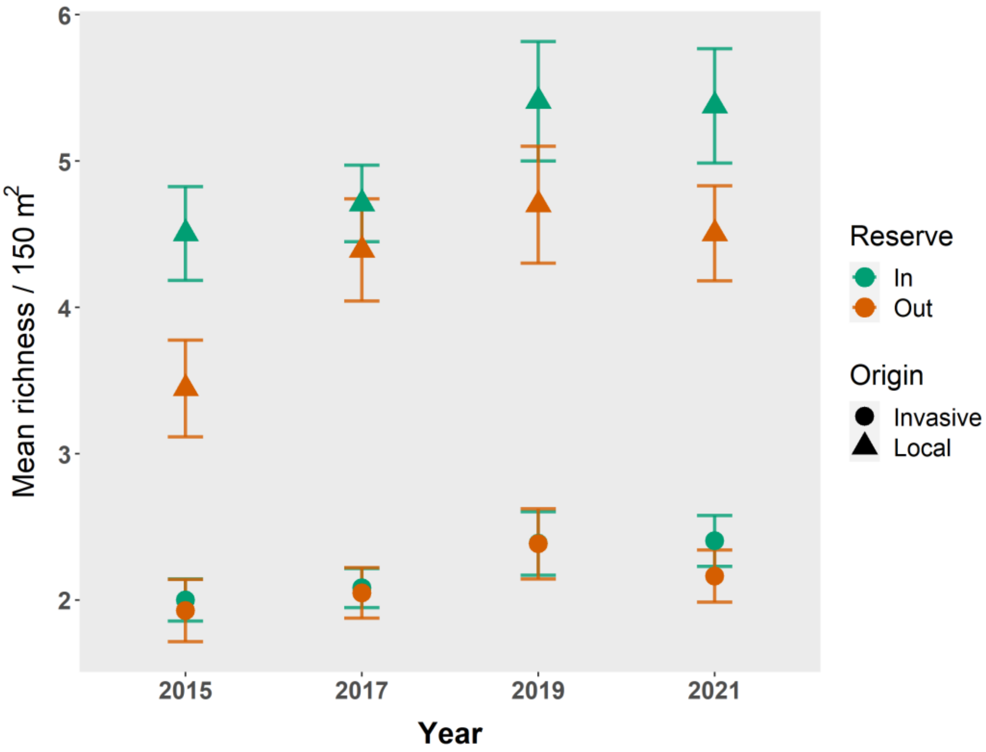


Figure 5.4 Mean species richness per transect of invasive and indigenous species, inside and outside the MPAs throughout the survey years in shallow water only, at all sites. Data present only shallow surveys to enable an equal for comparison. The x-axis shows the year, and the y-axis shows the mean species richness value per transect in an area of 150 sq m. Colors indicate whether the sampling was inside the MPAs (green) or outside them (orange) (sampling sizes are detailed in Table 2A, Appendix 2). The shapes indicate indigenous (triangle) or invasive (circle) species. Error bars show 95% confidence intervals.

Species richness was higher for indigenous species, both inside and outside the MPAs, with the differences in species richness between these sites more evident for indigenous species. A similar pattern was found for biodiversity (Fig. 13A, Appendix 3). There was also an increase in species richness up to 2019, for both indigenous and invasive species.

Invasive species contributed 35-66% of species biomass at the sampling sites, with the lowest percentage in Rosh Hanikra-Achziv (35%). The relative abundance of rabbitfish, long-time established invaders, was higher in Gdor and Dor-Habonim (both inside and outside the MPAs). However, their abundance decreased between 2017-2021 in both Gdor and Rosh Hanikra-Achziv. In contrast, the Red Sea goatfish, a newly established invader into the Mediterranean Sea, showed an increase in abundance throughout the years in the northern sites, especially in Rsh Hanikra-Achziv (inside and outside the MPA). Overall,

species richness and biodiversity were higher for indigenous species, although an increase in species richness for both indigenous and invasive species was found between 2015-2019. Twenty-five percent of species observed in shallow coastal waters down to 24 m depth were invasive. In total, 44% of all individual fish observed were invasive, with 90% comprising rabbitfish species: 82% marbled spinefoot, and 8% dusky spinefoot.

6.6 / Fish community structures at the control sites in Poleg and Palmachim

In addition to the regular Bioblitz sampling sites, determined by the location of MPAs with rocky substrates along the central and northern Israeli coast, two additional southern sites were added to the survey in 2019. These comprised the Poleg region (Sharon coast), where a future MPA has been proposed, and Palmachim, the southernmost site where an underwater marine park is currently being promoted and which will afford partial protection from fishing.

There is usually a lack of baseline data on species communities before MPAs are established. The sampling in Poleg and Palmachim has given us the ability to record the fish community before the area becomes protected and to compare it to the data that will be collected in the future, after establishment of the MPA. Furthermore, these data provide us with an immediate picture of the fish community structure along the Israeli coastline rather than just in its northern parts.

The **Poleg** sampling site encompasses a rocky habitat at 1.5-12 m depth, between two 50 x 70 m rocky areas. However, the rocky substrate breaks up between the waterline and the survey area (at 850 m distance from the shore), with most of the sea bottom thus comprising sand. The survey area consists in a flat rocky substrate with mixed and complex areas at its boundaries including sandy bottom and deep crevasses. This site was surveyed in 2021 in spring and fall (see Table 3A in Appendix 2 for sampling sizes).

The **Palmachim** sampling site also comprises a rocky habitat in shallow water of 2.5-8 m depth (the deepest rocky substrate that can be sampled by SCUBA). Sampling took place at rocky sites both near the shore and more distant from it, up to a distance of 270 m. The structural complexity of this rocky habitat varies between sampling points, with part of it including hills and sinks with a large variation in depth, while other parts are rather flat. This site was sampled in the spring and fall of 2021 and in the spring of 2018 (see Table 3A in Appendix 2 for sampling sizes).

The results provided in Section 6.2 suggest that there is a geographical gradient in the fish community structure. Consequently, we examined the community structure of the above-mentioned southern sites and compared them to the communities at the control sites (outside the reserves) of four regular sampling sites.

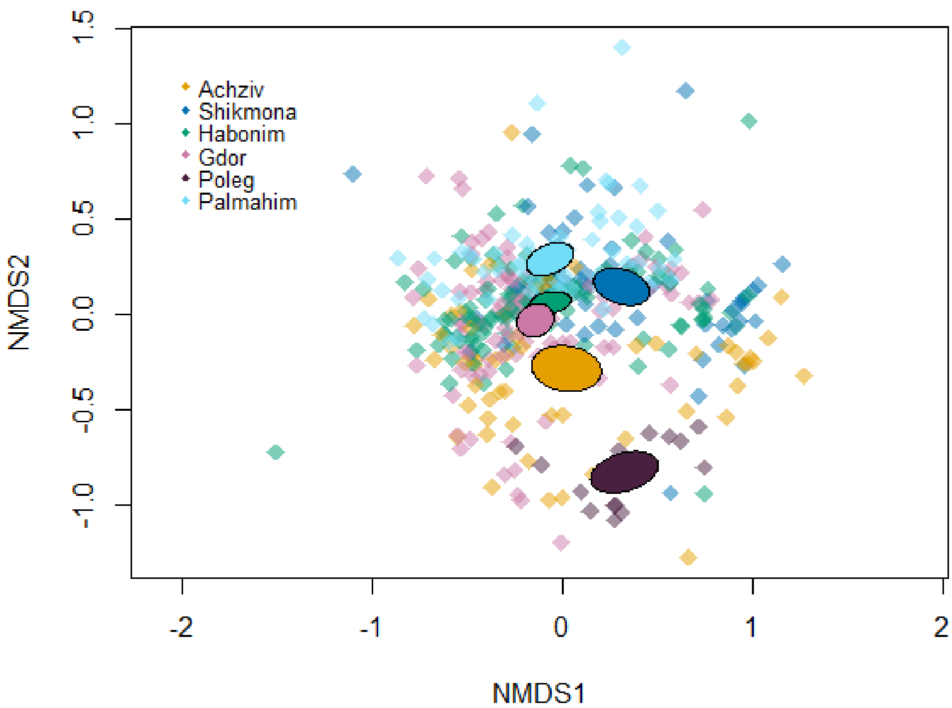


Figure 6.1 nMDS ordination presenting the distances between fish communities at each site, in all surveys, outside the MPAs, at a depth down to 9 m. Distances were calculated using the Bray-Curtis dissimilarity index. Each point in space represents a transect and is graphed according to the log-transformed abundance values of each species. The colors correspond to sites (Rosh Hanikra-Achziv – yellow; Shikmona – blue; Dor-Habonim – green; Gdor – pink; Poleg – violet; Palmachim – light blue). Ellipses, color-coded in the same way, represent the difference between fish communities in each site. Stress = 0.19.

Fish communities outside the MPAs, similarly to those inside them, were similar in Gdor and Dor-Habonim, both of which differed from the other sites, both the southern (Poleg and Palmachim) and northern (Rosh Hanikra-Achziv and Shikmona, Fig. 2.2) sites. The community structure varied between Palmachim, Poleg, Shikmona, and Rosh Hanikra-Achziv. The community structure in Poleg was the most distinct, possibly due to either the spatial distance and separation of the rocky reefs from the shore or to their being enclosed in sand. However, the number of transects at this site is the lowest of all sites, and thus might require additional sampling efforts over the years in order to fully identify the fish community. The differences between sites are statistically significant, with 16% of the variance in community structure explained by the site location (Table 5A, Appendix 3).

In order to identify which species are most representative of each site, we examined the percentage of transects in which each common species was observed out of the total transects surveyed at each site. Here we include samples from all depths.

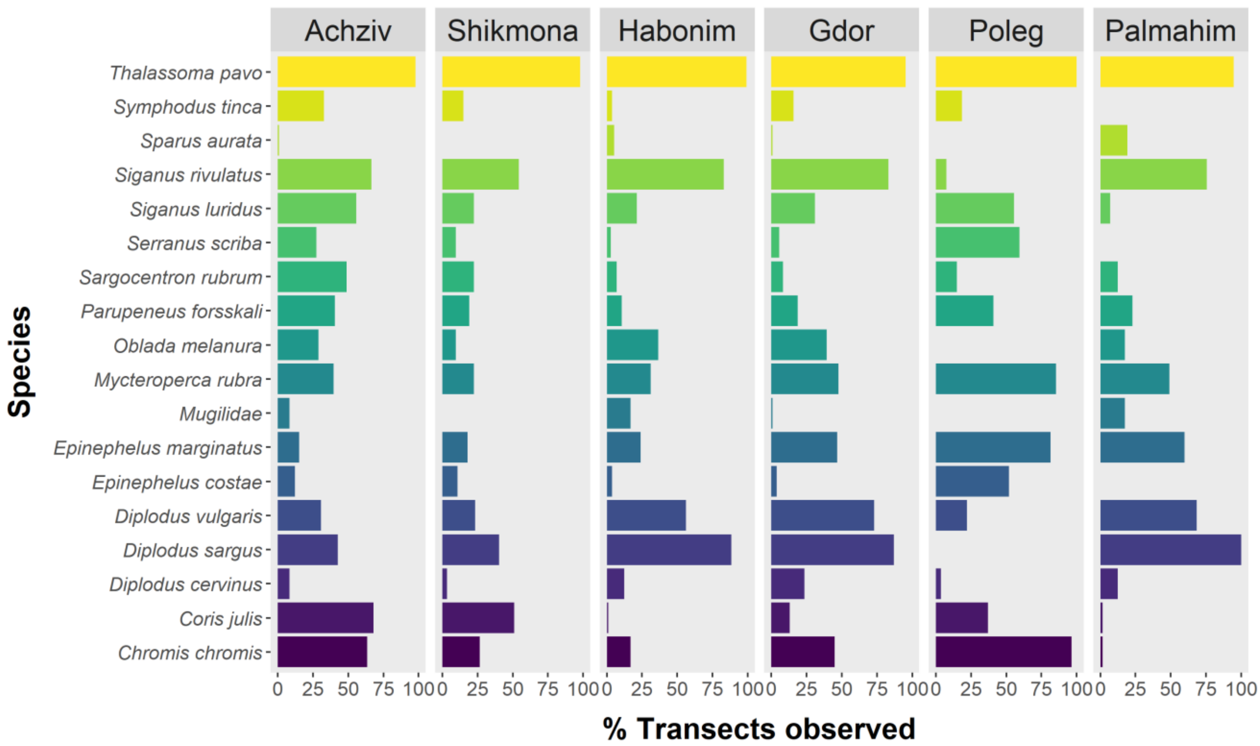


Figure 6.3 Percentage of transects where common species were observed at each site, in all surveys, outside the MPAs, at all sampled depths. Common species are defined as the ten most observed species according to transect at each site. The percentage of observations of the species per site was calculated as the proportion of the number of transects where the species was observed out of the total number of transects carried out at that site (regardless of observed individual counts). The x-axis shows the percentage of transects where the species was observed out of the total number of transects at that site. The y-axis shows species' names.

- Similar to the combined results of inside and outside the MPAs (Fig. 2.3), the most representative species at all sites was the ornate wrasse.
- The blue-spotted seabream was one of the most observed species in Palmachim (and thus included in this analysis), but was rarely seen, if at all, at the rest of the sites. Its presence in Palmachim could be due to the escape of cultivated fish from the nearby open-sea fish cages.
- In Poleg, where shallow water was sampled but the reef is separated from the shore and breaks up between the shore and the sampling area, species that represent shallow depths, like the white and saddled seabreams and mullet species, were rarely observed or not observed at all. In contrast, species not representative of shallow water, like the Mediterranean rainbow wrasse, Mediterranean chromis, and grouper species, were frequently observed at this site.
- The three grouper species – dusky, mottled, and golden groupers – were the most observed species in Poleg, possibly due to the high complexity of the reef at this site.
- Despite the Palmachim samplings depth being confined to shallow waters, like Dor-Habonim, where the habitat is also similar, there are species that were present in Dor-Habonim but not in Palmachim. These species included combers, East Atlantic peacock wrasses, and golden groupers. The percentage of transects where these species were present was however very low in Dor-Habonim, so it is possible that they were present but not detected in Palmachim due to lower sampling effort. The mottled and dusky groupers were observed more frequently in Palmachim than in Dor-Habonim.
- Six of the 18 common species were not observed at all at the sampling sites, two of them were absent from Poleg only, and three were absent from Palmachim only. Because these sites were subjected to a significantly lower sampling effort than the other sites, it is possible that they will be detected in future surveys.

The fish community structure differed among the sampled sites, except at the control sites of Gdor and Dor-Habonim MPAs. The community structure in Poleg was distinct from the rest of the sampling sites.

7 / Discussion

The current report summarizes eight surveys that were carried out inside MPAs along the Israeli coast of the Mediterranean Sea and at adjacent control sites outside these MPAs. The surveys took place during the years 2015, 2017, 2019, and 2021, in the fall and spring seasons. Throughout the survey years many changes occurred in the local marine system. On the one hand, seawater temperature and the establishment of invasive species continued to rise; while on the other hand, in 2016, fishing regulations were updated after many years, with the aim of improving the state of the fishing industry in Israel through the sustainable management of fishing resources. The enforcement of these new regulations by rangers of the INPA began in 2018, and protection enforcement in MPAs strengthened. There has also been an improvement in the way that surveys are conducted, as sampling methods have become more accurate and the teams more professional. In the context of these changes, the report disentangles and investigates the effects of each MPA, of their location along the Israeli coastline, of the bottom depths surveyed, and of the sampling seasons, on the underlying fish communities.

A total of 83 fish species were observed during the surveys, of which 41 species are of commercial value (such as the dusky grouper) and 42 species are of no commercial value (such as the ornate wrasse). Of the total number of species, 63 are local species and 19 are invasive species originating from the Red Sea (the latter species belong to the Clupeidae family. As they could only be identified to the family level, they could not be classified as either native or invasive). Only the observations of non-cryptic species were analyzed, since the low detection level of cryptic species often results in underestimation.

The structure of the fish communities, the richness and biodiversity of species, as well as the general biomass, were found to differ between the survey sites, seasons, and depth categories, from the shoreline down to a maximum depth of 24 m. Variation was found between the MPAs and their control areas in fish community structure, representative species, species richness, and biodiversity. Differences in biomass and size, with emphasis on species of commercial value, are discussed in detail in the BioBlitz Chapter A report.

The effectiveness of MPAs is reflected in some of the examined indices.

The higher species richness and biodiversity found inside the MPAs compared to outside them indicate well-functioning MPAs and their effectiveness in providing protection for a variety of fish in the Mediterranean Sea (Claudet et al., 2006; Côté et al., 2001). The average species richness and biodiversity throughout the years were higher inside the MPAs than in the adjacent control areas, when accounting for all sites (Fig. 1.2 and 1.3). Whereas in the Shikmona and Gdor MPAs species richness and biodiversity were higher inside them consistently throughout the years, in Dor-Habonim this pattern was found only in three of the four years surveyed (2015, 2019, and 2021, Fig. 11A, Appendix 3). In Rosh Hanikra-Achziv, the patterns varied for the different depth categories (Fig. 7A, Appendix 3).

An interesting pattern observed in Shikmona, Gdor, and Rosh Hanikra-Achziv (apart from at the shallow depth) was the increase in biodiversity and species richness over the years, both inside and outside the MPAs (Fig. 1.2, Fig. 11A Appendix 3); i.e., this increase was also observed in the non-protected areas. Accordingly, it is unlikely that the increase was due only to increased enforcement of fishing regulations inside the MPAs, although the largest increase in Shikmona and Gdor took place between 2017 and 2019, paralleling the increased enforcement inside the MPAs. It is possible that the new fishing regulations (which ban, for example, bottom-trawl fishing in the north of Israel and in shallow waters along the entire coast, as well as the use of SCUBA in spearfishing) have impacted the entire ecosystem, leading to the increase in species richness that was also seen outside the MPAs.

Another possible explanation for the increase in the number of observed species is that of the establishment of new invasive species in Israeli waters. As these species become more common, the average number of species per transect increases. An example of this can be found in the rise in Red Sea goatfish observations, observed for the first time off the coast of Israel in 2013. The encounters with this species have increased significantly throughout the years (Fig. 5.3). Concurrently, an increase in species richness and biodiversity was also observed for local species (Fig. 5.4). It is also possible that the noted increase in species richness is due to improvements in the surveyors' skills over time, with these increases in fact reflecting the surveyors' improved ability to identify more species as well as rarer ones.

The fish community structure was observed to differ between the MPAs and their control areas (Fig. 1.1, Fig. 9A, Appendix 3); and, accordingly, different representative species were observed. Some species consistently characterized the MPAs (Fig. 14A, Appendix 3) and their average biomass per transect inside the MPAs was higher than outside them. The mottled grouper, for example, was usually observed in higher biomass inside the MPAs than in the control areas outside the MPAs at all sites. Similar patterns have been found in many other studies (Hackradt et al., 2014; Polunin & Roberts, 1993). The mottled grouper belongs to the Epinephelinae sub-family, which is a highly desirable species, of high commercial value and ecological importance (for more on this subject, see the Bioblitz Chapter A report: 'Fishing and Nature Reserves'). However, no species were found that solely characterized the control sites: i.e., there were no species whose biomass was higher only outside the MPAs. This finding indicates the impact of fishing on fish communities outside the MPAs.

Fish communities differ along the Israeli coast and are affected by depth.

The great similarity in the fish community structure between Dor-Habonim and Gdor, and their distinction from the fish communities at the two northern sites, Rosh Hanikra-Achziv and Shikmona, imply that fish assemblages differ according to the geographical latitude (Fig. 2.2). While there were some species that characterized all the surveyed sites, such as the ornate wrasse, other species like porgies or mullets, specifically characterized the southern sites, or the dusky spinefoot that specifically characterized the northern sites (Fig. 2.3). At each site, different bottom depths were surveyed according to the maximum depth at each MPA: at Dor-Habonim and Gdor only shallow depths were surveyed (down to approximately 6 m), while at Shikmona and Rosh Hanikra-Achziv deeper areas were also surveyed (down to approximately 24 m). However, even when examining only the shallow depths (for an equal comparison of all sites), the fish communities in Dor-Habonim and Gdor were shown to differ from the northern sites more than they differed from one another (Fig. 4A, Appendix 3). There could be several explanations for this variation, one of which is that while the northern sites feature a continuous rocky habitat between shallow and deep water, the southern sites’ rocky habitat is limited to the shallow depths only (ca. 6 m and 12 m Dor-Habonim and in Gdor, respectively), making these MPAs unable to support species that seek continuous rocky reefs along a depth gradient.

Additionally, around Shikmona and Rosh Hanikra-Achziv the sea bottom deepens closer to the shore compared to at the Dor-Habonim and Gdor sites, creating a more complex bathymetry (Ben-Avraham et al., 2006), and allowing deeper-sea fish to be found nearer to the shore. A steep variation in depth may also affect the local currents, the concentration of nutrients in the water, the number and assemblage of juveniles drifting with the currents, the properties and amount of sand transported with the currents, and more (Barry & Dayton, 1991; Hays, 2017). While it is impossible to determine with certainty the main causes of the variations between sites, it is clear that in order to protect the diversity of fish communities along the Israeli Mediterranean coast, it is necessary to protect multiple marine areas.

The highest species richness and biodiversity (average per area) were observed at the Rosh Hanikra-Achziv site, both inside and outside the MPA (Fig. 2.1, Fig. A2, Appendix 3). This is the largest and oldest of the surveyed MPAs. Fishing bans have been enforced there for nearly three decades and the only local fishing previously allowed was rod fishing from the shore. As of April 2017, this latter method of fishing too became banned in most parts of the MPA except for its southernmost 500 m. Species richness and biodiversity may vary greatly when examined on a fixed sampling unit scale (here 150 m2) compared to the scale of an entire sampling site, which encompasses a large area. Such difference in species composition can be the result of habitat heterogeneity or the dispersion ability of certain species. While Shikmona displayed the lowest species richness among the sites, its total richness (after accounting for sampling effort) was the highest, with a varying species composition between the sampled sections. The diverse habitats found in the MPA – abrasion platforms and complex to flat rocky reefs alongside sandy habitats may also contribute to the spatial variation in the species composition. It is also possible that the presence of rocky habitat at the surveyed medium depth and at greater depths (not analyzed) contributes too, although this pattern was seen also when examining only the shallow depth.

Like the species richness and biodiversity, the structure of the fish communities too differed between the surveyed depths, with notable differences between the three depth categories at the Rosh Hanikra-Achziv site (Fig. 3.1). These differences were seen both inside and outside the MPA (Fig. 6A, Appendix 3). Consequently, there is a need to protect all depths and habitats encompassed by MPAs. Shallow habitats may only support certain species. The Gdor MPA, for example, in which the maximum depth is 5 m, is host to breeding batoid fishes (Chaikin et al., 2020), which are protected species and some of which are considered vulnerable or endangered (IUCN, 2020). Grouper species however mainly characterized deeper water (Fig. 3.2), questioning the ability of shallow-water MPAs to support these species, or to support large individuals. In this report, the categorization of species representative of each depth category is based on biomass, which includes the number of individuals and their size, and not only their abundance. The tendency of large groupers to be found at greater depth is consistent with the findings of other studies carried out in the Mediterranean (Harmelin & Harmelin 1999, Vivien, 1999; Bodilis et al., 2003; Aharonov, 2002). It is also possible that the higher presence of groupers in deeper water is a behavioral adaptation to contend with the fishing pressure in shallower waters (Frank et al., 2018,) such as that of anglers fishing from the shore.

Another possible explanation for the differences in fishing community between depths is that of topographical complexity. The limestone in Rosh Hanikra-Achziv is characterized by complex convex and concave formations, which are found mainly at depths of 15-25 m. The "Little Achziv Canyon," which extends from a depth of approximately 15 m and deeper, combines limestone walls, caves, notches, nooks and sandy areas, thereby providing a variety of niches with different physical characteristics that can support a variety of species.

At the control sites, together with other sites where fishing is allowed (Poleg and Palmachim), a unique fish community structure was found for each site (apart from Gdor and Dor-Habonim, where the two community structures are similar). Here too several explanations can be attributed to these differences. First, perhaps the factor that most distinguishes the Poleg site from the other sites is that of its different habitat. Although it is a rocky habitat, it is completely disconnected from the shore with no continuous rocky substrate from shore to the sampling area. There is no continuous rocky reef between the sampling points, some of which are separated by sandy areas. The high rate of grouper sightings in Poleg, for example, may be due to the high complexity observed at the edges of these rocky areas, where depth ranges from 7 m at the top of the rocky reef to 12 m at its base. These areas present highly complex elements, characterized by multiple and wide zones. The number of transects in Poleg was the lowest of all the sites, and it is possible that the low sampling effort influenced the results. Nevertheless, if this habitat is indeed favored by groupers, and is also characterized by a different community structure, then its preservation is of great significance. The different community structure observed in Palmachim may be due to uneven sampling effort between sampling seasons, as in 2018, when most of the transects were conducted, the sampling took place only in the spring. Continued monitoring at these sites will conduce to a better characterization of their fish community structure. Moreover, if these areas become protected in the future, continued data collection will provide a baseline assessment of the state of the ecosystem prior to protection. Such data will provide a very crucial point of reference for examining the effectiveness of the MPA.

