Rāhui Monitoring Report
Maitai Bay, Karikari Peninsula

September 2023

Ceara Wallace & Vince Kerr

A guardian of balance on the reef: a large snapper, *Pagrus auratus,* seen at Maitai Bay during a survey.
(photo by Ceara Wallace)

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For: **Te Whānau Moana me Te Rorohuri**

Thanks for the support from *Mountains to Sea Conservation Trust* and *Foundation North*.

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Summary

A fully no-take rāhui at Maitai Bay has been in place since 2017. It acts in a holistic approach that considers the ecology of the entire bay rather than a single target species. By removing all fishing pressures, the hope is not only to restore the population of exploited species but help in the ecological recovery of the kelp forest and reef fish that exist within it.

Our monitoring program, which has been in place since the start of the rāhui, aims to document the ecological recovery resulting from the no-take rāhui as a tool for conservation. Recovery of heavily fished species is a specific focus. Relative abundance and diversity of reef fish species were measured using the Shallow Reef Timed Swim Survey. Snapper density was measured using a baited underwater video (BUV) survey.

Summer monitoring this year was limited to February and March due to unfavourable weather patterns. We completed three rounds of the Shallow Reef Timed Swim Survey. The findings showed no significant difference in the abundance or diversity of reef fish species. In the results for the three key indicator species, there was an increase in the average total snapper numbers, most notably in the 1-24cm size classes, no significant change in red moki numbers, and an indication of a decline in butterfish in the last two years. Both survey results provide evidence of an increase in snapper biomass within the area since the start of the rāhui.

This report is the sixth of its kind sharing data from annual monitoring. The intention is to keep a record of the work done in 2023 so that it becomes part of a complete long-term data set started in 2018.

Kaupapa

In an act of stewardship towards their rohe and Moana, *Te Whanau Moana me Te Rorohuri,* a Ngati Kahu hapū, placed a rāhui tapu over Maitai Bay at the end of 2017. The boundaries cover all of Maitai Bay and most of the neighbouring Waikato Bay and extend to the Pinnacles (see *Figure 1*). The rāhui was placed due to growing concerns about the decline in fish numbers around the Bay and the extensive kina barrens along the coastline. The hapū hope that the protection granted by the rāhui will restore balance, mauri and mana to their Moana. They also intend to use the rāhui to help implement a long-term plan to leave a healthy ecological legacy for future generations.

The protection and monitoring of Maitai Bay's marine ecosystem combines modern MPA and conservation strategies with traditional indigenous knowledge and practices. Through a monitoring programme established with help from *Mountains to Sea Conservation Trust* (MTSCT), kaitiaki from *Te Whanau Moana me Te Rorohuri* and MTSCT ecologists have been able to document the restoration process since the rāhui tapu has been in place.

Introduction

The first modern "no-take" marine protected area (MPA) as a conservation measure was not an entirely new concept. Historically, Pacific Island communities have used a variety of tools to control marine and coastal resource use, rāhui being a significant one of those tools (*Fabre et al.* 2021). In the current climate, where the necessity is for urgent proactive action, traditional marine closures like rāhui are providing a valuable option for communities (Goetze *et al.* 2016; Kerr 2018; Kerr 2018; Wallace & Kerr 2022). Mātauranga Māori guides the Traditional use of rāhui and gives a community agency to manage their marine resources and the ecological future of their environment.

It is well-documented that creating a long-term no-take marine area increases the biodiversity and abundance of marine fauna and flora within that area. The ban on fishing in these designated areas allows top predator populations to recover, which has the flow-on effect of helping to restore the ecology and ecosystem functions. The most common example in Northern New Zealand would be the return of large snapper and crayfish within protected areas, which regulate local kina populations through predation, allowing for the recovery of kelp forest (Ballantine 2014).

Snapper are the most sought-after fish species in Northern New Zealand receiving high levels of exploitation by both commercial and recreational fisheries. They are also the most common predator species within northeastern New Zealand, so are an important indicator species when recording the health of an ecosystem (Parsons *et al.* 2014). Snapper are generalist feeders and primarily prey on invertebrates from soft sediment and rocky reefs (Colman 1972; Choat & Kingett 1982; Babcock *et al*. 1999). The boundaries for the Maitai Bay rāhui (see *Figure 1*) were chosen to encompass a range of soft bottom and reef habitats, depths and wave exposure conditions. (Kerr *et al.* 2020).

This report examines the effect of the rāhui on the diversity and abundance of reef fish species at Maitai Bay. Three indicator species, snapper, red moki and butterfish are reported on in more detail, examining abundance, size classes and biomass. The aim is to repeat the surveys to create a long-term picture of the restoration process.

At the six-year mark of full protection, it is still relatively early to expect to see significant changes due to the rāhui protection. The recovery rate of reef communities varies depending on the species and ecosystem. Studies done at Leigh and Tāwharanui Marine Reserves (areas comparable to Maitai Bay) show that a decline in kina barrens and recovery of kelp forests took 15-20 years after protection was in place (Babcock *et al.* 1999). This implies the greater reef community that relies on kelp forest habitat would also take longer to recover fully. At this stage, we expect to start seeing the recovery of exploited species like snapper and crayfish, which generally occur within just 5-15 years of protection (Cole *et al.* 1990; Shears & Babcock 2002).

Currently, there is a lot of momentum around marine conservation through media and initiatives. The success of the conservation rāhui at Maitai Bay now sets an ideal precedent for locally-led action. Despite the challenges, for the past 7 years, the rāhui has been led strongly by hapu, gaining continual and growing support from the growing community. This begs the question of whether this action can be successfully replicated up and down the New Zealand coast. Already in places such as Mimiwhangata, similar protection concepts are being trialled and in time, hopefully, more and more groups will feel empowered to take action.

Figure 1. *Maitai Bay rāhui boundaries*

METHODS

In 2023, monitoring of Maitai Bay rāhui and the surrounding area was carried out over February and March. The Shallow Reef Timed Swim and Baited Underwater Video Surveys were conducted this year as part of routine monitoring. These methods have been used every year since 2019. Replication of the surveys over time allows recovery trends to be reliably tracked. Species are referred to by their common names, and a full list of their Māori and scientific names is provided in *Appendix 1*.

