Rāhui Monitoring Report

Maitai Bay, Cape Karikari

5th year of 'no-take' marine protection

November 2022

Ceara Wallace & Vince Kerr

Blue Maomao schooling in Maitai Bay
Photo: 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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Keywords: rāhui, urchin barren, kina barren, marine reserve, snapper, crayfish, baited underwater video, Ecklonia, kaitiaki, Maitai Bay, Cape Karikari

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Summary

Records of large-scale fishing around Cape Karikari have existed since Joseph Banks (the botanist on the Endeavour) first wrote of it in his journal in 1769, citing an ‘abundance of nets, up to 1000m long’ being used. The stories of the Muriwhenua people and their dependence on fisheries resources in the region go back even further (Waitangi Tribunal Report, 1988). The impact of this extensive and long-term removal of fish from the sea has more recently become evident in the presence of growing kina (urchin) barrens all along the coast. This degradation has been associated with the loss of top predators, such as large snapper and crayfish. Te Whānau Moana me Te Rorohuri, the local hapū and kaitiaki of Maitai Bay, took initiative to reverse this by implementing a full ‘no-take’ rāhui to restore the mauri (health) of their Moana. Annual monitoring has taken place since 2017 to investigate and learn more about the area and restoration process occurring within the rāhui.

This report marks the 5th year of the Maitai Bay rāhui and its corresponding annual monitoring. A team led by Vince Kerr, involving hapū members and researchers from *Mountains to Sea Conservation Trust* (MTSCT), conducted the 2022 monitoring efforts, which started in February and ended in May. The surveying included three methods previously used: Shallow Reef Fish Timed Swim, Reef Fish Diversity Dive, and Baited Underwater Video (BUV) surveys. The goal is to use these complementary methods to document the ecological changes happening within the rāhui and surrounding area.

Two novel methods were trialed during this year’s monitoring program. The first, a Manta Board Tow Survey, was done in an attempt to determine the presence of juvenile snapper populations over the sand flat areas of Maitai Bay and is reviewed in *Appendix 3*. The second was in response to increasing interest in finding an active approach to addressing the issue of kina barrens and fast-tracking kelp regeneration. A small kina culling project was trialed to see if kina removal in an area could benefit the settlement and regeneration of *Ecklonia* (kelp). The trial methods and findings are reviewed separately in a stand-alone report (Kerr, 2022).

Monitoring conditions this season were adverse due to the extended presence of the La Niña weather pattern that remained strong throughout the 2022 summer. Despite this, the findings from this season’s monitoring showed promising progress in the recovery of fish life as a result of the rāhui.

Results from the Shallow Reef Timed Swim Surveys show larger snapper individuals are turning up in the rāhui and there is the beginning of a clear trend in the overall snapper biomass increasing within the survey area since the fishing ban. The BUV results further support the finding of increased snapper biomass within the rāhui compared to areas surveyed outside. Footage from the BUV surveys captured snapper estimated to be as long as 100cm within the rāhui. Observations from the Reef Fish Diversity Dive surveys were generally consistent with previous years. The effort from all surveys this year captured 48 fish species as total diversity compared with the 45 species recorded in 2019.

This report aims to provide a record of the 2022 monitoring and discusses the current condition of Maitai Bay rāhui and the surrounding area. Along with previous years’ work on the program, it also

hopes to add to the existing knowledge regarding the benefit of 'no-take' rāhui and their value to coastal conservation in New Zealand.

Kaupapa

Te Whānau Moana me Te Rorohuri, a Ngati Kahu hapū and kaitiaki of the Karikari peninsula, placed a rāhui tapu over Maitai Bay at the end of 2017. The rāhui boundaries cover all of Maitai Bay, and most of the neighbouring Waikato Bay, and extend out to the offshore Pinnacle (see *Fig. 1*).

Figure 1: Maitai bay rāhui boundaries

This action came after rising concerns about the decline in fish numbers and the growing kina barrens along their coast. It was a conservation initiative to protect and restore diversity and abundance to their Moana (ocean). The hapū intends the rāhui to:

- *Bring balance back to our Moana*
- *Restore the depleted areas*
- *Restore Tapu, restore Mana*
- *Implement a sustainability plan for future generations*

The hapū has taken a holistic approach to manage their Moana, using cultural and scientific knowledge to inform decisions regarding their rohe. Recognising the importance of tikanga Māori based decision-making, MTSCT has supported the hapū and helped establish a monitoring programme to document the restoration process. The initiative was designed for ongoing, long-term marine monitoring of the area.

Introduction

Kina Barrens

Kina (*Evechinus chloroticus*) is a species of sea urchin endemic to New Zealand which grazes on kelp. Kina barrens can be described as open areas of rocky reef that are dominated by kina and devoid of kelp. They are rife throughout the East Coast of northern New Zealand and the concern is for the rate at which they are spreading. Large snapper and crayfish with strong jaws and developed claws can crush through the shell of kina and eat them. There is strong evidence to show the removal of top predators like large snapper and crayfish result in these higher populations of kina, which in turn decimate kelp forest (Andrew & Choat, 1982; Jones, 2013). Kelp forests are critical to maintaining the biodiversity and health of our coastal Moana as most of New Zealand's shallow reef community relies on them for habitat and food. Studies comparing protected and non-protected areas show it is possible to reverse this trophic cascade. This is through increasing the number of predatory fish in reserves, which results in the initial depletion of kina, followed by a later increase in kelp growth (Jones, 2013; Shears & Babcock 2002). In the case of Maitai Bay, the hope is that the 'no-take' rāhui will allow the return of these larger predator species and, in turn, help bring the kina densities back to a healthy balance and encourage the restoration of the kelp forest.

Marine Reserves & Rāhui

Marine reserves are zoned areas of a marine environment that have a level of protection placed over them. For example, a marine reserve in New Zealand (established under the Marine Reserves Act 1971) would be, by law, a fully no-take marine protected area. No-take marine reserves are a gold standard for marine conservation as they are created with the purpose to protect and preserve all marine life in a specific area. This is the same goal the hapū is striving for at Maitai Bay with their rāhui.

In Māori culture, a rāhui is usually a form of tapu restricting access to or use of, an area or resource. It is a traditional means of placing a 'prohibition against a particular area or activity, typically one in force temporarily to protect a resource' (Moorfield, 2004). Concerning the ocean and fisheries, rāhui are used to ban the harvesting of a particular species or harvesting from a particular area. They can be set up overnight and be in place temporarily (e.g. for a breeding cycle) or remain long-term depending on the need or restoration sought. Rāhui are usually managed locally by the kaitiakitanga of the area. The rāhui is given its traditional authority by the mana of the person or group that imposes it.

