Hikurangi Marine Reserve

Assessing the effects of protection on key subtidal reef species and the intertidal reef community

2016–2024

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Cover: Hikurangi Marine Reserve, facing south. *Photo: Shawn Gerrity*

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Abstract

The Hikurangi Marine Reserve was established in 2014 under the Kaikōura (Te Tai ō Marokura) Marine Management Act (2014) in recognition of the outstanding marine environment at Kaikōura. The reserve is a no-take area designed to protect a diverse array of habitats and marine species. Due to its location along a coastline with considerable fishing pressure, Hikurangi Marine Reserve is well-positioned to protect a variety of exploited marine species. Here we test for reserve effects on several key species with ecological, cultural, recreational, or commercial importance.

Shore-based, potting, and dive surveys sampled abundances and sizes of several key species along the inshore portion of Hikurangi Marine Reserve and nearby non-reserve sites between 2016 and 2024. These included pāua, rock lobster (kōura), several species of reef fish, kina, intertidal reef invertebrates, and algae. Data were compiled and analysed to test for spatial and temporal differences between reserve and non-reserve sites.

Results were variable but indicated that after 10 years of reserve status the Hikurangi Marine Reserve has had positive effects on some key species. Pāua were larger in size but significantly less abundant in the reserve compared to non-reserve sites. Potting surveys showed that rock lobster, particularly females, were larger and more abundant inside the reserve compared to non-reserve sites. Fish community composition and species richness were similar between reserve and non-reserve sites. However, reserve sites had greater abundance of blue cod, blue moki, and butterfish, compared to non-reserve sites. Kina were found in low densities overall but were more abundant inside the reserve than outside. The reserve contained a large and stable stand of habitat-forming bull kelp (rimurapa), providing an important source of propagules for recovery of nearby kelp stands negatively affected by recent marine heatwaves and the 2016 Kaikōura earthquake. The intertidal reef community within the reserve was highly diverse, with several endemic algae and invertebrate species present.

We determined that the inshore portion of the Hikurangi Marine Reserve has had positive effects on some key species compared to nearby non-reserve sites. However, it was difficult to detect how the reserve has impacted these species over time due to limited replication of surveys through time and high data variability. We offer suggestions for how future surveys can adjust efforts to clarify the impacts of the Hikurangi Marine Reserve on key species.

This report provides information about size and abundance of key species in the Hikurangi Marine Reserve, presenting quantitative time series datasets. Future monitoring efforts will be able to use this data to continue to assess long-term marine reserve effects.

Keywords

Marine reserve, monitoring, species, pāua, rock lobster, fish, bull kelp, intertidal, communities, habitat.

Introduction

Marine reserves are specially designated areas in the territorial sea with the highest level of regulatory protection from human disturbances. Within Aotearoa New Zealand's 44 marine reserves, the removal of any living or non-living material from the foreshore (mean high-tide mark) to the sea floor is prohibited, but non-extractive activities such as diving and boating are allowed. Under the Marine Reserves Act 1971[1], marine reserves are established to preserve marine biodiversity, allow ecosystems to return to a natural state, and to facilitate scientific research.

The Hikurangi Marine Reserve (HMR) was established in 2014 under the Kaikōura (Te Tai ō Marokura) Marine Management Act 2014[2] in recognition of the outstanding marine environment at Kaikōura. As the largest (104 km^2) and deepest (up to c. 1400 m deep) mainland marine reserve, HMR was designed to protect a diverse array of habitats. These include deep-water canyons, soft-bottom benthic habitats, as well as rocky subtidal and intertidal reefs. The HMR is situated within a highly productive and biodiverse marine ecosystem, due to the nutrient-rich convergence of warm and cold-water currents in the Hikurangi Trench (Guy and Smith 2014).

The HMR is located 16 km south of the Kaikōura township alongside State Highway 1 (SH1), where it covers approximately 2 km of coastline and projects approximately 24 km out to sea (Fig. 1). Due to its proximity to Kaikōura, ample boat access, and numerous access points from SH1, this portion of the coastline has high usage by recreational and commercial fishers, divers, and tourists. Thus, the marine reserve is well-positioned to offer protection from fishing and gathering, while providing a natural attraction for other recreational activities. Notably, the HMR was affected by the 2016 Kaikōura earthquake and experienced about 0.41 m of vertical coastal uplift (Clark et al. 2017).

1 Marine Reserves Act 1971, section 18I. www.legislation.govt.nz/act/public/1971/0015/latest/DLM398194.html
2 Kaikōura (Te Tai ō Marokura) Marine Management Act 2014. www.legislation.govt.nz/act/public/2014/0059/latest/DLM5851202.html

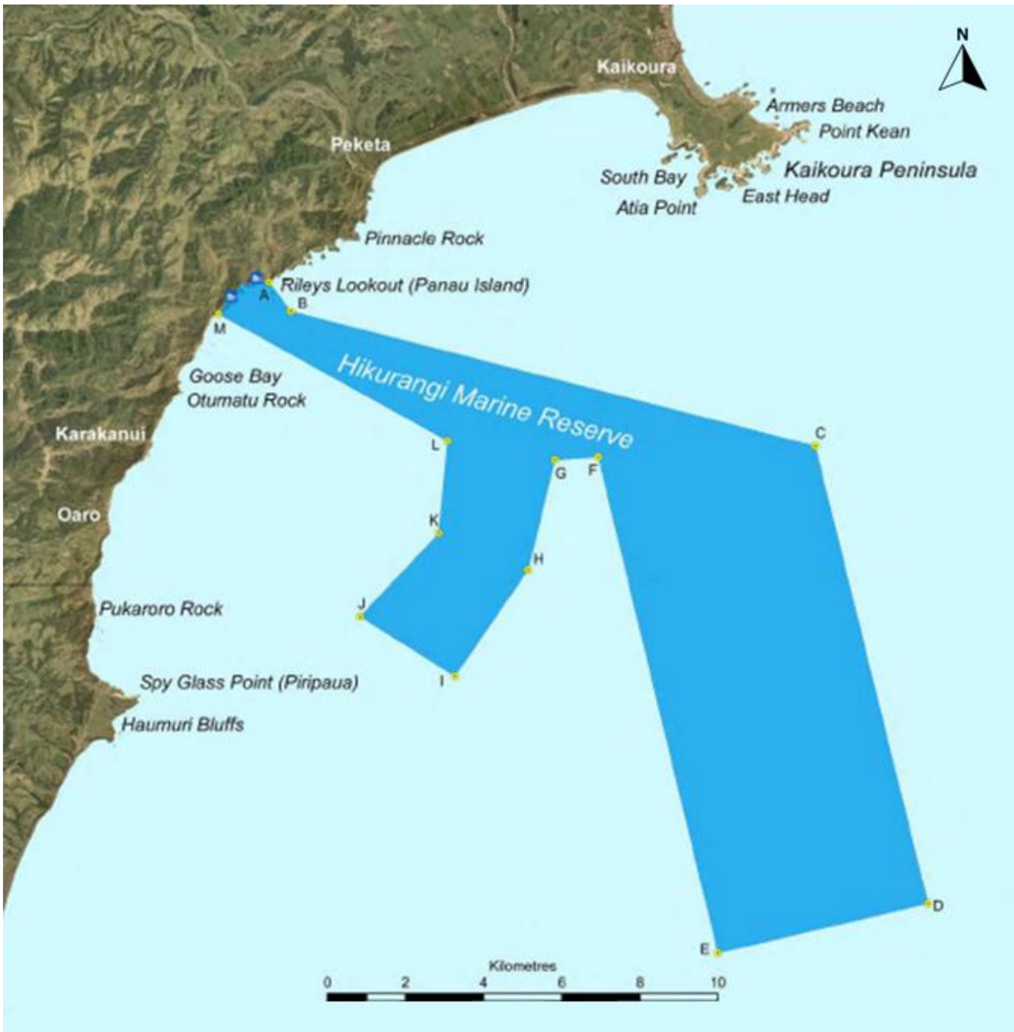

Figure 1. Map showing the spatial extent of Hikurangi Marine Reserve (dark blue polygon). Sourced from Department of Conservation website.

The HMR is a well-studied area with a history of scientific reporting detailing the ecology and biodiversity of the reserve's marine ecosystem. This includes long-term monitoring of rocky intertidal and subtidal algae and invertebrate communities by the Marine Ecology Research Group, University of Canterbury (see Alestra et al. 2019 and 2020, Falconer et al. 2023, Schiel et al. 2023). Another study assessed the effects of shore-based pāua fishing from the 2021 pāua season and included Hikurangi as a site (Gerrity and Schiel 2023). The Department of Conservation (DOC) has conducted monitoring of pāua, rock lobster, several fish species, kina, and intertidal reef algae and invertebrates inside the HMR and at nearby non-reserve sites over time.

The Marine Monitoring and Reporting Framework (2022) provides DOC's approach to monitoring marine reserves, outlining 10 themes as main monitoring objectives. Theme 4 addresses the importance of monitoring key species, which are defined in the framework as species that:

> … "either have a disproportionately large role in maintaining the structure of an ecological community (termed ecological keystone species; Paine 1969) or shape the cultural identity of a people, as reflected in the fundamental roles they have in diet, materials, medicine, recreation, economies and/or spiritual practices (termed cultural keystone species; Garibaldi & Turner 2004)".

The purpose of this report is to analyse and interpret field survey data from the HMR and nearby non-reserve sites, and to test for reserve effects on key species. The report also draws on results from previously published research. The two main research questions are:

1. Is the number and size of key species significantly different inside the Hikurangi Marine Reserve compared to nearby non-reserve sites?
2. Does the number and size of key species change over time inside the Hikurangi Marine Reserve?