Shallow Reef Timed Swim Fish Survey

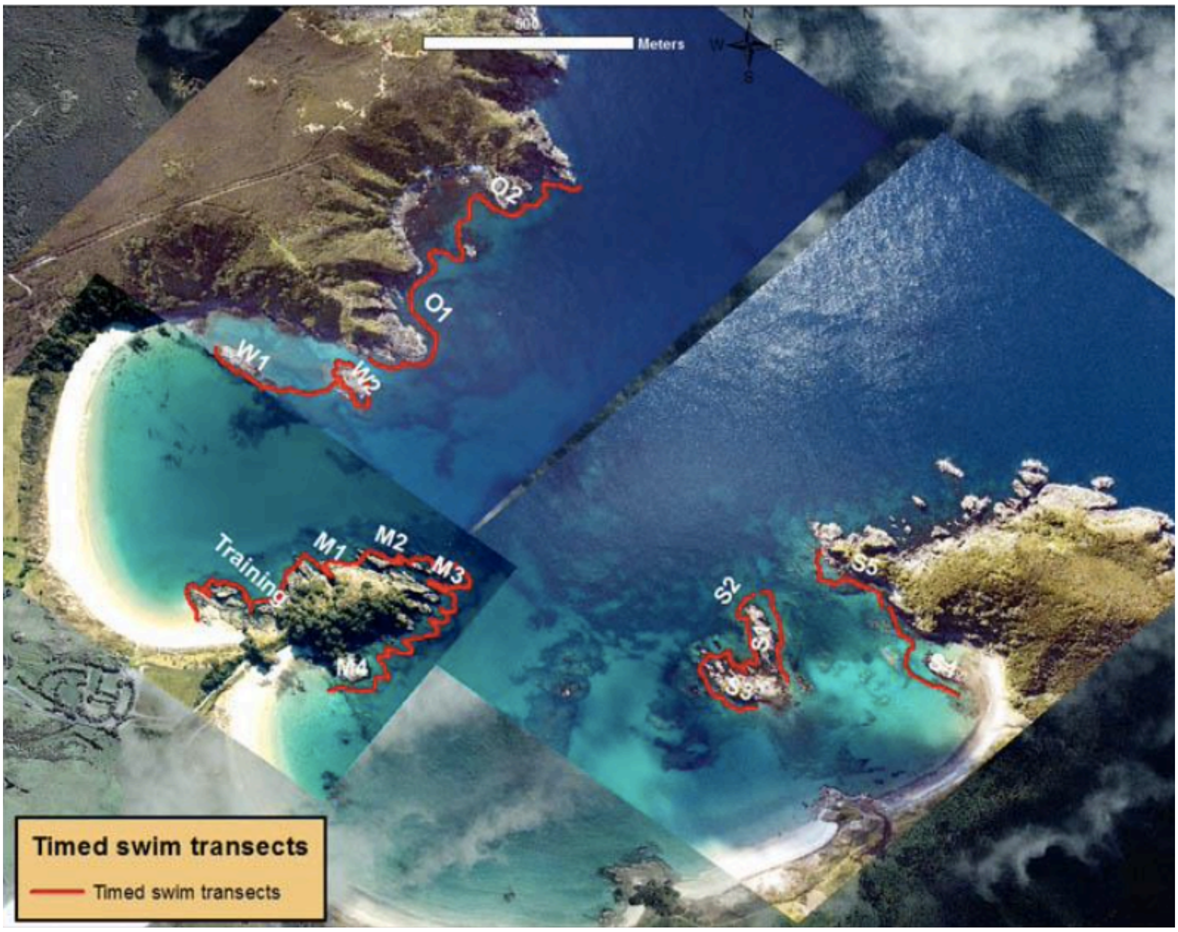


Figure 2. *Timed Swim Fish Survey transect routes for Maitai Bay and the surrounding area.*

Timed swim surveys are an internationally used survey technique to determine the relative abundance of fish species within an area, specifically species within shallow reef habitats. 2023 marks the sixth consecutive year this survey has been conducted at Maitai Bay. A full discussion of method strengths, weaknesses, and value in the long-term monitoring strategy can be found in *Kerr et al.* (2018 & 2019).

Sampling Area

Thirteen swim transects (*Figure 2*) were carefully mapped to cover a range of shallow reef habitat types both within and outside the rāhui area. Northern transects (M1, M2, M3, M4, W1, W2, O1, O2) are within the rāhui, and those at the Southern end (S1, S2, S3, S4, S5) lie just outside the boundary (*Figure 1*).

A complete habitat map was created for the waters of Maitai Bay. The series of maps for the rāhui and surrounding area can be found in *Kerr et al.,* 2020, where a total of sixteen habitats were classified. An effort was made to represent the diversity of these habitats in the transects chosen for the Timed Swim survey (Kerr 2018; Kerr *et al*. 2020).

Merita Point (M1, M2, M3, M4) and Waikura (W1, W2) are both areas made up of rocky reefs with varying coverage of shallow mixed weed and kelp. Transects M4 and W1 are also affected by extensive kina barren. Okura Point (O1, O2) is on the north-eastern end of the bay and is made up of shallow mixed weed and shallow *Ecklonia* forest. Blue Maomao Point (S5) is noted for its ecological abundance and high biodiversity due to the currents off the point supplying food and nutrients. Here there are rocky reefs covered in a mix of shallow kina barren and *Ecklonia* forest. The southern reef (S1, S2, S3, S4) lies just outside the rāhui boundaries and is predominately dominated by shallow mixed weed, shallow *Ecklonia* forest and shallow urchin barren.

Method Description

A single diver (on snorkel) swims along a mapped transect route for 15 minutes as slowly and quietly as possible. As the diver moves along, they record the species and number of fish seen within 6-10 meters of themselves. For snapper, red moki and butterfish, a size class category for each individual is recorded based on their estimated length (to the nearest 10cm). This method is repeated for all transects with metrics including date, tide (moon phase), time at the start of the swim, visibility and conditions recorded. Transects can be surveyed multiple times throughout the monitoring period.

Indicator Species

Snapper, red moki and butterfish were chosen as indicator species for monitoring as they were targeted catch species in the monitoring area. Tracking their recovery over time should indicate the effectiveness of the rāhui fishing ban. Recording the size classes for each individual from these species allows us to track trends in the population size distribution over time (i.e. to determine whether the number of larger fish is increasing and recruitment of young fish over time within the rāhui). The size categories (in centimetres) for the 2022 survey were Snapper: 1-10, 11- 24, 25-34, 35-44, 45-59, 60-69, 70-79, 80+; Red Moki: 1-15,16-29,30-50, 50+; Butterfish: 1-10, 11- 24, 25-39, 40+. Knowing the size class of snapper individuals also allows for biomass (total weight) to be calculated.

Snapper Biomass

Snapper length estimates were converted to estimates of biomass using the equation:

$$W = aL^b$$

where W is the weight (g), L is length (mm), a is 7.194×10^{-5} and b is 2.793 (Taylor & Willis. 1998).

Each size class's biomass was calculated and combined to determine the average total snapper biomass per transect. This allows us to compare the biomass of snapper within the rāhui to similar areas surveyed outside using the same method. Calculating biomass also enables us to follow any trends in biomass that occur over time.