Today it is widely accepted that biodiversity and abundance of fish are greater in marine protected areas compared to non-protected areas. By establishing more no-fishing areas through marine reserves and rāhui, we slow the removal of top predators, encourage kina populations to return to healthy levels, and allow kelp forest and ecosystem functions in those areas to recover.

What has been created around Maitai Bay for marine conservation is unique and valuable to preserving the health of Northland's coastal marine environment. As a reef with such extensive kina barrens and strong Māori history and guardianship, it is an ideal location to be placed under protection through rāhui and studied. From this report we hope to continue to learn about the restoration process and the ecology of Maitai Bay and its wide array of habitats.

METHODS

All monitoring was carried out at Maitai Bay and the surrounding area around the rāhui. Species are referred to by their common names but a full list of their Māori and scientific names is provided in *Appendix 1*. The 2022 surveys follow the same sampling area and general methods defined by Kerr *et al*., (2018 & 2019). The trial methods are described separately. All methods are designed to be reliably replicated over time allowingfor recovery trends to be tracked. The five surveys completed during the 2022 monitoring period all address a slightly different approach to observations made and data collected. Together they provide a fuller picture of the current condition of the area.

Timed Swim Fish Survey

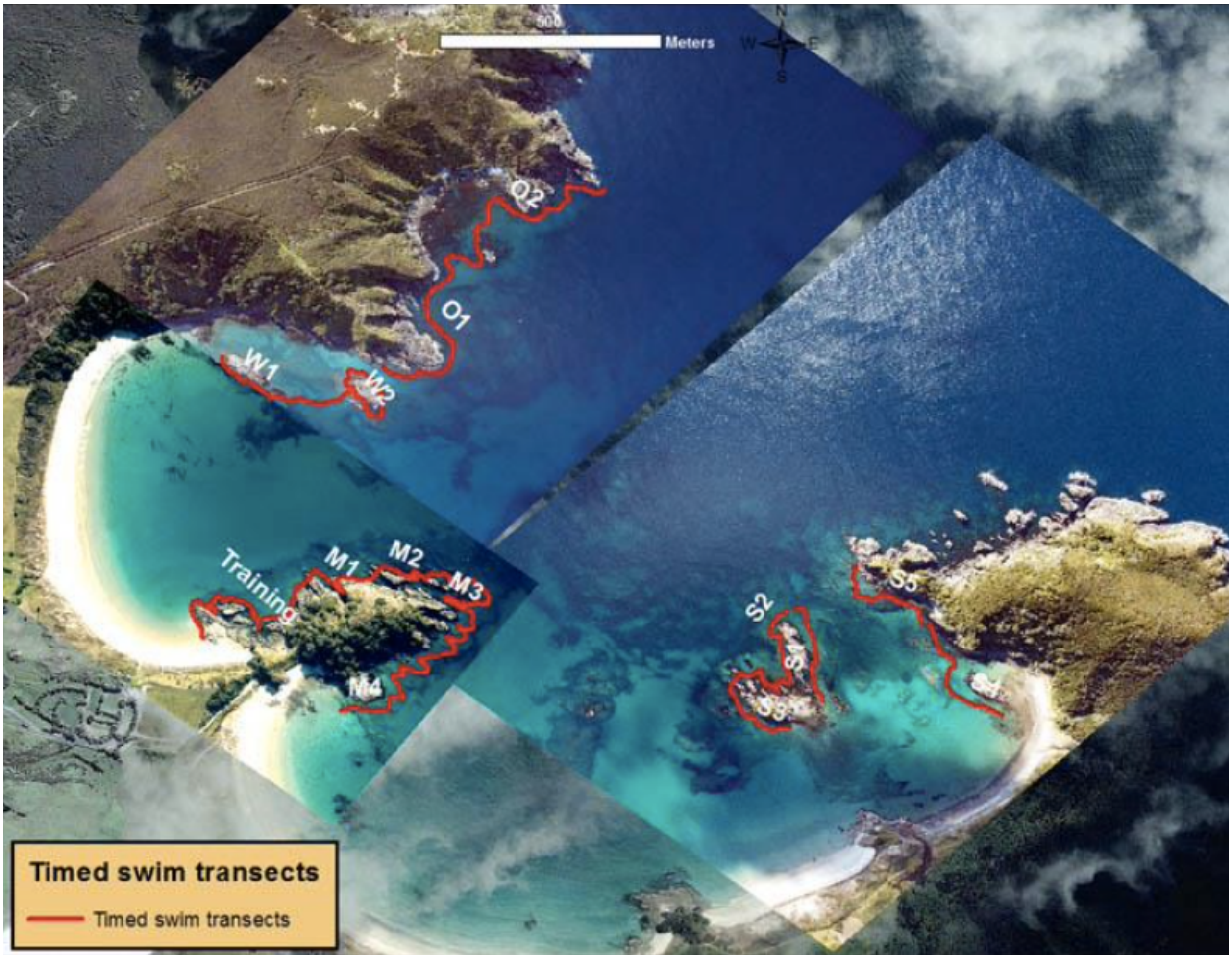

Figure 2: Timed swim fish survey transect routes for Maitai bay rāhui and surrounding area.

Timed Fish Swim Surveys, sometimes referred to as Roving Diver Surveys, are used globally to determine the relative abundance of fish species within an area. This report describes the 5th consecutive year the survey has been completed at Maitai Bay. This method specifically targets fish species within the shallow reef habitat. Refer to Kerr *et al.,* (2018 & 2019) for a discussion of strengths, weaknesses and the value of using this method as part of the long-term monitoring strategy for Maitai Bay.

Sampling Area

The 13 swim transects (*Fig. 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 (*Fig. 1*).

Method Description

Divers involved in the survey must have sound knowledge of local fish species, a watch, and a pencil and slate each. 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 continually record the species and number of fish seen within 6-10 meters of themselves. For snapper, red moki and butterfish, a relative size class category for each individual is also recorded based on their estimated length (to nearest 10cm). This method is repeated for all transects with metrics including date, tide (moon phase), time at the start of swim, visibility and conditions recorded for each. 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 are considered the most targeted catch species for the monitoring area. Tracking their recovery over time should provide a better indication of 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 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).