To answer these questions, we analysed a large data set collected from surveys inside and outside of the Hikurangi Marine Reserve between 2016 and 2024. We also reviewed relevant findings from previously published scientific reports. This report provides a concise assessment of the Hikurangi Marine Reserve relative to key species and offers recommendations to improve future monitoring efforts. This information will aid discussions about the HMR, which is scheduled for a 10-year review in 2025 (Kaikōura Marine Management Act, 2014).

Methods

Survey overview

Between 2016 and 2024, pāua, rock lobster, kina, reef fish, and intertidal reef algae and invertebrates were sampled inside and outside of the HMR using a variety of survey methods (Fig. 2). Survey sites inside the HMR were confined to the shallow inshore portion of the marine reserve.

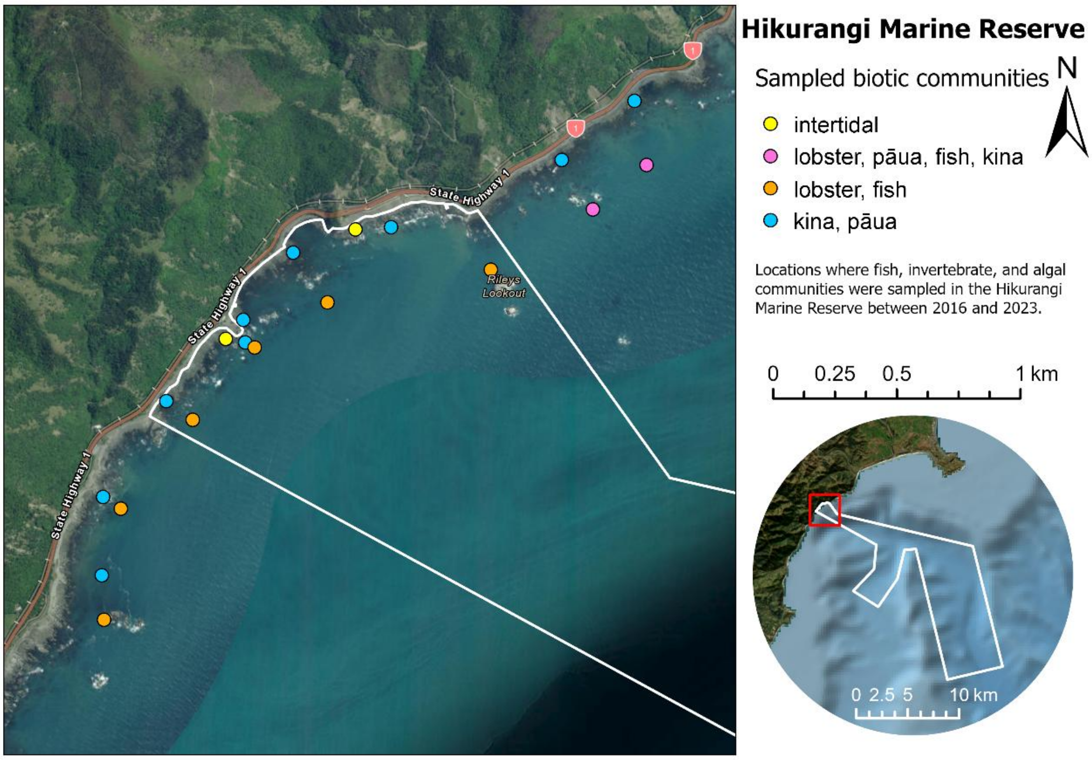

Figure 2. Survey sites inside and outside the Hikurangi Marine Reserve. Reserve boundaries are shown with white lines. Each dot marks a survey site, and the colour of dot indicates what biotic communities were sampled there.

For all surveys, abundance was sampled as density, or number of individuals per unit area (or number per pot for rock lobster potting surveys). This is hereafter referred to as “abundance”. Size measurement methods vary by species and are specified below.

Pāua (blackfoot pāua; *Haliotis iris*) abundance and size (shell length) was sampled in 2016, 2017, 2022, and 2024 at 11-26 sites (5-12 reserve and 4-14 non-reserve, site number varied across years) by dive surveys using 1 m x 1 m quadrats (n = 28-42 quadrats site^{-1} year^{-1}) (see Davidson and Laferriere 2016). Pāua size and abundance were also sampled in dive surveys at 4 fished sites and 1 site inside the HMR, at two time points spaced 3 months apart (see Gerrity and Schiel 2023). These time points were before and after the 2021 reopening of the Kaikōura pāua fishery, which had been closed for 5 years following the 2016 earthquake.

Rock lobster (kōura; *Jasus edwardsii*) abundance (density) and size (carapace length) were surveyed in 2016 and 2024 by underwater visual census (UVC) along a 5 m x 25 m dive transect at 8 sites (4 reserve and 4 non-reserve) (see Davidson and Laferriere 2016). It was not possible to handle rock lobster during UVC surveys, so size was measured by placing a ruler along the carapace. Potting surveys assessed rock lobster abundance (number per pot) in 2020 using 15 pots inside, 15 pots north of the reserve, and 15 pots south of the reserve (45 pots total) (see Freeman, 2017). In 2021 there were 30 pots per site (90 total). Because rock lobster could be individually handled in potting surveys, size was measured as tail width across the second abdominal segment (i.e., the standard fishing retention measurement).

Kina (New Zealand sea urchin; *Evechinus chloroticus*) abundance (density) and size (test width) were sampled in 1 m x 1 m quadrats in 2022 at 10 sites (5 reserve and 5 non-reserve) and in 2024 at 26 sites (12 reserve and 14 non-reserve) by dive surveys (see Davidson and Laferriere, 2016).

Reef fish communities were visually counted and identified along a 5 m x 30 m dive transect at 8 sites (4 reserve and 4 non-reserve) (see Davidson and Laferriere, 2016). The fish species sampled included marblefish (*Aplodactylus arctidens*), blue moki (*Latridopsis ciliaris*), spotty (*Notolabrus celidotus*), banded wrasse (*Notolabrus fucicola*), butterfish (*Odax pullus*), blue cod (*Parapercis colias*), and scarlet wrasse (*Pseudolabrus miles*).

Intertidal algae and invertebrates were sampled for abundance annually from 2019-2023 using ten 1 m x 1 m quadrats in each of the low, mid, and high intertidal reef zones at two sites inside the HMR. Aerial drone surveys with multispectral imaging technology conducted in 2020 provided visual assessments of intertidal and shallow subtidal biogenic habitats and algal communities along the HMR coastline (Tait 2021).

Statistical methods

Abundance (density) of pāua, rock lobster, kina and reef fish, as well as species richness (number of different species) of reef fish populations were analysed using ANOVA or PERMANOVA with Protection (reserve and non-reserve) and Year (when multiple years were sampled) as fixed factors and Site nested in Protection as a random factor. Univariate abundance data for pāua, rock lobster UVC, and kina were analysed using PERMANOVA because they failed to meet the assumptions of ANOVA, even after transforming. For these analyses, Euclidian distance was used to create the resemblance matrix.

Fish community composition was analysed using PERMANOVA following the same design as abundance, except Bray Curtis (with a dummy variable of 0.1) was used to create the resemblance matrix.

To analyse size structure of pāua, rock lobster, and kina, discrete size classes were created from shell length, tail width, or test width every 5 or 10 mm between the minimum and maximum recorded sizes. The percentage of individuals in each size class was calculated as a proportion of the total population abundance. The cumulative percentage across each Site x Year combination (when multiple years or dates were sampled) was then calculated. The cumulative percentage of pāua, rock lobster, or kina in each size class was then analysed using a PERMANOVA with Year and Protection as fixed factors and Site, nested within Protection, as a random factor. The resemblance matrix was created using Euclidian distances. Note that because carapace length was measured for rock lobster in UVC surveys, tail width was calculated based on sex-specific equations from Fry et al. (2014) to better relate these values to minimum legal sizes for fishing.

Results

Pāua

Pāua densities were highly variable across all sites but were significantly higher outside the HMR ($PseudoF_{1,36}$ = 3.74 p = 0.028; Figs. 3 and 4; Table 1). Average abundance of pāua increased at reserve and non-reserve sites from 2016 to 2022, but then declined by 2024, although there were no significant differences over time (Fig. 3).

On average pāua were larger inside the HMR than outside, but this difference was not statistically significant through ($PseudoF_{1,24}$ = 0.01, p = 0.76; Fig. 4; Table 1). Interestingly, by 2024 a considerable proportion (30-40%) of the pāua at non-reserve sites were of legal harvest size (125 mm from 2021-24, and 130 mm from 2025, Fig. 4).

We note that sampling effort was not consisent through time, which likely increased the variablity in the data. The number of quadrats sampled per site ranged from 28-42 and in 2024 the number of sites sampled increased from 9 to 26.