Baited Underwater Video (BUV) Survey

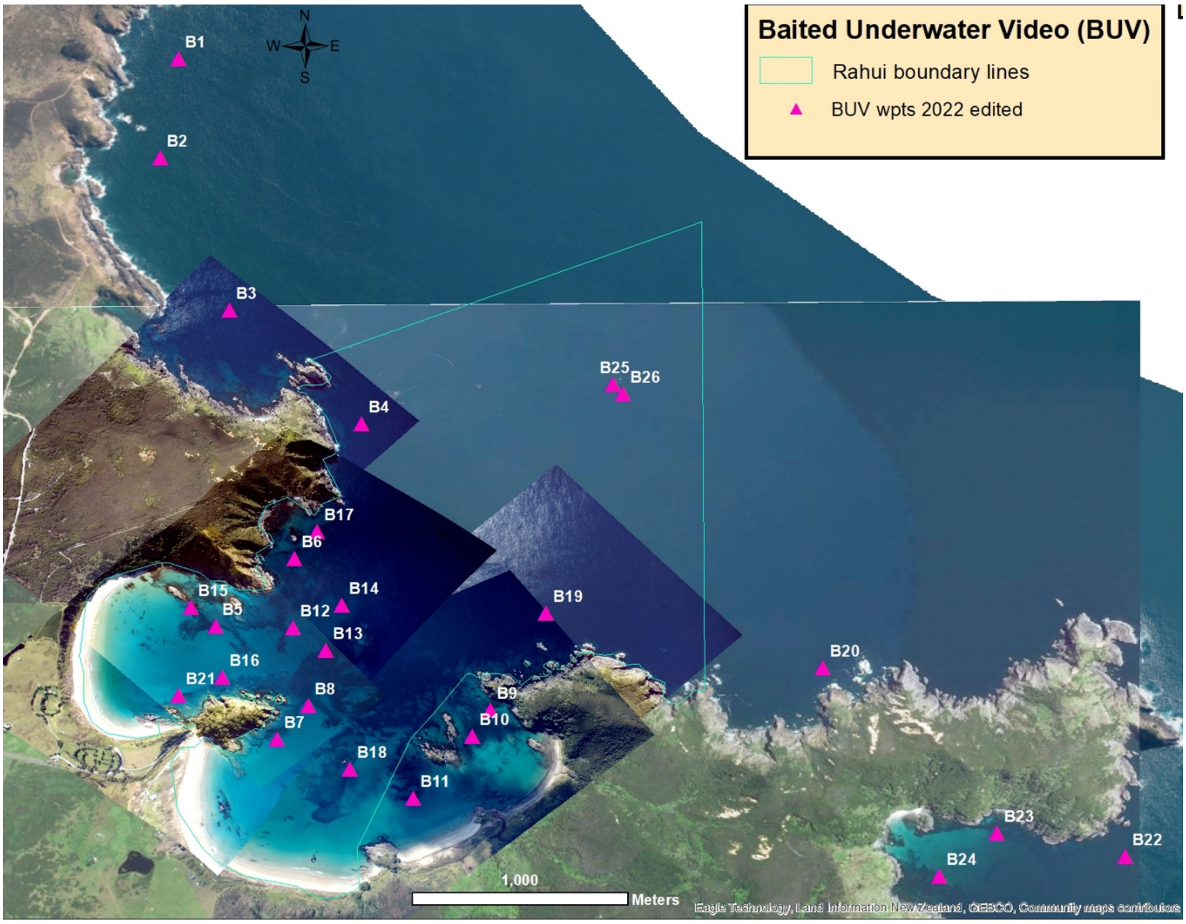


Figure 3. *2023 BUV survey drop sites for Maitai Bay rāhiu and the surrounding area.*

Baited Underwater Video (BUV) surveys are used to determine the relative abundance of carnivorous reef fish and are a common fish surveying tool used globally (Willis & Babcock, 2000) and extensively in northeastern New Zealand. In this case, we are using the BUV to determine the relative density of snapper, inside and outside the boundaries of the protected marine area of the rāhui. One round of BUV drops was completed over two consecutive days in March for the 2023 monitoring period. The BUV equipment, sample sites and survey methods were kept identical to those described in Kerr *et al.*, (2019 & 2020).

BUV Apparatus

The BUV apparatus (*Figure 4*) consists of a frame of two aluminium bars welded together at a roughly 60-degree angle. The horizontal bar sits on the bottom, is 120 cm long and marked at 10 cm intervals. A plastic bait cage is attached to the centre of this bottom bar. At the top of the upright bar, a GoPro camera is mounted and angled towards the centre of the lower bar and bait cage. The camera's field of view is set to include the entire length of the lower bar in the frame (*Fig. 5*). A pressure-resistant float is attached to the top of the frame, providing buoyancy to ensure it remains upright once deployed. A roughly 20-meter floating rope is also attached to this top point on the frame with a second float buoy on the end to mark the deployed BUV from the surface and to aid BUV retrieval.

Site Selection

The site selection process was designed to cover two habitat zones: 'sheltered' and 'exposed', with an exposed sub-zone for the two sites on the pinnacle. These zones span the wider Maitai Bay and the rāhui area, as per the report by Kerr *et al.* (2019). A total of 16 sites were selected within the rāhui area and 10 sites outside. This arrangement ensures that data across habitat zones is comparable inside and outside the rāhui area.

Method Description

Each site is labelled and plotted on the research vessel's sounder. The vessel is then maneuvered directly above the site where the BUV apparatus, containing a bait cage filled with 100g chopped pilchards and a GoPro camera turned on and recording, is lowered overboard using a line. The second float is left on the surface above the site to mark its location (refer to *Figure 4* for BUV deployment arrangement). Once the apparatus is submerged, a timer is set onboard to ensure that each drop generates at least 30 minutes of continuous undisturbed footage. The frame is then retrieved and reset, and the process is repeated for the next site.

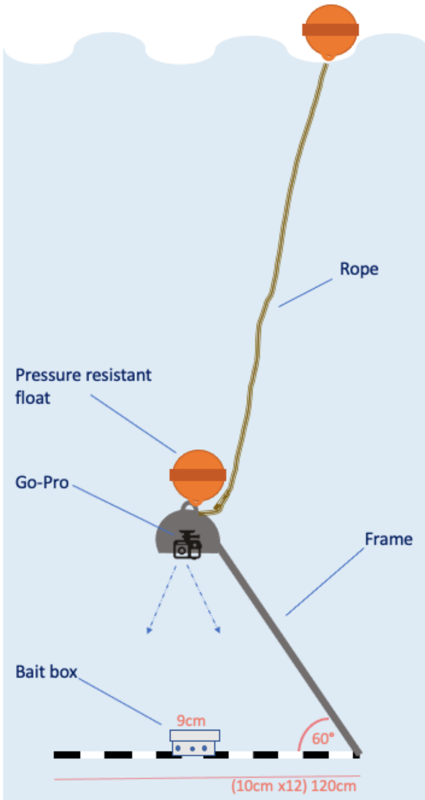


Figure 4. *Diagram of a deployed BUV apparatus.*

BUV Analysis

The video footage of each drop site is thoroughly analysed to determine the fish diversity, maximum count of snapper, and maximum biomass of snapper for each sample site. The maximum snapper count refers to the highest number of snapper observed in a single frame during the 30-minute footage. The maximum snapper biomass is the total estimated maximum weight of snapper documented in a single frame. In our analysis, we have decided to change the biomass calculation method to better capture the addition of large snapper arriving in the rāhui area. We calculated the maximum biomass from frames with the maximum snapper count and from frames we predicted may have equal or greater biomass. We selected the frames with fewer individuals present but larger in length, hence potentially greater biomass in total. Individual snapper lengths were measured in still frames of the video sequence to determine biomass and calibrated against the scale bar. We took great care to measure fish length as accurately as possible when the fish were at the same level as the bottom bar.

RESULTS

Shallow Reef Timed Swim Survey

The 13 transects were surveyed three times over February and March 2023. The data collected during these surveys is summarized in *Table 1* below. In total, 39 transects were surveyed, and 15,953 fish were counted, including 1 butterfish, 194 red moki, and 1891 snapper. The visibility varied from less than 5m at times to a maximum of 20m at other sites.

Transect	No. of fish counted	No. of species	Diver Initial	Date	Visibility
M1	416	18	CW	10-Feb-23	20m
M1	468	12	VK	12-Mar-23	10m
M1	444	13	VK	23-Mar-23	10-15m
M2	430	15	CW	10-Feb-23	15m
M2	202	8	VK	12-Mar-23	10m
M2	426	14	VK	23-Mar-23	10-15m
M3	1278	13	VK	10-Feb-23	15m
M3	98	11	VK	12-Mar-23	10m
M3	105	10	VK	23-Mar-23	10-15m
M4	167	8	VK	10-Feb-23	15m
M4	120	11	VK	12-Mar-23	10m
M4	358	9	VK	23-Mar-23	10-15m
O1	1010	16	CW	10-Feb-23	15m
O1	335	15	VK	13-Mar-23	20m
O1	851	17	CW	23-Mar-23	10-15m
O2	1171	14	CW	10-Feb-23	15m
O2	421	14	VK	13-Mar-23	20m
O2	969	21	CW	23-Mar-23	10-15m
S1	605	14	CW	10-Feb-23	10m
S1	131	10	VK	13-Mar-23	10-15m
S1	249	9	VK	25-Mar-23	10m
S2	1088	15	CW	10-Feb-23	10m
S2	186	13	VK	13-Mar-23	10-15m
S2	185	10	VK	25-Mar-23	20m
S3	725	15	CW	10-Feb-23	10m
S3	128	8	VK	13-Mar-23	10-15m
S3	167	9	VK	25-Mar-23	
S4	253	11	VK	10-Feb-23	15m
S4	270	11	VK	13-Mar-23	10-15m
S4	253	13	CW	25-Mar-23	<5m
S5	150	12	VK	10-Feb-23	15m
S5	421	11	VK	13-Mar-23	10-15m
S5	363	15	CW	25-Mar-23	5-10m
W1	227	15	VK	10-Feb-23	15m
W1	111	8	VK	12-Mar-23	10m
W1	520	15	CW	23-Mar-23	10m
W2	45	6	VK	10-Feb-23	15m
W2	143	10	VK	12-Mar-23	10m
W2	464	13	CW	23-Mar-23	10m
Mean	409.05	12.36			
Total	15953	34			

Table 1. *Summary information from each transect surveyed in 2023 using the timed swim method.*

The average number of species for a transect was 12.4 species. The lowest count for a single transect was 6 species recorded on W2, a site with extensive kina barren. The highest count was 21 species from transect O2, a more exposed area with areas of deep *Ecklonia* forest.