The biomass of each size class was calculated and these were 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 may occur over time.

Reef Fish Diversity Dive Survey

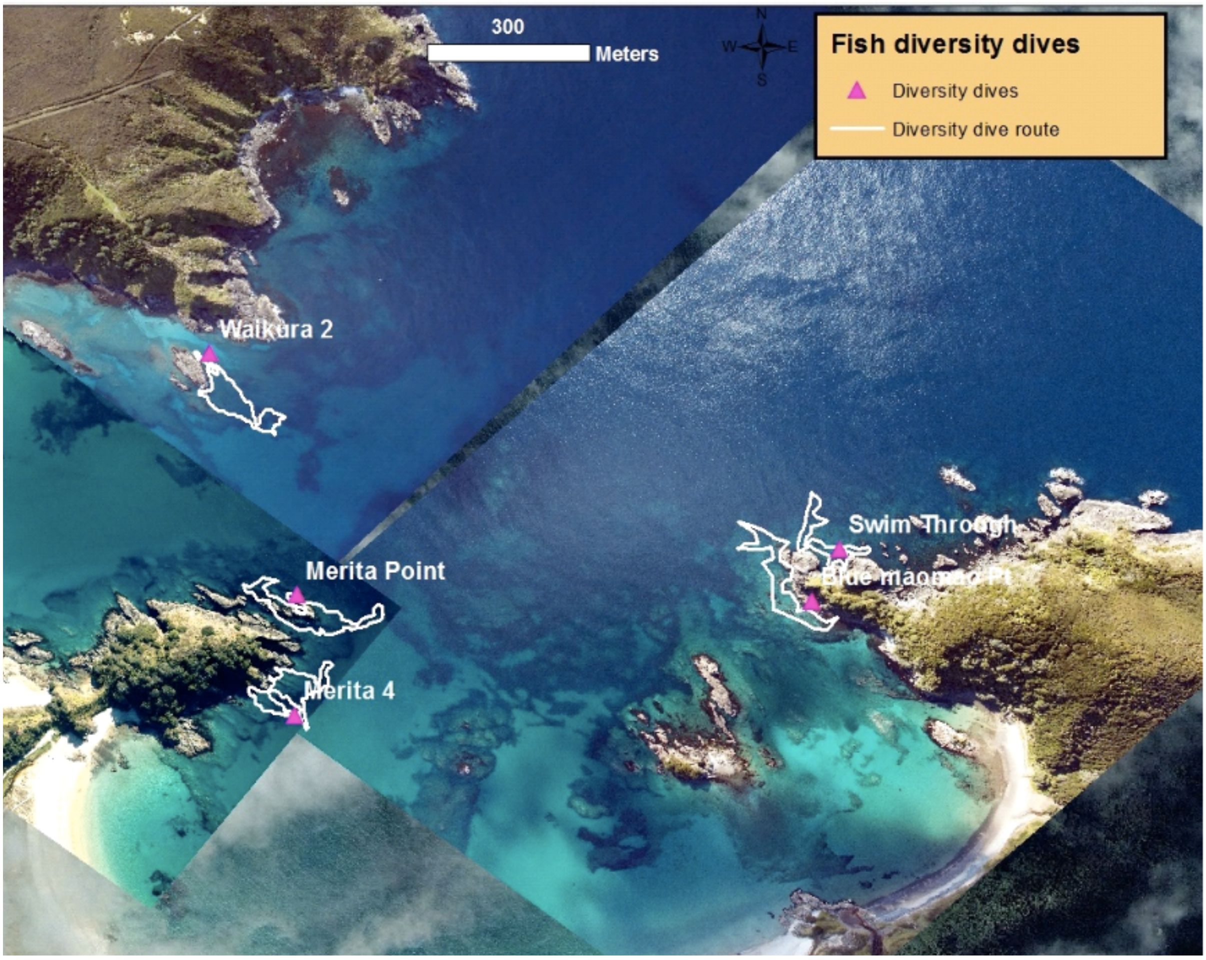

Figure 3. Reef fish diversity dive survey sites across Maitai Bay rāhui.

The Reef Fish Diversity Dive Survey attempts to observe as many species as possible at a site. It is a valuable method as it provides an opportunity to record species that may be missed during other surveys, such as cryptic and herbivorous fish that spend time at depth below 10m or hidden within the kelp and reef substrate. The five survey sites were chosen as representative of shallow reef habitat (*Fig.3*). When results of this method are coupled with the Timed Swim and BUV surveys, the full list of species observed becomes a measure of the total reef fish diversity for Maitai Bay.

Using SCUBA gear, a solo diver follows a pre-planned dive route over the reef searching for and recording every fish species that is present on an underwater slate. See *Fig. 3* for the approximate routes the diver follows for each of the five sites. The diver aims to cover as large an area as possible using one tank of air, starting at the deepest point and slowly working their way up covering all habitats. Special attention is paid to finding the more cryptic species hidden amongst the kelp or rock crevices.