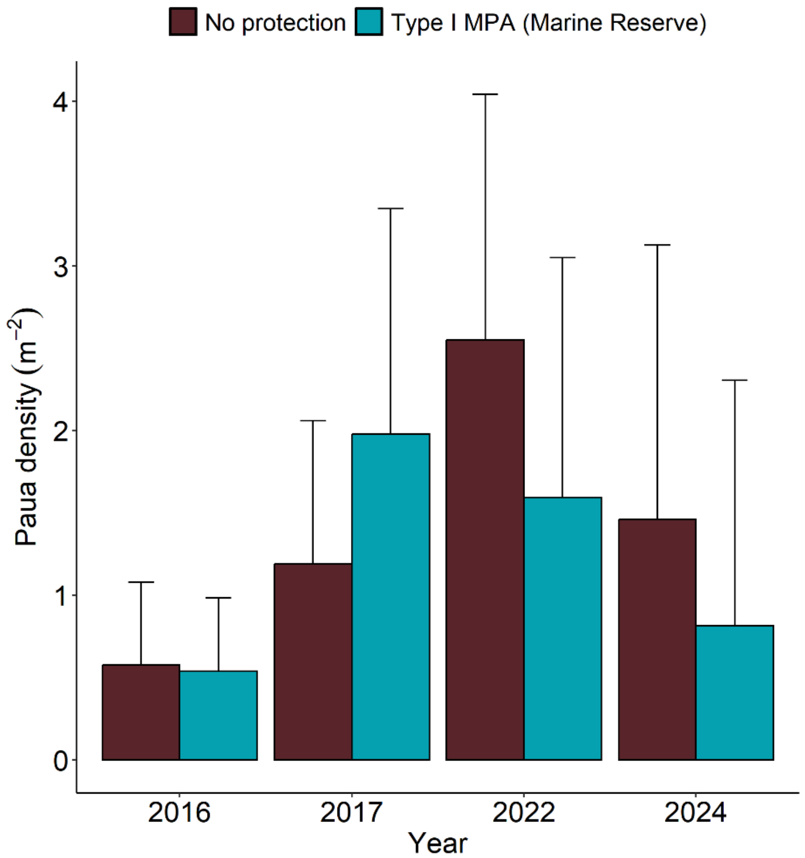

Figure 3. Density (mean + SE m^{-2}) of pāua inside and outside the Hikurangi Marine Reserve in 2016, 2017, 2022, and 2024. N (the total number of quadrats per protection status per year) was: 123 / 173 (2016), 148 / 175 (2017), 151 / 158 (2022), and 431 / 377 (2024) in the non-reserve and reserve sites, respectively. These N values differ each year because the number of quadrats per site varied from 28-42 and in 2024 the number of sites increased from 4-5 to 12-14 per protection level.

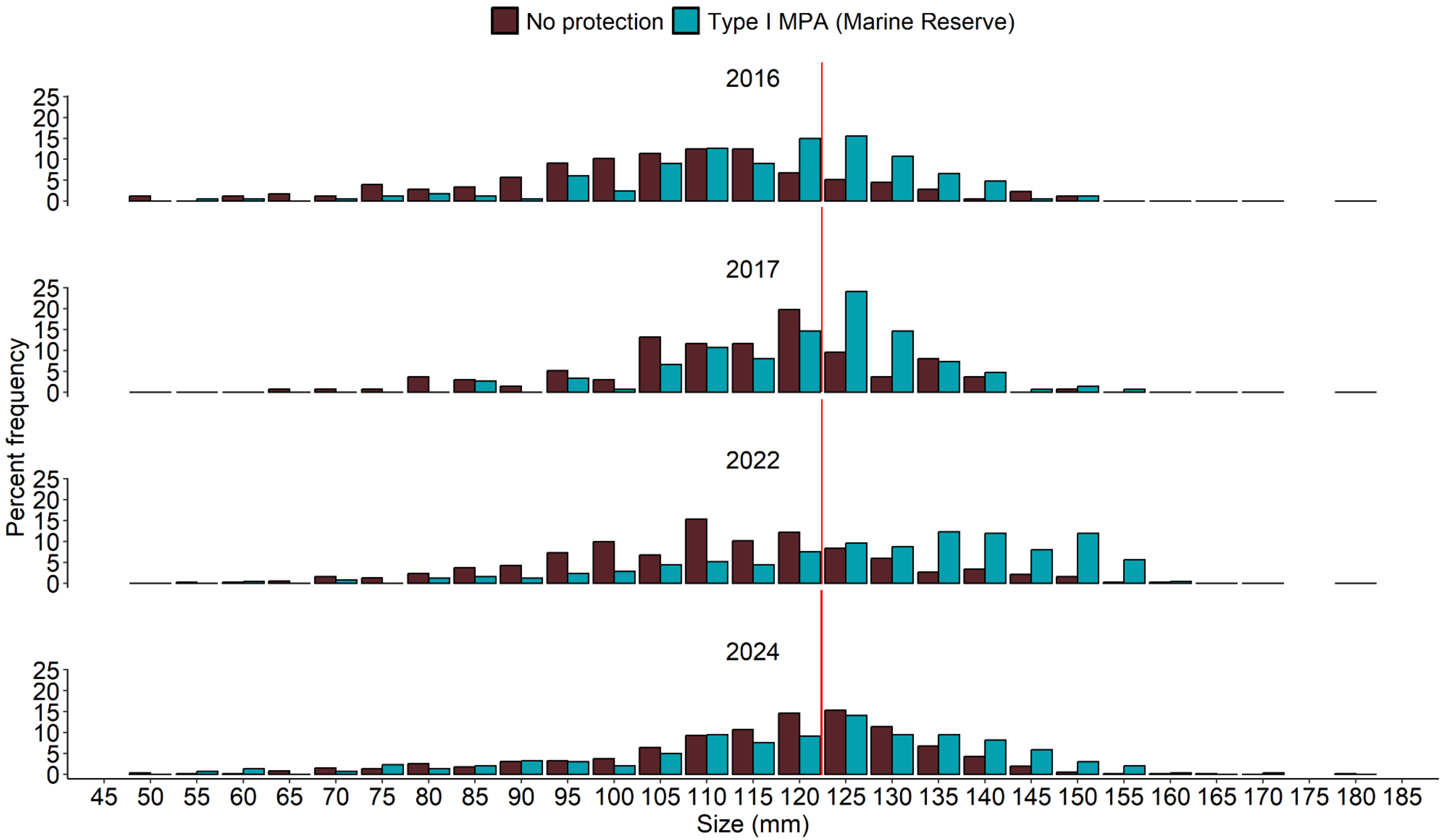

Figure 4. Length-frequency histogram of pāua sampled inside and outside of the Hikurangi Marine Reserve in 2016, 2017, 2022, and 2024. Proportion of measured pāua (%) in each size class are presented for each year and site type. The red vertical line indicates the minimum legal size for retention of pāua (125 mm).

Table 1. Summary statistics for density (number of individuals m^{-2}) and size (in mm) of pāua inside and outside the Hikurangi Marine Reserve in 2016, 2017, 2022, and 2024. For size, N is the total number of measured pāua.

Variable	Year	Marine Reserve			Non-reserve		
		mean	SD	SE	mean	SD	SE
Density	2016	0.54	1.09	0.49	0.58	1.23	1.73
	2017	1.98	3.36	1.50	1.19	2.14	2.29
	2022	1.59	3.56	1.59	2.55	3.66	2.99
	2024	0.81	3.65	1.05	1.46	4.08	3.16
		mean	SD	N	mean	SD	N
Size	2016	119.59	16.40	167	107.84	20.29	177
	2017	124.69	12.71	150	116.93	15.84	137
	2022	131.72	19.22	252	113.88	17.77	385
	2024	123.18	20.82	306	118.64	19.26	627

Additional dive surveys designed to assess the effects of shore-based fishing showed that the size distribution of pāua in the HMR did not change significantly before and after the 2021-22 pāua fishing season, suggesting the reserve effectively restricted harvest (Fig. 5). In contrast, at 4 non-reserve (fished) sites pāua size structure shifted signficantly towards smaller size classes before and after the 3-month fishing season, indicating fishing had a strong effect in reducing pāua size ($PseudoF_{1,10}$ = 6.45, p = 0.018; Fig. 4).

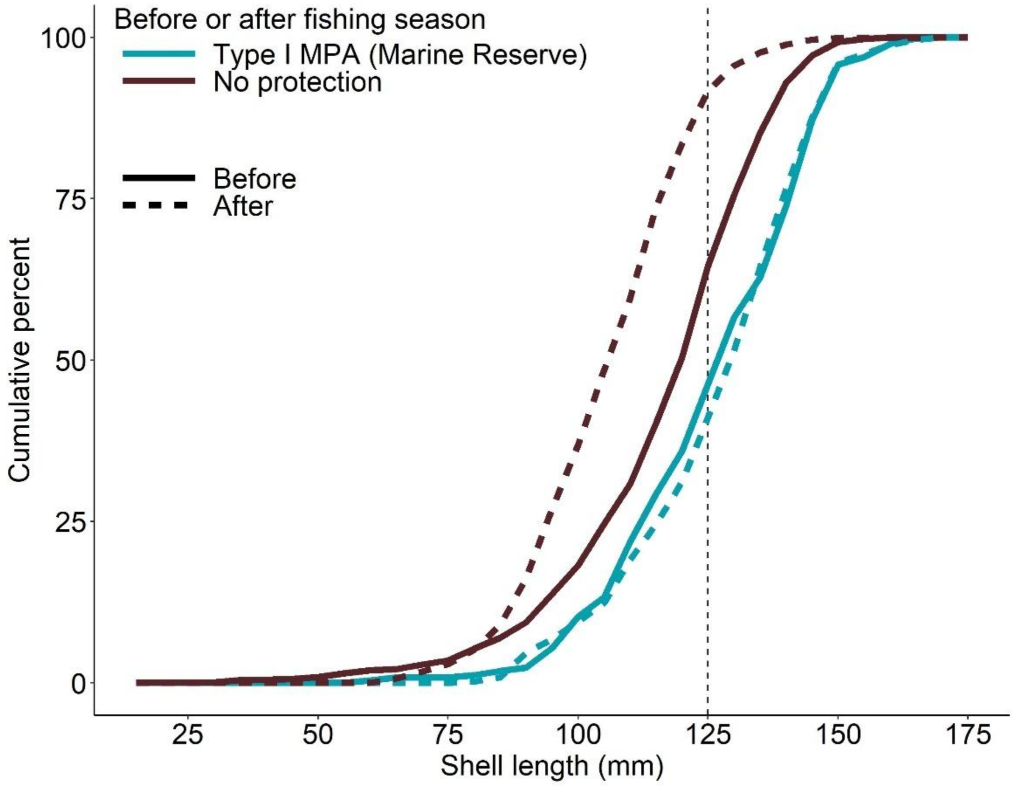

Figure 5. Cumulative percent of shell length for pāua in the Hikurangi Marine Reserve and at 4 nearby non-reserve sites (combined) before and after the 2021 Kaikōura pāua fishing season.