Table 2 compares the summarised shallow reef timed swim survey data from the last 6 years of monitoring at Maitai Bay. There has been a big jump in the average number of fish counted per transect from 140 in 2018 to 409 in 2023. This year the highest species count for a transect was 21 species, with an average number of species (12.36) recorded per transect. We expect this number to continue to rise as habitats recover at Maitai Bay.

Timed Swim summary table	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Number of transects in survey	8	13	13	13	13	13
Total transects surveyed	16	45	67	38	37	39
Total hours surveying	4	15	17	9.5	9.25	9.75
Total fish counted	2,239	17,550	22,912	29,251	17,814	15,953
Average No. fish per transect	140	352	342	770	481	409
Average No. species per transect	9.5	10.4	11.1	12.53	10.84	12.36
Highest No. species per transect	14	20	20	22	17	21
Lowest No. species per transect	7	5	5	5	5	6

Table 2. *Summary of data recorded during timed swim fish surveys completed at Maitai Bay between 2018 and 2023.*

Indicator Species

Table 3 summarises the additional data collected for snapper, red moki, and butterfish. The mean total counts were calculated across all transects surveyed. Across all surveyed transects, the mean total count of snapper was the highest count yet at 48, with the majority of individuals belonging to the 1-10cm size class. There is not yet a clear trend in snapper numbers but we are starting to see an increase each year in the number of juvenile snapper between 1-24cm, as seen in *Figure 6*. The mean total numbers of red moki have been fluctuating since 2018 with a slight suggestion that there may be an increase over time. However, it is still too early to confirm (see *Figure 8*). On the other hand, the mean count of butterfish shows a decline in the last three years, following a peak in 2020, (see *Figure 9)*.

Indicator Species	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Total snapper count	194	1522	583	778	1268	1891
Mean Total Snapper count	**12**	**34**	**9**	**20**	**34**	**48**
Total Red Moki Count	33	155	434	192	80	194
Mean total Red Moki Count	**2**	**3**	**6**	**5**	**2**	**5**
Total Butterfish Count	1	8	28	15	6	1
Mean total Butterfish Count	**0.06**	**0.18**	**0.42**	**0.39**	**0.16**	**0.03**

Table 3. *Summary of the mean total count of indicator species overall in transects surveyed in Maitai Bay between 2018 and 2023 from Shallow Reef Timed Swim Surveys.*

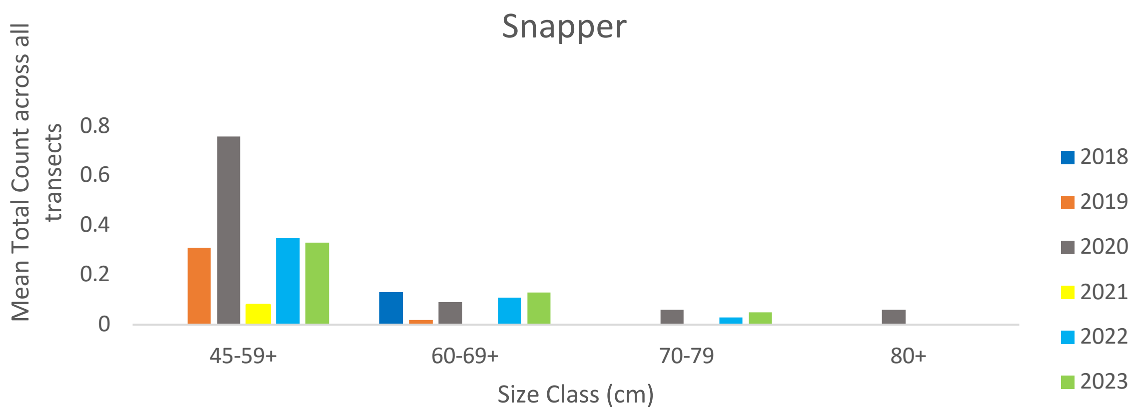


Figure 5. *Comparison of mean total snapper count per transect for size classes of 45cm or greater from 2018 to 2023 survey data from Maitai Bay monitoring.*

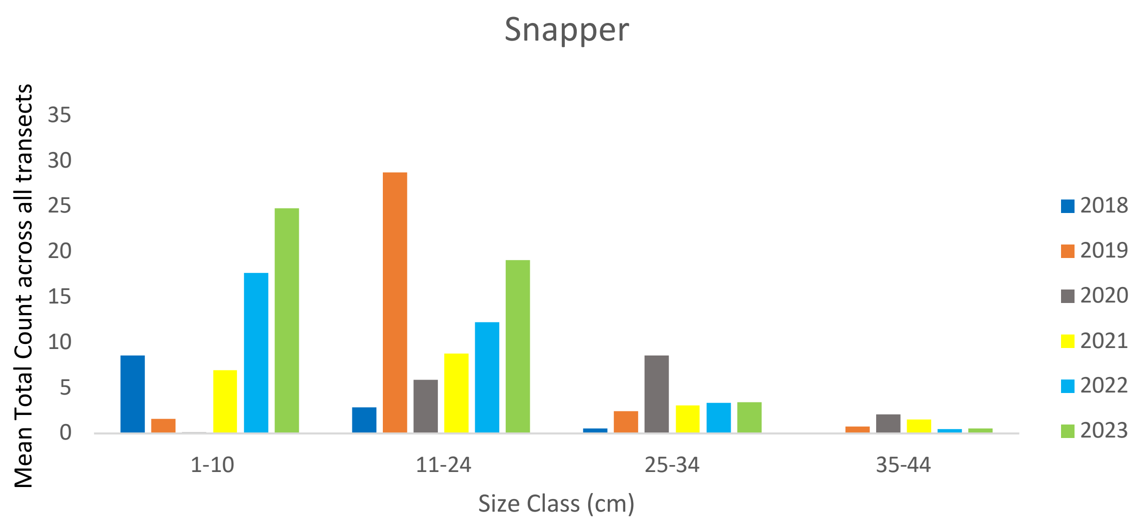
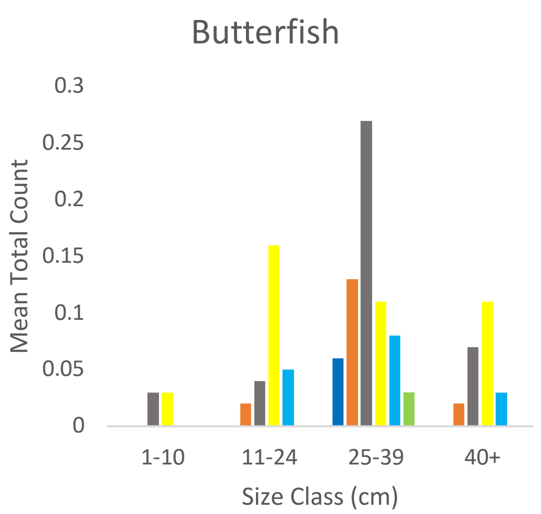


Figure 6. *Comparison of mean total snapper count per transect for size classes of 44cm or less from 2018 to 2023 survey data from Maitai Bay monitoring.*