The fall season is characterized by a different community structure, higher species richness and biodiversity, and higher biomass.

The seasons of the year are characterized by different conditions that significantly affect the marine environment and the life contained within it. A key difference lies in the temperatures that characterize the survey seasons. In the spring, the water temperature is still low from the winter (ca. 18°C), especially near the shore where the surveys were conducted. In the fall, the temperature is still high from summer, when the water had warmed (Bosc et al., 2004) to ca. 25°C. Differences in the fish community structure (Fig. 4.1 and 4.2), in the overall biomass (Fig. 4.3), and in the species richness and biodiversity (Fig. 4.4, Fig. 19A Appendix 3) between the survey seasons (spring and fall) were observed at all sites. The fall saw a higher fish biomass, as well as a greater abundance and diversity of fish species. Another difference lies in the increase in species richness decreased throughout the survey years (Fig. 4.4).

The primary productivity during spring is relatively high due to a mixing of the water column through winter, which causes nutrients from the depth, such as nitrogen and phosphorus, to rise to the upper water layer (Bosc et al., 2004). This high productivity increases the amount of food available in the water, which is consumed by the fish during spring (the breeding season of most species of fish) and is manifested a few months later in the number of ofspring. Accordingly, in the fall season, following recruitment (the process in which juvenile fish join the adult populations), the number of individuals is higher and, therefore, the probability of detecting more species increases (the greater the number of individuals observed, the higher the chance that they will represent more species). The lower biomass observed in the spring season can also be attributed to the behavior of the fish. It is possible that in the spring we observed fewer species and a lower biomass than in the fall because the adults were busy breeding, which sometimes takes place in specific locations that are not covered by in the survey areas. For example, groupers gather in specific locations for breeding purposes in the spring (Marino et al., 2001), and white seabreams gather for breeding purposes at greater depths than where they are usually observed (Aspillaga et al., 2016). Moreover, the dynamics of migratory species (such as the greater amberjack, observed mainly during spring), which are rarely seen during surveys due to method limitations, could affect the presence of smaller prey species and lead to lower species richness and diversity.

Invasive species characterize the entire Israeli coast and new species are becoming established over time.

Invasive species were found at all the surveyed sites, both inside and outside MPAs (Fig. 5.1, Fig.

14A, Appendix 3). Although each site possessed its characteristic invasive species, there was an overlap between species at the different sites. The abundance of both long-term and new invasive species, such as species of Siganus (rabbitfish) and the Red Sea goatfish, respectively, did not differ between the MPAs and the adjacent control sites (Fig. 5.2 and 5.3). The successful establishment of the newly invasive Red Sea goatfish can be clearly seen at the Rosh Hanikra-Achziv MPA, where the relative biomass of invasive species has remained low to date. These findings suggest that MPAs probably do not provide effective protection against the establishment of invasive species – a debated issue among conservationists. Nonetheless, while the relative abundance of invasive species out of the total biomass should have shown a decrease between 2017-2019 at all sites (fig. 5.1), between 2019-2021 it decreased only in Dor-Habonim. In order to better understand how the system might more effectively handle invasive species (protection over a longer time period, monitoring and enforcement of fishing regulations, or a combination of these), or whether the changes in abundance result from natural fluctuations in population sizes, it is vital to continue this research in the coming years.

Optimal protection of the fish communities requires the presence of MPAs along the Israeli coast, at a wide range of depths and during all seasons.

The fish communities that characterize rocky areas along Israel's Mediterranean coast vary between seasons, between geographic locations along the coastline, and between different depths. The findings described here highlight the need for their continued protection by means of marine MPAs. Protection of a limited depth range, a small area, or a limited geographical area, means only partial protection for the fish community. Different fish communities characterize different areas along the coast according to their geographical location and to the environmental and biological conditions, necessitating the protection of different areas spread along the entire Israeli coast.

MPAs offer an effective tool for protecting marine ecosystems and the species that inhabit them. A network of connected MPAs along the Israeli coastline, from south to north, covering the entire range of depths and distances from the shore, and representing a diversity of substrate habitats (Yahel and Angert, 2012) is vital in order to provide effective protection for all fish species.

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Appendix 1

Changes in the world of fishing in Israel during the years 2015-2021:

In 2015, the effects of marine reserves on fish communities were first examined. Since then, significant changes have occurred in the world of fishing in Israel. In 2016, the finance committee of the Knesset approved a revision of the fishing regulations with respect to commercial and sport fishing (fishing regulations, 2016 update, Ministry of Agriculture). The purpose of the new regulations is to improve the state of the fishing industry in Israel through the sustainable management of the fisheries resource. The key changes in commercial fishing regulations include, for example: Restrictions on trawler fishing: in the new fishing regulations, it is strictly forbidden to fish from trawlers in the northern part of Israel – from the Lebanese border in the to Nahsholim in the South. This method of fishing was also forbidden in rocky areas in all territorial (sovereign) waters of Israel. Every year trawler fishing is prohibited during the recruitment season (where juveniles join the adult fish populations) for up to 90 consecutive days during the period of May 1 to August 31, based on the determination of the chief fishing official.

Appendix 1.1 Update of fishing regulations

In 2016, the finance committee of the Knesset approved a revision of the fishing regulations with respect to commercial and sport fishing (fishing regulations, 2016 update, Ministry of Agriculture). The purpose of the new regulations is to improve the state of the fishing industry in Israel through the sustainable management of the fishery resources. The key changes in commercial fishing regulations include, for example:

Restrictions on trawler fishing: the new fishing regulations strictly prohibit fishing from trawlers in the northern part of Israel – from the Lebanese border in the north to Nahsholim in the south. This method of fishing has also been prohibited in rocky areas in all territorial (sovereign) waters of Israel. Trawler fishing is also prohibited annually during the fish recruitment season (when juveniles join the adult fish populations) for up to 90 consecutive days between May 1 and August 31, based on the determination of the chief fishing official.

Prohibition of shore fishing during the breeding season: fishing is prohibited annually for 60 to 90 consecutive days during the period of March 1 to July 1, based on the determination of the chief fishing official. In practice, this prohibition is in effect for shorter periods. During the transitional period (the first three years 2017-2019) up until the time of full implementation of the regulations, the maximum duration of the ban was set at 45 days. In practice, however, during those years and even in 2020, the duration of the complete ban on fishing during the breeding season did not exceed 30 days in any year. During those years there was also a fishing ban on groupers during part of their specific breeding season, in addition to the general fish breeding season. This prohibition applied to all methods of fishing, including rod fishing from shore, based on the determination of the chief fishing official.

In addition, the fishing regulations include minimum catch sizes with the aim of allowing individual fish to reach breeding size; the prohibition of certain fishing methods (e.g. dragnet fishing); increasing the minimum mesh sizes for fishing nets; and denoting the distance from the shore required for the various fishing methods.

With regard to sport fishing, whose extent is increasing and now comprises a significant component of the fish haul in Israel (Frid and Gavrieli, 2019), there have been a number of significant changes, including a complete ban on fishing using artificial breathing equipment for diving and applying daily catch limits. In addition, fishing bans on all species in general, and groupers in particular, during the different fish breeding seasons, are now also valid for sport fishing.

In practice, the enforcement of the new regulations began in the summer of 2018 with the introduction into operation of the Marine Unit of the Israel Nature and Parks Authority. The regulations have been summarized in an information booklet to make them accessible to the fisher community (Israel Nature and Parks Authority, 2018).

Updates of the protected natural assets: In 2021, the golden grouper was declared a protected species and fishing it is banned.

Appendix 1.2 The establishment of the Marine Unit of the Israel Nature and Parks Authority

After many years in which the fishing regulations were rarely enforced, the Israel Nature and Parks Authority was authorized in 2018 by the Ministry of Agriculture to enforce the regulations for which the fishery department is responsible. Intensive monitoring and enforcement work pertaining to the fishing regulations (including the new regulations of 2016) began in the summer of 2018, following the recruitment and training of suitable personnel. In addition to the unit's activities in the Mediterranean, the monitoring work is also carried out in Lake Kinneret (Sea of Galilee) by professional personnel with specialized equipment.

Up until the establishment of the Marine Unit of the Nature and Parks Authority, the supervision of marine reserves comprised a designated ranger for the Rosh Hanikra reserve (from the 1990s), a marine ranger for the Carmel Coast, Shikmona, and Dor-Habonim reserves (from 2016), and a part-time ranger for the southern Mediterranean reserves - Avtach and Shikma.

As of May 2018, the monitoring system comprises 12 marine rangers and 4 enforcement boats in the Mediterranean. Under the agreement to enforce the fishing regulations, marine rangers engage in a variety of activities, including educating the fishers, monitoring fishing licenses on land and at sea, fishing licenses for boating, fishing equipment and haul (including in stores and markets), and enforcement of regulations pertaining to prohibited fishing methods and seasons. In addition, the rangers help to administer the established Mediterranean marine reserves, monitor reserve activity (including enforcing the specific fishing bans of each reserve that define what kind of fishing is permitted or prohibited), and enforce nature conservation laws (such as those that protect natural assets) also outside the reserves.

Appendix 1.3 Fishing bans for rod-fishing from shore in the Rosh Hanikra-Achziv reserve

As of April 2017, rod-fishing from shore has been prohibited in the Rosh Hanikra-Achziv reserve, with the exception of the southern stretch of the reserve from the monument to clandestine immigration in front of the Achziv resort village, along 500 m of the coastline, to the southern border of the reserve area surveyed (the Rosh Hanikra-Achziv reserve with its southern border at the archeological ruins). In this area, rod fishing from shore is allowed only for fishers using the "buss" fishing rod – a pole, line, and hook that extend to no further than 20 meters from the fisher.

This ban on fishing rods, which has been enforced along most of the reserve's coastline, was due to a significant increase in the number of fishers using rods in the reserve, and to the other elaborate fishing gear used that increased the overall fishing haul and effectiveness. In addition, there was an increase in the total biomass fished from the waters of the reserve, an increase in the number of turtles and additional protected natural assets caught in the areas of the reserve (such as rays and sharks that were accidentally caught by coastal fishers), as well as in the number of large fish from species that play an important role in the marine food web, such as groupers.

When the reserve was expanded to the northern borders of the city Nahariya, rod fishing on the southern end was allowed.

Appendix 2 - Methods

Appendix 2.1 Survey participants

The sampling, documentation, species definition, compilation of the survey database, and analysis of the findings were collaboratively carried out by researchers and students from several institutions: The School of Zoology - Tel Aviv University, The Steinhardt Nature Museum - Tel Aviv University, The Maurice Kahn Sea Research Station, The School of Marine Science - Haifa University, The School of Marine Science - Ruppin Academic Center, The Israel Oceanographic and Limnological Research, and the INPA.

Appendix 2.2 Survey description

Surveys were conducted in 2015, 2017, 2019, and 2021 during two seasons annually: spring and autumn. In total, 8 surveys were conducted using the "BioBlitz" approach (Table A1, Appendix 2): namely, intensive and simultaneous sampling and documentation of various taxonomic groups (fish, invertebrates, and algae in the benthic zone), inside the reserves and outside at control sites featuring similar substrate characteristics in terms of depth, type (rocky), and complexity. The sampling points at the control sites were within several meters to a few kilometers from the reserve borders, depending on the physical characteristics of the habitats. Each marine reserve (including its control sites) was allocated one working day per season. Sampling in the various reserves was conducted as far as possible on successive days.

Table A1 Survey dates in 2015, 2017, 2019, and 2021 by season

Reserve	Spring	Autumn	Year
Dor-Habonim	April 27	November 2	2015
Shikmona	April 28	November 3	2015
Rosh Hanikra-Achziv	April 29	November 5	2015
Gdor	April 30	November 12	2015
Dor-Habonim	June 4	October 15	2017
Shikmona	June 5	October 19	2017
Rosh Hanikra-Achziv	June 6	October 18	2017
Gdor	June 7	November 7	2017
Dor-Habonim	April 8	October 27	2019
Shikmona	April 29	October 28 November 27	2019
Rosh Hanikra-Achziv	April 30	October 31	2019
Gdor	April 7	October 30	2019
Dor-Habonim	May 2	October 10	2021
Shikmona	May 3	October 25	2021
Rosh Hanikra-Achziv	May 4	October 26	2021
Gdor	April 25	September 29	

Appendix 2.3 Survey work methods

The fish surveys were conducted using visual assays (observation and documentation only) in belt transects 25 m long and 6 m wide (3 m from each side of the tape measure). The location of the transects was determined by advance planning (deliberate sampling) with the goal of achieving a representative survey of the rocky terrain within both the reserve and the control sites. The substrate of the control sites was similar to that of the reserve in terms of physical characteristics (rocky substrate), distance from the coastline, and separation from other rocky areas.

The transects were carried out at three different depths, as detailed below, where possible (given the maximum depth of the surveyed reserve). At each depth, three sites were surveyed inside the reserve and two in the control area outside the reserve.

Appendix 2.4 Site location and depth

The transects were made parallel to the shore (to maintain a uniform depth along the transect). The number of transects per site was limited by the dive limitations of the surveyors and ranged from 2-4 transects per site.

Sampling was conducted, where possible, in three depth categories:

Shallow: 0-9 m.

Medium: 9.1-17.4 m, if the reserve possessed this depth range.

Deep: 17.5-26.4 m, if the reserve possessed this depth range.

In the Rosh Hanikra-Achziv reserve, all three depths were surveyed. In 2015 and 2017, two depths were surveyed (shallow and medium) and in 2019 and 2021 a deeper area was also surveyed, which is now outside the borders of the reserve (west of it). In the Dor-Habonim reserve, only shallow depths were surveyed. In Gdor, the shallow depth was surveyed and, in 2015 only, the medium depth outside the reserve was also surveyed.

Appendix 2.5 Sampling protocol

The survey points in and out of the reserve were marked on the morning of the survey by buoys and their locations were accurately documented. With the descent of the divers into the water, a maximum visibility distance test was carried out to ascertain the distance at which individual fish could be seen and identified. The test was conducted by two surveyors, one of whom held a page showing two black rectangles. The second surveyor swam away from the first one holding a rolling measuring tape. When the two rectangles appeared to merge into one, the surveyor stopped and recorded the distance. This distance was defined as the visibility measure in the water.

The range of visibility in all the surveys ranged from 3-30 m. In a survey conducted in the spring of 2019 in the Dor-Habonim and Gor reserves, the sea conditions made it difficult to carry out the survey, and visibility in the water was extremely low compared to the survey in the spring of 2017. The average visibility in Gdor in the spring of 2017 was 12.2±1.9 m compared to 4.6±0.9 m in the spring of 2019 . In Dor-Habonim, the average visibility in the spring of 2017 was 12.8±2 m compared to 6.5±1.7 m in the spring of 2019.

After testing the visibility range, the tape measure was rolled up and reused to measure a 25 m transect in the opposite direction, while recording all the fish found in the field, including identifying the species of the fish, assessing the number of individuals of the same species, the size of the fish, and their distance from the center of the transect. To analyze the data, we included all fish recorded at a distance of up to 3 meters in each direction from the center of the transect.

Documentation was carried out on waterproof forms. In the event that the survey was conducted by two experienced surveyors, two repetitions were obtained for the same transect, and the average value between the two surveyors was used in the data for analysis. In the event that one of the surveyors was less experienced, only the data of the senior surveyor were included.

After the surveyors finished the first transect, they continued to make another transect in the opposite direction (north or south). If the surveyors had sufficient dive time, they continued to make two more transects to the east or west of the starting point, thereby avoiding repetition of the same transect area.

Table A1 Survey efforts in 2015, 2017, 2019, and 2021 by site and depth

Site	Depth	Spring		Autumn		Total transects in the site
		Inside the reserve	Outside the reserve	Inside the reserve	Outside the reserve	
Rosh Hanikra-Achziv	Shallow	28	29	48	35	374
	Medium	31	30	44	46	
	Deep	16	19	22	26	
	Total	75	78	114	107	
Shikmona	Shallow	37	33	42	30	240
	Medium	26	17	38	17	
	Deep					
	Total	63	50	80	47	
Dor-Habonim	Shallow	63	60	66	66	256
	Medium		1			
	Deep					
	Total	63	61	66	66	
Gdor	Shallow	73	41	77	55	246
	Medium					
	Deep					
	Total	73	41	77	55	
Total all transects						1116

Appendix 2.6 Data analysis

All data analysis was carried out using R software, which is both a programming language and a work environment for analyzing statistics and creating graphics.

The data were analyzed for each survey separately, and a comparison was made between the survey sites, the different seasons, the year of the survey, and between the reserves for the outside control sites. The seasons in which surveys were carried out - spring and autumn - differ in the characteristics of fish communities (species composition and abundance) due to various environmental conditions (such as water temperature). However, a preliminary examination of the data revealed no clear and consistent differences between the seasons with reference to the indicators examined. Consequently, the results for each year include the average of all data collected during the two survey seasons.

The examined indicators are: the abundance of fish (the number of individuals found), the fish biomass, and the distribution of the fish lengths. The abundance and biomass were calculated as an average value by transect (150 m^2) while the distribution of lengths was based on all the lengths found

Appendix 2.7 Abundance and biomass

An examination of the overall biomass of fish inside and outside the reserves was carried out using the sizes estimated by the surveyors and the conversion from length to weight. Since a constant ratio of length to weight is maintained in individuals of the same species, it is possible, based on the species of fish, to convert its length into weight using the following formula:

$$W = aL^b$$

where W equals the weight of the fish, L equals the length of the fish, and the parameters a and b-are constants specific to the species. For the current survey, values a and b are from Fishbase (Froese and Pauly).

In some data analyses, there was a separation of commercial fish species and non-commercial species. Commercial species are edible fish that have economic value, such as species from the grouper subfamily (dusky grouper *Epinephelus marginatus*, mottled grouper *Myycteroperca rubra*, and golden grouper *Epinephulus costae*), all called "groupers" in this report, and the Sparidae family (such as the white seabream, zebra seabream, and saddled seabream).

Within commercial species, a further distinction was made between all species and Siganus (rabbitfish) species – *Signaus Rivulatis* and *Siganus Luridus* - which are of low-to-medium commercial value. These latter species are invasive species that have been very successful in the Israeli Mediterranean and, as herbivores that feed on algae and plant matter, they have caused a significant change in rocky substrate habitats. Since the habitat that characterizes rabbitfish is that of the rocky shallows, surveys such as BioBlitz offer a good opportunity to examine their relative status in the fish community.

Non-commercial species are not considered edible due to their taste, toxicity and, sometimes, because of body size, and therefore are not a target for fishing. These include, for example, species from the family of wrasses (the ornate wrasse, East Atlantic peacock wrasse, five spotted wrasse, etc.). The complete list of species, divided according to commercial and non-commercial species, is provided in Table A3 in Appendix 3.

Appendix 3 - Detailed results

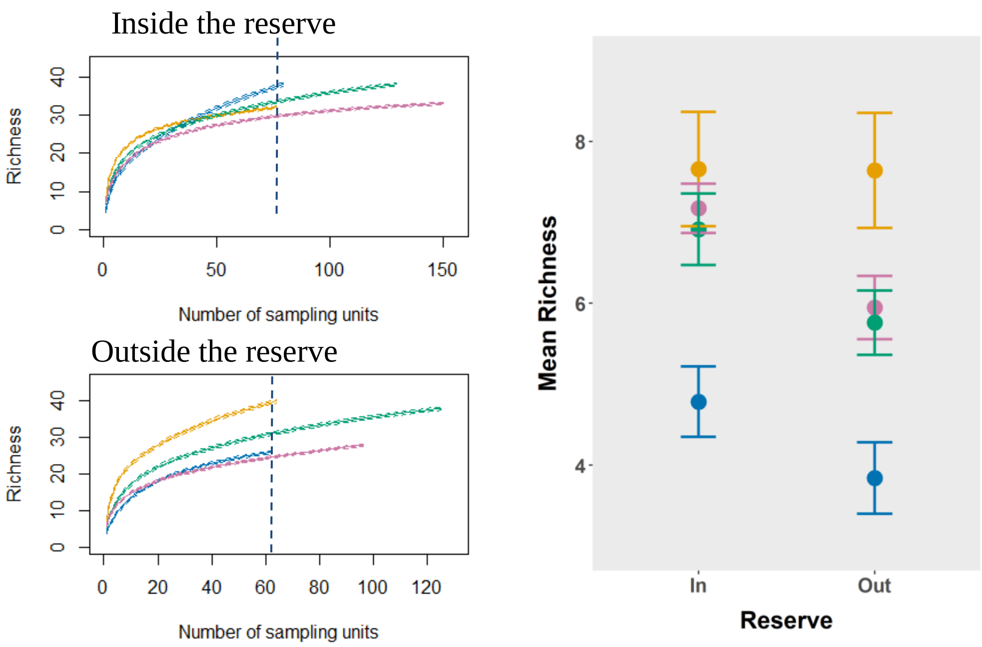


Figure 1A. The species richness in the various sites, in all surveys, at a shallow depth only, inside and outside the reserves. The colors represent the different sites Rosh Hanikra-Achziv - yellow, Shikmona - blue, Dor-Habonim - green, Gdor - pink). Average species richness for the transect (a): The X-axis indicates whether the sampling was conducted inside or outside the reserve and the Y-axis represents the average value for the transect. Error bars represent a 95% confidence interval. Species richness for the site inside the reserve (b) and outside the reserve (c): the X-axis represents the number of transects (sampling effort) and the Y-axis represents the number of species. The point of comparison between the sites is the point where the shortest trend line ends (dashed vertical line).

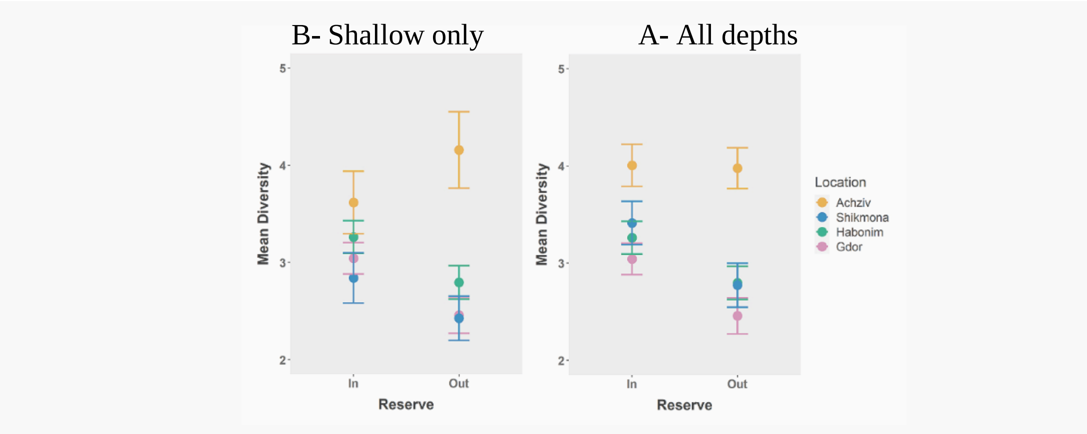


Figure 2A. The average species diversity for the transect at the different sites, in all surveys, at all sampling depths (a) and only at a shallow depth (b), inside and outside the reserves. The X-axis indicates whether the sampling was conducted inside or outside the reserve and the Y-axis represents the average value for the transect. The colors represent the different sites (Rosh Hanikra-Achziv - yellow, Shikmona - blue, Dor-Habonim - green, Gdor - pink). Error bars represent a 95% confidence interval.