Baited Underwater Video (BUV) Survey

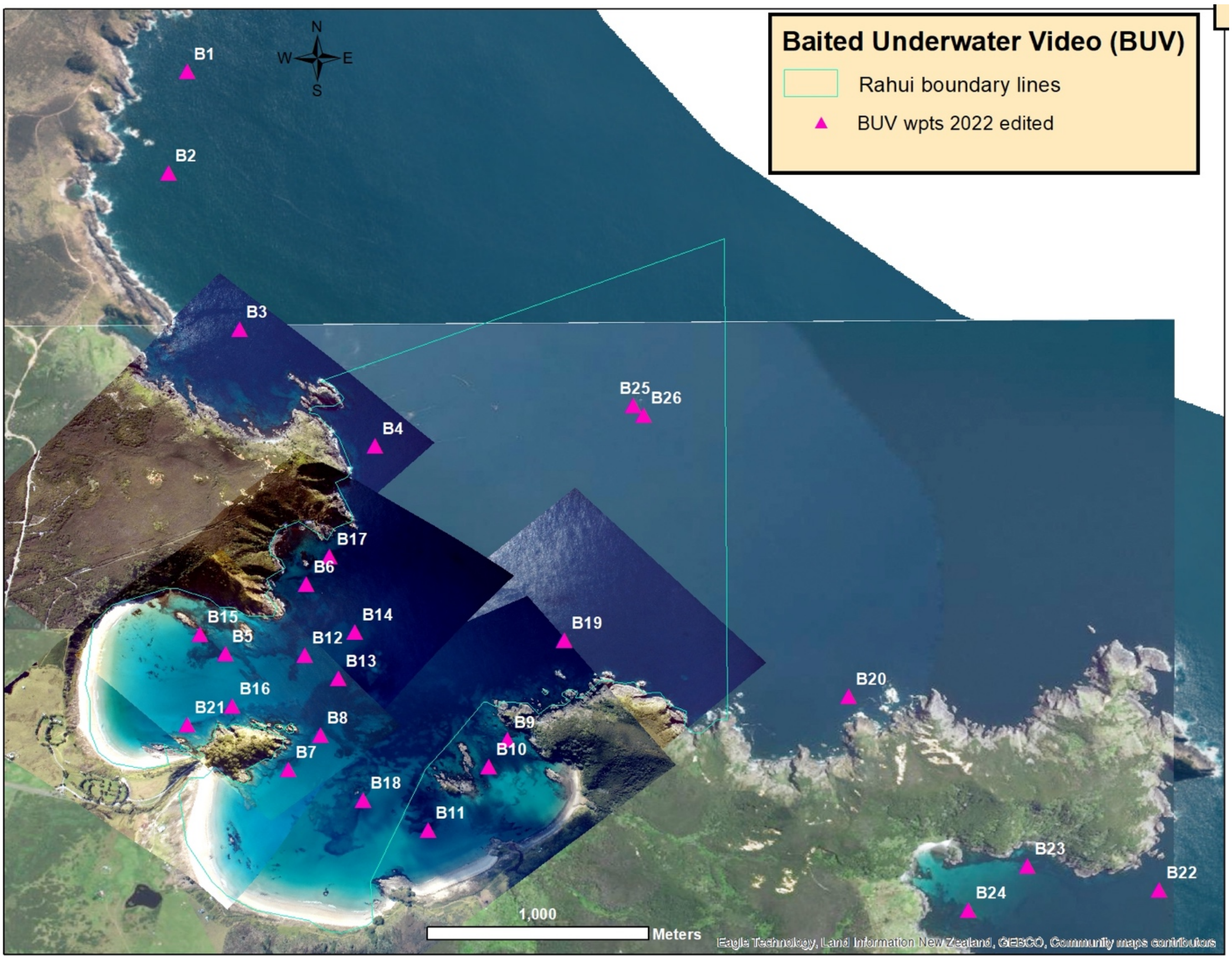

Figure 4. *Updated BUV survey drop sites for Maitai Bay rāhui and the surrounding area.*

Baited Underwater Video (BUV) Surveys are used to determine differences in the relative abundance of carnivorous fish species between protected and non-protected marine areas (Willis & Babcock, 2000). One round of BUV drops was completed (over two consecutive days) for the 2022 monitoring period. The survey team included a skipper and one crew for deploying equipment. 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 (*Fig. 5*) consists of a frame made of two aluminium bars welded together at a roughly 60-degree angle. The horizontal bar sits on the bottom, is 120cm long and clearly marked at 10cm 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. 6*). 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

Site selection was designed to cover two habitat zones, 'sheltered' and 'exposed' (with exposed sub-zone for the 2 sites on the pinnacle), spanning the wider Maitai Bay and the rāhui area (Kerr *et al.,* 2019). This includes 16 sites chosen within the rāhui and 10 sites outside. This arrangement means data across habitat zones is comparable for inside and outside the rāhui area.

Method Description

Each site is labelled and plotted onto the research vessel sounder. The boat manoeuvers directly above the mark for a drop site. The BUV apparatus, with bait cage filled with 100g chopped pilchards, and GoPro ON and recording, is then lowered overboard using the line so that the second float remains on the surface directly above the site (see *Fig. 5* for arrangement of deployed BUV). A timer onboard is set ensuring that each drop generates a minimum of 30 minutes of continuous and undisturbed footage while the BUV is submerged. The frame is then brought back onboard, re-set, and the protocol repeated for the next site.

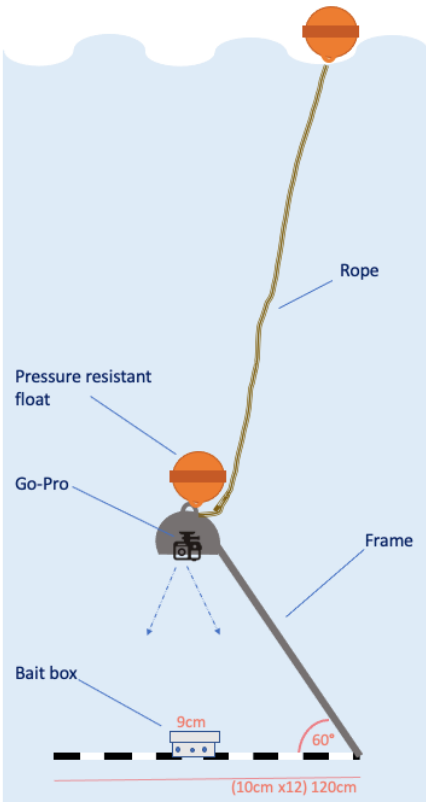

Figure 5. *Diagram of a deployed BUV apparatus.*

BUV Analysis

For each drop site, the video is analysed to determine total fish diversity, MAX snapper count and MAX snapper biomass for each sample site. MAX snapper count = the maximum number of snapper recorded in a single frame during the 30-minutes of footage. MAX snapper biomass = the estimated total maximum biomass of snapper recorded in a single frame. MAX biomass has previously been calculated from the same frame as MAX snapper count. We have decided to vary the biomass calculation method in our analysis in order to better capture the addition of the large snapper arriving in the rāhui area. MAX biomass was calculated from frames with MAX snapper count as well as frames that we predicted may have equal or greater biomass – i.e. frame with fewer individuals present but larger in length, hence potentially greater biomass in total. To determine biomass, individual lengths for snapper were measured in still frames of the video sequence and calibrated against the scale bar. Care was taken to measure fish length as accurately as possible when the fish were at the same level as the bottom bar. See *Fig. 6* for reference.