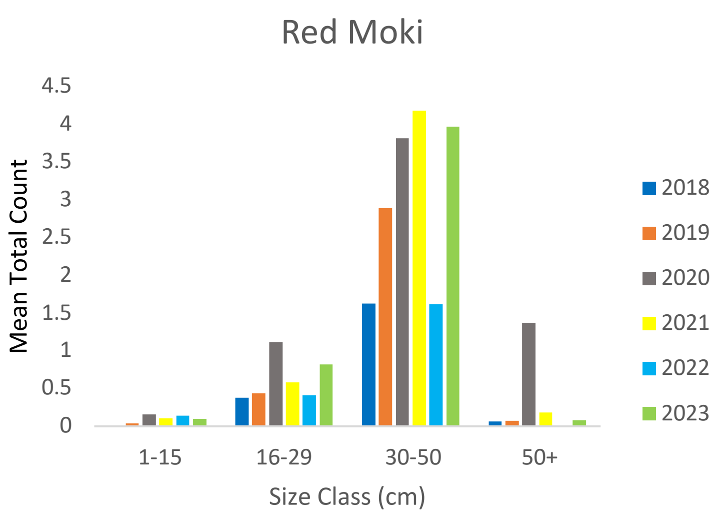


Figure 7 & 8. *The mean total count of red moki and butterfish per transect is shown in size classes from each year of monitoring at Maitai Bay from 2018 to 2023.*

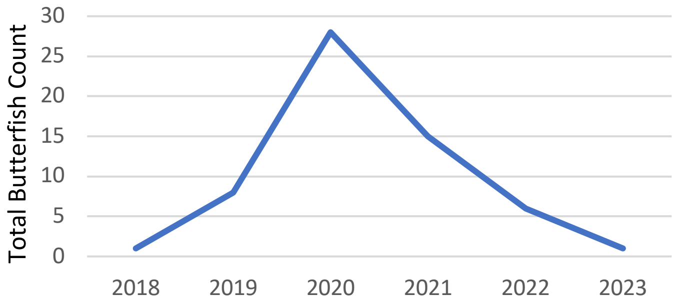


Figure 9. *Total counts of butterfish from Timed Swim Surveys from 2018 to 2023.*

Snapper Biomass

Mean snapper biomass per transect shows an increasing trend from 1.8kg in 2018 at the start of the rāhui to 8.8kg in 2023 (*Figure 10)*. Larger snapper individuals account for most of the recorded biomass, and we have noticed a slight increase in their presence in the last two years (*Figure 5*).

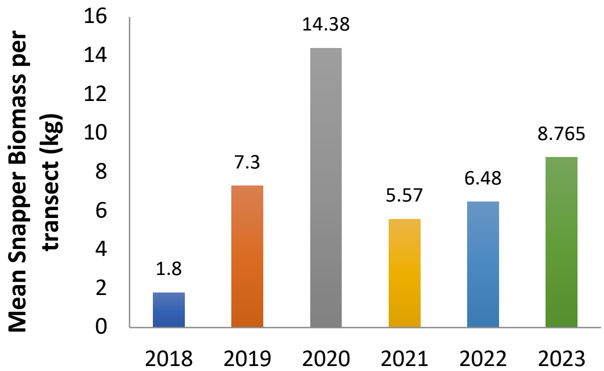


Figure 10. *Comparison of mean snapper biomass per transect from 2018 to 2023.*

Baited Underwater Video Survey

All 26 BUV sites were surveyed in 2023, and 25 were considered successful (meaning the frame remained in position for the full 30 minutes, the quality of the footage was good enough to analyse, and there was no kelp or sediment interference). Footage from the Pinnacle site B26 had to be excluded due to the frame moving during filming. Noteworthy is a 100cm snapper individual recorded on the B26 footage. This is mentioned in *Table 4* to show large individuals were present, but it is not included in any of the analyses and final totals and averages. *Table 4* shows the summary of the data recorded. Across all deployments, a total of 557 fish were counted, and 28 species were recorded. See *Appendix 1* for the full list.

Site		Inside / Outside Rāhui	Diversity (No. of species)	Total fish Count (incl. all species)	MAX No. Snapper	Max Length	Mean Length (cm)	Mean biomass (kg)	Total biomass (kg)
B1	Exposed	Out	8	20	6	20	15.83	0.11	0.7
B2	Exposed	Out	4	15	11	30	21.82	0.28	3.10
B3	Exposed	Out	5	25	11	30	21.36	0.27	2.98
B4	Exposed	In	4	15	10	40	26.50	0.50	4.99
B5	Sheltered	In	8	16	7	55	30.71	0.93	6.51
B6	Sheltered	In	4	18	13	25	19.23	0.22	2.86
B7	Sheltered	In	4	14	10	50	31.00	0.75	7.54
B8	Sheltered	In	3	11	9	40	22.78	0.35	3.16
B9	Sheltered	Out	4	19	15	40	23.46	0.34	4.47
B10	Sheltered	Out	6	18	11	15	11.43	0.05	0.38
B11	Sheltered	Out	4	18	15	40	25.67	0.44	6.61
B12	Sheltered	In	3	11	9	35	22.78	0.33	2.98
B13	Sheltered	In	3	9	7	25	17.14	0.15	1.08
B14	Sheltered	In	5	18	6	25	19.17	0.19	1.17
B15	Sheltered	In	2	7	6	50	27.50	0.83	3.30
B16	Sheltered	In	2	7	5	25	18.00	0.19	0.96
B17	Sheltered	In	10	35	7	40	30.71	0.68	4.76
B18	Sheltered	In	2	6	5	70	37.50	1.96	7.83
B19	Exposed	In	9	37	5	50	38.00	1.42	7.09
B20	Exposed	Out	7	116	9	40	22.22	0.33	2.99
B21	Sheltered	In	1	7	7	60	28.57	0.86	6.02
B22	Exposed	Out	10	41	7	30	22.86	0.30	2.08
B23	Exposed	Out	6	13	5	30	24.00	0.34	1.70
B24	Exposed	Out	6	23	8	30	21.88	0.27	2.17
B25	Pinnacle	In	15	38	11	70	45.00	2.56	12.78
B26	Pinnacle	In				100	95.00	15.02	30.05
		TOTAL	**28**	**557**	**215**	-	-	-	**100.18**
		MEAN	5.4	22.28	8.6	**39**	-	-	**4.01**

Table 4. *Summary of 2023 data from the 26 surveyed sites during the 2023 BUV surveys of Maitai Bay Rāhui and the surrounding area. Cells highlighted in blue were values taken from frames with the greatest MAX snapper biomass but not MAX snapper count. All other values came from frames with MAX snapper count and MAX biomass.*

The maximum length of snapper recorded was 70cm on two occasions, both within the rāhui boundaries. (note exception at B26). The maximum snapper count recorded in a single frame was 15 individuals at sites B11 and B9, both outside the reserve. Snapper were the most abundant species but notable species in this year's survey include the presence of multiple gurnard and blue cod.

Max Snapper Count / Max Snapper Biomass

A total of 215 snapper were recorded across all sites; 117 inside and 98 outside the rāhui. *Table 5* highlights the mean maximum snapper count was higher (12.47) outside the rāhui compared to inside (7.8). However, the average biomass was nearly doubled inside (4.9kg) compared to outside (2.7kg). This indicates a difference in the size distribution of the snapper. See the profiles of snapper count and biomass inside and outside the rāhui in *Figures 11* and *12*.