Rock lobster – underwater visual census

Because identification of sex was not always possible during underwater visual census (UVC) surveys, males and females are combined here. UVC surveys showed that rock lobster were more abundant inside than outside of the HMR in both 2016 (mean ± SE: 3.6 ± 2.0 vs. 2.0 ± 1.4 125 m^{-2}) and 2024 (5.6 ± 4.0 vs. 2.6 ± 1.7 125 m^{-2}; Fig. 6). However, this was not significant ($PseudoF_{1,7}$ = 2.30, p = 0.159), due to high variability among sites.

Rock lobster (males and females combined) tended to be slightly larger outside (mean ± SD tail width: 59.7 ± 10.8 mm) than inside (50.2 ± 14.3 mm) the HMR in 2016, but not significantly so. This pattern was reversed in 2024 (54.7 ± 6.8 outside vs. 57.0 ± 10.3 mm inside; Fig. 7), but was again not significant ($PseudoF_{1,10}$ = 1.52 p = 0.264).

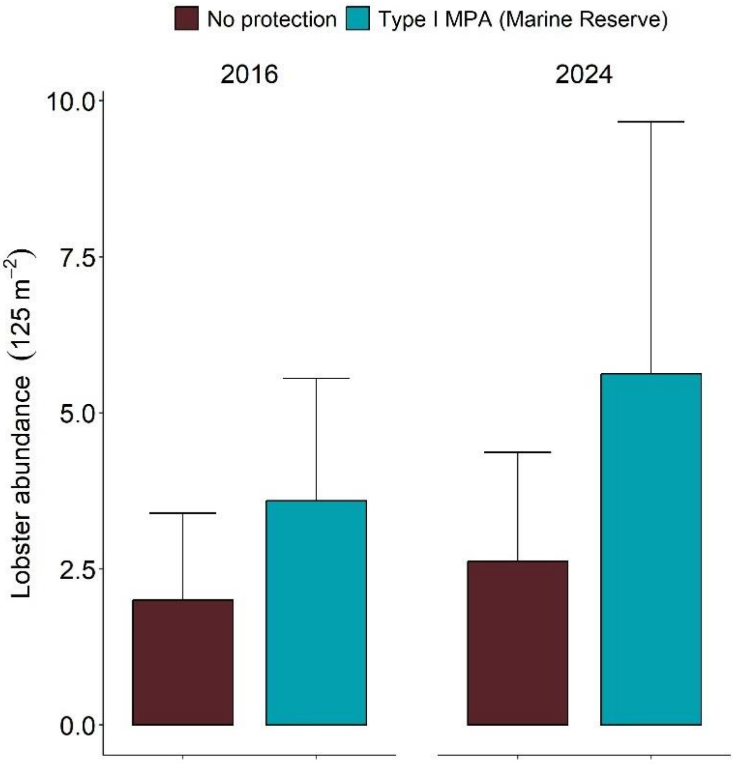

Figure 6. Abundance (mean + SE 125 m^2) of rock lobster (male and female combined) from UVC surveys inside and outside of the Hikurangi Marine Reserve in 2016 and 2024. N = 4 sites per site type.

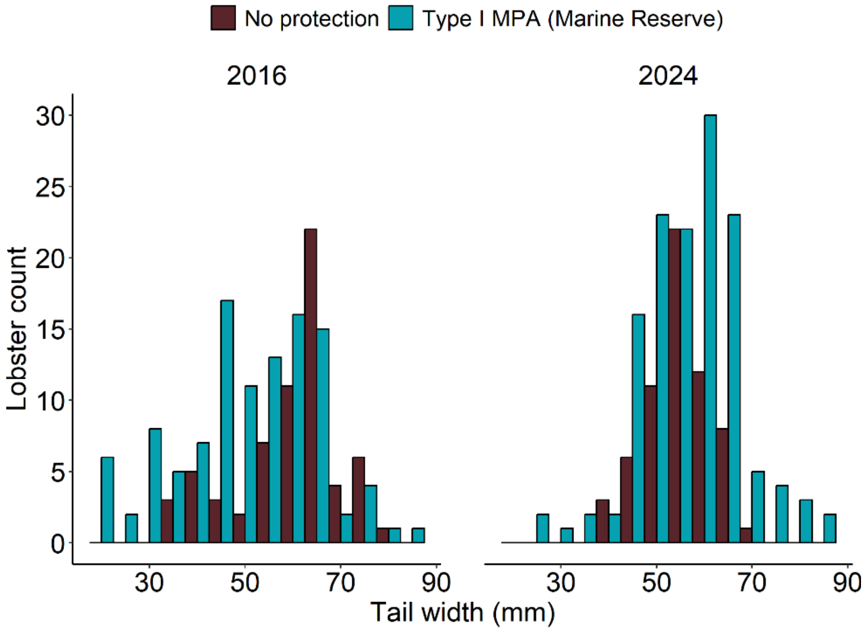

Figure 7. Size frequency histogram of tail widths (mm) of rock lobster (male and female combined) from UVC surveys inside and outside of the Hikurangi Marine Reserve in 2016 and 2024. N = 104 and 103 individuals outside of the marine reserve in 2016 and 2024 and N = 265 and 443 individuals inside the marine reserve in 2016 and 2024.

Rock lobster – potting surveys

Unlike UVC, potting surveys allowed accurate identification of rock lobster sex. Based on potting surveys conducted in 2020 and 2021, female rock lobsters were significantly more abundant inside (mean ± SE in 2020: 32.6 ± 6.6 and 2021:17.2 ± 4.3 individuals pot^{-1}) than outside (2020: 4.9 ± 1.3 and

2021: 16.0 ± 5.1 individuals pot^{-1}) of the HMR ($F_{2,110}$ = 11.23 p < 0.001, Fig. 8). For male rock lobster, there was a significant interaction between year and protection status ($F_{1,127}$ = 5.72 p = 0.018), mainly driven by a decrease in the number of individuals in the marine reserve between 2020 and 2021 (2020: 8.4 ± 1.0 and 2021: 4.4 ± 0.8 individuals pot^{-1}) compared to outside (2020: 4.9 ± 1.1 and 2021: 5.9 ± 1.4 individuals pot^{-1}). Female rock lobster abundance decreased significantly ($F_{2,110}$ = 7.76 p = 0.006) over time across reserve and non-reserve sites combined (18.7 ± 3.2 individuals pot^{-1} in 2020 and 11.4 ± 2.0 individuals pot^{-1} in 2021).

Male and female rock lobster were significantly larger inside the reserve (pooling males and females: mean ± SD inside reserve in 2020: 65.9 ± 6.6 and 2021: 65.3 ± 6.3 mm) compared to outside of the HMR (pooling males and females: mean ± SD outside reserve in 2020: 59.2 ± 7.0 and 2021: 58.3 ± 6.4 mm; $PseudoF_{2,128}$ = 32.1 p < 0.001; Fig. 9). Females (63.8 ± 6.3 mm) were significantly larger than males (58.9 ± 8.5) at all sites in both years ($PseudoF_{2,128}$ = 112 p < 0.001; Fig. 9).

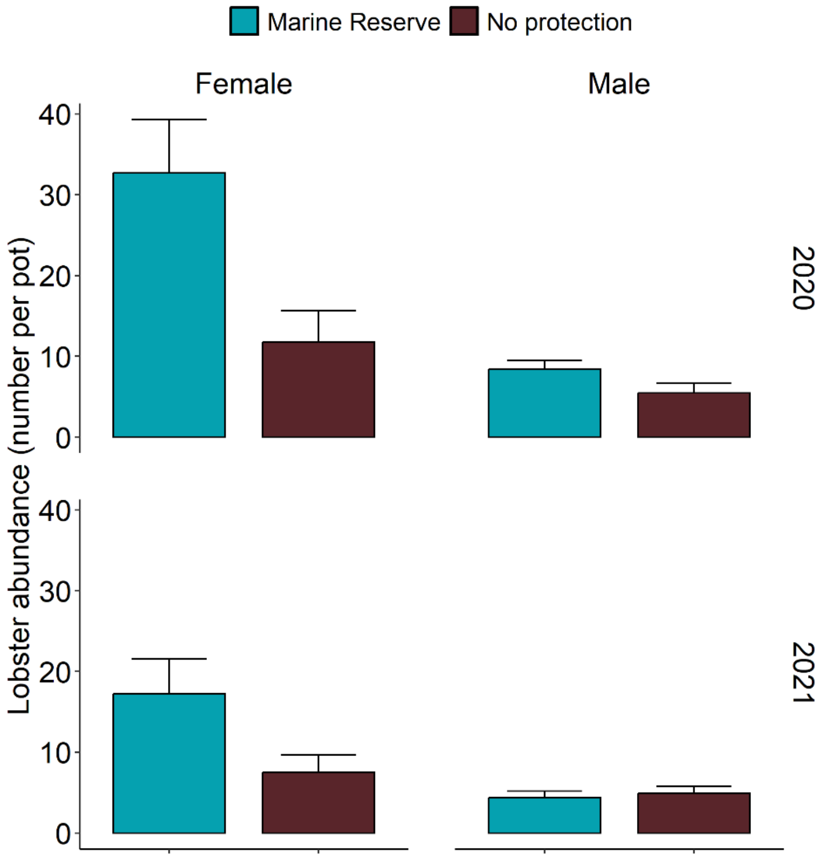

Figure 8. Abundance (mean + SE pot^{-1}) of female and male rock lobster inside the Hikurangi Marine Reserve, compared to controls to the north and south of the reserve, in 2020 and 2021 (n = 15-60 pots location^{-1} year $^{-1}$).