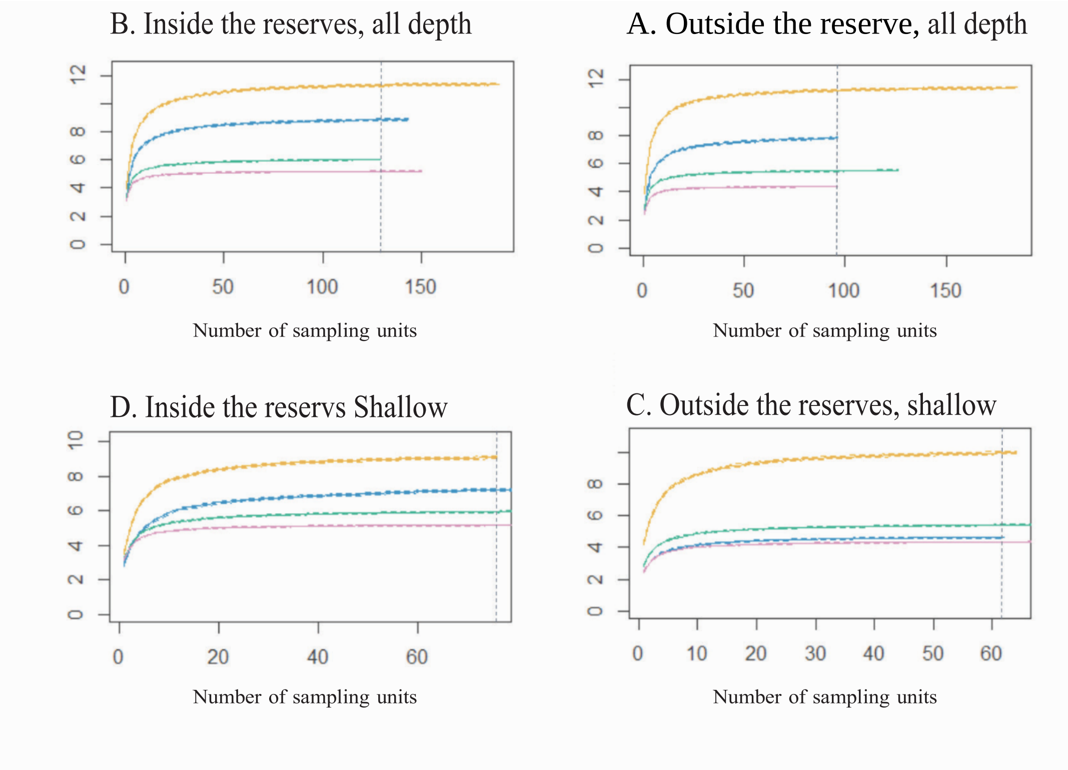


Figure 3A. Refraction curves for the variety of species at different sampling depths (upper panel - all sampling depths, lower panel - shallow depth only) at the various sites, in all surveys, outside the reserve (a, c) and inside the reserve (b, d). The X-axis represents the sampling effort (the number of transects) and the Y-axis the species diversity (Shannon Index). The colors represent the different sites (Rosh Hanikra-Achziv - yellow, Shikmona - blue, Dor-Habonim - green, Gdor - pink). The point of comparison between the sites is the point where the short trend line ends (vertical dashed line).

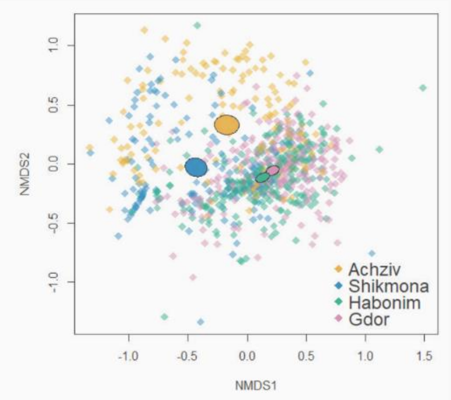


Figure 4A. nMDS ordination showing the distances between the fish communities in the various sites, in all surveys, inside and outside the reserves, at a shallow depth only. Distances were calculated using the Bray-Curtis index. Each point in the space represents a transect and is graphed according to the abundance values of each species. The values were log transformed. The colors represent the different sites (Rosh Hanikra-Achziv - yellow, Shikmona - blue, Dor-Habonim - green, Gdor - pink). Ovals in matching colors represent the separation between the fish communities in the different sites. 0.2=Stress.

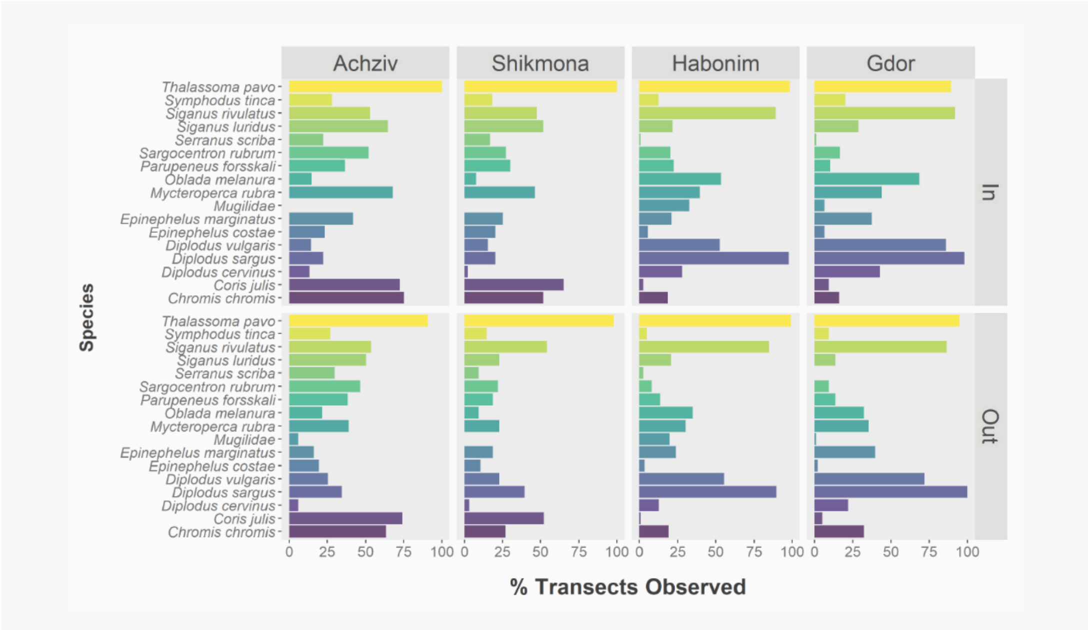


Figure 5A. Percentage of sightings of common species at each site, in all years, separated into reserves and control sites. Common species were defined as the 10 species observed in the greatest number of transects at a certain site. For each site, the percentage of observations was calculated as a ratio between the number of transects in which each common species was observed out of the total transects performed. The X-axis represents the percentage of transects in which any species was observed out of all the transects at the same site and the Y-axis shows the names of the species.

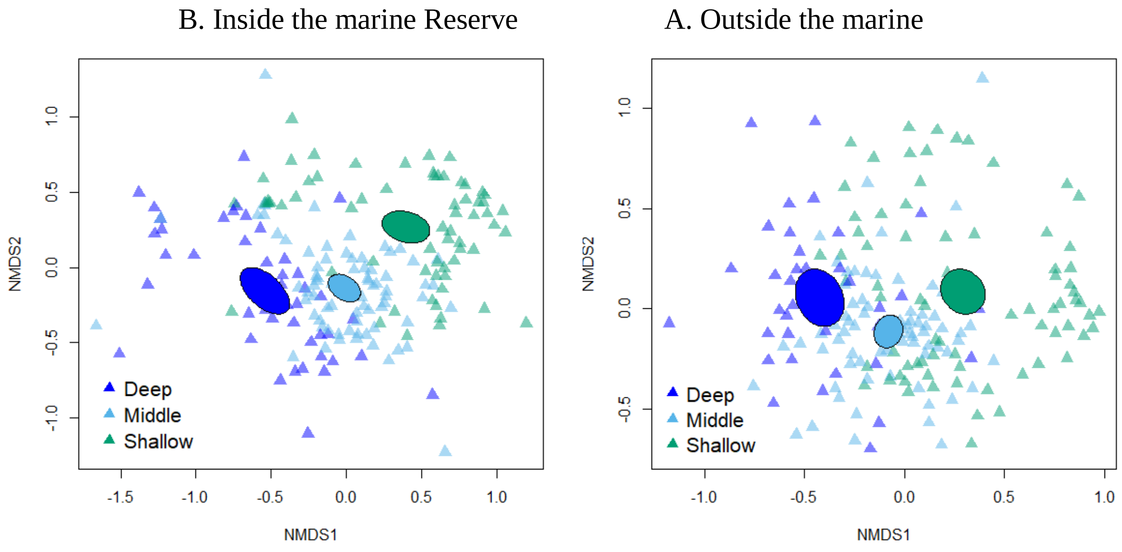
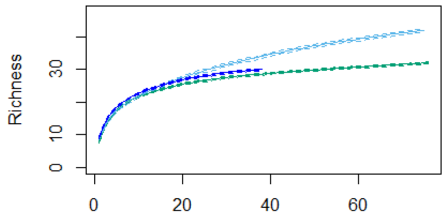


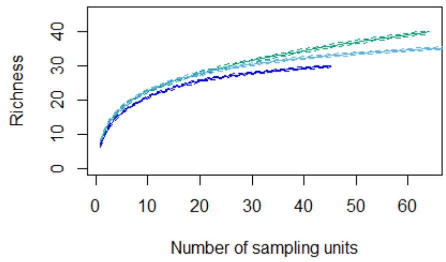
Figure 6A. nMDS ordination showing the distances between the fish communities at the different depths in Rosh Hanikra-Achziv, in all surveys inside the reserve (a) and outside the reserve (b). Distances were calculated using the Bray-Curtis index. Each point in the space represents a transect and is graphed according to the abundance values of each species. The values were log transformed. The colors represent the different depths (shallow-green, medium-light blue, deep-blue) (for sample sizes see Table A2, Appendix 2). Ovals in matching colors represent the separation between the fish communities at the different depths. Stress values: A-0.23, B-0.18.

A. Species richness

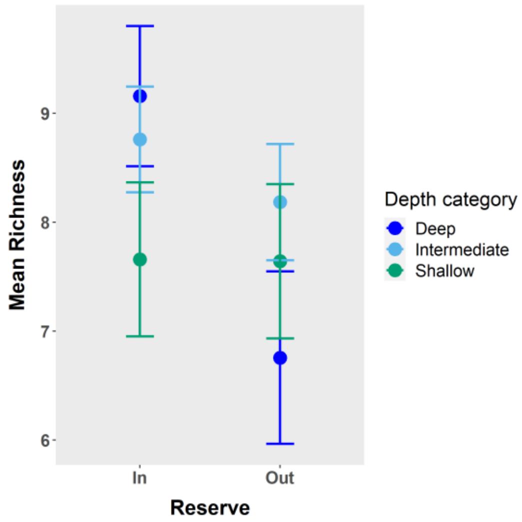
ii. Species richness per depth, inside the reserve



iii. Species richness per depth, outside the reserve

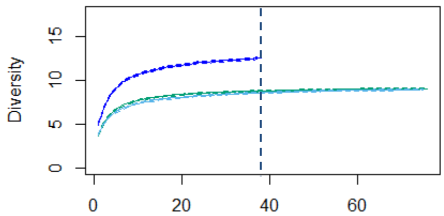


i. Mean species richness per transect

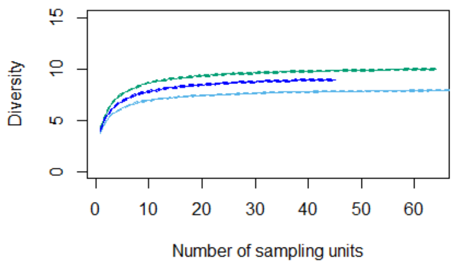


B. Species diversity

ii. Species diversity per depth, inside the reserve



iii. Species diversity per depth, outside the reserve



i. Mean species diversity per transect

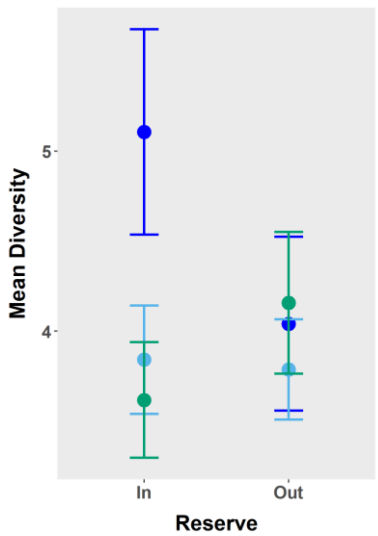


Figure 7A. Species richness (a) and diversity (b) at the Rosh Hanikra-Achziv site at the different sampling depths in all surveys. Species richness and diversity (Shannon Index) average by transect (a.i and b.i), right panels: The X-axis indicates whether the sampling was conducted inside or outside the reserve and the Y-axis represents the mean value for the transect. Error bars represent a 95% confidence interval. Species richness and diversity for the site (a.ii, a.iii, b.ii and b.iii), left panels: the X-axis represents the number of transects (sampling effort) and the Y-axis represents the total value of the number of species. The comparison point between the depths is the point where the shortest trend line ends (dashed vertical line). The colors represent the depth categories (shallow-green, medium-light blue, deep-blue) (for sample sizes see table A2, Appendix 2).

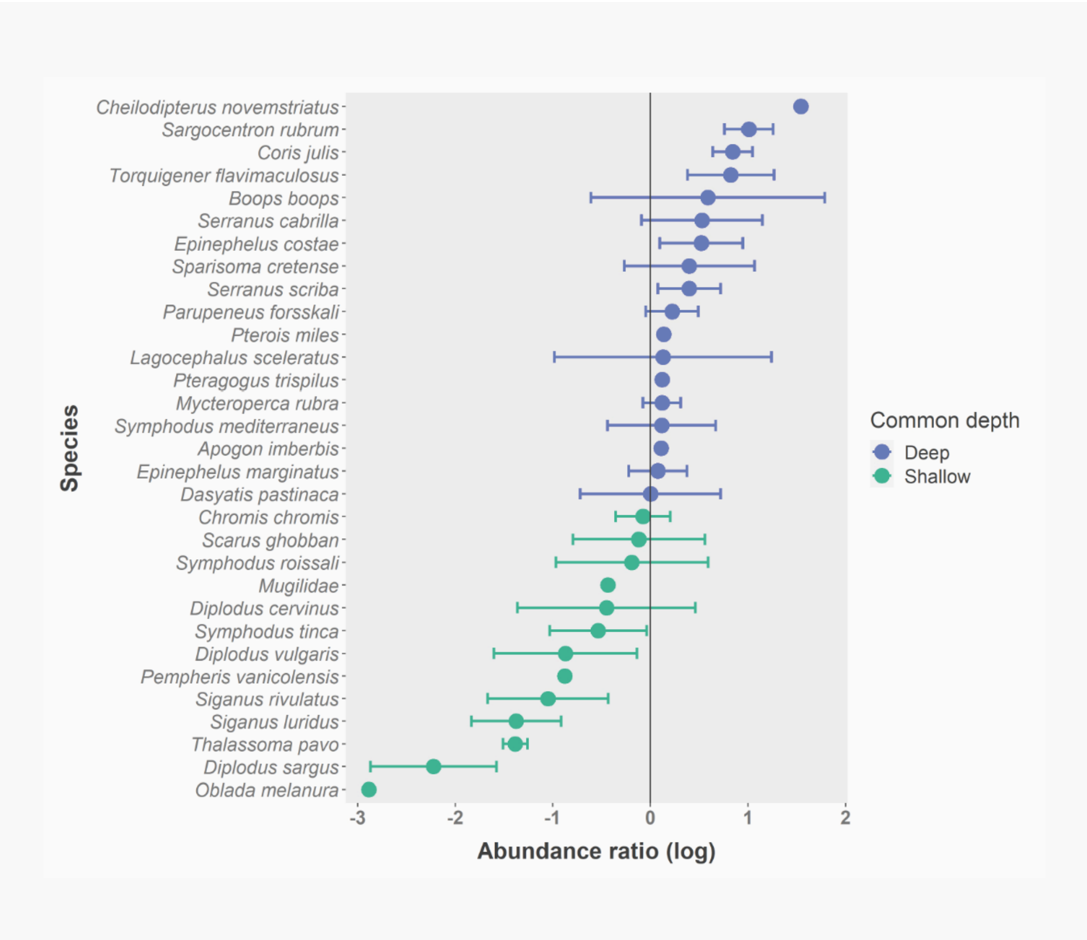


Figure 8A. Distribution of the species abundance in the shallow and deep waters in Rosh Hanikra-Achziv. For each species, the ratio between the average abundance per transect at the deep depth and the average abundance per transect at the shallow depth was calculated. The ratio was log transformed. A negative ratio indicates that the frequency of the species was higher in the shallow depth (green), and a positive ratio indicates a higher frequency in the deep depth (blue). Species observed in less than 10 transects were not included in the analysis. Error bars represent standard error. Species for which no error bars appear were only observed at one of the two depths.

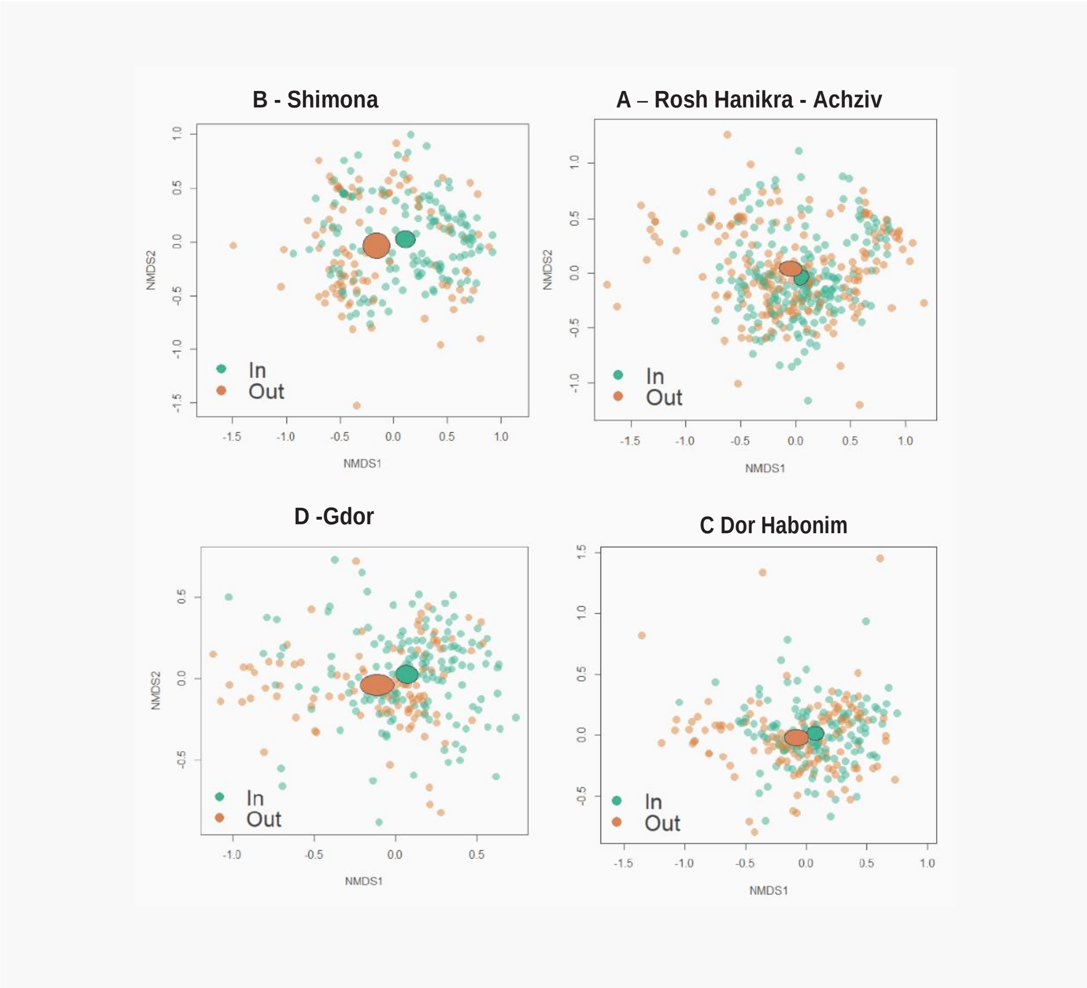


Figure 9A nMDS ordinations showing the distances between the fish communitites inside and outside the reserve at each site. The data at each site: (a) Rosh Hanikra-Achziv, (b) Shikmona, (c) Dor-Habonim, (d) Gdor, include all years and seasons of sampling. Distances were calculated using the Bray-Curtis index. Each point in the space represents a cross-section and is graphed according to the abundance values of each of the species. The colors represent the inside of the reserve (green) and the control sites outside it (brown) (for sample sizes see Table 2A, Appendix 2). Ovals in matching colors represent the separation between the fish communities inside and outside the reserves. The stress values were: 0.21, 0.20, 0.18 and 0.20 (for Rosh Hanikra-Achziv, Shikmona, Dor-Habonim and Gdor, respectively).

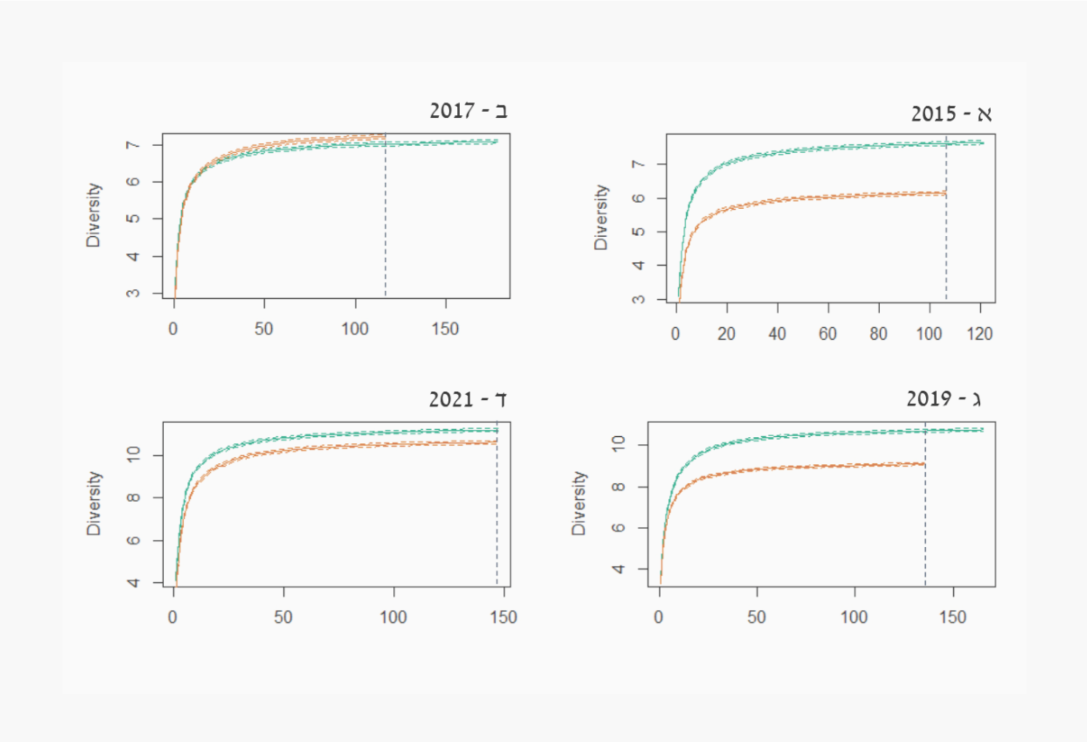


Figure 10A. Refraction curves for the variety of species in the different sampling years, inside and outside the reserves. The X-axis represents the sampling effort (the number of transects) and the Y-axis the species diversity (Shannon Index). The colors represent whether the sampling was conducted inside (green) or outside the reserve (brown). The years of the survey appear on the graphs, in ascending order from right to left. The point of comparison between inside and outside the reserve is the point where the shortest trend line ends (dashed vertical line).