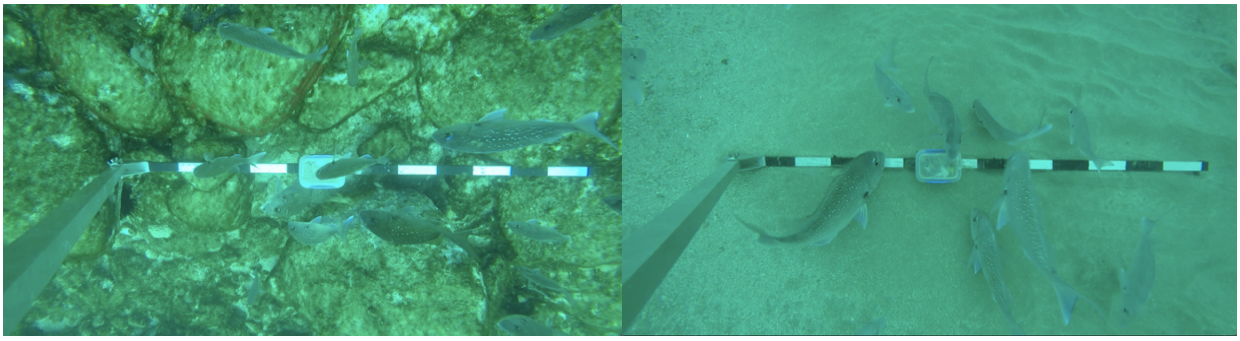

Figure 6. *Screen shots from BUV footage from sites B6 (left) and B26 (right).*

RESULTS

Shallow Reef Fish Timed Swim Survey

Surveys of the 13 established transects were repeated 2 to 3 times during the summer months of February and March 2022. The survey information is summarised in *Table 1* below. In total 37 transects were surveyed amounting to 9.25 hours of diving and 17,814 fish being counted. This included 1268 snapper, 80 red moki, and 6 butterfish. The average visibility across dives was around 6 meters, and only once on transect S5 (see *Fig. 2*) did it exceed 10 meters.

Transect	No. of fish counted	No. of species	Diver Initial	Date	Swim Start Time	Tide	Visibility
M1	166	11	CW	16-Feb	1400	0836 H	5-6m
M1	305	8	VK	15-Mar	1450	0627 H	6m
M1	187	8	CW	31-Mar	1508	0752 H	6-8M
M2	80	12	CW	16-Feb	1420	0836 H	5-6m
M2	188	12	VK	15-Mar	1430	0627 H	6m
M2	325	15	CW	31-Mar	1525	0752 H	10M
M3	27	6	VK	16-Feb	1400	0836 H	5-6m
M3	147	10	CW	15-Mar	1500	0627 H	6m
M3	144	9	VK	31-Mar	1503	0752 H	6-8M
M4	44	5	VK	16-Feb	1420	0836 H	5-6m
M4	203	15	CW	15-Mar	1430	0627 H	6m
M4	264	9	VK	31-Mar	1533	0752 H	6-8M
O1	2567	13	VK	16-Feb	1300	0836 H	5-6m
O1	291	11	VK	31-Mar	1200	0752 H	6-8M
O2	465	16	VK	16-Feb	1320	0836 H	5-6m
O2	794	15	VK	31-Mar	1240	0752 H	6-8M
S1	348	17	CW	16-Feb	1200	0836 H	5-6m
S1	98	7	VK	15-Mar	1200	0627 H	4-6m
S1	345	11	VK	31-Mar	1315	0752 H	6-8M
S2	219	10	VK	16-Feb	1200	0836 H	5-6m
S2	107	11	VK	15-Mar	1220	0627 H	4-6m
S2	903	12	VK	31-Mar	1315	0752 H	6-8M
S3	320	9	VK	16-Feb	1220	0836 H	5-6m
S3	59	7	VK	15-Mar	1250	0627 H	6m
S3	104	9	VK	31-Mar	1350	0752 H	6-8M
S4	207	8	WR	16-Feb	1220	0836 H	5-6m
S4	774	11	CW	15-Mar	1200	0627 H	8-10m
S4	583	12	CW	31-Mar	1338	0752 H	6-8M
S5	138	8	WR	16-Feb	1200	0836 H	5-6m
S5	796	16	CW	15-Mar	1140	0627 H	10-20m
S5	1290	15	CW	31-Mar	1420	0752 H	10M
W1	74	9	WR	16-Feb	1300	0836 H	5-6m
W1	2495	12	CW	15-Mar	1040	0627 H	6m
W1	913	13	CW	31-Mar	1214	0752 H	6-8M
W2	514	13	CW	16-Feb	1300	0836 H	5-6m
W2	250	7	VK	15-Mar	1050	0627 H	4-6m
W2	1080	9	CW	31-Mar	1245	0752 H	6-8M
Mean	481.5	10.8					

Table 1. *Summary information from each transect surveyed in 2022 using timed swim method.*

Overall, 32 fish species were recorded. See *Appendix 1* for the full list. The average diversity count (number of species) for a transect was 10.8 species, the lowest count being 5 and the highest 17. The lowest count came from transect M4, the area most affected by kina barrens. The highest count was recorded at transect S1, a slightly more exposed and diverse area with less kina barren. These were also the two sites with the largest range in species count across the different survey dates, a difference of 10 species from alternative survey days.

Table 2 presents a comparison of the summarised shallow reef fish timed swim survey data for each year since 2018. Because of the weather patterns during the 2022 monitoring season, observations for the timed swims occurred over a period of less than two months (for comparison, 2019 surveys were done over 5 months). Survey efforts for 2022 and 2021 were also less than previous years due to unfavourable surveying conditions. The average number of fish counted per transect shows a general trend of increase since the 'no-take' protection was implemented. In the last 5 years the average has increased from 140 in 2018, to 481 in 2022 (the highest being 770 in 2021). The slight increase in species diversity since 2018 to present is unlikely to be statistically significant. However, this number is expected to increase significantly as areas of kelp forest fully recover in Maitai Bay.

Timed Swim summary table	**2018**	**2019**	**2020**	**2021**	**2022**
Number of transects in survey	8	13	13	13	13
Total transects surveyed	16	45	67	38	37
Total hours surveying	4	15	17	9.5	9.25
Total fish counted	2,239	17,550	22,912	29,251	17,814
Average no. fish per transect	140	352	342	770	481
Average no. species per transect	9.5	10.4	11.1	12.5	10.8
Highest no. species per transect	14	20	20	22	17
Lowest no. species per transect	7	5	5	5	5

Table 2. *Summary of data recorded during Timed Swim Fish Surveys completed at Maitai Bay between 2018 and 2022.*

Indicator Species

Additional information was collected for snapper, red moki and butterfish. The average total count of snapper was the same as it was in 2019 but the distribution across size classes was is different in 2022. In the last two years of surveying, we have started to see snapper appearing in the larger size classes of 70cm and upwards (*Fig*. 7). In 2022 there was also a big jump in the number of juvenile snapper present (*Fig. 6*).