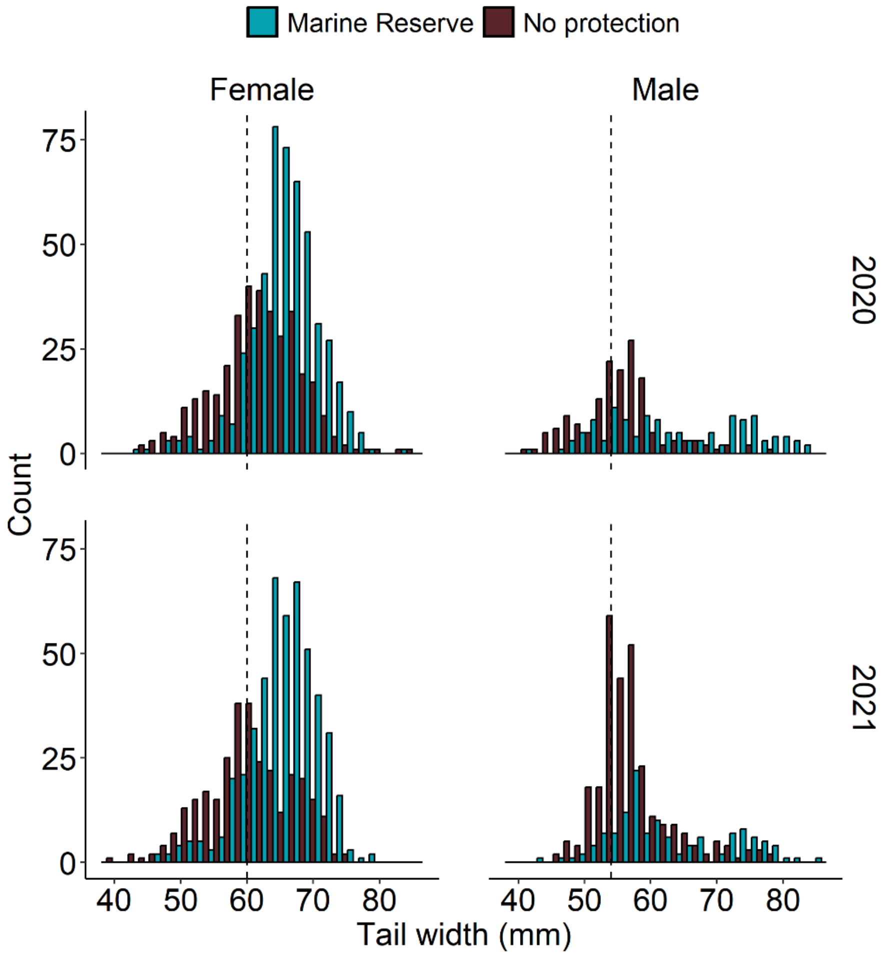

Figure 9. Size frequency histogram of female and male rock lobster tail width inside and outside of the Hikurangi Marine Reserve in 2020 and 2021 from potting surveys. Dashed lines show the minimum legal size for retention of females (60 mm) and males (54 mm). Combining males and females, N = 513 and 593 in 2020 and 2021 at the non-reserve sites and 609 and 616 in the Marine Reserve in 2020 and 2021. Number of pots in 2020 and 2021 was 45 and 90, respectively (15-30 reserve and 30-60 non-reserve).

Reef fish

There were no significant differences in reef fish community composition inside versus outside of the HMR ($PseudoF_{1,6}$ = 1.79, p = 0.11). Species richness tended to be higher inside rather than outside of the HMR, although this was not significant ($F_{1,6}$ = 5.08, p = 0.07). Fish were significantly more abundant inside the HMR (mean ± SE: 9.2 ± 3.4 150 m^{-2}) than outside (2.8 ± 0.9 150 m^{-2}) ($F_{1,6}$ = 7.14, p = 0.037; Fig. 10). All species sampled were at least twice as abundant inside than outside of the marine reserve, but this difference was especially pronounced for blue moki, which was 16 times more abundant inside than outside of the HMR (See Table 2). There was only 1 survey for reef fish, so trends over time could not be investigated.

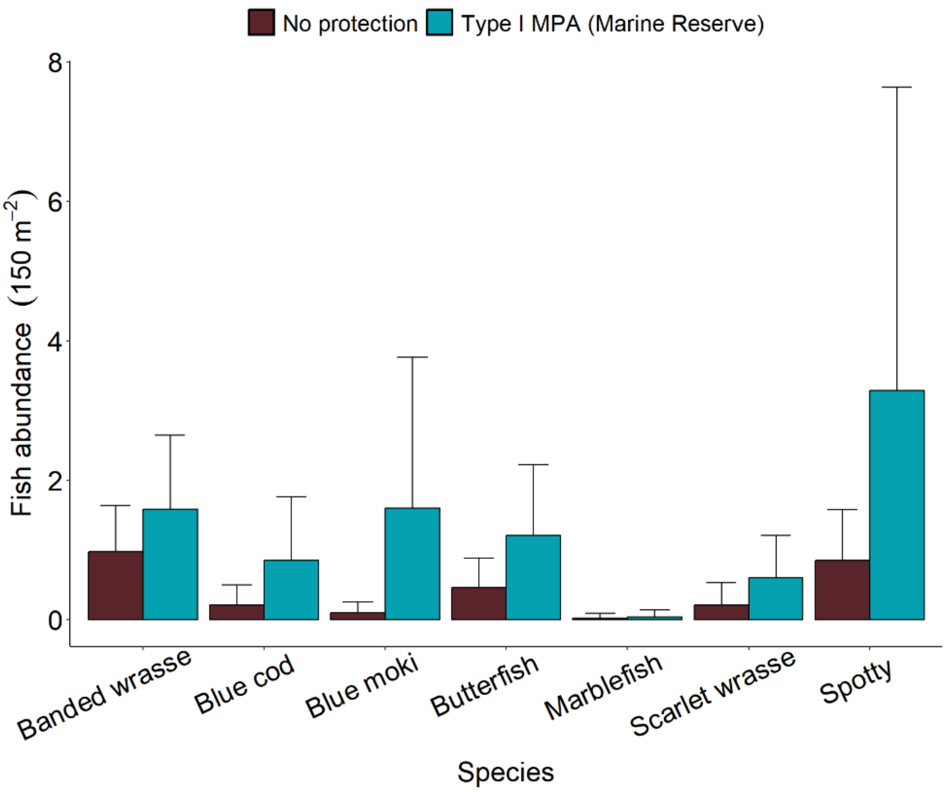

Figure 10. Abundance (mean + SE 150 m^2) of reef fish species at sites inside and outside of the Hikurangi Marine Reserve in 2016. N = 4 sites per site type.

Table 2. Summary statistics for abundance (mean ± SE 150 m^2) of reef fish at sites outside (no protection) and inside the Hikurangi Marine Reserve in 2016. N = 4 sites per site type.

Fish Type	No Protection			Marine Reserve		
	Mean	SD	SE	Mean	SD	SE
Banded wrasse	0.98	1.33	0.66	1.58	2.12	1.06
Blue cod	0.21	0.58	0.29	0.85	1.82	0.91
Blue moki	0.10	0.31	0.15	1.60	4.33	2.16
Butterfish	0.46	0.85	0.42	1.21	2.04	1.02
Marblefish	0.02	0.14	0.07	0.04	0.20	0.10
Scarlet wrasse	0.21	0.65	0.33	0.60	1.22	0.61
Spotty	0.85	1.44	0.72	3.29	8.70	4.35

Kina

Kina were significantly more abundant inside (mean ± SE: 0.13 ± 0.04 m^{-2} in 2022 and 0.48 ± 0.11 m^{-2} in 2024) than outside (0.06 ± 0.02 m^{-2} in 2022 and 0.16 ± 0.04 m^{-2} in 2024) of the HMR ($PseudoF_{1,1111}$ = 4.51, p = 0.03). Kina abundance increased significantly from 2022 to 2024 at both reserve and non-reserve sites ($PseudoF_{1,1111}$ = 6.01, p = 0.01; Fig. 11). There was no significant difference in kina size between locations ($PseudoF_{1,26}$ = 1.63, p = 0.15; Fig. 12) although there was a significant difference between years ($PseudoF_{1,26}$ = 11.54, p = 0.001), indicating that kina were bigger in 2024 than 2022 (mean ± SE test size 2022-2024 = 81-93 ± 25 mm outside and 82-104 ± 18-22 mm inside the HMR).