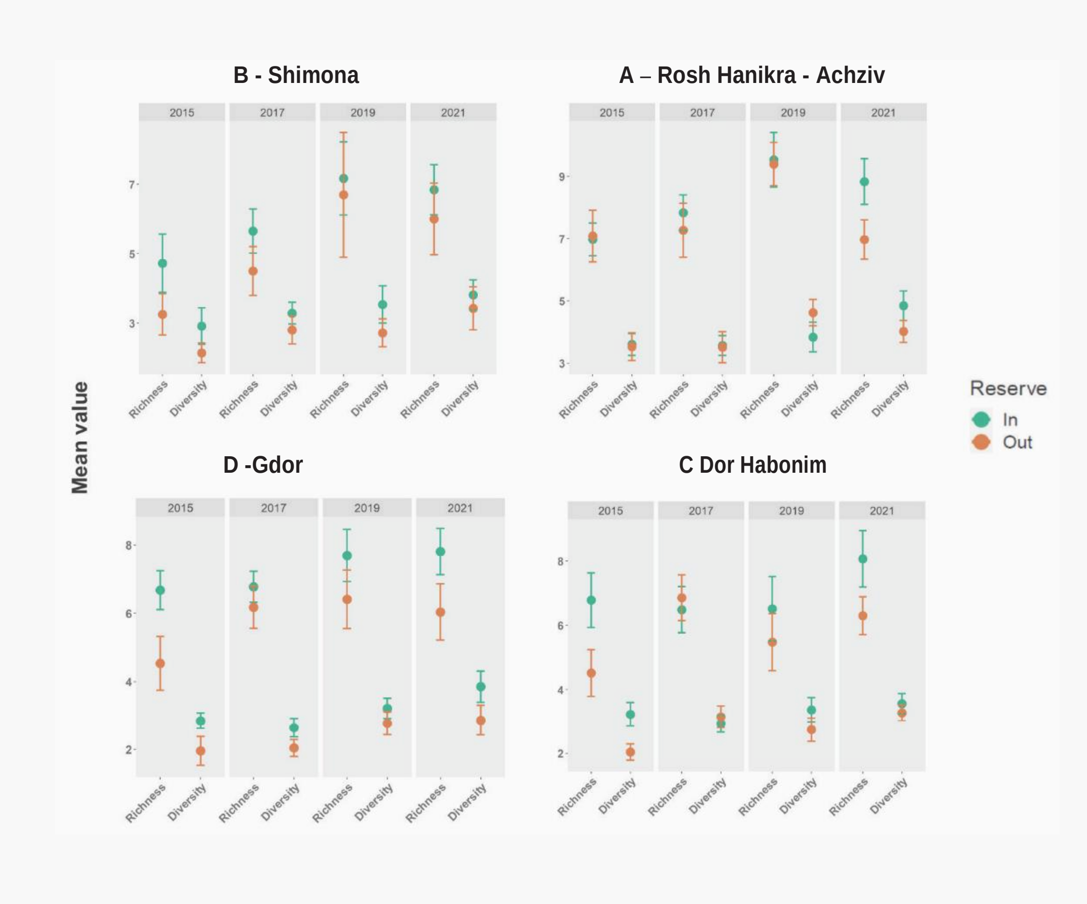


Figure 11A. Average species richness and diversity per transect at each site over the years, at all depths, inside and outside the reserve (A - Rosh Hanikra-Achziv, B - Shikmona, C - Dor-Habonim, D - Gdor). The X-axis represents the index - Richness or Species Diversity, and the Y-axis represents the average value for the transect. The colors represent inside (green) and outside the reserve (brown) (for sample sizes see Table 2A, Appendix 2).

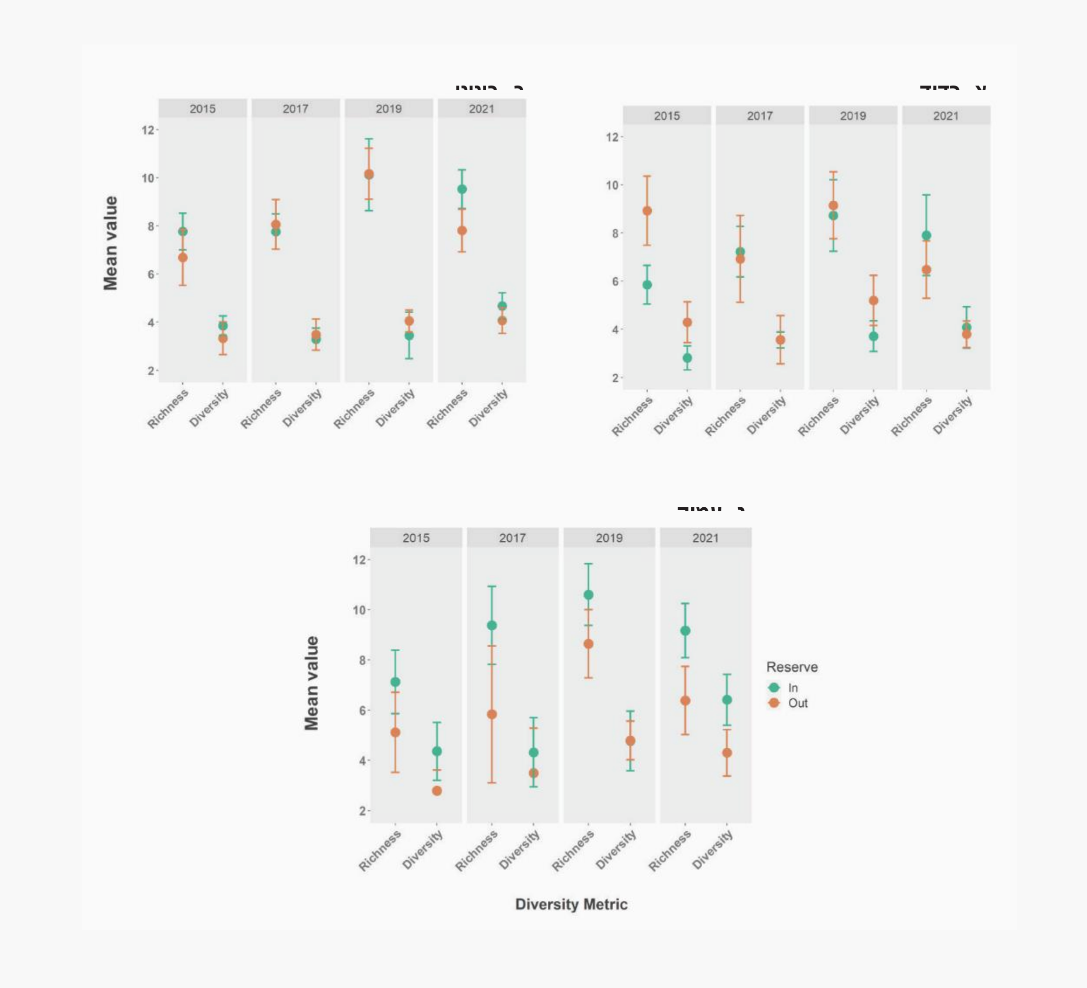


Figure 12A. Average species richness and diversity per transect for Rosh Hanikra-Achziv over the years, inside and outside the reserve, at the different depths: (a) shallow, (b) medium, (c) deep (see details of depths in Appendix 2.4). The X-axis represents the index - Richness or Species Diversity, and the Y-axis represents the average value for the transect. The colors represent inside (green) and outside the reserve (brown) (for sample sizes see Table 3A, Appendix 2). Error bars represent a 95% confidence interval.

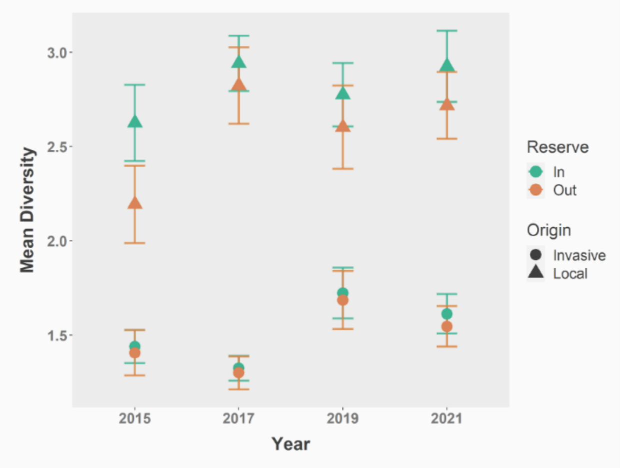


Figure 13A. The average diversity of native and invasive species per transect inside and outside the reserves, throughout the years of the survey, in shallow depths only, at all sites. The data includes only surveys carried out at a shallow depth for comparison. The X-axis represents the survey years and the Y-axis represents the average species diversity value for the transect Colors represent the reserve area (green) and control areas (brown) (for sample sizes see Table A2, Appendix 2). Shapes represent the origin of the species - native (triangle) or invasive (circle). The error bars represent a 95% confidence interval.

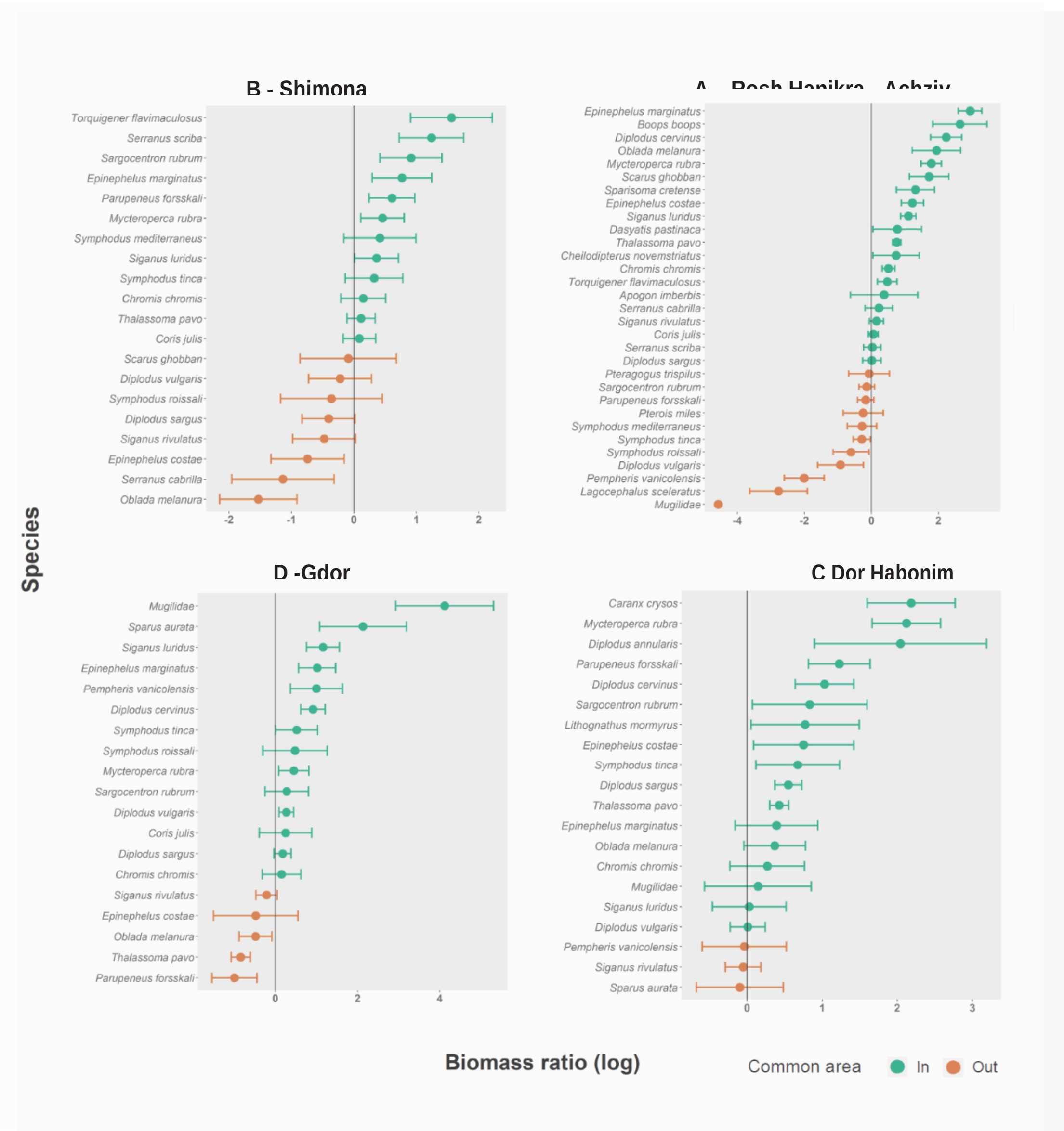


Figure 14A. Distribution of species biomass inside and outside each reserve, in all surveys (at all depths and sampling seasons). For each site (a) Rosh Hanikra-Achziv, (b) Shikmona, (c) Dor-Habonim, (d) Gdor, the species observed in at least 10 transects are shown. For each species, the ratio was calculated between the average biomass per transect inside the reserve and the average biomass per transect outside the reserve: a positive ratio indicates that the biomass of the species was higher inside the reserve (green), and a negative ratio indicates a higher biomass outside the reserve (brown). The ratio was log transformed. Error bars represent standard error. Species for which error bars do not appear were only observed in one area (inside or outside the reserve).

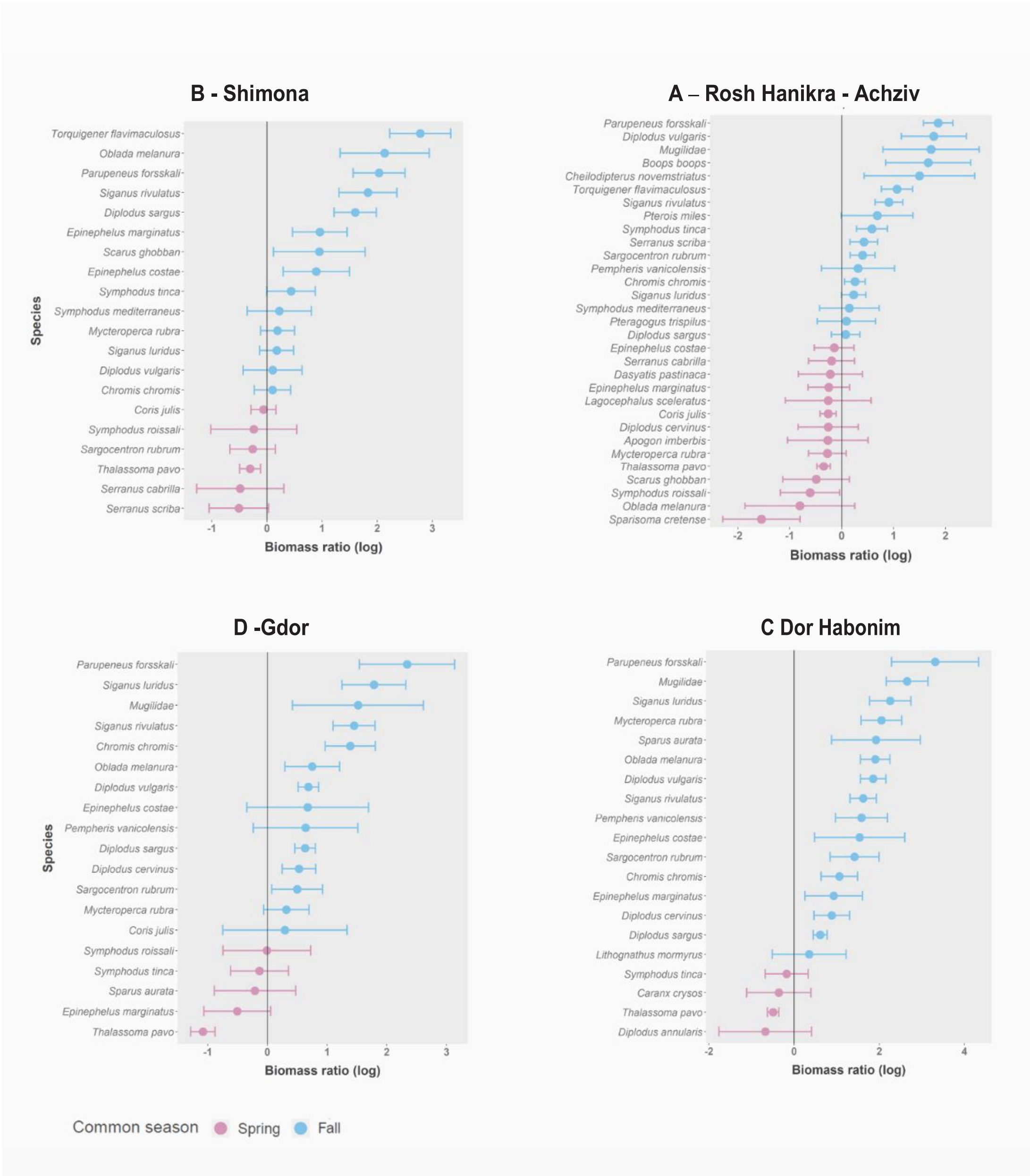


Figure 15A. Distribution of species biomass in the two sampling seasons at each site (inside and outside the reserve together), in all years, at all depths. Each site (a) Rosh Hanikra-Achziv, (b) Shikmona, (c) Dor-Habonim, (d) Gdor shows the species observed in at least 10 transects. For each species, the ratio was calculated between the average biomass per transect in the fall and the average biomass per transect in the spring: a positive ratio indicates that the biomass of the species was higher in the fall (light blue), and a negative ratio indicates that it was higher in the spring (purple). The ratio of biomass between seasons was log transformed. Error bars represent standard error.

Figure 16A. nMDS ordinations showing the distances between the fish communities in the different seasons at each site (inside and outside the reserve together), in all years, at all depths. The data at each site) (a) Rosh Hanikra-Achziv, (b) Shikmona, (c) Dor-Habonim, (d) Gdor, include all years of the survey. Distances were calculated using the Bray-Curtis index. Each point in the space represents a cross-section and is graphed according to the abundance of each species. The values were log transformed. The colors represent the spring season (purple) and the fall season (light blue) (for sample sizes see Table A2, Appendix 2). Ovals in matching colors represent the separation between the fish communities inside and outside the reserves. Stress values: 0.21, 0.20, 0.18 and 0.20 (for Rosh Hanikra-Achziv, Shikmona, Dor-Habonim and Gdor, respectively).

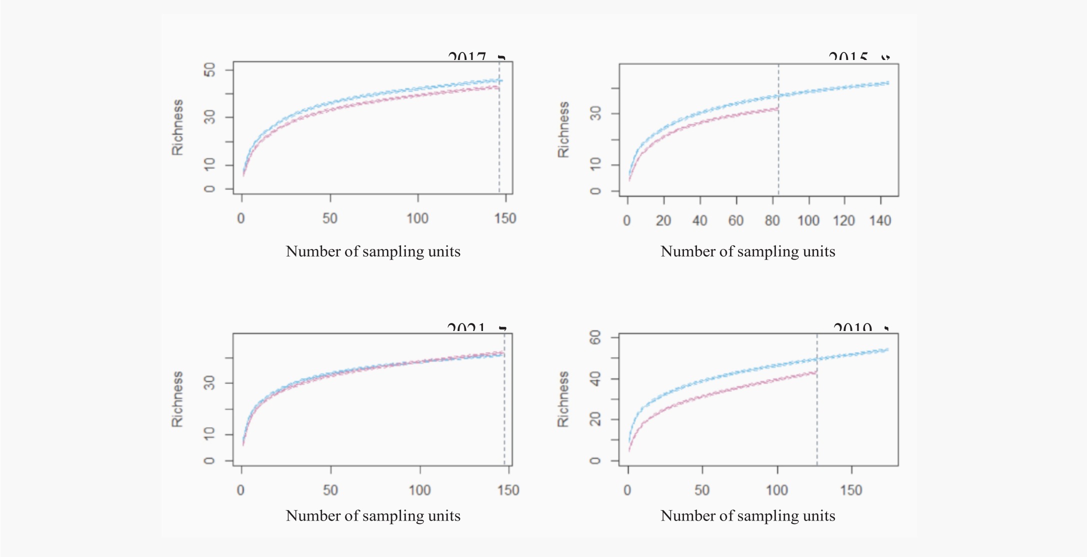


Figure 17A. Refraction curves for species richness in the different sampling years, in the fall and spring seasons, at all depths, at all sites, inside and outside the reserves. The X axis represents the sampling effort (number of transects) and the Y axis the species richness. The colors represent the sampling season (fall - blue, spring - purple). The years of the survey appear on the graphs, in ascending order from right to left. The point of comparison between the seasons is the point where the shortest trend line ends (dashed vertical line).

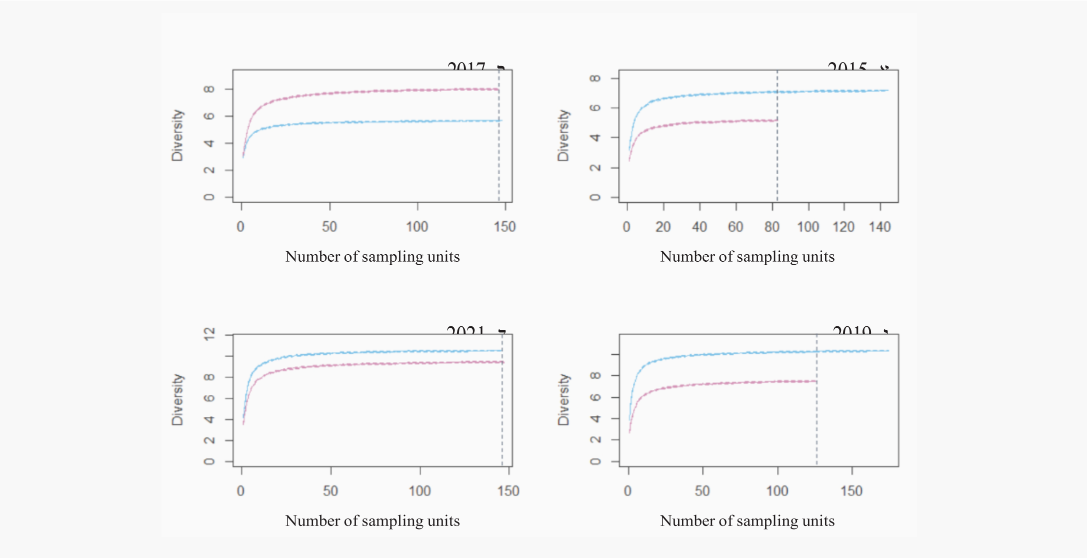


Figure 18A. Refraction curves for species diversity in the different sampling years, in the fall and spring seasons, at all depths, at all sites, inside and outside the reserves. The X-axis represents the sampling effort (the number of transects) and the Y-axis the species diversity (Shannon Index). The colors represent the sampling season (fall - blue, spring - purple). The years of the survey appear on the graphs, in ascending order from right to left. The point of comparison between the seasons is the point where the shortest trend line ends (dashed vertical line).

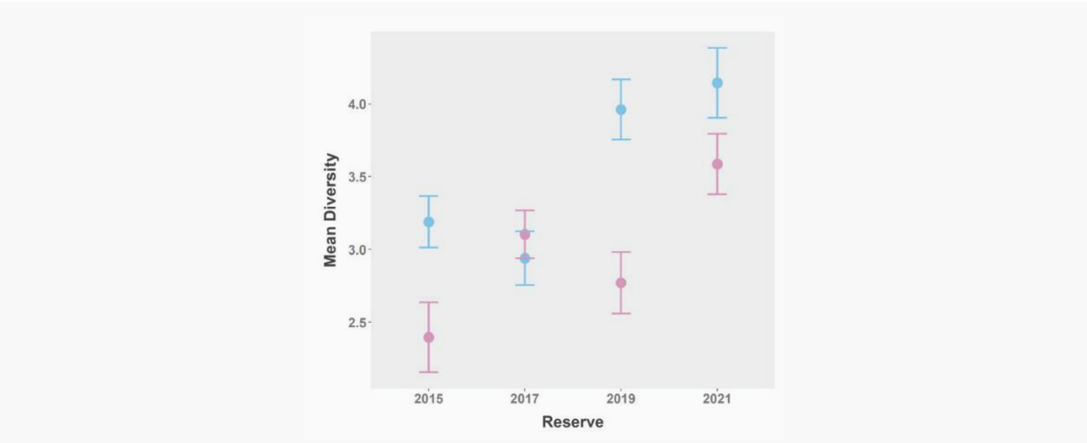


Figure 19A. The diversity of species in the fall and spring seasons, in the different sampling years, at all sites, inside and outside the reserves, in the shallow depth only. The X-axis represents the years of the survey and the Y-axis represents the average value of species diversity (witness index) for the transect. The colors represent spring (purple) and fall (light blue) (for sample sizes see Table A2, Appendix 2). The data includes only surveys carried out at a shallow depth for comparison. Error bars represent a 95% confidence interval.

Table 5A. The results of the Adonis tests to test the effect of different variables on the structure of the fish community. An explanatory variable indicates a variable whose influence on the community structure was tested, the depth indicates which depth categories were included, the number of transects indicates the number of transects included in the analysis, R2 indicates the amount of variance explained by the explanatory variable, and the p-value indicates whether the results are significant (a value of less than 0.05 is significant).

Explanatory variable	Depth	Number of transects	R2	p-value
Location (Sites)	Shallow	781	0.15	0.001
Location (Sites)	Medium	1114	0.23	0.001
Location– Plamachim and Poleg Control Sites,	Shallow	401	0.16	0.001
Location– Plamachim and Poleg – Control Sites,	Medium	126	0.14	0.001
Status (MPA or control site)	Shallow	781	0.01	0.001
Status (MPA or control site) – Rosh Hanikra -Achziv	Medium	374	0.02	0.001
Status (MPA or control site) – Shikmona	Medium	239	0.03	0.001
Status (MPA or control site) – Dor HaBonim	Shallow	255	0.02	0.001
Status (MPA or control site) – Gdor	Shallow	246	0.04	0.001
Season (Spring or Fall)	Shallow	781	0.11	0.001
Season (Spring or Fall)- Rosh Hanikra -Achziv	Medium	374	0.04	0.001
Season (Spring or Fall)– Shikmona	Medium	239	0.08	0.001
Season (Spring or Fall)– Dor HaBonim	Shallow	255	0.18	0.001
Season (Spring or Fall)– Gdor	Shallow	246	0.20	0.001
Depth - Rosh Hanikra -Achziv	Medium	374	0.16	0.001

Table 6A. ANOVA test results (similar to a linear model) for species richness inside and outside the reserves over the years. The interaction between years and protection status (inside/outside reserve) was also examined. Variables whose effect is statistically significant (p value less than 0.05) are marked in green in the p-value column.