Indicator Species	**2018**	**2019**	**2020**	**2021**	**2022**
Mean total snapper count	12	34	9	20	34
Mean total red moki count	2	3	6	5	2
Mean total butterfish count	0.06	0.18	0.42	0.39	0.16

Table 3. *Summary of the average total count of indicator species overall in transects surveyed in Maitai Bay between 2018 and 2022 from Shallow Reef Fish Timed Swim Surveys.*

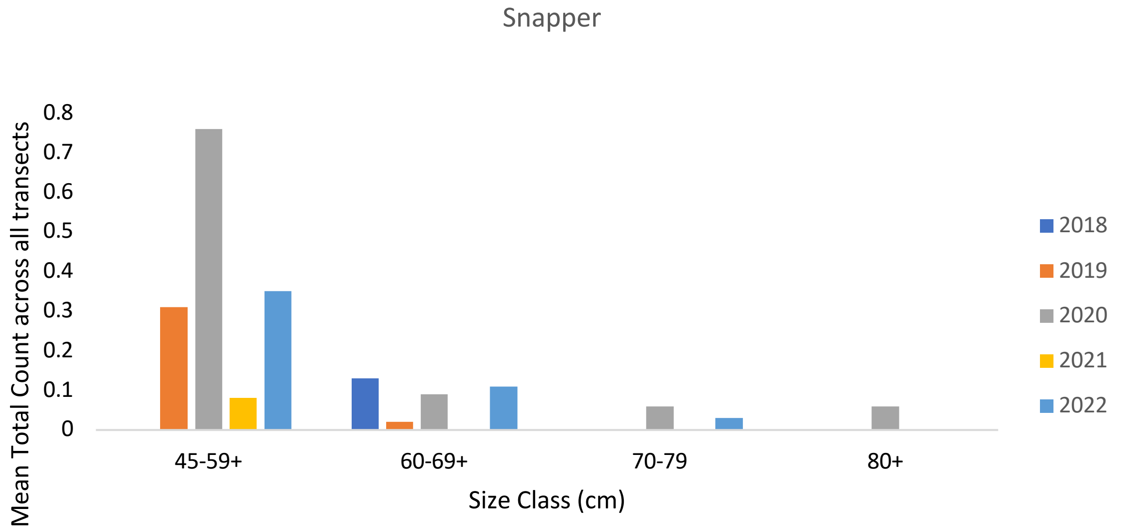

Figure 7. Comparison of average total snapper count per transect for larger size classes from 2018 to 2022 survey data from Maitai Bay monitoring.

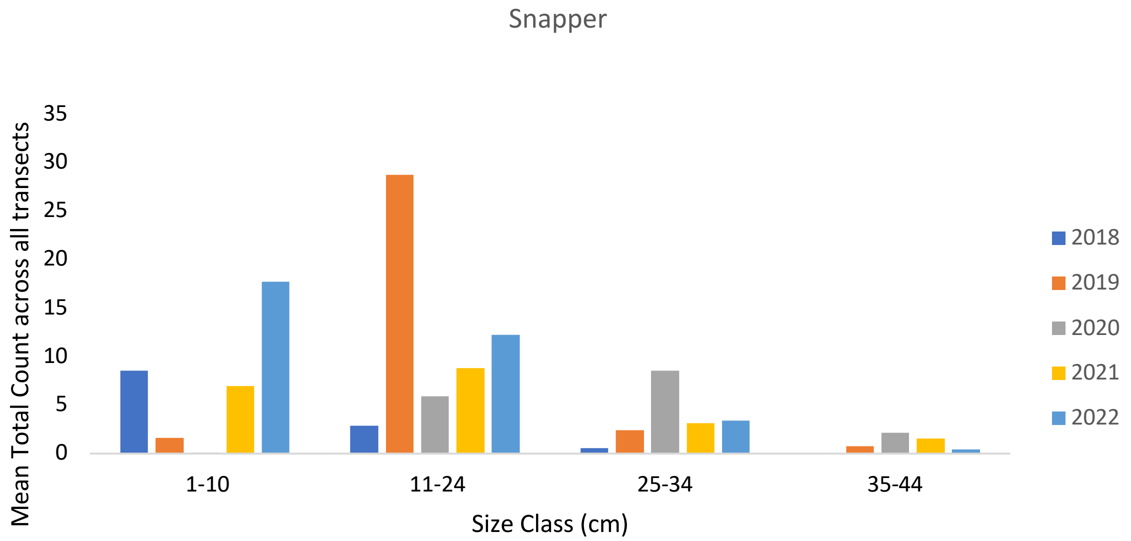

Figure 8. Comparison of average total snapper count per transect for smaller size classes from 2018 to 2022 survey data from Maitai Bay monitoring.

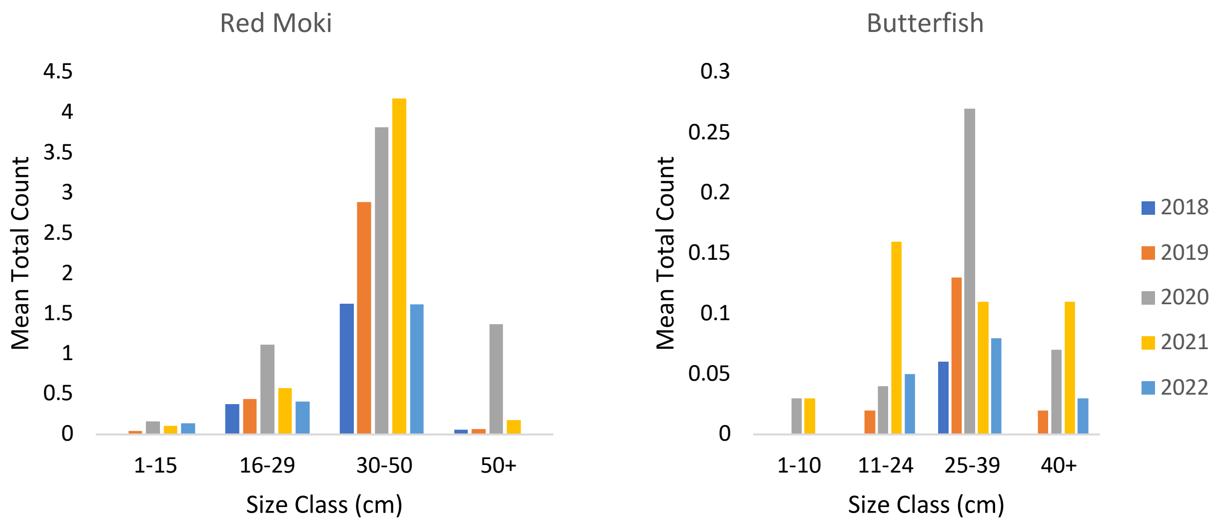

Figure 9. & 10. Average total count of red moki & butterfish per transect shown in size classes for each year of monitoring from 2018 to 2022.