Location	Number of sites	Total MAX Snapper count	Mean MAX Snapper count	Mean Length* (cm)	Mean Biomass (kg)	Total Biomass (kg)
In Rāhui + P	**15**	**117**	**7.8**	**44**	**4.87**	**73.02**
Outside Rāhui	10	98	12.47	31	2.72	27.16

Table 5. *Summary of snapper counts and biomass for the 2023 BUV survey. *This value was calculated using the mean length from each BUV site and then finding the mean of all the totals for all sites inside and outside the rāhui.*

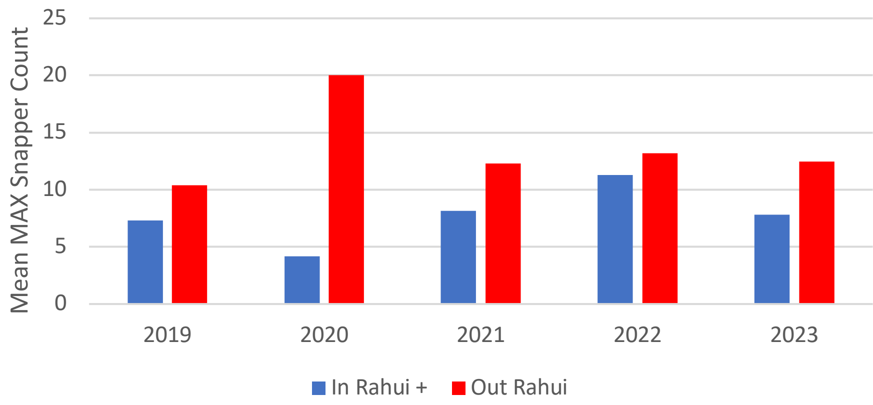


Figure 11. *The average total MAX snapper count across sites within and outside the rāhui (the + indicates average includes the 2 pinnacle sites) for the 4 years the surveys were completed.*

There is no clear trend in the average MAX snapper count over the last five years other than there consistently being more snapper outside the rāhui than inside (see *Figure 11*). This is an interesting observation and could be due to several factors as discussed below.

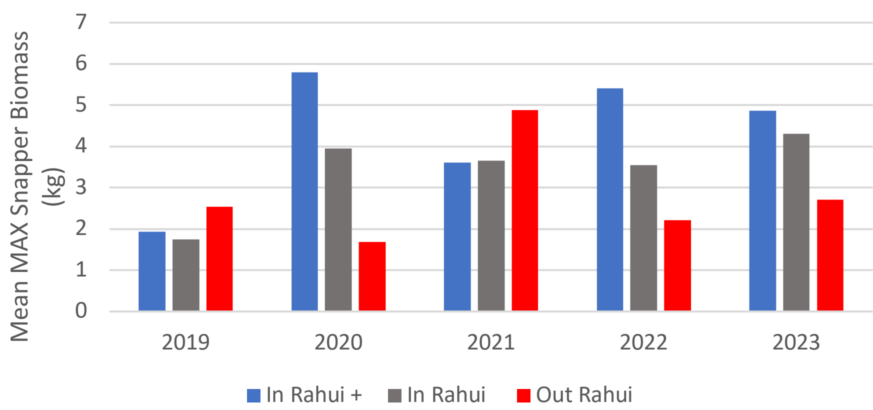
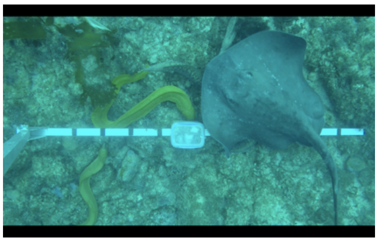


Figure 12. *The average total MAX snapper biomass across sites within and outside the rāhui (the + indicates average includes the two pinnacle sites) for the 4 years the surveys were completed.*

Year	MAX Snapper Count	Mean MAX Snapper count	Mean Biomass (kg)	Total Biomass (kg)
2023	215	**8.6**	**4.01**	100.18
2022	301	**21.63**	**4.41**	105.89
2021	252	**10.08**	**4.04**	96.95
2020	85	**4.47**	**1.44**	27.34
2019	214	**8.56**	**2.18**	54.456

Table 6. *Summary of totals for snapper counts and biomass for BUV surveys since 2019.*

In 2023, the MAX snapper count was the same as in 2019 and a lot less than the previous year. A drop from an average of 22 snapper per BUV in 2022 to 9 in 2023 (*Table 6*). Interestingly though, the biomass was consistent in those 2 years. This indicates that there may have been fewer snapper present but those were larger on average.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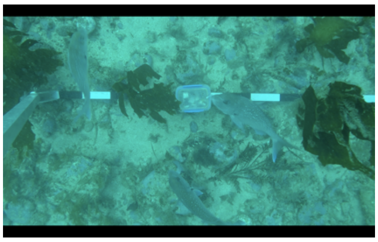
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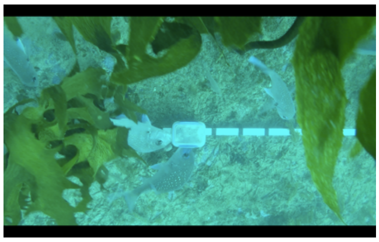
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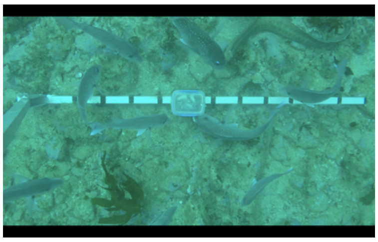
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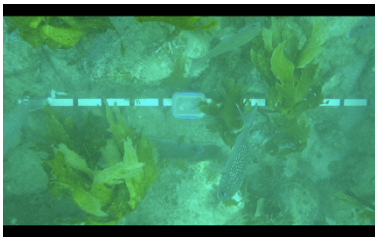
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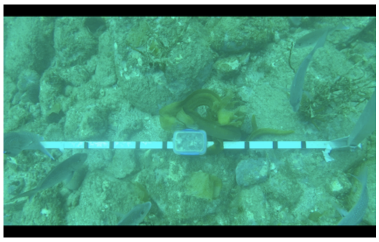
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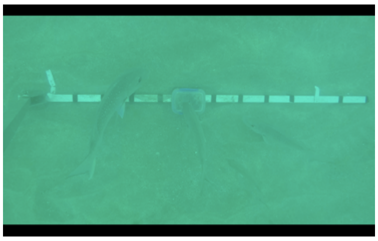
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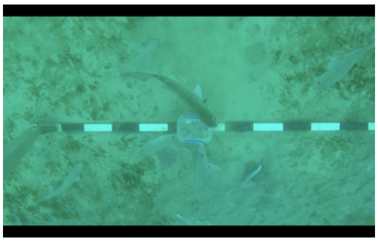
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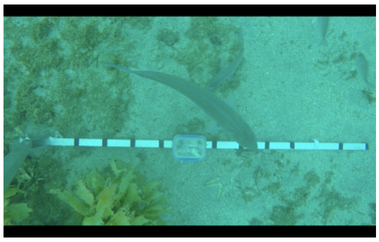
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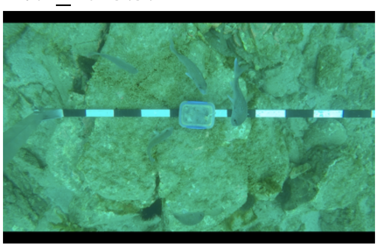
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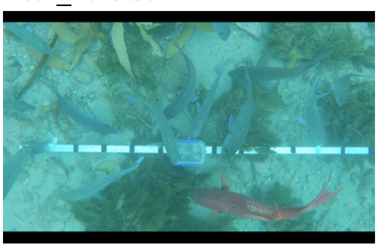
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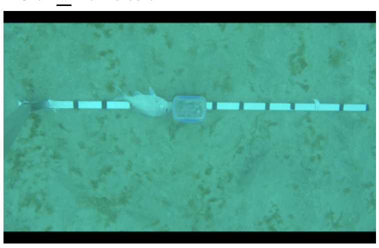
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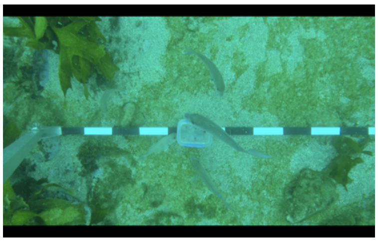
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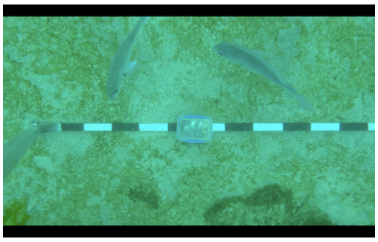
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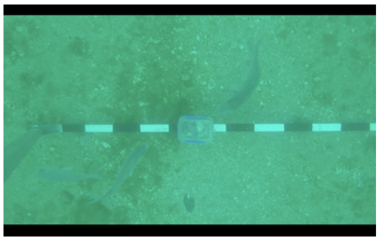
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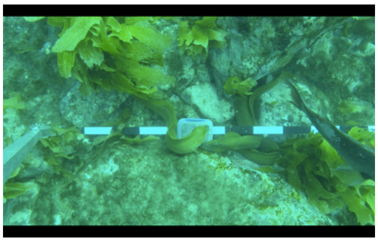
B16.2_2023.3.25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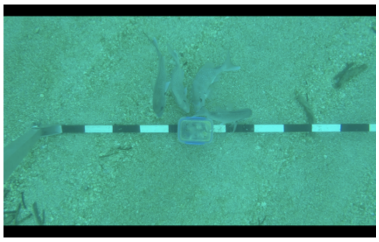
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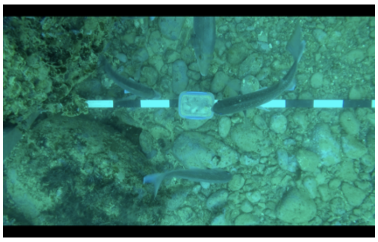
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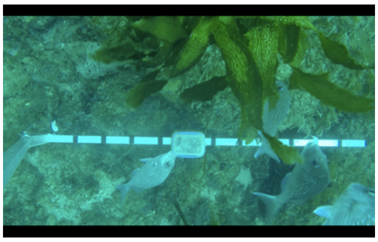
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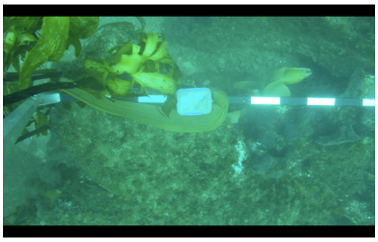
B21.2_2023.3.24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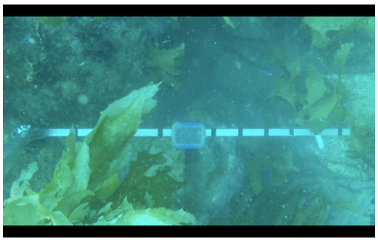
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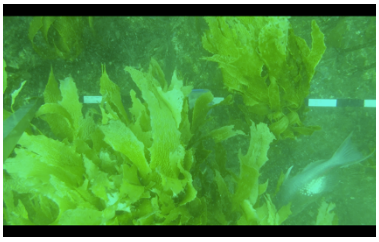
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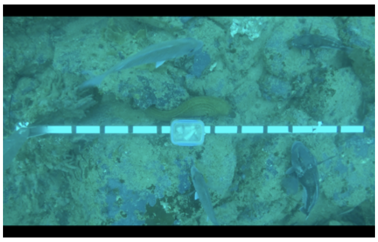
B25.2_2023.3.25