Variable	Estimate	Std. Error	p-value
Intercept (Year 2015, Reserve In)	2.87	0.15	<0.001
Year 2017	0.02	0.19	0.894
Year 2019	0.41	0.19	0.033
Year 2021	0.78	0.20	<0.001
Reserve – Out	-0.44	0.21	0.040
Year 2017 * Reserve Out	0.26	0.29	0.363
Year 2019 * Reserve Out	0.28	0.28	0.444
Year 2021 * Reserve Out	0.01	0.29	0.980

Table 7A. ANOVA results (similar to a linear model) for species diversity (Shannon Index) inside and outside the reserves over the years. The interaction between the years and protection status (inside/outside reserve) was also examined. Variables whose effect is statistically significant (p value less than 0.05) are marked in green in the p-value column.

Variable	Estimate	Std. Error	p-value
Intercept (Year 2015, Reserve In)	6.04	0.32	<0.001
Year 2017	0.41	0.40	0.307
Year 2019	1.04	0.41	0.011

Year 2021	1.30	0.43	0.003
Reserve – Out	-1.11	0.46	0.015
Year 2017 * Reserve Out	0.71	0.61	0.245
Year 2019 * Reserve Out	0.09	0.61	0.872
Year 2021 * Reserve Out	-0.15	0.62	0.799

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For any clarification questions or comments, please contact Dr. Ruthy Yahal, Marine Ecologist, Science Division, Nature and Parks Authority - Ruthy@npa.org.il

Marine Bioblitz

A quantitative Survey of Marine Nature Reserves in the Israeli Mediterranean Sea

Summary report for surveys conducted

in 2015, 2017, 2019, 2021

Chapter 3: Benthic community

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Israel Nature and Parks Authority, 2022

ISRAEL NATURE AND PARKS AUTHORITY

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Opening Remarks

Surveys of marine reserves in the Israeli Mediterranean Sea have been carried out since 2015, during two seasons biannually, totaling eight surveys to date. The surveys initially included control sites near the reserves and have since been expanded to include additional sites of interest along the Israeli coastline. This highly comprehensive survey includes fish, invertebrates, and algae.

The main significant result from the report is that marine reserves do indeed offer protection from fishing and influence the composition of fish, invertebrate, and algae communities, or, with some changes, have a real potential to do so. The Rosh Hanikra Marine Reserve, a relatively large reserve where fishing bans have been enforced for many years, has been shown to protect the fish well, as is evident from the biomass of the commercially valuable fish species, especially the dusky grouper, a flagship species in the Eastern Mediterranean. There is an abundance of groupers in the reserve, with a high number of fish that have reached the necessary breeding size. The success of reserves in protecting fish is also evident in other marine reserves, but the differences in the other marine reserves are much less evident, mainly because they are smaller and the edge effect (most of the reserve is "edge)" is significant.

The obvious conclusion is, in my opinion, sharp and clear. The Nature and Parks Authority' master plan for marine reserves, in accordance with the general policies of the Planning Committee, is fundamental to nature conservation in the sea and offers the ideal way to protect nature everywhere, and particularly through the establishment of marine reserves in the Mediterranean Sea.

I would like to thank the very many researchers and students from all the relevant research institutions for their immense efforts invested in consistently carrying out the surveys. I also thank to Eyal Miller, Yigael Ben Ari, and all the marine rangers for their great logistical support and their participation in the survey; Mai Lazarus, Ori Frid Landau1 and Rei Diga for analyzing the data and writing the various chapters of the report; and Ruthy Yahel for contributing to the writing but especially for being the inspiration and driving force of the entire project.

Dr. Yehoshua Shkedy, Chief Scientist, INPA

Summary

The world's seas and oceans are in decline due to the increasing impact of human activities and their derivatives such as fishing, physical destruction of habitats, pollution, global atmospheric changes, and the invasion of alien species. The protection of diverse habitats and the establishment of large Marine Protected Areas (MPAs) offer a central tool in preserving and restoring ecosystems and the animals and plants that inhabit them.

The current report presents the impact of four MPAs in the Israeli Mediterranean Sea on the benthic community – the algae and invertebrates inhabiting the rocky substrate. The surveys were carried out in 2015, 2017, 2019, and 2021 during two seasons: spring and fall, both inside the reserves and outside them in nearby control areas with similar characteristics. The species included in these surveys belong to a wide range of taxonomic groups and differ in their systematics, trophic level, and ecological function in the ecosystem. Thus, the responses of the benthic community to the protection afforded by marine nature reserves are complex and challenging to estimate. In addition, from 2019 the survey methods underwent change in order to establish a reproducible and informative protocol for an ongoing monitoring program.

The results of the surveys of the benthic community have yielded an up-to-date species inventory of algae and invertebrate species in the rocky substrate inside the nature reserves and the adjacent control areas. Algae cover a considerable percentage of the rocky substrate (between 40%-90%) throughout all the years and the community structure changes between seasons. Inside the nature reserves, on average, a higher number of algae species was observed compared to in the control areas. Moreover, differences in the algal community composition were observed between areas within the nature reserves and the control areas outside of them, but no specific species composition was observed, probably due to the high spatio-temporal variability of this community.

The invertebrates surveyed belong to eight different taxonomic phyla: bryozoans, cnidarians, crustaceans, echinoderms, mollusks, annelids, sponges, and tunicates. These surveys enabled us to report the cover and density of each group and the structure of the benthic community as a whole. Invertebrates accounted for between 8% to 18% of the coverage of the rocky substrate where sponges, bryozoans, and bivalves are the most

dominant groups in terms of density and coverage of the substrate. No differences were observed in the total invertebrate coverage inside the nature reserves compared to the control areas outside of them, but the community structure differed between sites. The community composition of key taxonomic groups (sponges and tunicates) did not differ between areas inside the nature reserves and the control areas outside of them. However, differences were observed in the sponge community structure, density, and coverage between different sites and different bottom depths, stressing the need to protect different areas and depths along the Israeli Mediterranean coastline.

A transition from the dominance of native species to the dominance of introduced species was observed throughout the sampling years within the nature reserves and the control areas outside of them. In contrast, all species of sponges surveyed were native to the Mediterranean Sea.

The great taxonomic diversity along with the difficulties in species identification pose significant challenges to surveying, analyzing, and estimating the ecological status of the benthic community and the effectiveness of marine nature reserves in its conservation. During the following surveys, our goal was to fine-tune the methods in order to characterize indicator species for the state of the ecosystem and to determine the relevant indices for assessing the status of marine nature reserves in the future.

Table of Contents

1 / Introduction

The world's seas and oceans are in decline due to the increasing impact of human activities and their derivatives, such as fishing, physical destruction of habitats, pollution, global atmospheric changes, and the invasion of alien species (He & Silliman 2004, Islam & Tanaka, 2002; Stachowicz et al., 2010; Bruno, & Hoegh-Guldberg, 2019). Besides the obvious damage to the marine ecosystem and all its components, the services it provides to humans are also impacted – food supply, oxygen and energy sources, regulation of atmospheric processes, etc. (Worm et al., 2006). These services depend on the existence of healthy ecosystems (Palumbi et al., 2009). In order to preserve the natural resources necessary to our existence and at our disposal, we must protect the marine environment.

Among the known tools for protecting the marine environment, protecting representative habitats and large areas constitutes an effective and important tool for preserving and strengthening the natural ecosystem (Edgar et al., 2014). We can divide nature reserves into two main categories: no-take Marine Protected Areas (MPAs) and partially protected areas. MPAs are areas with defined borders, in which the physical environment, animals, and plants are protected through the prohibition of detrimental activities such as fishing, aquaculture, digging, mining and drilling, disposal of pollutants, and more. In contrast, activities such as non-motorized boating, swimming, and diving are allowed in MPAs. MPAs make it possible to preserve and restore the habitats of all the components of the food web that dwell within them, as well as the overall ecological functioning of the area (Lester et al., 2009,) and offer a central tool for the protection and restoration of specific species (Giakoumi et al., 2017)

The scientific literature published in the last decade (Guidetti et al., 2017; Giakoumi et al., 2017; Edgar et al., 2014) clearly indicates the benefits that no take MPAs have in ecological functioning and in achieving conservation goals compared to only partially protected marine areas (Giakoumi et. al, 2017). The factors that enable the success of a reserve are its status as a no-take reserve, high levels of enforcement, a large reserve area, age of the reserve, and distance from sources of human disturbance (Edgar et al., 2014). The level of enforcement in MPAs has been proven to be a key factor in the efficiency and achievement of the reserves' goals, even in older MPAs that have a relatively small area (up to 30 square kilometers; Giakoumi et al., 2017). The success of an MPA in which any exploitation or harming of natural resources is prohibited, compared to areas that are outside the MPA, manifests itself in a significant increase in general biomass, abundance, individual size, and species richness (Lester et al., 2009).

The impact of MPA's along the Israeli Mediterranean coastline on fishing and the fish community have been discussed in Chapters 1 and 2 of this report. The current chapter focuses on the benthic community – algae and invertebrates inhabiting the rocky substrate inside and outside marine nature reserves.

In contrast to the fish community, the species included in the invertebrate community belong to a wide range of taxonomic groups and differ in their systematics, trophic level, and ecological function in the ecosystem. Thus, the responses of the invertebrate community to the protection offered by marine nature reserves are complex and challenging to estimate.

The potential effects of marine nature reserves with a ban on fishing and the exploitation of other resources were broadly discussed by Lester et al. (2009). The current review compares data from 124 marine reserves across the world to data before the declaration of MPAs or in control areas outside of them. In their work, Lester et al. compared the biomass, density, individuals' size, and species richness of fish, invertebrates, and algae. In general, the impact of MPA's on benthic invertebrates and algae was indirect, unlike the impact on fish (especially commercially preferred species, see Chapter 1), which showed an increase in the size and number of individuals inside MPA's. They found that invertebrates respond in different ways. For example, while the density of invertebrates has increased substantially in many MPAs, a decrease in their density was observed in other MPAs. This decrease was probably due to both the direct and indirect effects of predation, and competition over food or space, etc. The set of indices of invertebrates and algae (biomass, density, species richness, size etc.) were either not correlated directly to the presence of MPAs, or the presence of an MPA explained only a small proportion of the observed variability.

It is possible be that the high variability was due to the large differences between MPAs such as: the MPA size, age, location, management tools applied, and the extent of fishing before and after the declaration in its area (Lester et al., 2009).

In addition to examining an MPA's effect, this report summarizes the status of invertebrates and algae on the rocky substrate in the areas surveyed: the percentage cover of the substrate, species' inventories, and characteristics of the groups – for example in relation to the presence of invasive species.

1.1 / Marine reserves in Israel

From the mid-1960s to the beginning of the 2000s, seven small marine reserves were established in Israel, encompassing a total area of 10.4 km2, which constitutes about a quarter of Israel's maritime area in the Mediterranean Sea. Most of the reserves extend from the coastline to a few hundred meters westward into the sea. These reserves protected most of the islets off the coast of Israel and the habitats of the tidal zone and the shallow water environment but did not represent all the habitats in the marine environment. Due to the increase in the scope of economic activity at sea and the intensifying threats to the marine environment, there has been increased consensus among both environmental organizations and in the government planning institutions that it is necessary to take additional actions to preserve the marine environment in general and the natural assets and marine habitats in particular (Yahel & Angert, 2012; Ministry of Energy, 2016; Director of Planning, 2020; Technion, 2015.)

The master plan for marine reserves was prepared by the Nature and Parks Authority (INPA) (Yahel and Angert, 2012). The plan is based on the protocol of the Barcelona Convention for the Protection of the Mediterranean Sea and the principles that appear on the subject of "Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, 1995". These protocols include the protection of representative parts of all marine habitats (from the most common to the rare and unique), marine environments that are in danger of disappearing, environments vital for the survival, reproduction, and restoration of important species in the system, and sites of special importance from a scientific or other aspect. In addition to the need to protect representative parts of the marine environment, the master plan also refers to the scope of the protected area. The United Nations CBD (Convention on Biological Diversity) defined the conservation targets in the sea as comprising 10% of the total marine area of each country by the year 2020. The Aichi Biodiversity Targets for the scope of the conservation area will shortly be updated and will increase the marine protected area to 30% by the year 2030. This goal was also adopted within the framework of the UN's Sustainable Development Goals (SDGs).

A comprehensive policy for the planning of the sovereign area of the Israeli Mediterranean Sea was published in 2020 by the Planning Director and designated 8.6% of the sovereign water area as target areas for MPAs (Planning Director, 2020) in accordance with the master plan and the policy document promoted by the INPA in collaboration with the Society for the Protection of Nature (SPN) and other environmental organizations. In 2019, plans for the marine reserve "Yam Rosh Hanikra" were announced, expanding the existing reserve (where the surveys were conducted) to a distance of 15 km2 from the coastline and covering an area of 100 km2. In 2021, plans for the "Rosh Carmel" marine nature reserve were announced, expanding the existing Shikmona reserve to a distance of about 12.5 km from the coast, and covering an area of about 50 km2. Today, about 4% of the surface of the Israeli sovereign waters is defined as a nature reserve. In addition, the Avtach marine nature reserve between the cities of Ashdod and Ashkelon is in advanced planning stages with the aim of expanding its protection of the shallow sandy habitat on the Mediterranean seabed, up to a distance of about 7 km west of the coastline and a maximum bottom depth of 38 m. In addition, plans are being promoted for offshore nature reserves across from the Sharon and Carmel coastlines, which will protect the kurkar ridges and the sponge gardens that grow on it, at

13-17 km off the coastline and at a depth of 85-135 meters. These reserves and additional reserves, once established, will protect diverse habitats in the sea and over large areas suitable for the habitat of marine animals.

This report summarizes eight surveys, conducted in 2015, 2017, 2019, and 2021, and examines the effects of the established MPAs with rocky substrates on the benthic community within them.

2 / Survey objectives

The surveys conducted in 2015, 2017, 2019, and 2021 were designed to examine whether the currently established MPAs protect the flora and fauna within their borders, and to assess whether they contribute to the stabilization of the ecosystem both inside and outside the reserves.

Four general goals were defined for the surveys:

Document the species found inside and outside the MPAs.

Describe the spatial patterns of marine flora and fauna down to a depth of about 25 m along the Israeli coastline.

C. Compare the animal and plant communities within Mediterranean Sea MPAs to similar nearby control areas with similar substrates.

D. Create a quantitative baseline of the flora and fauna currently found inside MPAs for future comparisons.

3 / Survey sites

The surveys were conducted at four MPAs along the Israeli Mediterranean coast and at adjacent control sites (see map 1): Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor.

Map 1. The survey sampling sites against the background of the master plan for marine reserves in the Mediterranean Sea. The boundaries of the reserves are marked with a dashed orange line. The sampling points inside and outside the reserves are marked in light blue. From north to south: Rosh Hanikra-Achziv, Shikmona, Dor-Habonim, and Gdor reserves. Note that the maps of each MPA are on different scales.

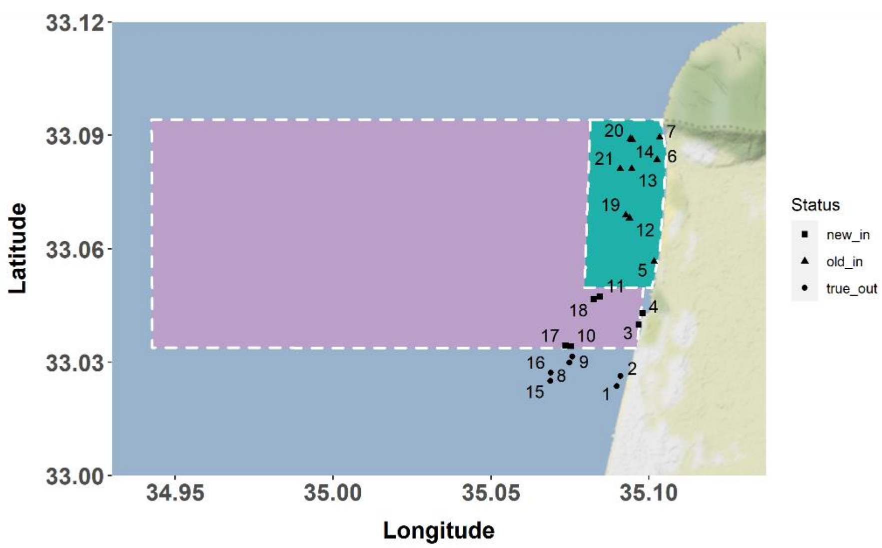
All sampling points, both within the MPAs and at the control sites, were characterized by rocky substrates and no surveys were conducted at sites characterized by sandy substrates. The sampling points at the control sites were ten meters to a few kilometers from the MPA borders, depending on the physical habitat characteristics.

Sampling in each reserve and its control sites was conducted at rocky points with similar substrate complexity, similar distance from the shore, and similar depths. However, there was variation between MPAs in size, maximum bottom depth, distance from the shore, and habitat characteristics. The regulations that determine the permitted and prohibited activities (including fishing activities) also vary from reserve to reserve. Similarly, the length of time during which each MPA has had active monitoring and enforcement also varies, from long-term enforcement (about three decades) to that of only a few years.

4.1/ Rosh Hanikra-Achziv

The surveys were conducted in the "Rosh Hankira-Achziv Reserve" as defined by its 2005 borders, prior to the 2019 expansion. The smaller, original, reserve extends from the Israel-Lebanon border to the ruins of the Port of Achziv, from the coastline out to 2 km west, and including a strip of indented beach about 5 km long. This reserve was, even before its expansion, the largest and most diverse in Israel in terms of habitats and natural assets. The reserve includes abrasion platforms, sandy beaches, caves and burrows in the coastal rocks, an underwater kurkar (limestone) ridge, rocky islands, and an underwater "canyon" (which is actually a steep limestone wall whose bottom reaches the sandy substrate.) The maximum depth of the reserve is 45 m.

In 2019, the Rosh Hanikra Reserve was expanded. The reserve in its new form includes the original reserve, where the surveys were carried out, with a coastline extended 1.8 km southwards towards the northern part of Nahariya, and out to 15 km west of the shore. The total area of the new reserve is 10-fold larger than the area of the original reserve and now covers 100 km^2.



Map 2. The sampling points in Rosh Hanikra-Achziv Reserve and the adjacent control site. The sampling points are marked in black. The MPA area up until 2019 in shown in green and the expanded area in purple. The shape of the sampling points represents the current official protection status as of the expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the

area considered “protected” for the surveys is only the green area.

In view of the short period of time from the expansion of the reserve until the 2021 surveys – and the fact that the fishing ban and other protections measures are still not being enforced in the new territory, the area defined as “inside the reserve” has been defined by the same criteria as in the previous surveys.

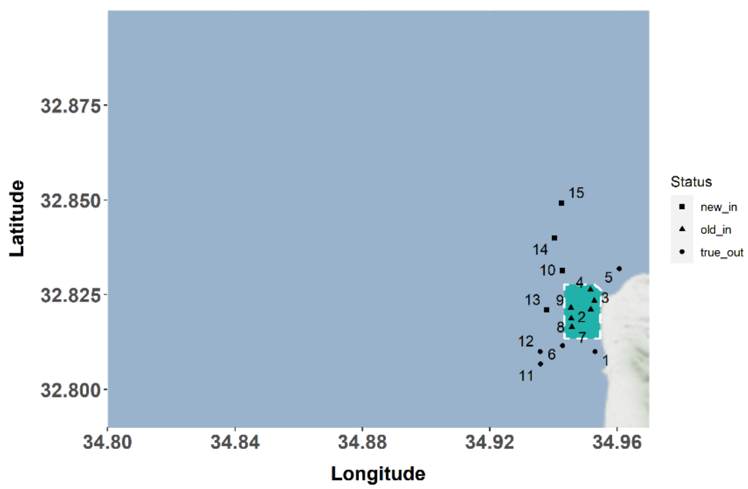
<u>Fishing and enforcement activities in the reserve:</u> The Rosh Hanikra-Achziv reserve is the only reserve which has long-standing monitoring and protection of its natural assets by designated marine rangers. Monitoring inside the MPA began in the 1990s. Up until 2006, the fishing ban was enforced from the shore out to 1 km west, but since 2006 this area has been expanded to include the entire area of the reserve (up to 2 km west of the shore). The only type of fishing ban not enforced inside the reserve over the years was rod fishing from shore, which also started to be enforced in April 2017, with the exclusion of the most southern part of the reserve.

4.2 / Shikmona

This MPA is located off the southern coast of the city of Haifa, from the Israel Oceanographic and Limnological Research institute in the north, to the estuary of the Lotem River (next to the "Maxim" restaurant on the beach) in the south. The MPA extends from the shore 1 km westward. There are abrasion platforms along the shoreline of the Shikmona reserve and. the substrate comprises intermittent rocky and sandy areas. The maximum bottom depth of the reserve is 15 meters.

In 2020, the Shikmona reserve was expanded into the Rosh Carmel Reserve, enlarging the borders to the north and west and increasing the total reserve area to approximately 50 km^2. The maximum depth of the reserve today is 300 m. In view of the short period of time from the expansion to the 2021 survey – and the fact that the fishing ban is still not enforced in the new reserve, the area defined as “inside the reserve” is defined by the same criteria as in the previous surveys.

Fishing activity and enforcement in the reserve: At the time of the first survey in 2015, there was still no enforcement of the fishing ban in the reserve. In 2016, dedicated marine rangers began work in the reserve, and the monitoring and enforcement of the sports fishing ban was increased (with the exception of rod fishing from the shore).

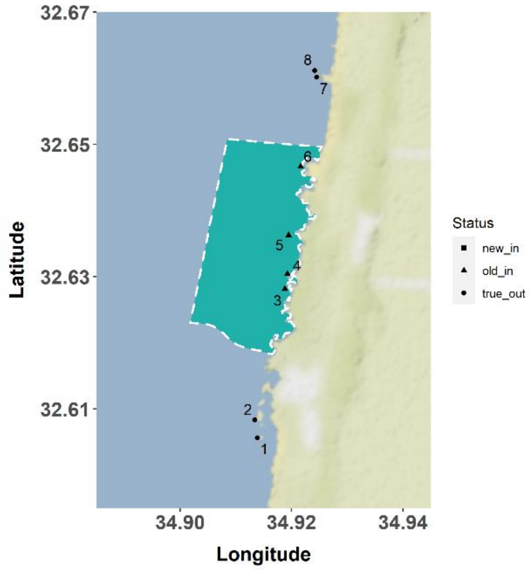


Map 3. The sampling points in the Shikmona Reserve and the adjacent control area. The sampling points are marked in black. The area of the reserve until 2020 is shown in green and the area after the expansion is shown in purple. The shape of the sampling points represents the official protection status as of the MPA expansion (square - inside the expanded reserve, triangle - inside the original reserve, circle - outside the expanded reserve). Note that the area considered "protected" at the time of the surveys is limited to the green area.

4.3 / Dor Habonim

The reserve extends along a 3.5 km coastline between the settlements of Nachsholim and HaBonim and out to 2 km from the shore. The coastline is winding, rugged and rich in unique alcoves, along which stretch well-developed abrasion platforms. The habitat of the rocky substrate in the reserve extends from the abrasion platforms to a maximum depth of 6 m, and further west is a soft substrate (sand and silt) habitat of down to a maximum depth of 21 m.

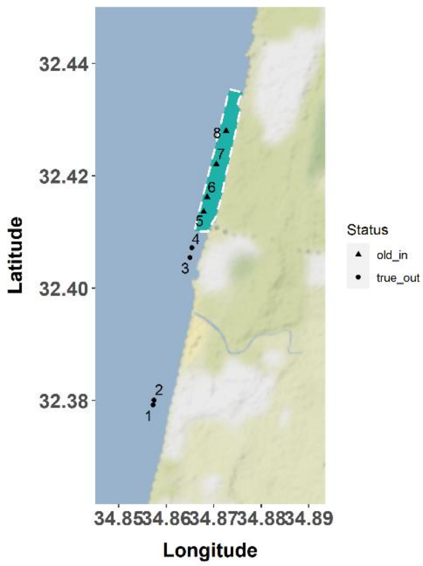
Fishing activity and enforcement in the reserve: at the time of the first survey in 2015, there was still no dedicated marine monitoring inside the reserve and enforcement was carried out by the coastal team. In 2016, dedicated marine rangers began working in the reserve, and supervision and enforcement of the sport fishing ban was increased (with the exception of rod fishing from the shore.) However, there is a group of commercial fishers from the nearby village of Fureidis whose activity predates the reserve, and they were given personal commercial fishing permits inside the reserve during its establishment. Therefore, in practice, this reserve does not function as a no-take reserve.