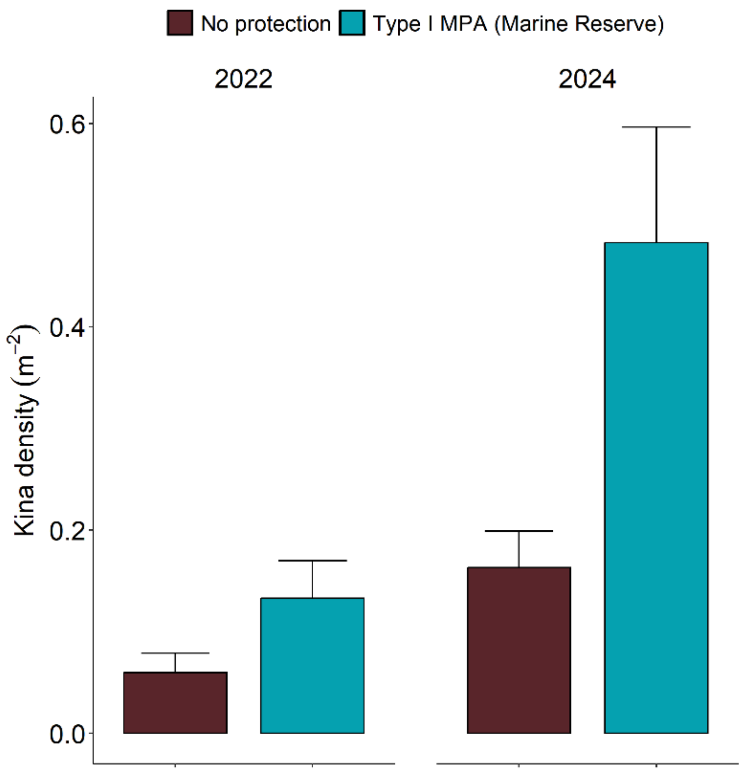

Figure 11. Density of kina (mean + SE m^{-2}) inside and outside of the Hikurangi Marine Reserve in 2022 and 2024. The number of sites in 2022 was 10 (five per protection level) and in 2024 it was 26 (12 reserve and 14 non-reserve).

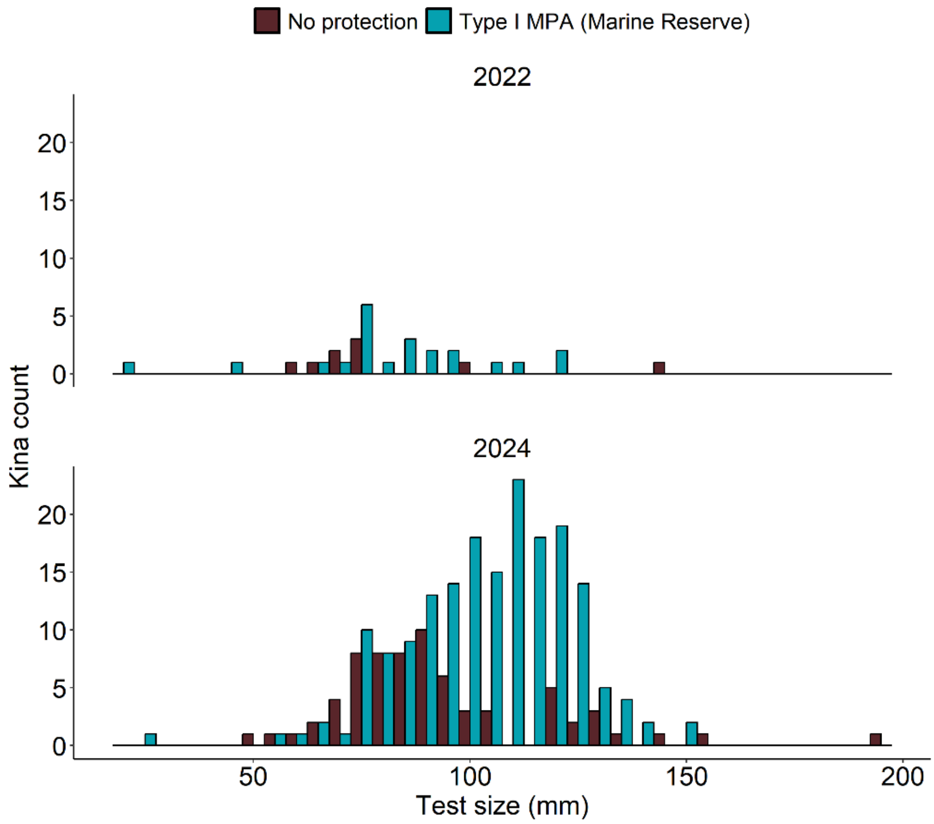

Figure 12. Size structure of kina populations inside and outside of the Hikurangi Marine Reserve in 2022 and 2024. The total number of kina in 2022 and 2024 inside the reserve was 21 and 182. Outside of the reserve it was 9 and 70, respectively. The number of sites in 2022 was 10 (five per protection level) and in 2024 it was 26 (12 reserve and 14 non-reserve).

Intertidal reef community

Abundance of intertidal reef algae and invertebrates was variable across tidal zones and through time (Fig. 13). Notably, in the low intertidal reef zone, cover of the important habitat-forming bull kelp (*Durvillaea spp.*) was stable at 15-20% over 5 years of surveys (Falconer et al. 2023). Other habitat-forming large brown algae and coralline algae were also highly abundant, with each having > 40% average cover. Limpets and other mobile herbivores were also abundant in the mid and high tidal zones. Sessile invertebrates such as barnacles and small mussels were abundant in the high tidal zone. No large beds of mussels (i.e., green-lipped or blue mussels) were observed in the reserve.

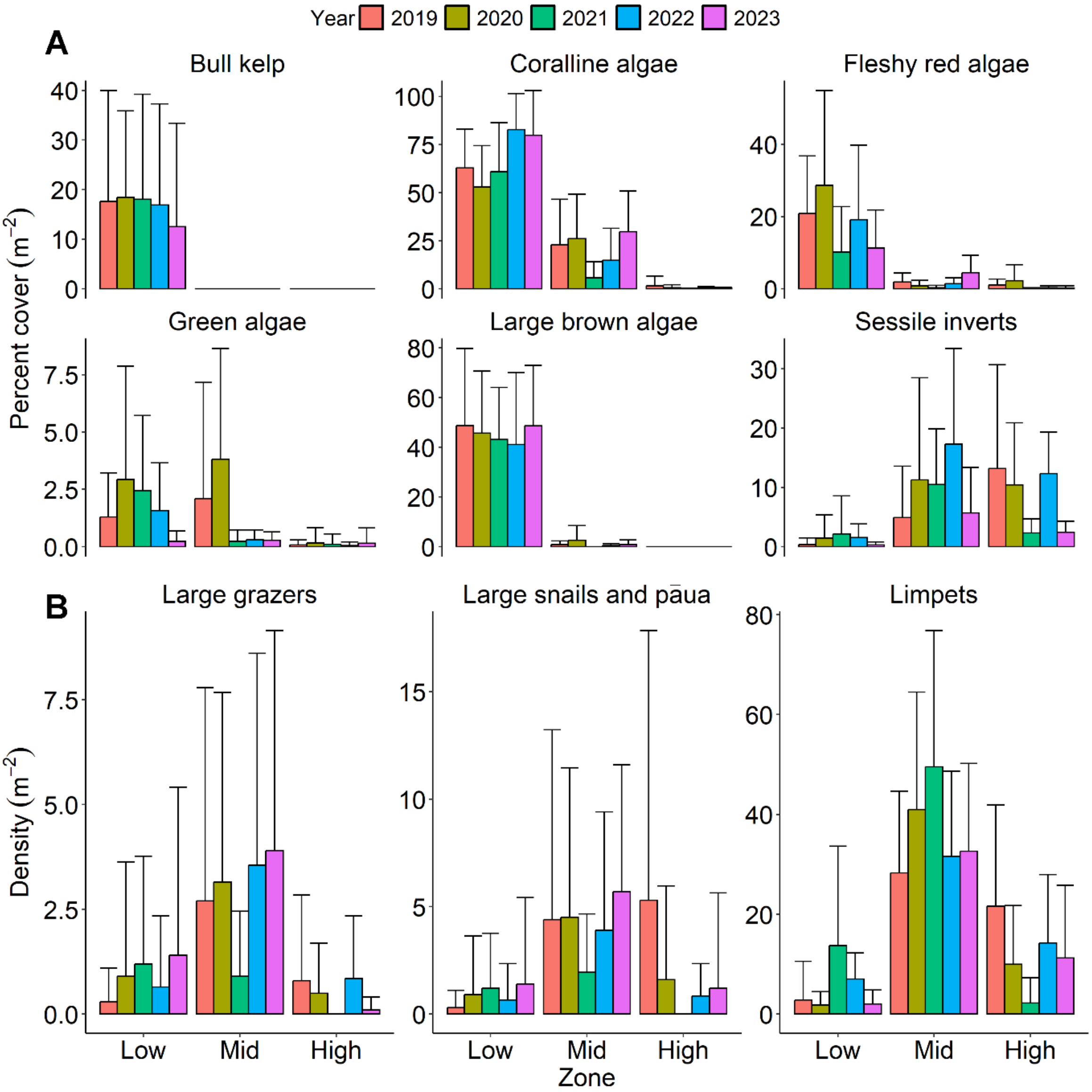

Figure 13. Average A) percent cover and B) density (mean + SE m^{-2}) of key intertidal reef taxa at three tidal zones (Low, Mid, High) inside the Hikurangi Marine Reserve from 2019-2023. N = 10 quadrats per zone per year.

Intertidal and shallow subtidal macroalgal canopies, were assessed with aerial multispectral imaging technology. Drone surveys in 2020 showed that HMR had moderate to sparse canopies of the bull kelp *Durvillaea antarctica/poha*, but extensive canopies of the bull kelp *Durvillaea willana* (Tait 2021). Other large brown algae such as *Carpophyllum maschalocarpum* and several *Cystophora* species were also abundant in the low intertidal and shallow subtidal (Fig. 14). A range of red algae and encrusting and articulated coralline turfs were also observed throughout.