Snapper Biomass

In the last two years we have started to observe snapper in the larger size classes of 70cm in length and upwards (see *Fig. 7*). Another way to visualise the significance of the appearance of these larger individuals is to calculate the relative biomass. Just after the rāhui was created in 2018, the recorded average biomass of snapper per transect was 1.8kg. Since then, there has been a trend of increasing biomass (see *Fig. 11*) with 6.48kg calculated in 2022.

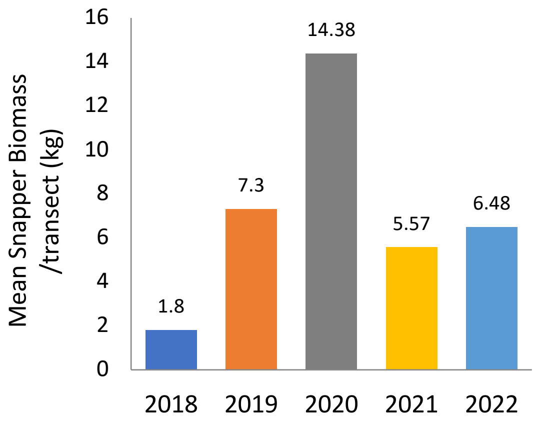

Figure 11. *Comparison of average snapper biomass per transect from 2018 to 2022.*

Reef Fish Diversity Dive Survey

All five diversity dive sites were successfully surveyed in 2022. Close to an hour was spent diving each site as the diver carefully looked for all fish species present in that area. The map in *Fig. 3* shows the location of the five survey sites and the approximate route the divers followed.

A summary of the results is presented in *Table 4*. The number of species counted per site in 2022 ranged from 14 species at Waikura 2 to 26 at Blue Maomao West, which was the highest diversity recorded to date for a site. Both Blue Maomao sites had the highest count of species recorded since the first survey in 2019. Visibility was 15-20m on this day and sites were very active with small groups of kingfish, kahawai and jack mackerel at the point, and blue maomao in big numbers. Blue Maomao Point is known for being one of the special areas of the shallow rocky reefs in the rāhui. The habitat and ecosystem here are more diverse than at the other sites. The reef drops off sharply from shore to 12m and extends outwards sloping off to 22m depth. There are patches of kelp forest, rock walls, caves, and large cracks and crevices creating rough ground. Off the point, there is a noticeable current and often large congregations of schooling fish can be observed, likely using the upwellings and eddies to assist their feeding. The lowest fish diversity site was Waikura 2 where the habitat is a lot less varied, with a shallow rocky ridge that extends out surrounded by sand flat (*Fig. 3*). A total of 34 species were counted across the five sites. The total count has remained relatively constant across the 2019, 2020, and 2022 surveys.

Diversity dive summary	Species Count		
Dive Site	2019	2020	2022
Waikura 2	18	17	14
Merita 4	15	14	16
Merita Point	20	20	23
Blue Maomao East	23	21	24
Blue Maomao West	22	23	26
TOTAL	**36**	**32**	**34**

Table 4. *Species counts for the five fish diversity sites from 2019, 2020 and 2022 surveys.*

Total Biodiversity

The total number of fish species recorded across all survey methods was 48. Of that total, 34 species were represented in the diversity dive survey (see *Appendix 1*). This survey method captured the highest total species count of the three survey methods used (*Table 5*). Notable less common species that may have otherwise been missed using other methods included a black spotted grouper, painted moki and dwarf scorpion fish.

Survey	Species Count
Shallow Reef Timed Swim	32
Reef Fish Diversity Dive	34
Baited Underwater Video	26
All surveys combined	**48**

***Table 5**. Total species counts from all surveys done in 2022.*

Baited Underwater Video (BUV) Survey

In total 25 of the 26 established BUV sites were surveyed in 2022 and 24 drops were successful. It is important to note the difference in habitat across the survey sites. 14 sites surveyed were included within the rāhui; 10 are in sheltered coast and 4 were exposed. 10 sites were sampled outside the rāhui, of which 3 are sheltered and 7 exposed (see map in *Fig. 4*). Footage from site B5 had to be excluded from analyses due to kelp interference. There was no drop done at site B21. *Table 6* shows the summary of data recorded.

Site		Inside / Outside Rāhui	Diversity (no. of species)	MAX # snapper	Max Length	Mean Length (cm)	Mean biomass (kg)	MAX biomass (kg)
B1	Exposed	Out	11	8	30	18.13	0.18	1.46
B2	Exposed	Out	8	14	50	22.14	0.38	5.36
B3	Exposed	Out	13	12	30	16.25	0.15	1.75
B4	Exposed	In	5	14	45	23.57	0.43	5.97
B6	Sheltered	In	4	20	30	18.25	0.18	3.62
B7	Sheltered	In	3	18	35	22.22	0.31	5.55
B8	Sheltered	In	3	16	35	21.88	0.30	4.75
B9	Sheltered	Out	3	9	20	21.88	0.09	0.81
B10	Sheltered	Out	6	9	20	14.44	0.09	0.85
B11	Sheltered	Out	3	11	30	20.91	0.26	2.82
B12	Sheltered	In	2	18	40	26.94	0.52	9.35
B13	Sheltered	In	5	5	40	26.00	0.51	2.57
B14	Sheltered	In	6	5	25	17.00	0.15	0.75
B15	Sheltered	In	2	17	35	17.06	0.17	2.97
B16	Sheltered	In	2	2	20	17.50	0.14	0.28
B17	Sheltered	In	3	3	45	26.67	0.71	2.13
B18	Sheltered	In	2	14	50	21.79	0.38	5.34
B19	Exposed	In	7	11	30	21.36	0.27	2.82
B20	Exposed	Out	6	21	25	17.38	0.15	3.08
B22	Exposed	Out	8	17	30	20.00	0.21	3.64
B23	Exposed	Out	4	13	35	17.31	0.18	2.37
B24	Exposed	Out	4	18	25	17.50	0.16	2.83
B25	*Pinnacle*	In	12	4	100	50.00	5.45	21.80
B26	*Pinnacle*	In	1	21	70	22.86	0.62	13.03
TOTAL			**26***	**300**	-	-	-	**105.89**
MEAN				12.5	35.87	21.63	0.50	4.41