Map 4. The sampling points in the Dor HaBonim Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve is shown in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.)

4.4 / Gdor

This reserve extends from the south of Givat Olga to Michmoret along a 2.8 km long coastline and out to a distance of 300 meters west of the shore. The disintegration of the limestone cliffs in this coastal strip has created many marine habitats along the shoreline: abrasion platforms and coastal rocks, shallow lagoons, and sandy bays. The maximum depth of the reserve is 5 m.



Map 4. The sampling points in the Gdor Reserve and the adjacent control area. The sampling points are marked in black. The area of the established reserve appears in green. The shape of the sampling points represents the protection status (square - inside the reserve, circle - outside the reserve.) In addition to this area, the areas defined as reserve areas and as control sites outside the reserve have remained the same as the areas defined in the previous surveys conducted.

Fishing and enforcement activities in the reserve: with the commencement of work of the marine unit of the Nature and Parks Authority in May 2018, monitoring and enforcement of the fishing ban inside MPAs have been increased (with the exception of rod fishing from the shore).

In the years 2015-2017 there was a large gap between the number of transects sampled inside and outside the reserve (Table number, 2A Appendix.) The reason for this was the paucity of suitable control sites with rocky substrates similar to those of the reserve and located close by. In order to reduce the gap between the number of sampling points inside and outside the reserve, as of 2019 we reduced the number of sampling points within the reserve.

In the Israeli Mediterranean Sea there are two additional MPAs without rocky substrates and therefore no visual surveys were conducted there: the Avtach Marine Reserve and the Shikma Sea Reserve, as well as the Dor Islets of the Maagan Michael Reserve which do not include marine areas and therefore were not surveyed.

5 / Summary of methods

The surveys were conducted in 2015, 2017, 2019, and 2021 during two seasons: spring and fall. Each season is characterized by different environmental factors (such as: water temperature, nutrients, and phytoplankton concentrations), which may affect the algae and invertebrate communities (e.g., density, coverage, and composition). To account for seasonality the benthic community was surveyed inside and outside of the nature reserves during both seasons each year. From 2019 the survey methods were changed (see below) in order to establish a replicatable and informative protocol for an ongoing monitoring program.

4.1 / Participants

All surveys, documentation, identification of species, data acquisition and analysis were performed by a full and collaborative team of researchers and students from the following institutions: School of Zoology, George S. Wise Faculty of Life Sciences and the Steinhardt Museum of Natural History - Tel-Aviv University, The Leon H. Charney School of Marine Sciences - University of Haifa, The Faculty of Marine Sciences - Ruppin Academic Center, Israel Oceanographic and Limnological Research, and the Israeli National Park Authority.

4.2 / Survey descriptions

In total, eight campaigns have been performed to date using the 'BioBlitz approach' – intensive surveys and documentation of different taxonomic groups (i.e., fish, invertebrates, and algae). The surveys were conducted inside the nature reserves and in control areas adjacent to the reserves that display similar characteristics the substrate type, complexity, and depth. Sampling points within the control areas (outside the nature reserves) covered distances ranging from tens of meters to a few kilometers from the reserves’ borders, according to the physical characteristics of the habitat. Each marine reserve (and the control areas) were assigned one sampling day in each season (Table 1). Efforts were made to survey in the different reserves on successive days.

Table 1. Dates of the surveys in 2015, 2017, 2019, and 2021 in both seasons

Site	Spring	Fall	Year
Dor-Habonim	27 April	2 November	2015
Shikmona	28 April	3 November	2015
Rosh Hanikra-Achziv	29 April	5 November	2015
Gdor	30 April	12 November	2015
Dor-Habonim	4 June	15 October	2017
Shikmona	5 June	19 October	2017
Rosh Hanikra-Achziv	6 June	18 October	2017
Gdor	7 June	7 November	2017
Dor-Habonim	8 April	27 October	2019
Shikmona	29 April	28 October 27 November	2019
Rosh Hanikra-Achziv	30 April	31 October	2019

Gdor	7 April	30 October	2019
Dor-Habonim	2 May	10 October	2021
Shikmona	3 May	25 October	2021
Rosh Hanikra-Achziv	4 May	26 October	2021
Gdor	25 April	29 October	2021

4.3 / Sampling points and depths

Sampling points were marked by buoys from a small skiff in the early morning of the survey day inside and outside the nature reserves, and the locations were documented by GPS. In order to maintain similar depth, long-shore transects were performed. The number of transects in every sampling point was limited by the depth, bottom time, and air consumption of the divers, and ranged between 1-6 transects. During 2015 and 2017 the surveys were limited to bottom depth shallower than 9 m. In 2019 and 2021 the surveys were expanded to intermediate (9.1 – 17.4 m) and deep (17.5 – 27 m) bottom depths, in the reserves that feature these depths. From 2019 the intermediate bottom depths were added to the Shikmona site, and in Rosh Hanikra-Achziv, both intermediate and deep bottom depths were added to the survey.

4.4 / Survey procedure

In every sampling point two professional surveyors worked simultaneously with each diver surveying a transect and documenting the data on waterproof forms. When a transect was complete a new parallel transect was surveyed, in order to represent a new area. In addition, from 2019, another method that use photo-quadrats along line transects was performed to survey the alga community (see details below).

4.4.1 Benthos surveys in 2015 and 2017

Transects of the benthic community were limited only to shallow bottom depths (< 9 m) inside the nature reserves and in the control areas outside them. Sampling points were predetermined on a bathymetric map to ensure a good representation of the rocky substrate at each site. Three sampling points were positioned inside the nature reserves and two sampling points were positioned outside the nature reserves. Sampling points were positioned as far as possible from each other to ensure a good representation of the habitat. In spring 2015 at the site Gdor, transects were performed only inside the nature reserve.

Table 2. Combined sampling effort in 2015 and 2017 of the benthic community for the different seasons, sites, and bottom depths (numbers represents sampling quadrats).

Site	Spring		Fall		Depth	Sum of quadrats
	Outside	Inside	Outside	Inside		
Rosh Hanikra-Achziv	40	59	50	70	Shallow	219
Shikmona	40	40	30	70	Shallow	180
Dor-Habonim	40	58	40	70	Shallow	208
Gdor	20	59	60	70	Shallow	209
Total					816	

4.4.2 Benthos surveys in 2019 and 2021

The line intercept method (LIM) was applied while accounting for the effectively sampled area of each individual and size category (ESA, m2, Zvuloni & Belmaker, 2016). This method presents an efficient way to survey large and small organisms (> 1 cm) while eliminating the inherent biases of traditional point sampling techniques and allowing for percentage cover calculations, densities, and size frequency distributions for each taxon. Transects were performed in all depth categories (if such existed at the site) inside the nature reserves and in the control areas outside them. Sampling points were predetermined on a bathymetric map to ensure a good representation of the rocky substrate at each site. Sampling points were positioned as far as possible from each other to ensure a good representation of the habitat. Sampling points were marked by buoys from a small skiff, with three sampling points were positioned inside the nature reserves and two sampling points outside them.

Line transects (10 m long) were surveyed at sampling intervals of 0.1 m (10 cm). To represent different rocky features the line was fitted to the local relief by attaching several small fishing weights using plastic clips. At every point along the line, the organism (if present) was documented and classified to a taxonomic group (Bryozoa, Cnidaria, Crustacea, Echinodermata, Mollusca, Annelida, Porifera and Tunicata). Additionally, from the fall of 2019, if an invertebrate was observed, the maximum projection on the line was measured using a plastic caliper to enable subsequent estimation of size-dependent densities. Algae were categorized by their height above the substrate: short algae – less than 2 cm, and long algae – more than 2 cm. From 2021 a third category was added that included encrusting crustose coralline algae. At the end of each transect, the aerial length was measured for future estimation of the transect complexity.

From 2021 we focused on two taxonomic groups – sponges (porifera) and tunicates (tunicate), and their species richness was assessed inside the nature reserves and in the control areas for every site and season. After the line-transects were complete, an expert in each taxonomic group surveyed its close surroundings for five minutes and listed all species encountered. Individuals that could not be identified in the field were collected and preserved for future identification by experts from the Steinhardt Museum of Natural History. These species inventories enabled data analysis of the presence-absence data. Algae that were observed in the field were also collected for identification in the lab for maximal richness estimations.

In order to assess the percentage cover and composition of different algae species (aside from the height index), from the fall of 2019 a method that use photo-quadrats along 10 meter line transects was added. This method focuses on algae species because the photos are limited to the top coverage of the rock and therefore may underestimate cryptic invertebrate species. Photo analysis was performed with CoralNet platform (Beijbom et al., 2015), which enables species (or genus) identification of algae and invertebrates based on machine-learning technique. In every transect a set of 11 photos was taken (Sony X100 IV) with a fixed frame of 50*50 cm at a distance of 1 m above the substrate. Subsequently, in the CoralNet platform, a set of 25 points was randomly imposed on each photo and categorized as algae species, which were then transformed into species percentage cover on the rocky substrate.

The indices exmined in 2019 and 2021:

- Percentage cover of total algae and total invertebrates
- Percentage cover of different invertebrate taxonomic groups
- Species richness of algae, sponges, and tunicates
- Percentage o cover of algae height index in different sites and depths
- Densities (individuals m-2) of different invertebrate taxonomic groups in different depths
- Community composition of focus groups - sponges and tunicates

Table 3. Combined sampling effort in 2019 and 2021 of the benthic community for the different seasons, sites, and bottom depths (numbers represents line transects).

Site	Depth	Spring		Fall		Sum of transects
		Outside	Inside	Outside	Inside	
Rosh Hanikra-Achziv	Shallow	13	14	14	23	64
	Intermediate	7	10	11	19	47
	Deep	3	9	8	7	27
Shikmona	Shallow	8	19	10	11	48
	Intermediate	6	8	3	10	27
	Deep	4	0	8	0	12
Dor-Habonim	Shallow	25	29	25	29	108
Gdor	Shallow	17	22	15	19	73
Total						406

4.5 / Data analysis

Point intercept measurements of invertebrates from 2019 and 2021 were transformed to densities by considering the effectively sampled area (ESA, m2) of each individual size and the configuration of the sampling unit (the number of points and distance between the points), and calculated using the equation of Zvuloni & Belmaker (2016):

$$ESA_i = \bigcup_{k=1}^{n} \pi r_{i\,(k)}^2$$

where ESAi is the effectively sampled area for organism i with a radius ri, k is the sampling point index along the line, n is the total number of sampling points, and U is the union of the areas of all n circles with radius ri along the transect line. ESAi is much larger for large individuals and smaller for small individuals, thereby correcting the inherent bias of the over-representation of larger organisms in standard point-sampling techniques. The density of an individual i encountered during a point intercept survey (PIM) can be calculated as 1/ESAi. The total density of a certain taxon was calculated for each transect as the sum of the calculated densities of all individuals from that taxon in the transect (Zvuloni & Belmaker, 2016).

The sponge and tunicate community compositions were assessed using multivariate analyses to examine all the species of the community in parallel. A Non-Metric Multidimensional Scaling (nMDS) is an example of such an analysis. This non-parametric analysis that helps visualize the dissimilarity between samples (e.g., transects; Kruskal, 1964). Bray-Curtis index (Faith et al., 1987) was used to calculate a dissimilarity matrix of all samples based on their species composition. The dissimilarity between transects is expressed by the distance between them and can be visualized which of the transects are more alike. To assess the credibility of the graphical visualization and its interpretation a 'Stress' value is calculated. Lower stress values better represent graphical visualization and the difference between communities. Values between 0.05-0.1 are denoted excellent, values between 0.1-0.2 are denoted good, and values above 0.3 are denoted poor.

5 / Results

Surveys were performed in 2015, 2017, 2019, and, 2021 to determine whether the currently declared marine nature reserves protect the flora and fauna within them and to assess whether they contribute to ecological stabilization within and outside the protected area.

Four general goals were defined for the surveys (see above).

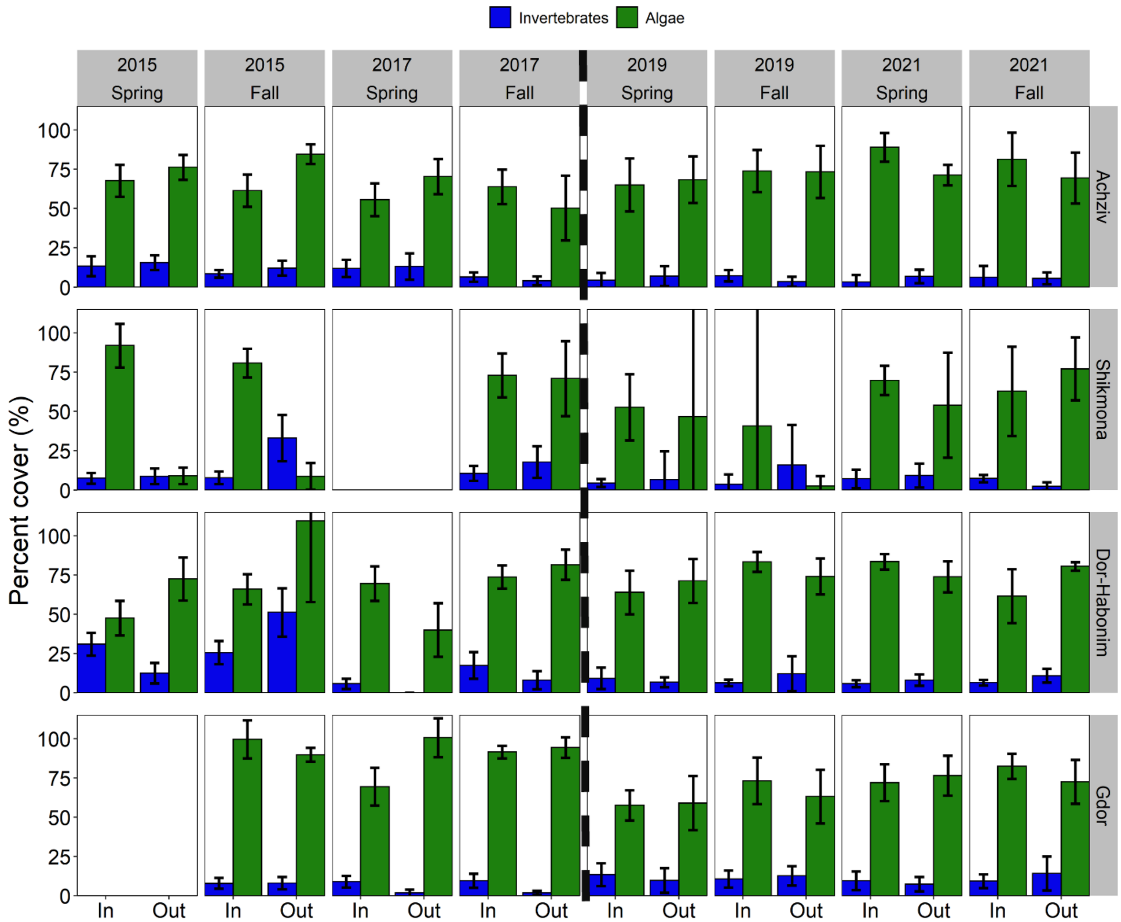


Figure 1. Mean coverage of algae (green bars) and invertebrates (blue bars) on rocky substrate at shallow bottom depths (0-9 m) during all years and sites. Percentage cover was obtained from quadrats (2015 and 2017), or line transects (2019 and 2021). The upper panel represents the years and season of the survey, X-axis represents whether the surveys were conducted inside or outside a nature reserve, and the right panel represents the sites. Error bars represent a 95% confidence interval. The dashed black line represents the change of the method from 50*50 cm quadrats to 10-m line-transects. See Tables 2 and 3 in the `Methods` section for the sampling effort. Empty squares represent missing data or data that were incomplete and were removed from the analysis. Photo-quadrats are not included in this analysis.

The rocky substrate at shallow bottom depths (0-9 m) is dominated by algae that cover between 40% to 90% of the substrate while invertebrates cover between 8% to 18% of the substrate. This pattern held true for all years, seasons, and sites, inside and outside the reserves, except for 2015. It should be noted that the high percentage cover of algae and the low percentages of sessile invertebrates appeared both inside the reserves and in the control areas outside them. In addition, this overall trend was maintained even after the sampling method was changed in 2019. Rosh Hankara-Achziv and Gdor showed the most stable distribution along years and seasons between algae and invertebrates' coverage of the substrate, compared to Shikmona and Dor-Habonim.

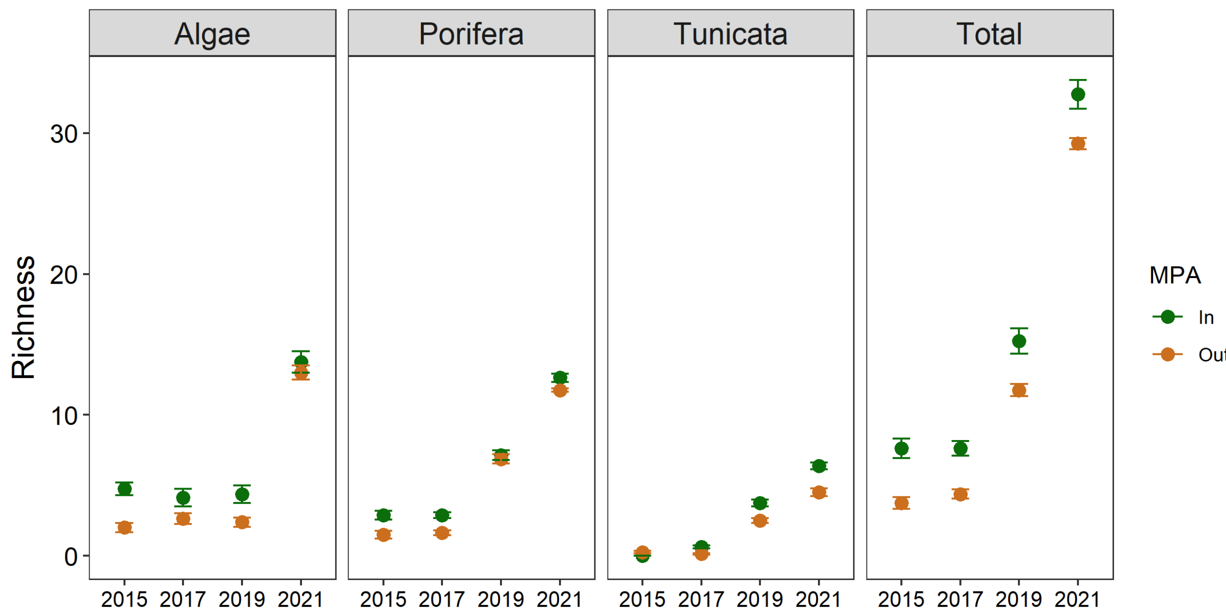


Figure 2. Mean species richness of algae, sponges (porifera), and tunicates and all groups combined (total) for all surveys performed for each year. Color represents surveys inside (green) and outside (orange) nature reserves. Error bars represent SE. n = 8 surveys every year.

The mean species richness of algae, sponges ,and tunicates was higher inside the reserves (green color) compared to the control areas outside them (orange color), for all the sampling years. The sampling effort in 2015 and 2017 inside the reserves was 35% higher on average than in the control areas (see the number of sampling squares in Table 2 in the `Methods` section). In 2019 and 2021 the sampling effort inside the reserves was 17% higher on average than in the control areas based on the number of sampling stations. It is important to emphasize that the method for estimating species richness differed between sampling years, which led to an artificial increase in species richness in 2021. Nevertheless, the trend indicating that the species richness is higher in the reserves compared to the control areas, was maintained for every sampling method carried out in the field.

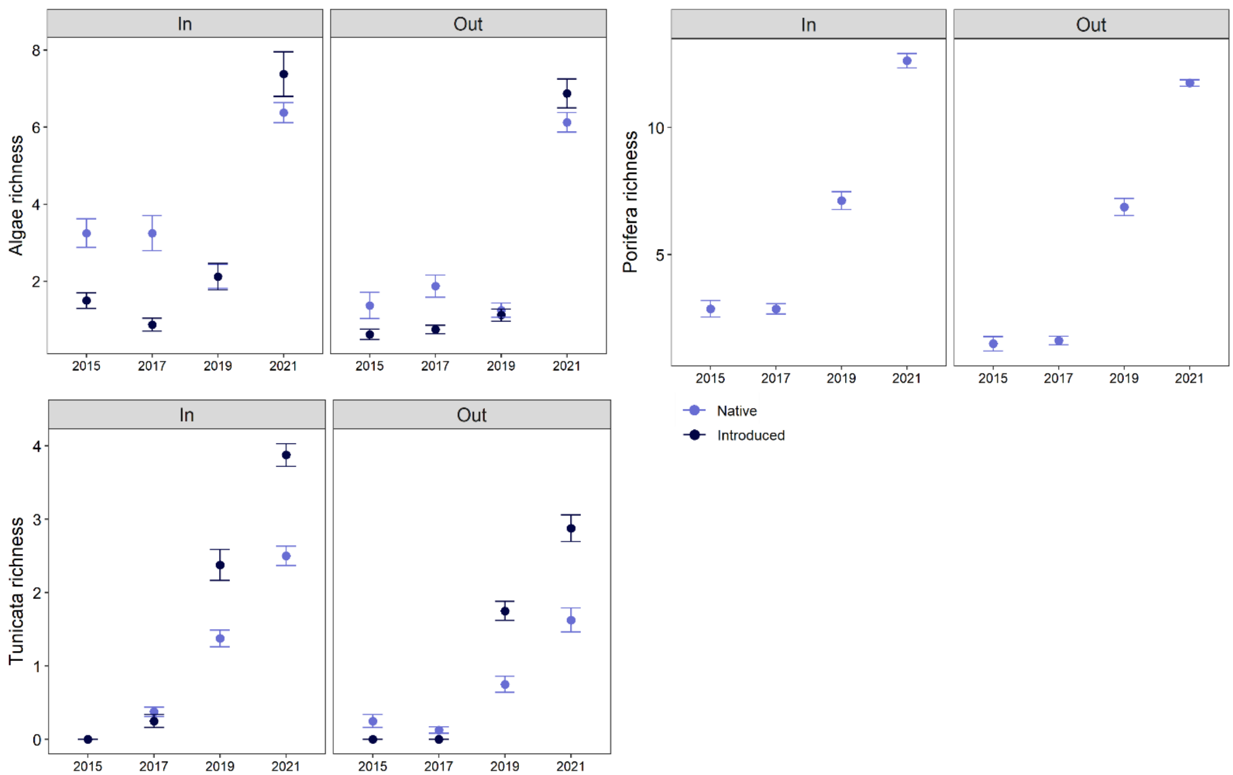


Figure 3. Mean richness of native (Mediterranean origin, light blue) and introduced (Indo-Pacific origin, dark blue) species of algae, sponges (porifera), and tunicates inside and outside the nature reserves for every sampling year. The upper panel represents whether sampling was performed inside or outside the nature reserve. Error bars represent SE, n = 8 surveys every year.