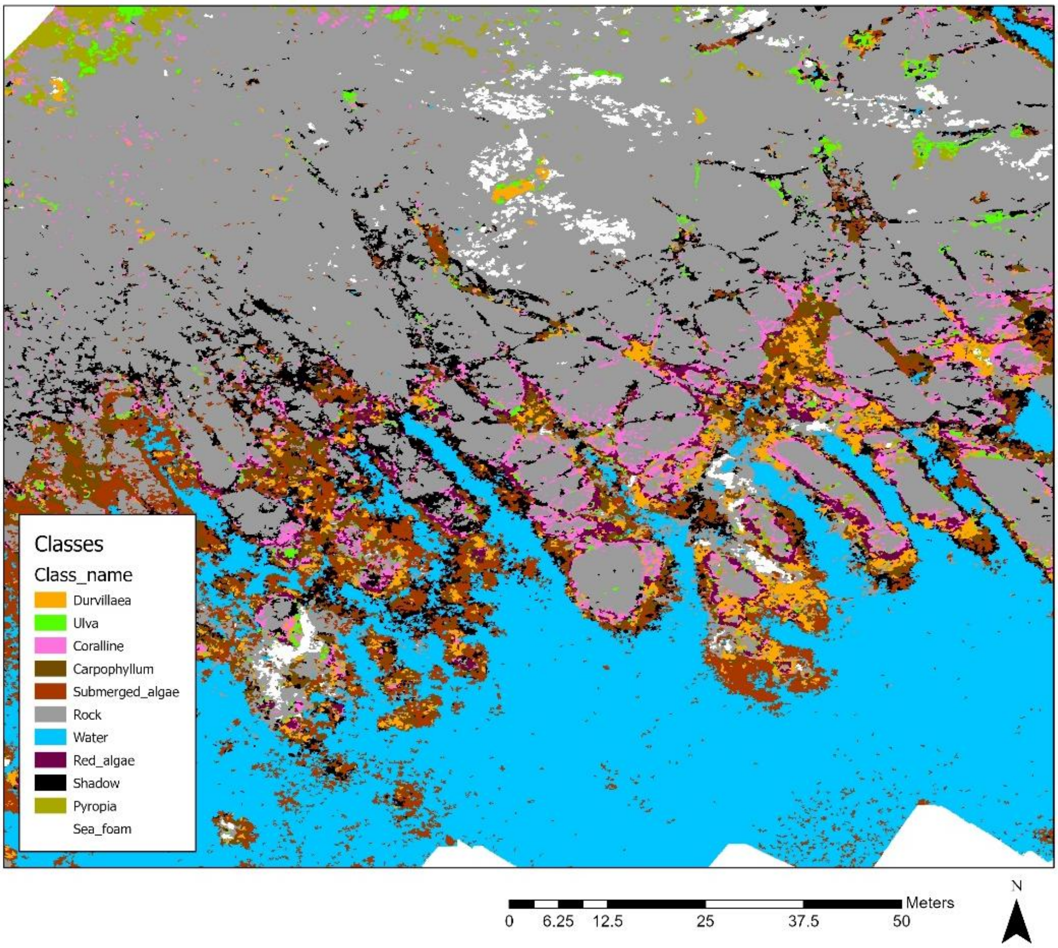

Figure 14. Classified multispectral imaging output layers, for about 150 linear meters of the Hikurangi Marine Reserve coastline, from 2020 aerial drone surveys, showing segmented region classification (the key applies to both images). Multispectral image(s). The different colours correspond to various macroalgal taxa and abiotic features including bare rock. Image from Tait (2021).

Discussion

Pāua

No strong trends were evident from UVC pāua surveys due to high variability in the data, so it is difficult to interpret reserve effects. Pāua were less abundant inside the HMR compared to non-reserve sites, perhaps due in part to the closure of the pāua fishery along the earthquake-affected coastline from November 2016 to December 2021. The closure effectively turned about 130 km of coast into a pāua reserve for 5 years and resulted in a widespread buildup of biomass at many sites, which may have lessened any prior contrast in pāua abundance between the HMR and non-reserve sites. We also note that survey effort increased considerably through time, which likely affected the variability in the data. Thus, the observed changes in pāua abundance and size-structure are difficult to interpret and may reflect new areas being surveyed rather than spatiotemporal changes or reserve effects.

While no significant positive effects of the HMR on pāua abundance were evident from UVC surveys, additional surveys by the Marine Ecology Research Group (Univ. Canterbury) showed that the HMR protected broodstock during the 2021 reopening of the fishery, which saw very high shore-based fishing effort near the reserve (Gerrity and Schiel 2023). There were an estimated 42 tonnes of pāua harvested in 3 months by shore-based recreational fishers in the Kaikōura Marine Area, with some of the greatest effort concentrated just outside of the HMR boundaries (Holdsworth 2022). Nearly 5,000 divers were estimated to have fished the areas immediately outside the reserve over the 90-day season (Fig. 15;

adapted from Holdsworth 2022). Pāua biomass and size structure inside the HMR remained consistent throughout the fishing season, while sites accessible to shore-based fishing experienced depletion of legal-sized pāua by up to 92% (Gerrity and Schiel 2023). This illustrates the ability of the HMR to prevent localised depletion and preserve broodstock aggregations of pāua during periods of intensive fishing. The protection offered by the HMR may become increasingly important at preserving pāua spawning biomass, with a recent increase in the recreational allowance from 5 t to 18 t for in the PAU3A management area, which includes the Kaikōura coast (Jones 2024), and a consistent record of harvest exceeding the allowance (Holdsworth 2022, Holdsworth et al. 2023, Holdsworth et al. 2025).

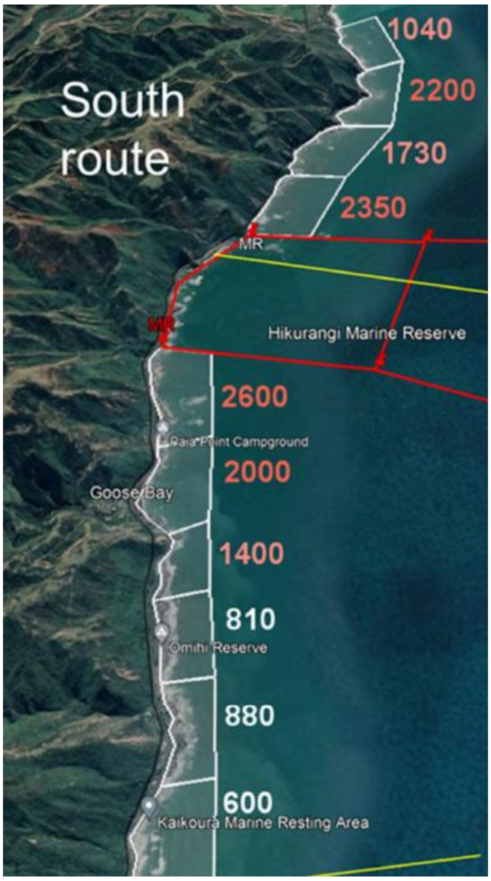

Figure 15. Map showing the estimated number of divers in the water over the 90-day pāua fishing season in 2021-22 in each survey strata (white line borders). The red lines indicate the boundaries of the Hikurangi Marine Reserve. Figure modified from Holdsworth (2022).

Despite the reserve status and abundant signage, substantial illegal pāua harvest was documented inside the HMR over the course of study. Nearly 50 incidents of attempted pāua harvest occurred in just one day during the 2021 season (RNZ 2022, Gerrity and Schiel 2023). There was a significant decline in the abundance of pāua in the intertidal reef zone inside the HMR during the 2016-2021 earthquake-related fishery closure, suggesting illegal take (Gerrity and Schiel 2023). In 2023, poachers were caught removing 468 pāua from the southern portion of the reserve (Wardle 2023). The pāua were returned live to the HMR by DOC marine reserve rangers after being processed as evidence. Follow-up surveys a week after their return showed that many survived the ordeal (Fig. 16). While there is great effort to enforce the marine reserve regulations by Department of Conservation rangers and Fisheries New Zealand compliance officers, the easy access of the HMR to the state highway makes it vulnerable to illegal harvest. Despite evident pāua poaching in the reserve, however, there remains several groups of large pāua in very accessible intertidal habitats.

Figure 16. A group of pāua that had been poached from the Hikurangi Marine Reserve in 2023 but were returned alive to the reserve by Department of Conservation rangers, photographed about one week after their release by Shawn Gerrity.

Despite the overharvesting of pāua by amateur fishers during the 2021-22 season, by 2024 there was a large proportion of legal-sized (125 mm) pāua at non-reserve sites. This may reflect the high productivity and growth rates of pāua stocks in the region, and/or be the result of stricter recreational controls instituted since 2022 at the behest of the Kaikōura Marine Guardians and mana whenua. These included a shift of the fishing season to winter months, a shortened season from 3 to 2 months, and reduced daily bag limits from 5 to 3 pāua per person. These regulatory changes likely contributed to lower recreational harvest estimates in subsequent fishing seasons in the Kaikōura Marine Area compared to the 2021-22 reopening, although the 5 t allowance was exceeded each season (11.66 t in the 2-month 2023 season, and 15.83 t in the 2-month 2024 season, Holdsworth et al. 2023, Holdsworth et al. 2025).

In the most recent 2025 recreational pāua season, the minimum legal size for retention has been increased from 125 mm to 130 mm, which will protect a large proportion of stock at non-reserve areas in the 125-129 mm size range (Virgin et al. 2025). Combined, these regulatory controls are some of the most stringent in the country and may further improve the pāua size structure and biomass at non-reserve sites over time. As pāua fishing regulations are continually refined, and catch allowances increased, the HMR provides a valuable baseline or target from which to gauge management efficacy in exploited areas.