B26.2_2023.3.25

Figure 13. *Screenshots taken from the 26 BUV recordings show the variation in benthic environment, biodiversity, and kelp and sediment interference between sites. Each photo caption refers to the video file name the respective screenshot was taken from.*

As seen in *Figure 13* the conditions varied across BUV sites from a clear line of sight across the bait cage and measuring frame to high sediment and kelp interference. For sites B7, B15 and B16 with high sediment in the water column, the contrast was turned up on the footage during analysis to make it easier to distinguish between any movement and the sandy bottom. For site B24, swell movement meant not every frame was covered in kelp and diligent care was taken with the footage speed slowed down to capture the number of max snapper present.

DISCUSSION

	Habitat Mapping	Shallow Reef Timed Swim	Reef Fish Diversity Dive	Baited Underwater Video	Kina Cull Trial	Manta Board Tow Trial	
2017	✗	✗	✗	✗	-	-	Rāhui established.
2018	✓	✓	✗	✗	-	-	*Rāhui Monitoring Preliminary Report*
2019	✓	✓	✓	✓	-	-	*Rāhui Monitoring Report*
2020	✗	✓	✓	✓	-	-	*Marine Habitat Mapping Report, Rāhui Monitoring Report*
2021	✗	✓	✗	✓	-	-	No report.
2022	✗	✓	✓	✓	✓	✓	5th year of rāhui. *Rāhui Monitoring Report*
2023	✗	✓	✗	✓	-	-	*Rāhui Monitoring Report*

Table 7. *A reference for surveys conducted and any notable events or reports published according to year for the Maitai Bay rāhui monitoring program.*

Interpreting the results in the current climate

Careful consideration goes into choosing which days to survey based on the appropriate swell, wind and cultural significance of the date (according to the maramataka). This season was particularly challenging due to the heavy rain and swell that relentlessly hit the Northeast Coast. According to NIWA the rainfall alone for Northland was more than 150% of what would normally fall during February. Despite every effort being made to find ideal weather windows during February and March, the visibility for some of the 2023 surveys was lower than the minimum of 10m in previous years. This made judging distances, counting and sizing fish difficult on certain transects and the error rate in our monitoring is not fully known, however, we ceased the survey on several occasions due to poor visibility. We cannot say if the extreme weather may have also influenced the abundance and diversity of fish within the surveyed area. Maitai Bay has large areas of shallow reefs and these reefs are affected by large swells entering the Bay from the East and Northeast. Many of the reef species would struggle with this degree of wave energy and would have to seek refuge on the deeper reefs. By monitoring and recording our findings consistently every year we expect to identify the long-term trends in the data and better understand the environmental fluctuations between monitoring periods.

Indicator Species

Our three chosen indicator species vary in habitat and feeding strategies which in part, influences each species' recovery rate. The observed numbers of increased snapper and red moki staying much the same is as predicted at the 6-year mark since full protection. This is explained in Wallace & Kerr (2022), and Shears & Babcock (2002). The apparent decline in butterfish numbers in the last three years of surveying is a concern. As adults, butterfish are entirely herbivorous and rely on dense algal cover for habitat and feeding (Choat & Clements 1992). Therefore, there is likely a direct correlation between butterfish numbers and the loss of kelp forest around Maitai Bay. This is also true for Red moki and similar herbivore species whose numbers are not showing an evident increase. There is a clear ecological connection between species and the extent of kelp forest. Among the many critical roles kelp forests play in their environment, they also provide protection and a safe-haven for many juvenile fish and invertebrate species. This in turn attracts other species which become residents or frequent visitors to these reef areas to prey on the kelp-dependent species. Hopefully, with the current protection status and return of predatory fish species to the Bay, we will see a rejuvenation of kelp forest within the area and the return of species that rely on it.

Snapper

The apparent trend of increasing snapper biomass was again observed in both the Timed Swim and BUV survey results this year. The BUV results showed greater snapper biomass within the rāhui than outside again too. Based on previous studies, it is assumed this increase in snapper density is likely a result of the immigration of large snapper into the protected area of the rāhui, rather than juvenile recruitment from within (Denny *et al.* 2004; Willis *et al.* 2003). This theory could be supported by the observations of larger snapper (80-100cm) showing up in the last two years of monitoring. Snapper that are 80cm are believed to be over 20 years old, so could not have grown to this size as a result of the 6 years of rāhui protection (Millar *et al.* 1999), and instead, these individuals have taken up residence on the reef during their seasonal movements (Willis *et al.* 2003).