When comparing species richness of native species (light blue) and introduced species (dark blue), a transition from the dominance of native species to the dominance of introduced species was observed throughout the sampling years. In 2015 and 2017, on average, native species of algae and tunicates were observed more commonly both inside the reserves and in the control areas outside them in comparison to introduced species. In

2019, the mean richness of introduced species and native species of algae remained the same, while in 2021 the richness of introduced algal species was higher than that of native species both inside and outside the reserves. From 2019 on, the richness of introduced tunicates was higher than that of native species. Sponges along the Israeli Mediterranean coastline consist entirely of native species, with introduced species (of Indo-Pacific origin) not being surveyed (found) in all the sampling years

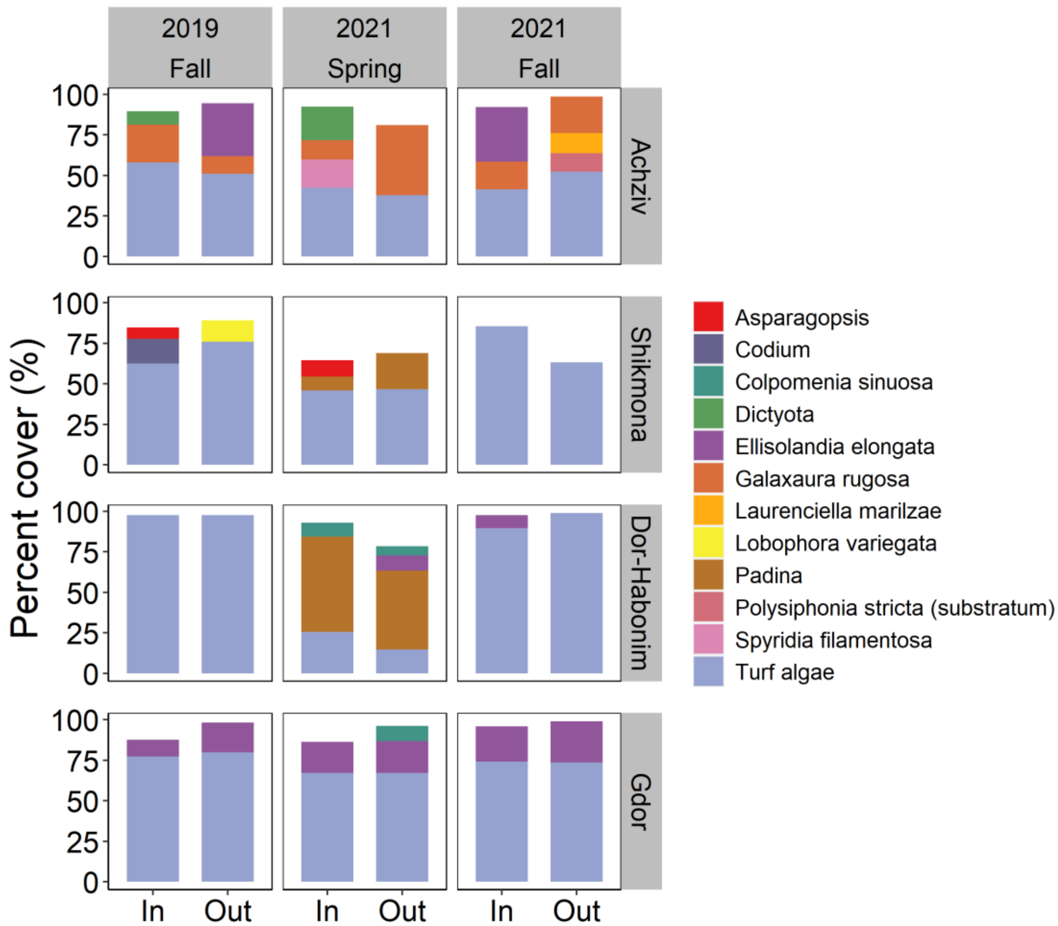


Figure 4. Mean percentage cover of dominant algal species at shallow bottom depths (0-9 m) at all sites surveyed by 50*50 cm photo-quadrats along 10 m line-transects. The upper panel represents the year and season of the survey, the X-axis represents whether the surveys were conducted inside or outside nature reserves, and the right panel represents sites. Only algae that covered at least 5% of the substrate are presented.

The coverage of rocky substrate at the surveyed sites consists mostly of turf algae – a complex of benthic algal mat shorter than two cm and heavily grazed by herbivorous fishes and sea urchins (grazers). It is often hard to distinguish (and identify) the different species in this complex and to assess what would have been their maximum height if they would not have been grazed. Hence, this definition is not taxonomic but functional according to the function that the algae fulfill within the ecosystem. High percentage cover of turf algae indicates high grazing pressure. In the fall, at all the sites except Rosh-Hanikra Achziv, turf algae covered over 60% of the rocky substrate. The Rosh Hanikra-Achziv site was characterized by a high diversity of algae, in addition to turf algae, in the two seasons surveyed. In Dor-Habonim, in spring of 2021, high percentage cover of Padina sp. was observed.

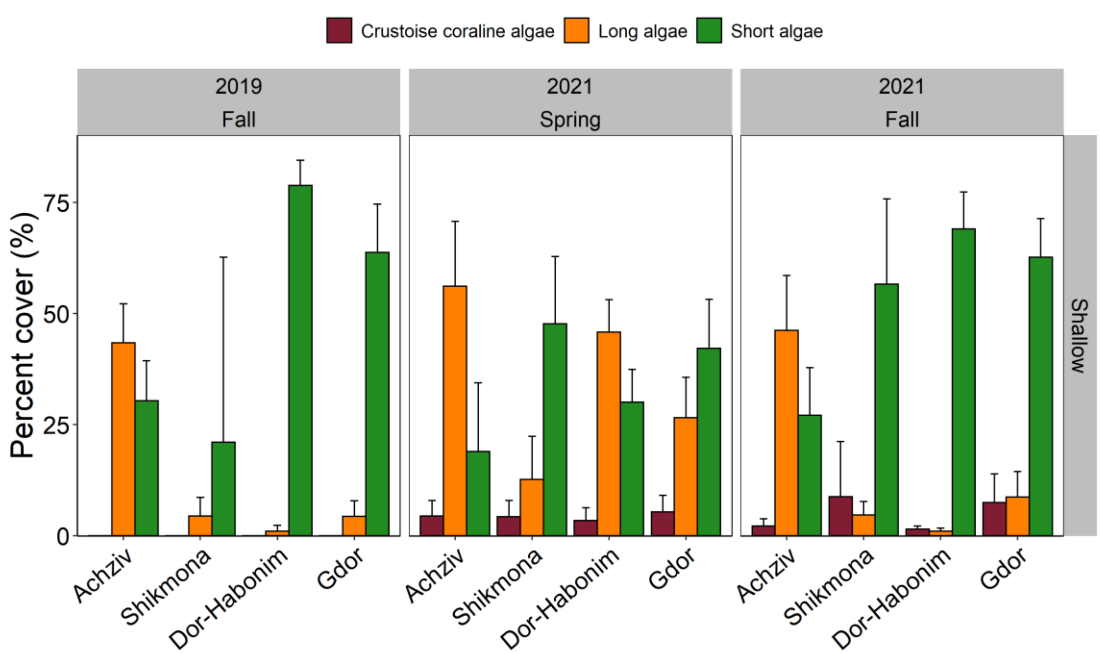


Figure 5. Mean percentage cover of algae divided according to their height above the substrate: crustose coralline algae (purple bars, surveyed only in 2021), algae shorter than 2 cm (green bars) and algae longer than 2 cm (orange bars) at all sites at shallow bottom depths (0-9 m). The upper panel represents the year and season of the survey. X-axis represents the sites and error bars represent 95% confidence interval for the mean.

Seasonal differences were observed in algae, as reflected in their length (height above the substrate). In both autumn seasons surveyed (2019 and 2021) the percentage cover of short algae (<2 cm) was higher than of long algae (>2 cm). In spring of 2021, a high percentage cover of long algae was observed at all sites, while at Rosh Hanikra-Achziv and Dor-Habonim, long algae covered more rocky substrate than short algae. In Rosh Hanikra-Achziv a high percentage cover of long algae was observed in all seasons surveyed (spring and fall). The percentage cover of crustose coralline algae (surveyed only in 2021, purple bars) was generally low at all sites. Since no differences were observed between the areas inside the reserves and the control areas outside them, the results are presented for each site.

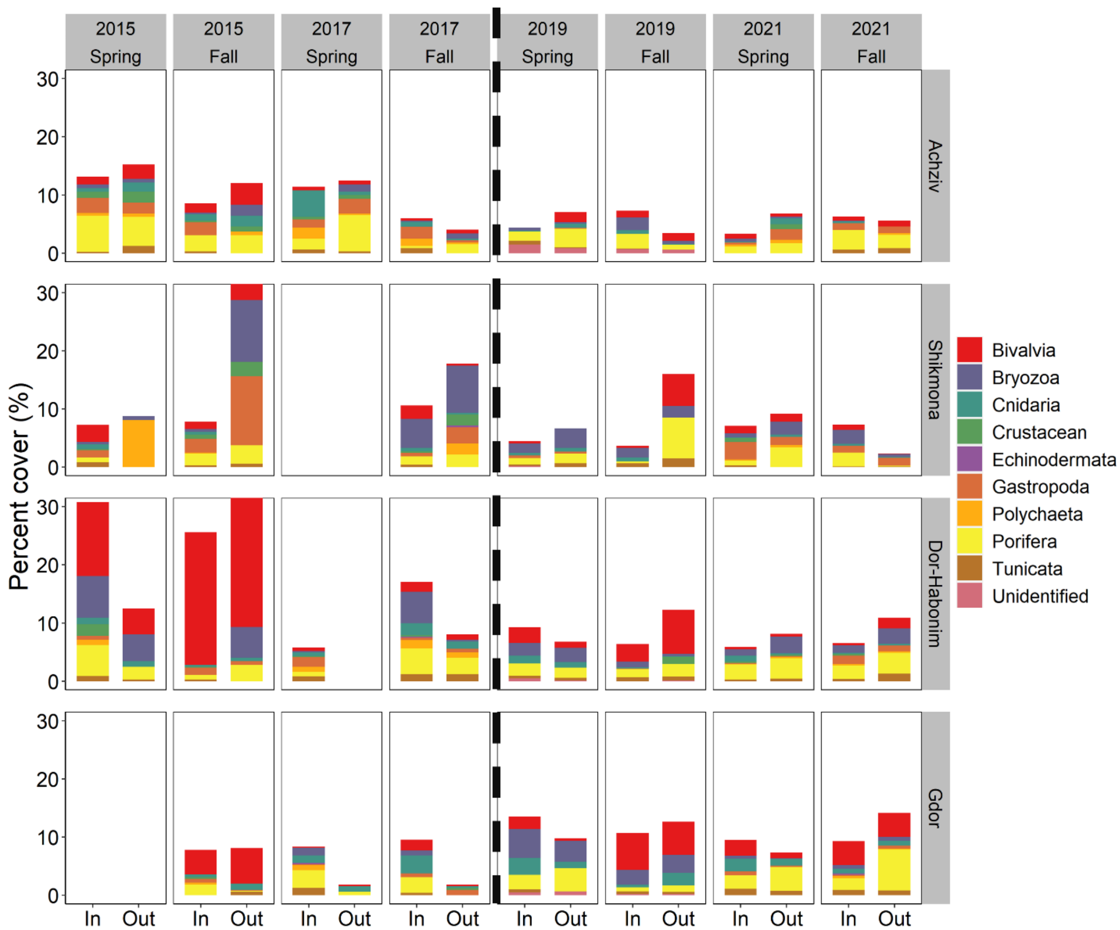


Figure 6. Mean percentage cover of different taxonomic groups of invertebrates at the shallow bottom depths (0-9 m) for every year and season, inside and outside the nature reserves. The upper panel represents the year and season of the survey, the X-axis represents whether the surveys were conducted inside or outside the nature reserves, and

the right panel represents sites. The dashed black line represents the change in the method from 50*50 cm quadrats to 10 m line-transects. In 2015 in Dor-Habonim a high percentage cover of the bivalve Brachidontes pharaonis was observed (up to 50% of the substrate) but the Y-axis was trimmed at 30% to enable comparison with other taxonomic groups.

Percentage cover of invertebrates ranged from 8% to 18%, except in 2015, when a higher percentage cover was observed, mainly in Shikmona and Dor-Habonim. Bivalves (red), sponges (yellow), and bryozoans (purple) were the main invertebrate groups in terms of percentage cover for all the sites, seasons and years during which surveys were conducted. No substantial differences were seen between the nature reserves and the control areas outside them. In addition, the percentage cover of invertebrates was similar regardless of the sampling method.

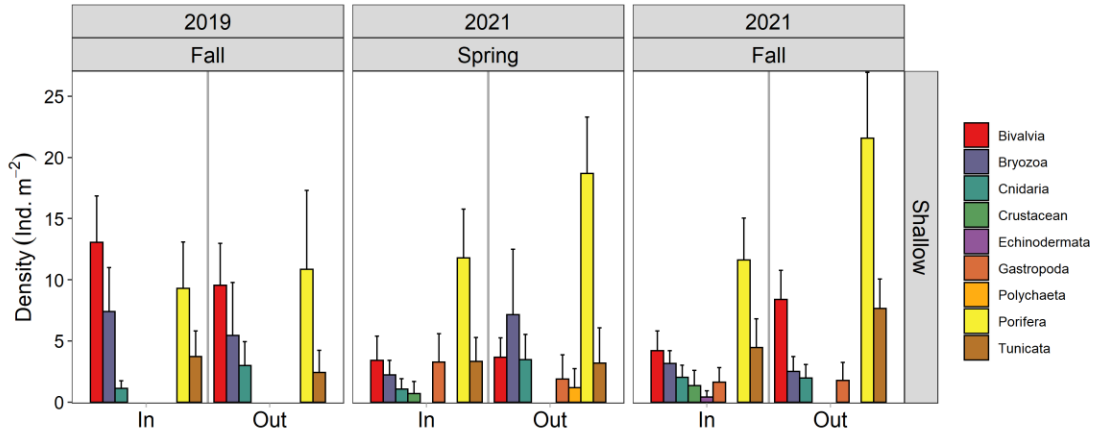


Figure 7. Mean density (individual m-2) of "large" invertebrates (>2 cm) divided into taxonomic groups at the shallow bottom depths (0-9 m), inside and outsidethe nature reserves in 2019 and 2021 for all sites combined. Density was deduced by accounting for the effectively sampled area of each taxon and size category (Zvuloni & Belmaker, 2016) of individuals larger than 2 cm. The upper panel represents the year and season the survey was conducted, X-axis represents whether the survey was inside or outside the nature reserves. Error bars represent a 95% confidence interval.

The mean density of "large" invertebrates (longer than 2 cm) at shallow bottom depths ranged from a few individuals per m2 to 22 individuals per m2. The densities of bivalves, sponges, and bryozoans were higher compared to other taxonomic groups, while echinoderm density was the lowest.

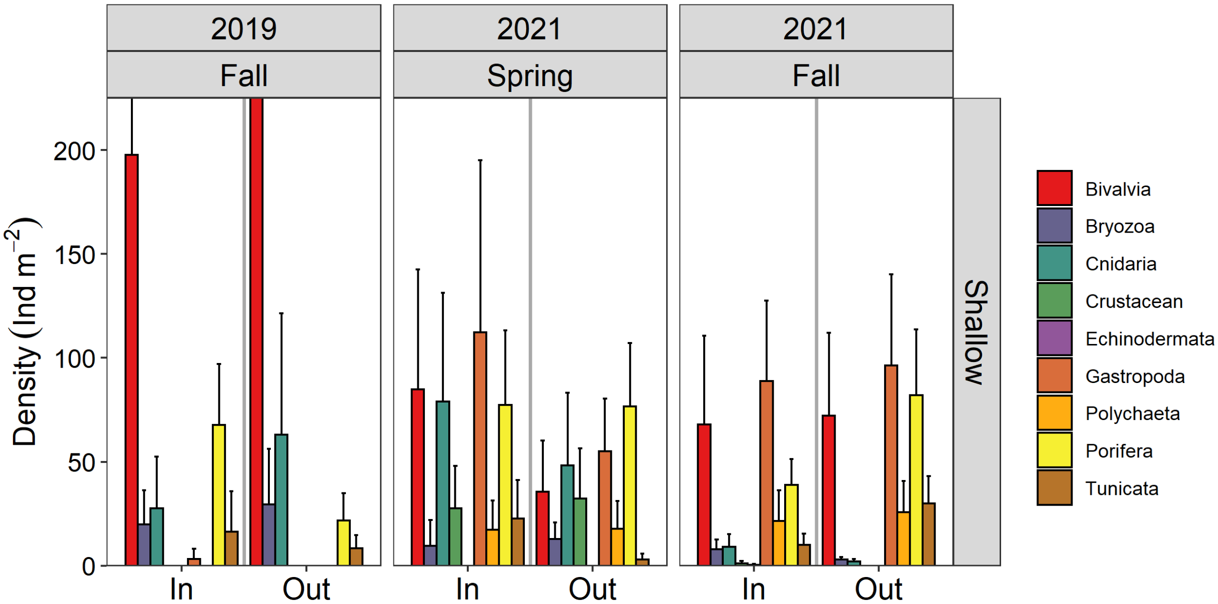


Figure 8. Mean density (individual m-2) of "small" invertebrates (1-2 cm) divided into taxonomic groups at the shallow bottom depths (0-9 m), inside and outside the nature reserves in 2019 and 2021 for all sites combined. Density was deduced by accounting for the effectively sampled area of each taxon and size category (Zvuloni & Belmaker, 2016) of individuals between 1-2 cm. The upper panel represents the year and season the survey was conducted, X-axis represents whether the survey was inside or outside the nature reserves. Error bars represent a 95% confidence interval. In fall 2019 the density of bivalves (red bars) was high especially outside the nature reserves (518 individuals m-2) due to many sightings of Brachidontes pharaonis. The Y-axis was trimmed at 225 individuals per m2 for ease of presentation.

The mean density of "small" invertebrates (1-2 cm) at the shallow bottom depths was higher than "large" invertebrates, and rangedfrom a few individuals to hundreds of individuals per m2. Bivalve density was the highest compared with other taxonomic groups in the fall of 2019 (mainly due to B. pharaonis sightings, mean of 518 individuals m-2). Other groups such as sponges and cnidarians (mainly hydrozoa) were observed in densities of tens of individuals per m2. In 2021 the density of bivalves was up to 85 individuals per m2 in both seasons. In the spring season more groups of invertebrates, such as crustaceans and cnidarians, were observed and at higher densities compared to in the fall. Taxonomic groups such as bivalves and sponges were observed in similar or higher numbers in the fall season compared to in the spring.

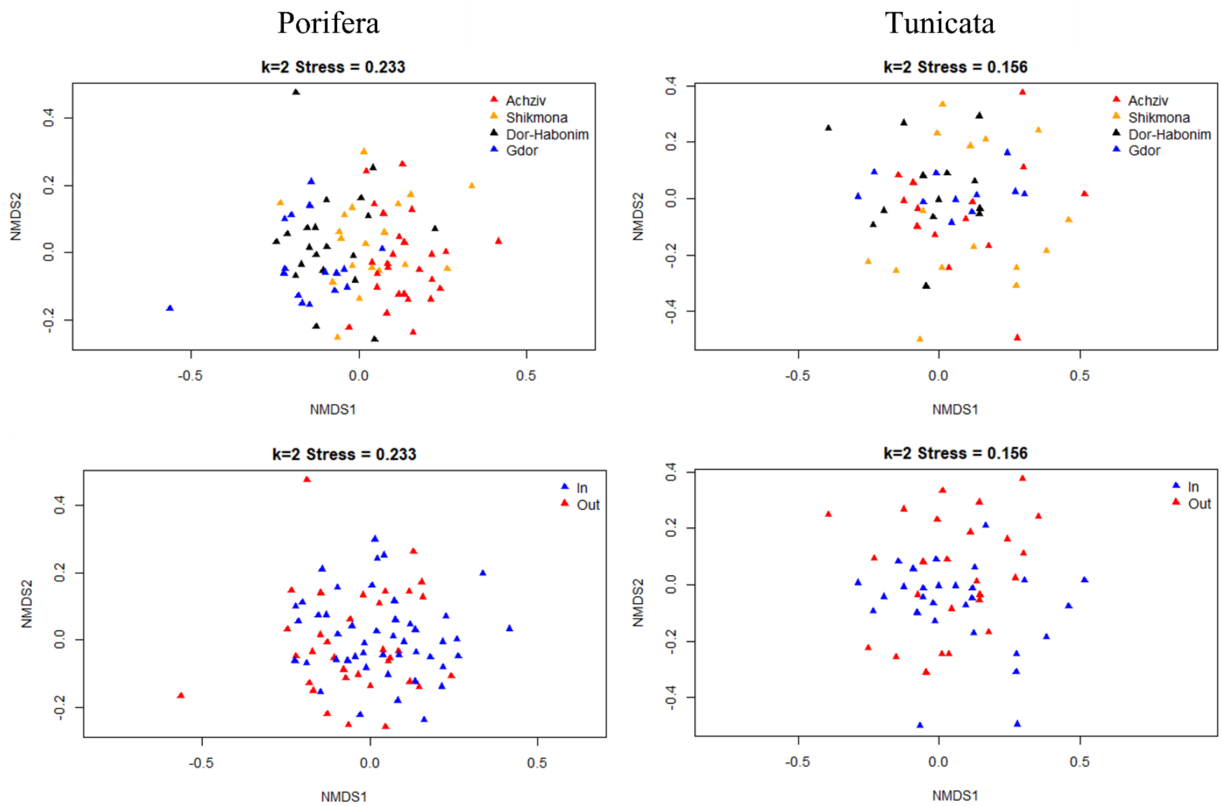


Figure 9. nMDS ordinations of the sponge community (porifera, left side) and tunicates (tunicata, right side) at the different sites (upper panel) and inside or outside the nature reserves (lower panel) in 2021 of both seasons combined. The similarity matrix was calculated using the Bray Curtis index. Each triangle represents a line transect with presence-absence data of every species. The colors in the upper panel represent the different sites. The colors in the lower panel represent whether the transects were conducted inside or outside the nature reserves. k=2, stress values are presented above each ordination.

The sponge community composition differed between sites but not between nature reserves and the control areas outside them. The community composition of tunicates was similar both between the sites and between the nature reserves and the control areas outside them.

5.1 / Results at different depths- Rosh Hanikra-Achziv

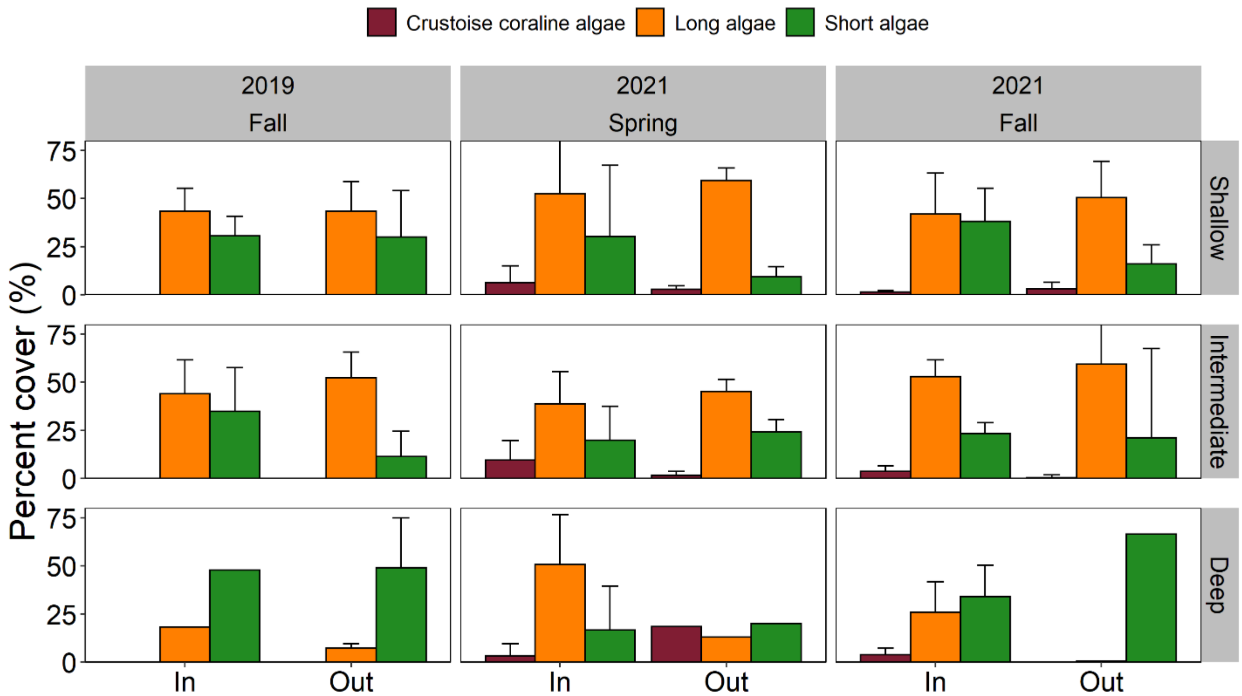


Figure 10. Mean percentage cover of algae divided by their height above the substrate in Rosh Hanikra-Achziv: crustose coralline algae (purple bars, surveyed only in 2021), algae shorter than 2 cm (green bars), and algae longer than 2 cm (orange bars) at the different depths. The upper panel represents the year and season of the survey. X-axis represents whether the survey was conducted inside or outside the nature reserve, and the right panel represents bottom depth categories. Error bars represent a 95% confidence interval. At the deep bottom depths (lower panel), bars without error bars are sampling points with less than three transects surveyed.

At the Rosh Hanikra-Achziv site, line-transects were performed for all bottom depth categories (shallow, intermediate, and deep). At the shallow and intermediate bottom depths, long algae (>2 cm) covered more area than short algae (<2 cm) both inside the reserve and in the control area. An inverse pattern was observed at the deep bottom depth where short algae covered more area than long algae. The percentage cover of crustose coralline algae (surveyed only in 2021, purple bars) was generally low except in the spring of 2021 at deep bottom depth outside the reserve, where coverage reached 18% of the rocky substrate. In the fall of 2021 at deep bottom depth outside the reserve only short algae were observed.