Rock lobster

Rock lobster are highly valuable culturally, recreationally and commercially in the Kaikōura region, and the health of the population is a top priority of the local community and managers. Potting surveys showed significant positive reserve effects on rock lobster abundance and size, although results from UVC dive surveys were unclear. Potting surveys showed female rock lobsters were more abundant and larger in the reserve in 2020 and 2021 compared to non-reserve sites, suggesting that the reserve provides refuge for broodstock. The surrounding portion of coastline is consistently fished by commercial and recreational fishers, many of whom dive and place craypots along the reserve boundaries. Thus the reserve effects on rock lobsters are unsurprising, and consistent with other studies showing that reserves have increased the size and abundance of adult rock lobster (inside reserves) in about 8.5 years (e.g. Pande et al. 2008). However, due to the complex nature of the rock lobster lifecycle and their large spatial ranges, the effects of marine reserves on the productivity of rock lobster populations, including larval export and juvenile recruitment, are not fully understood. Further work is needed to clarify the effects of the HMR on rock lobster populations beyond the reserve boundaries.

Despite the positive effects of the HMR, potting surveys showed declines in rock lobster abundance at all reserve and non-reserve sites from 2020-2021. This reflects recent concerns by local recreational and commercial fishers who have described noticeable declines in catch over the past 2-3 years. The HMR provides a rare, unfished study site to better understand the local-scale effects of rock lobster fishing and broader demographic change in populations. However, due to the large home range of rock lobsters and the long dispersal distances of larvae and post-larvae, the HMR may not necessarily protect the local population from external fishing effects. For example, population decline in non-reserve areas may affect larval supply to the reserve habitats. Continued surveys within and around the HMR will provide further information on these complex dynamics.

Reef fish

Most of the fish species surveyed here are common targets for line fishers and spear fishers. Reef fish communities were similar in composition between reserve and non-reserve sites, however the abundance of fish was much higher inside the reserve. Results showed that the reserve is offering protection to fish, particularly blue moki (16x more abundant in reserve), blue cod (4.3x), spotty (3.9x), and butterfish (2.7x). There is a significant literature describing the positive effects of reserves on fish size and abundance. Notably, Beentjes (2023) showed via potting surveys that the HMR and other closed areas had strong positive effects on blue cod populations, including increased abundance and body size. We note that the life history, feeding and movement patterns of the fish species analysed here are complex, and beyond the scope of this report. Also, as only one survey of reef fish was conducted (in 2016), additional surveys would improve reserve assessments and clarify temporal trends in fish abundance and community structure.

It should be noted that UVC methods used here are limited in their ability to accurately describe fish communities (Murphy and Jenkins 2010). If possible, this method should be coupled with other survey types, such as baited underwater video (BUV) or potting surveys. There is some debate as to whether marine reserves enhance fish populations outside the boundaries of the reserves. This could be an interesting inquiry for future research efforts around the HMR.

Kina

Kina were significantly more abundant inside the reserve than outside but were found in low abundances on average at < 0.5 kina m^{-2}. As a comparison, McShane and Naylor (1990) recorded kina abundances ranging from 0.1-5.5 m^{-2} in pristine habitats in Fiordland in the 1990’s. There were no observations from divers in 2025 indicating that kina were significantly reducing macroalgae canopies or forming ‘barrens’ in the HMR (Gerrity, pers. comm.). Kina were of a large average size (80-100 mm) considering that kina in the Kaikōura region reach maturity between 30-75 mm in diameter (Fisheries New Zealand 2025), and compared to sizes found in the Marlborough Sounds (Anderson et al. 2023).

Kina abundance and average size increased through time at sites inside and outside the marine reserve, but more sampling through time would be needed to determine if the populations are indeed growing. Kina are commonly found in the Kaikōura marine area but are not known to form barrens there (Dartnall 2020). Little is published about commercial and recreational fishing for kina in the Kaikōura region, although it is one of the smaller kina fisheries in New Zealand based on past recreational allowances and commercial quota (Miller and Abraham 2011). Thus, there does not seem to be significant fishing pressure on kina in the Kaikōura region. Nonetheless, kina have high cultural and economic value and are important component of Kaikōura's marine environment (Barker 2020, Radford et al. 2008). The HMR has extensive habitat suitable for kina, in the form of contiguous rocky reef and thriving macroalgal communities.

Intertidal reef community

The HMR has a healthy and diverse intertidal reef community. Previously published research has shown at least 121 intertidal reef species exist along the ~2 km of reserve shoreline, including endemic macroalgae (e.g. *Durvillaea poha*, *Durvillaea willana*, and *Marginariella boryana*), several limpet species, grazing snails, mussels and other invertebrates (Falconer et al. 2023). Intertidal reef surveys over 5 years show high abundance of crustose coralline algae in the low zone, which is an important settlement substrate for pāua larvae (Morse et al. 1979, Moss 1999).

Bull kelp (*Durvillaea* spp.) was abundant and stable in the low intertidal reef zone during 5 years of monitoring (Fig. 17). This is important considering that the local bull kelp population was severely damaged by the 2016 Kaikōura earthquake and subsequent marine heatwaves, during which many algal beds experienced high mortality (Alestra et al. 2020, Thomsen et al. 2021). Bull kelp provides biogenic habitat for a range of taxa including pāua and butterfish (Teagle et al. 2017) and is a taonga species. Previous work in the HMR has shown that the reserve is a refuge for bull kelp due to its high wave-exposure and cold-water upwelling, and may be an important source of reproductive propagules for recovery of damaged bull kelp stands along the coast (Falconer et al. 2022, Falconer et al. 2023). Surveys conducted by aerial drone indicate that the predominant bull kelp species in the HMR is *Durvillaea willana,* which is deeper dwelling than *Durvillaea poha*, and was less affected by the 2016 Kaikōura earthquake and coastal uplift (Tait 2021).

In addition to *Durvillaea spp.* other large canopy-forming macroalgae were detected in drone surveys along the HMR coastline, including *Carpophyllum* spp., *Lessionia* spp., and *Marginariella* spp. These taxa provide important vertical habitat at high tide for a range of fish and invertebrate species. Future monitoring of these important kelp stands may be best achieved with aerial drone surveys, which allow assessment of the wave-exposed habitats that are not accessible via shore-based surveys (Tait et al. 2021).

Figure 17. A patch of bull kelp (*Durvillaea* spp.) in a high wave exposure surge channel at the Hikurangi Marine Reserve. Photographed by Shawn Gerrity, November 2022.

Recommendations

Long-term monitoring of marine systems is costly and logistically challenging, especially in wave-exposed sites like the HMR. However, we recommend extending the survey time series to capture long-term trends. There was high variability of demographics of key species between sites, therefore consistent, bi-annual sampling of more fixed sites, with fewer transects, inside and outside of the HMR would be ideal (i.e. fish and pāua/kina one year and rock lobster the next). This should reduce some of the variability associated with sampling and improve interpretation of reserve effect patterns and trends over time.

Pairing UVC sampling with alternative methods such as potting surveys or BUV will improve assessments of mobile species such as rock lobster and blue cod. For taxa with patchy distributions like pāua, rock lobster, and kina, sampling a larger area will improve population assessments. The use of additional methods such as eDNA sampling, aerial drone surveys, and remote operated vehicle (ROV) surveys, which effectively increase the sample area, should be considered as resources allow.

We note that all sampling mentioned in this report was done in the extreme shallow inshore portion of the HMR, which represents a small portion of the whole reserve area. Research voyages conducted between 2016 and 2022 to the Hikurangi trench have characterised the seafloor (Bowden et al. 2023) but are outside the scope of this report. Sampling of these deeper habitats for key species, while logistically difficult and expensive, would clarify potential reserve effects on other key taxa. Remote survey methods such as BUV or ROV would allow key species to be assessed in deeper, less-accessible sites.

Lastly, we recommend a quantitative assessment of habitat types at repeat monitoring sites both inside and outside of the HMR. The shallow subtidal area of HMR has not been mapped. Having a detailed characterisation of this area would help differentiate the effects of reserve status with the effects of habitat on species composition and abundance.

Conclusions

These analyses indicate that after 10 years of reserve status the Hikurangi Marine Reserve is having a positive effect on several key species. The reserve had significantly higher abundances and larger sizes of some species commonly targeted by fishers in the area. The HMR has provided refuge to rock lobster and pāua broodstock along a coastline with high fishing pressure. The HMR may have increasing importance now that the Total Allowable Catch (combined catch allocation for commercial, recreational and customary fishers) for pāua has increased by 38 tonnes from 40.5 t to 78.5 t (Jones 2024). Furthermore, the coastal portion of the reserve is home to a large and stable stand of the important habitat-forming bull kelp and may be a source of propagules for recovery following major environmental disturbance.

The inshore portion of the HMR is having positive effects on several key species compared to non-reserve sites (research question 1). However, reserve effects through time (research question 2) were unclear due to limited replication of surveys through time. Populations of marine organisms are highly dynamic through time, and sampling over relatively long-time scales is required to distinguish natural variability from actual reserve effects. Nonetheless, these surveys provide important data on population demographics of key species and contribute to long-term monitoring of the impacts of the Hikurangi Marine Reserve.

Author contributions

SG: Writing – review & editing, conceptualization, methodology; SV: Writing – review & editing, formal analysis; ML: Writing – review & editing, project administration.

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Data availability statement

We encourage open science, open data, and authors to make available all data relevant to the conclusions of the manuscript. Data may be available on request to DOC.

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