The timed swim survey results also showed an increase in the number of juvenile snapper this year. Year-to-year variations in juvenile snapper are affected by many factors including spawning success, sea temperatures and other environmental factors.

Future Work

Crayfish population, and their importance to the kina barren issue?

In northern New Zealand, large snapper and spiny lobster or crayfish, *Jasus edwardsii,* are the main predators of kina. In our monitoring efforts, the focus has been on the abundance and biomass of snapper within the rāhui but to date, we have only made observations of the crayfish population in the area. It is thought that snapper and other predatory fish are responsible for predation on mainly small urchins (<50mm), while crayfish are responsible for a high proportion of predation on larger urchins (Shears & Babcock 2002; Andrew & Choat 1982; Andrew & MacDiarmid 1991). The exception to this generalised description of predation would be the very large snapper that can very easily smash a full-sized kina in their mouths.

The presence of the Tasmanian urchin *Centrostephanus rodgersii* is rising throughout northland New Zealand and is cause for concern as currently, the only known natural predator is our spiny lobster large in size. Adding a crayfish survey to the monitoring would be a valuable next step to fully understanding the ecological story of Maitai Bay. Ideally, the crayfish monitoring would involve local knowledge combined with Western methods. Through local observations over years of diving in the area, we have detailed knowledge of how the crayfish use the habitats and some locations of high-quality 'dens' which can be combined with long-term knowledge of abundance trends in the area. The survey would allow us to track the recovery of the crayfish population and the potential level of kina predation occurring within the rāhui.

Kina Harvesting

In 2022 a kina cull was trialled to control kina density in a small designated area to see whether such an effort would be successful in aiding the recruitment and settlement of *Ecklonia*. The goal was not to replace the ecological role of snapper and crayfish, but as a helping hand to keep the kina numbers down to a 'recovery threshold density' so that the kelp could re-establish on the reef (Kerr & Wallace 2022). Experimental removal of kina from urchin barren habitat in marine reserve sites in northeastern New Zealand over 12 months lead to a change from a crustose coralline algal and kina barren habitat to a macroalgal-dominated habitat (Shears & Babcock 2002). More studies have been done since with similar results, and as the research is published, we expect to see more evidence of kina removal in urchin barren habitat areas being beneficial to helping kelp forest regeneration. In 2023 the local hapu and community hosted a kina harvesting event, seeing the removal of more than 1000 kina. Although it is harder to quantify the benefit of this method, the hands-on approach allowed local tamariki, whānau and hāpu to engage with the rāhui on a personal level. This is highly beneficial to the long-term support and success of the rāhui and offers a proactive approach to achieving the goals of restoring the kelp forest.

Acknowledgments

Special thanks to Te Whānau Moana me Te Rorohuri for their strong leadership. Without them there would be no rāhui to learn from. Thanks to Whetu Rutene for sharing local knowledge and assisting on several survey dives. To Mountains To Sea Conservation Trust and Foundation North, thanks for the ongoing support and funding to make this monitoring possible.

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Appendices

Appendix 1: Total Fish Diversity for Maitai Bay, 2023

#	Family	Genus	Species	Common Name	Maori Name	Timed Swim	BUV
1	Aplodactylidae	*Aplodactylus*	*meandratus*	Marblefish	Kehe	✓	
2	Arripidae	*Arripis*	*trutta*	Kahawai	Kahawai	✓	✓
3	Berycidae	*Centroberyx*	*affinis*	Golden Snapper	Hauture		✓
4	Carangidae	*Seriola*	*lalandi*	Yellowtail Kingfish	Haku	✓	
5	Carangidae	*Decapterus*	*koheru*	Koheru	Koheru	✓	
6	Carangidae	*Caranx*	*lutescens*	Trevally	Araara	✓	✓
7	Cheilodactylidae	*Cheilodactylus*	*ephippium*	Painted Moki		✓	
8	Cheilodactylidae	*Cheilodactylus*	*douglasi*	Porae	Porae	✓	✓
9	Cheilodactylidae	*Cheilodactylus*	*spectabilis*	Red Moki	Nanua	✓	✓
10	Chironemidae	*Chironemus*	*marmoratus*	Hiwihiwi	Hiwihiwi	✓	✓
11	Dasyatidae	*Dasyatis*	*brevicaudata*	Shortailed Stingray		✓	✓
12	Diodontidae	*Allomycterus*	*jaculiferus*	Porcupine Fish		✓	
13	Hemiramphidae	*Hyporhamphus*	*ihi*	Piper		✓	
14	Kyphosidae	*Scorpis*	*violaceus*	Blue Maomao	Maomao	✓	✓
15	Kyphosidae	*Girella*	*tricuspidata*	Parore	Parore	✓	
16	Kyphosidae	*Kyphosus*	*sydneyanus*	Silver drummer		✓	
17	Labridae	*Bodianus*	*unimaculatus*	Red Pigfish		✓	✓
18	Labridae	*Notolabrus*	*celidotus*	Spotty	Paketi, Paekirikiri	✓	✓
19	Labridae	*Notolabrus*	*fucicola*	Banded Wrasse	Tāngahangaha	✓	
20	Labridae	*Notolabrus*	*inscriptus*	Green Wrasse		✓	
21	Labridae	*Pseudolabrus*	*luculentus*	Orange Wrasse			✓
22	Labridae	*Coris*	*sandageri*	Sandaggers Wrasse		✓	✓
23	Labridae	*Pseudolabrus*	*miles*	Scarlet Wrasse			✓
24	Monacanthidae	*Parika*	*scaber*	Leather Jacket	Kokiri	✓	✓
25	Mugilidae	*Mugil*	*cephalus*	Grey Mullet	Kanae	✓	
26	Mullidae	*Parupeneus*	*fraterculus*	Goatfish (tropical)	Āhuruhuru	✓	
27	Mullidae	*Upeneichthys*	*lineatus*	Goatfish bar-tailed	Āhuruhuru	✓	✓
28	Muraenidae	*Gymnothorax*	*nubilus*	Moray Gray			✓
29	Muraenidae	*Gymnothorax*	*obsesus*	Moray Speckled			✓
30	Muraenidae	*Gymnothorax*	*prasinus*	Moray Yellow			✓
31	Muraenidae	*Enchelycore*	*ramosa*	Moray Mosaic			✓
32	Myliobatidae	*Myliobatus*	*tenuicaudatus*	Eagle Ray	Whai keo	✓	
33	Odacidae	*Coridodax*	*pullus*	Butterfish	Mararii	✓	
34	Pempheridae	*Pempheris*	*adspersus*	Big Eye		✓	✓
35	Pinguipedidae	*Parapercis*	*colias*	Blue Cod	Rāwaru		✓
36	Pomacentridae	*Parma*	*alboscapularis*	Black Angelfish		✓	
37	Pomacentridae	*Chromis*	*dispilis*	Two-spot Demoiselle		✓	✓
38	Scorpidae	*Scorpis*	*lineolatus*	Sweep	Hui	✓	✓
39	Serranidae	*Caesioperca*	*lepidoptera*	Butterfly Perch	Oia		✓
40	Serranidae	*Hypoplectrodes*	*sp.*	Half banded perch			✓
41	Sparidae	*Pagrus*	*auratus*	Pink Snapper	Taamure	✓	✓
42	Triglidae	*Chelidonichthys*	*kumu*	Gurnard	Kumukumu / pūwahaiau		✓
43	Tripterygiidae		*sp.*	Common Triplefin		✓	
44	Tripterygiidae	*Obliquichithys*	*maryannae*	Swimming Blennie		✓	
45	Zeidae	*Zeus*	*japonicus*	John Dory	Kuparu		✓
46		Unknown sp.		Baitfish		✓	