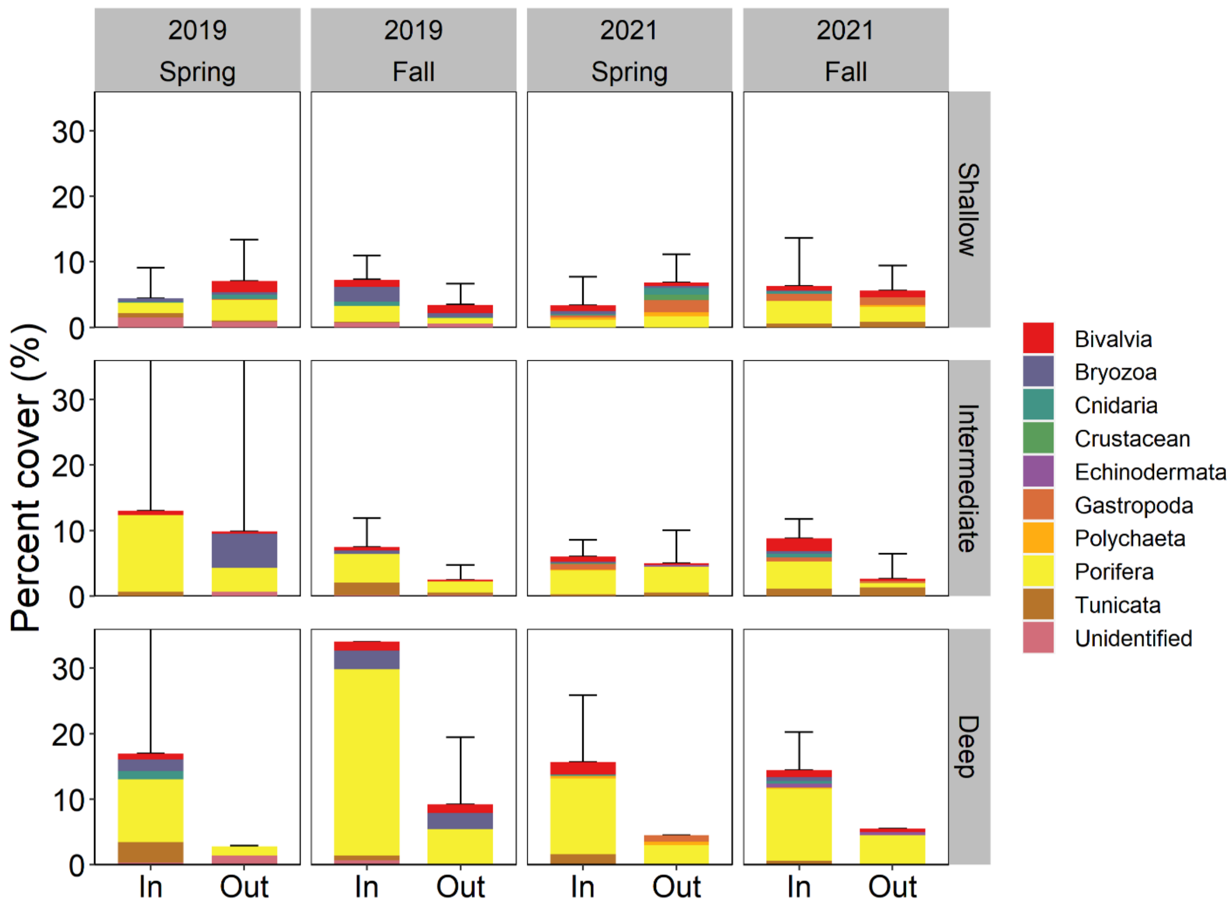


Figure 11. Mean percentage cover of different taxonomic groups of invertebrates in Rosh Hanikra-Achziv at the different bottom depths: shallow (0-9 m), intermediate (9.1-17.5 m), and deep (17.6-27 m). The upper panel represents the year and season of the survey. X-axis represents whether the surveys were conducted inside or outside the nature reserves, and the right panel represents different bottom depths. Error bars represent 95% confidence interval of the mean percentage cover of all invertebrate groups combined. At the deep bottom depths (lower panel), bars without error bars are sampling points with less than three transects surveyed.

The shallow bottom depth in Rosh Hanikra-Achziv included more invertebrate taxonomic groups than at the intermediate and deep bottom depth, but the total percentage cover of the rocky substrate was generally lower and reached up to 7% on average. Sponges (yellow color) comprised the group with the highest percentage cover observed at all depths. The percentage cover of invertebrates increased with depth and reached up to 34% of the rocky substrate in spring of 2019. The most dominant increase was in the sponge group. In addition, invertebrate percentage cover at the deep bottom depths was higher inside the reserve compared to in the control area.

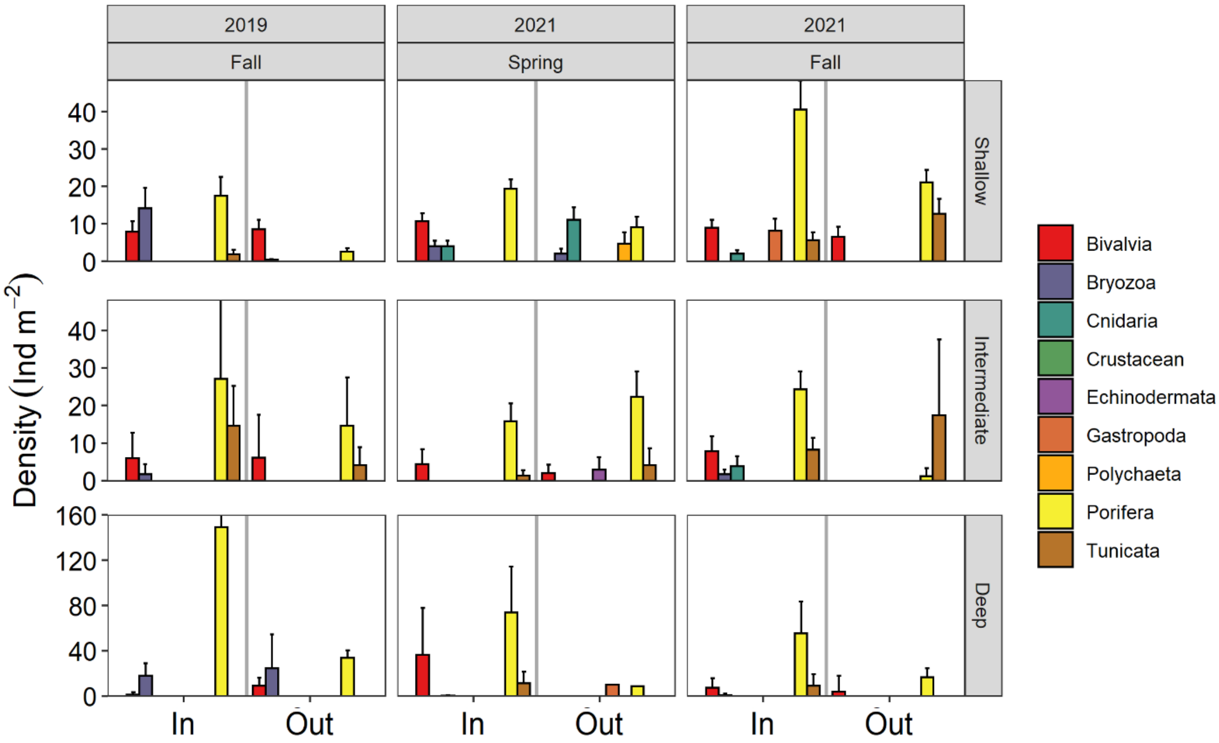


Figure 12. Mean density (individual m-2) of "large" invertebrates (>2 cm) divided into taxonomic groups in Rosh Hanikra-Achziv in the fall and spring of 2019 and 2021. The right panel represents different bottom depths: shallow (0-9 m), intermediate (9.1-17.4 m), and deep (17.5-27 m). Density was deduced by accounting for the effectively sampled area of each taxon and size category (Zvuloni & Belmaker, 2016) of individuals larger than 2 cm. The upper panel represents the year and season the survey was conducted, X-axis represents whether the survey was inside or outside the nature reserves. Error bars represent a 95% confidence interval. At the deep bottom depth (lower panel), bars without error bars are sampling points with less than three transects surveyed.

The mean density of "large" invertebrates (>2 cm) at the deep bottom depths was up to four-fold higher than at the shallow and intermediate depths (note the differences on the Y-axis). This trend was observed mainly in sponges (fall 2019) and bivalves (spring 2021). Sponge density was higher inside the reserve compared to in the control areas outside it, for all seasons and all depths, with the exception of the intermediate depth in spring 2021. Tunicates were observed mainly in the shallow and intermediate depths, while at the deep bottom depths there was a decrease in their density. In addition, the shallow bottom depth was represented by more taxonomic groups, such as cnidarians and polychaetas, compared to the intermediate and deep bottom depths.

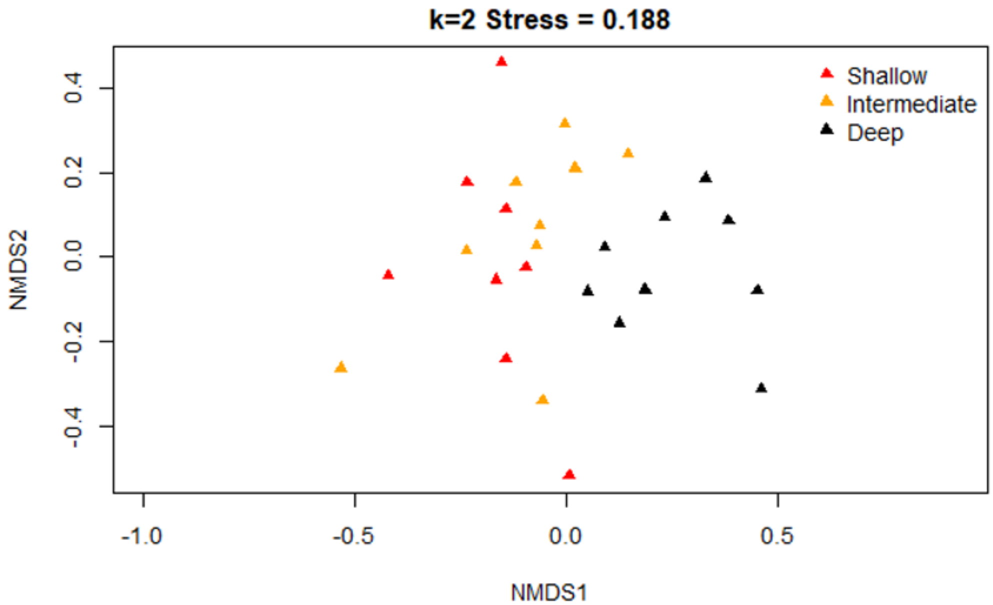


Figure 13. nMDS ordinations of the sponge community in Rosh Hanikra-Achziv at different bottom depths for both seasons combined of 2021. The similarity matrix was calculated using Bray Curtis index. Each triangle represents a line transect with presence-absence data of every species. The colors in the upper panel represent the different depths. k=2, stress value is presented above the ordination.

The sponge community composition changed at the different bottom depths. Some overlap between the sponge community composition was observed between shallow and intermediate bottom depths, with a clear distinction observed at the deep bottom depths.

6 / Discussion

This report summarizes eight surveys carried out in marine nature reserves and control areas outside of them along the Israeli coastline during the years 2015, 2017, 2019 and 2021. The current chapter focuses on the benthic community – algae and invertebrates on the rocky substrate inside and outside the marine nature reserves. The main goals of these surveys were to create species inventory lists, to create a quantitative database of the benthic community for future comparisons and the rapid identification of extreme changes, to compare the benthic community inside and outside the nature reserves, and to describe the spatial patterns of these communities.

During the years of the survey, the area experienced changes such as rising seawater temperature (Ozer et al., 2022) and the ongoing introduction of Indo-Pacific origin species (Zenetos & Galanidi, 2020), along with administrative changes such as the declaration of new areas as marine nature reserves, and the increased surveillance and enforcement of fishing bans within the nature reserves and regulations pertaining to the areas outside of them.

In contrast to the fish community, the expected changes in biomass, density, individual sizes, and species richness of invertebrates in marine nature reserves are not straightforward due to the indirect and complex effects of the habitat's food webs on these indices (Lester et al., 2009). The challenges. both in terms of taxonomy and functionality, of surveying such a diverse community, which includes algae, bryozoans, cnidarians, crustaceans, echinoderms, mollusks (including bivalves, gastropods, nudibranchs, and chitons), annelids, sponges, and tunicates, led to an examination and changes in the methods previously applied in these surveys. As of 2019, the sampling method of the benthic community (algae and invertebrates) underwent changed in order to examine additional tools for collecting data and to expand the indices and depths in the survey.

In this chapter, the benthic community has been divided into two main components: algae and invertebrates, which in turn are divided according to taxonomic groups or functional indices. Throughout all the years of the survey, algae constituted the dominant group in terms of percentage cover of the rocky substrate, reaching up to 90% coverage of the substrate (Fig. 1), as also described in a previous study (Rilov et al., 2018). No obvious effects of marine nature reserves on the algal coverage were observed. The location along the Israeli coastline (sites from north to south) and the bottom depth may be the main factors influencing algal coverage on the rocky substrate, but the current sampling method did not enable a simple statistical test. The algal community in the Eastern Mediterranean is highly dynamic, with different seasonal patterns and of a patchy nature (observed also in a monitoring program of the algal community on inter-tidal vermetid reefs (Rilov et al., 2020)). Hence, a long-term monitoring program is required in order to examine its trends and the effects that nature reserves have on this community. Nevertheless, the results of this report indicate that marine nature reserves indeed have some effect on the species richness of algae, which was higher inside the reserves compared to in the control areas outside them (Figu. 2), regardless of the method applied in the field.

In 2015 and 2017, most of the algal species observed were native (for example, in 2015, a mean of 3.25 native species was observed per sampling square of 30 x 30 cm, compared to a mean of 1.5 introduced species in the same square size). However, in 2021, most of the algal species observed were introduced species (a mean of 6.4 native species were collected at the site, compared to a mean of 7.4 introduced species at the site, see Fig. 3). The dominance of introduced species has also been observed in surveys of the rocky substrate near Haifa over the last decade (Rilov 2021). The composition of the algal community differed between the different sites, with turf algae mainly found at the Dor-Habonim and Gdor sites, especially during the fall. This phenomenon has been observed in other areas in the Levantine basin and is related to the intense overgrazing of algae by *Siganus rivulatus* and *S. luridus*, two species of introduced herbivorous fishes. These species have exerted heavy grazing pressure on the algal community, as shown in previous studies in Turkey and Israel (Sala et al., 2011; Vergés et al., 2014; Yeruham et al., 2020). In addition, some differences in the algal community composition were observed between areas within the nature reserves and the control areas outside of them (Fig. 4), but without a specific pattern, probably due to the high spatio-temporal variability of this community.

An ecosystem dominated by short algae (classified as turf algae) suffers from a dramatic reduction in biological diversity, biomass and functionality compared to a system dominated by long and erect algae (Peleg et al., 2020; Sala et al., 2011; Yeruham et al., 2020). To examine the effect of marine nature reserves on algal coverage, from the fall of 2019 a `height index` was used that classifies the algae into three categories according to their height above the substrate (encrusting, short, and long) and not by their taxonomic affiliation (although all encrusting algae in the survey are crustose coralline algae, depositing a calcareous skeleton). This index will enable the long-term monitoring of the ecological status of the ecosystem by non-expert surveyors without the need to identify all algal species. In seasons that included the index no difference in the ratio of short and long algae was observed between the nature reserves and the control areas outside them, but differences were observed between the different sites (Fig. 5). At the Rosh Hanikra-Achziv site, a high coverage of long algae was observed compared to short algae, irrespective of the season, which may indicate a more diverse habitat with high biomass and ecological function throughout the year compared to the other sites. In a survey conducted in the spring of 2011 inside and outside the Rosh Hanikra-Achziv nature reserve, and focused mainly on the reefs around its islets, erect soft and fleshy algae covered more area inside the reserve at the shallow bottom depths (Rilov et al., 2018). At the same sites, in the spring and fall of 2014 and 2015, a similar yet lesser trend was observed (Rilov, 2015). It can be assumed that the grazing pressure inside the reserve was lower, despite the high presence of herbivorous fish, due to the presence of predators benefiting from the prohibition of fishing inside the reserve (see Chapters A and B of this report).

At all other sites, the coverage of long algae on the rocky substrate was higher in the spring season (13% - 45%, 2021) compared to the fall season (1% - 9%, 2019 and 2021), when short algae covered more area. This seasonality was also observed in previous surveys on the rocky substrate along the Israeli coast (Rilov, 2015). In addition, this functional (rather than taxonomic) ecological classification of the algae makes it possible to observe seasonality reflected in the rapid growth and proliferation of algae during spring along the entire Israeli coastline. At the Rosh Hanikra-Achziv site, this pattern was different, as the coverage of long algae was high even during the fall.

The invertebrates surveyed belong to eight different taxonomic phyla: bryozoans, cnidarians, crustaceans, echinoderms, mollusks, annelids, sponges, and tunicates. The majority of the species are sessile animals lacking the ability to move along the substrate, with the exception of a limited number of mobile taxa such as hermit crabs (subphylum Crustacea), species belonging to the genus Cerithium, nudibranchs (phylum Mollusca), and species of echinoderms (which accounted for less than 1% coverage of the rocky substrate). In 2015 and 2017 three additional taxonomic groups were included in the survey (Platyhelminthes, Sipuncula, and Polyplacophora). The total coverage of the invertebrate community on the rocky substrate along the Israeli coastline ranged from 18% in 2015 and 2017 to 8% in 2019 and 2021. In 2015, at some of the sites a high coverage (>30%) was observed compared to other sites, which may explain the higher percentage cover found in the first years of the survey. At some of the sites high densities of the invading bivalve *Brachidontes pharaonis* have created dense mats on the substrate, while at other sites large aggregations of *Cerithium sp*. were observed. No difference in the total coverage of invertebrates between the areas within the nature reserves and the control areas outside them was found. However, differences in the community composition between sites were observed (Fig. 6). An interesting pattern is seen in the fluctuations in the population of the invading bivalve B. pharaonis over the years. In 2015 and 2019, *B. pharaonis* covered high areas (up to 40%), while in 2017 and 2021 the population coverage of the substrate had dramatically decreased (down to 4%). In addition, in 2019 the density of "small" bivalves (<2 cm, mainly B. pharaonis) was hundreds of individuals per m2, while in 2021 the density had dropped dramatically to dozens of individuals per m2 (Fig. 8). This pattern may reflect `boom and bust` cycles of the population, which tends to aggregate at high densities of hundreds of individuals per m2. A complete collapse of this population was observed in the summer of 2016 (Rilov et al., 2020), while in recent years some recovery has been detected (Rilov, 2021). Although the factors dictating the population collapse and recovery are not fully understood, it may be related to the marine heatwaves that are increasing in number in the Mediterranean Sea and causing the mass mortality of numerous species (Garrabou et al., 2022).

In this chapter, we distinguish between the densities of small (1-2 cm) and large (>2 cm) individuals. Small individuals dominated in most populations, with densities of up to hundreds of individuals per m2. These densities were observed both in the reserve areas and in the control areas outside them. Large individuals were observed at densities of up to 30 individuals per m2 for bivalves and sponges, while in most of the other taxonomic groups' densities were up to 10 individuals per m2. No consistent pattern was observed between areas inside the nature reserves and the control areas outside of them in terms of the densities of small individuals.

Sponges, bryozoans, and bivalves constituted the dominant groups in the invertebrate community on the rocky substrate in the Israeli Mediterranean coastline at the shallow bottom depths. These groups covered more areas than other groups, since they include large encrusting species (sponges and bryozoans) and species that tend to aggregate and create dens of mats or beds of many individuals within a small area (bivalves).

The bottom depth is an important factor influencing the invertebrate community. At the Rosh Hanikra-Achziv site similar taxonomic groups and coverage represented the shallow and intermediate bottom depths. However, at the deep bottom depths, sponges covered most of the rocky substrate and the total coverage of all invertebrate groups reached up to 34% of the rocky substrate. Additionally, the density of large sponges (>2 cm) increased 4-fold with depth and reached up to 160 individuals per m2, which together with bivalves and bryozoans dominated the community at the deep bottom depths (Fig. 12). Furthermore, long algae covered less area at the deep bottom depths (Fig. 10) compared to short algae. This may reduce the competition for space and resources and contribute to the high density of sponges at these depths.

The ability of experts to identify the key taxonomic groups made it possible to describe the community composition and the species richness of tunicates and sponges throughout all the years of the survey, which was not possible for the other taxonomic groups. The species richness of both sponges and tunicates was higher inside the nature reserves compared to in the control areas outside of them (Fig. 2). Note that the sampling effort was higher inside the reserves, which may explain this finding. Sponge and tunicate groups in the Israeli Mediterranean coastline differ between them in the fact that all sponge species observed were native species and no invasive species were observed for this group in all the transects surveyed. However, a transition was observed in tunicate species, in which native species were dominant in 2015 and 2017 while introduced species were dominant in 2019 and 2021 (Fig. 3).

The sponge community composition varied between the different sites along the coastline from north to south, probably due to the physical distance between them. No difference in the structure of the community was observed between areas inside the nature reserves and the control areas outside of them. At Rosh Hanikra-Achziv site, where three bottom depth categories were surveyed, sponge substrate coverage and density of large individuals increased with depth (Fig. 11 and 12). Furthermore, even though the distance between different bottom depths is small, the community structure differed between the different depth categories (Fig. 13).

In contrast to sponges, no differences in the tunicate community composition were found at the different sites, nor in areas inside the nature reserves compared to the control areas outside them (Fig. 9). Visualization of the tunicate community composition along the depth gradient at Rosh Hanikra-Achziv was not possible since the number of species was too low.

The advantage of the survey method applied in 2015 and 2017 – quadrats along a line transect, lay in the ability to identify encrusting sponge species that had not been sampled in previous years, such as *Didiscus stylifer, Diplastrella bistellata, Eurypon sp., Hymerhabdia pori, Lissodendoryx sp., Plakortis sp., Tedania (Tedania) anhelance,* and *Timea stellata*. In addition, specimens of calcareous sponges (such as *Ascandra contorta*) were sampled for the first time since the pioneering work of Tsurnamal conducted in the 1960s at bottom depths of down to 7 m in Israel (Tsurnamal, 1967, 1968, 1969a, 1969b). Although the majority of species recorded in the `BioBlitz` surveys appear in Tsurnamal's species inventory, some of the common species today are absent from his list. These species appear in the species' inventory by Levy (1957), who examined samples from greater depths, or were identified as new species to science from the coast of Lebanon, such as *Levantinella levantinensis, Phorbas topsenti*, and *Liosina blastifera* (Vacelet et al., 2007; Vacelet & Perez, 2008).

The new survey method implemented in 2019 and 2021, which encompasses lower taxonomic resolution along line transects and presence-absence data of sponge species observed per unit of time (five minutes), enabled the documentation of different morphological forms such as massive, encrusting, and rock-boring species along with the density of the sponge community. This method is also highly replicable and allows for comparison between years and sites over time. Nevertheless, because of the low taxonomic resolution cryptic species are underestimated.

The survey of the benthic community has yielded an up-to-date species inventory of algal and invertebrate species in the rocky substrate inside the nature reserves and the adjacent control areas. Algae cover a considerable percentage of the rocky substrate (between 40%-90%). The height index of the algae, which may indicate the functionality of the ecosystem, was affected by the location of sites rather than by the existence of a nature reserve. The Rosh Hanikra-Achziv site was characterized by a higher coverage of long algae compared to the other, southern, sites.

The survey incorporates eight taxonomic phyla (in the phylum Mollusca, gastropods and bivalves were distinguished) and reports both the cover and density of each group and the structure of the benthic community as a whole. Invertebrates accounted for between 8% and 18% of the coverage of the rocky substrate. Sponges, bryozoans, and bivalves were the most dominant groups in terms of coverage of the substrate. For key taxonomic groups (sponges and tunicates), identified down to a high level of detail, the community composition did not differ between areas inside the nature reserves and the control areas outside of them. However, differences were found between the different sites and different bottom depths, stressing the need to protect the different areas and depths along the Israeli Mediterranean coastline.

All species of sponges surveyed were native, while other taxonomic groups were composed of both local species, which made up the majority of algal and tunicate species until 2017, and introduced species, which made up the majority of species as of 2019. All the bivalves encountered in the survey (from 2015) were introduced species.

The great taxonomic diversity along with the difficulties in species identification pose significant challenges to surveying, analyzing, and estimating the ecological status of the benthic community, the environmental factors affecting it, and the effectiveness of marine nature reserves in its conservation. Based on the data collected to date, during the following surveys our goal will be to fine-tune the methods in order to characterize indicator species for determining the state of the system and to determine the relevant indices for assessing the status of marine nature reserves in the future.

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