Table 6. *Summary of data from the 24 successfully surveyed sites during the 2022 BUV surveys of Maitai Bay Rāhui.*

The maximum length recorded for a snapper was 100cm at site B25, off the Pinnacle, and estimated to be 21.8kgs using the equation $W = aL^b$ (Taylor & Willis 1998). The maximum snapper count recorded in a single frame was 21 individual snapper at sites B26, off the Pinnacle, and B20, an exposed site outside the rāhui (see *Fig. 4*). Across all deployments a total of 26 species were recorded and a total of 891 fish counted, snapper being the most abundant species. See *Appendix 1* for the full list of species recorded. Notable species not found through the other survey methods included golden snapper, john dory, eagle ray and short-tailed sting ray.

MAX Snapper Count / MAX Biomass

The results for sites B13 and B25 (highlighted in *Table 6*) were taken from frames that had the greatest MAX snapper biomass but not MAX snapper count. Data for the other sites came from frames that had both MAX snapper count and MAX biomass.

A total of 300 snapper were recorded across all the sites; 168 inside and 132 outside the rāhui. The average maximum snapper count per site was higher outside the rāhui, with 13.2 snapper per transect vs 11.27 snapper per transect inside the rāhui. However, the recorded average biomass was more than double inside the rāhui (5.4kg) compared to outside (2.2kg), see values recorded in *Table 7*. These results indicate a difference in size distribution of snapper and is discussed in more detail below.

Location	MAX snapper count	Mean MAX snapper count	Total Biomass (kg)	Mean Biomass (kg)
In rāhui (*n=14*)	**168**	11.27	**80.93**	**5.4**
Outside rāhui (*n=10)*	132	**13.2**	22.13	2.213

Table 7. *Summary data for snapper from BUV survey completed around Maitai Bay in 2022 (n=24 BUV sites).*

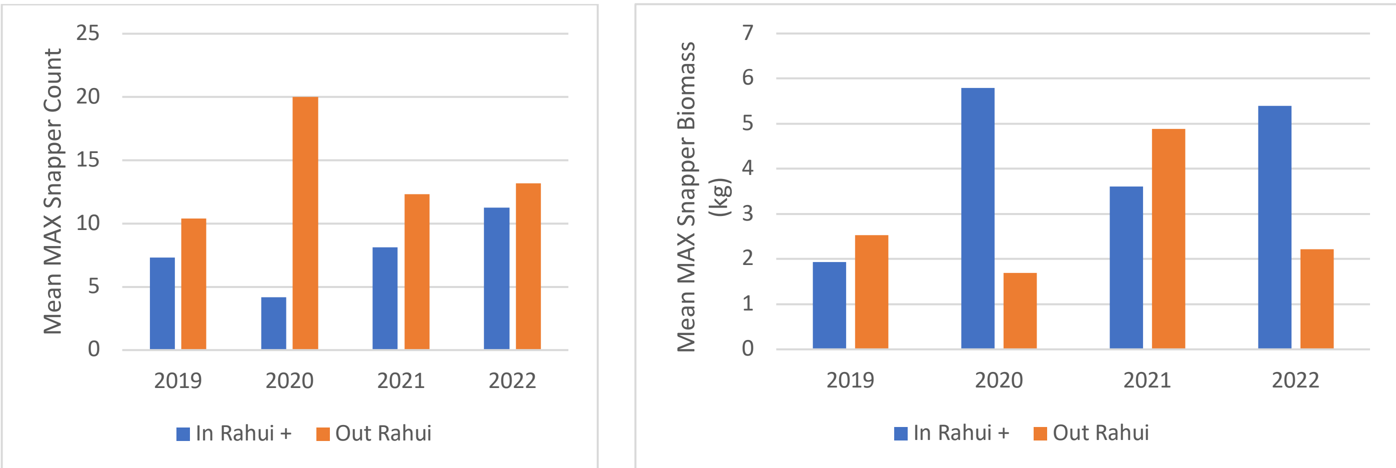

Figure 12. *The average total MAX snapper count & MAX snapper biomass across sites within and outside the rāhui (+ indicates average includes pinnacle sites) for the 4 years the surveys were completed.*

Looking at *Figure 12*, it is clear that since 2019 greater snapper numbers are consistently recorded outside the rāhui but this trend is not mirrored in biomass. The biomass within the rāhui has slowly risen in the last few years and in 2022 this difference inside vs outside the rāhui was more than doubled.

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*

Table 8. 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

Based on relevant literature and our observations there are likely two major factors at play influencing our results this year.

After 5 Years – Still Too Soon?

On an ecological scale for the recovery of reef communities, 5 years is too soon to be expecting significant changes happening as a result of the rāhui. Once an area is under protection, the recovery rates of species and ecosystems vary. Work done at Leigh and Tāwharanui Marine Reserves showed that a decline in kina barrens and recovery of kelp forests took 15-20 years (Babcock *et al.,* 1999). This is supported by our mapping and annual observations which show the progress of kelp forest recovery at Maitai Bay is not yet substantial at the 5-year mark. Thus the greater reef community that relies on kelp forest habitat will also take longer to recover fully. We expect to start seeing the recovery of exploited species like snapper and crayfish which generally occur within 5-15 years (Cole *et al.,* 1990; Shears & Babcock, 2002).

Current Climate

The La Niña weather pattern that began in 2020 has remained strong during 2021 and through to the 2022 summer, affecting the Maitai Bay monitoring done over this period. This change in a weather pattern caused bigger swells and east wind conditions during the 2021 and 2022 seasons, which significantly lowered the visibility for observations. Typically we would expect an averaging effect across our yearly data set with visibility on most days of 10 meters or more, and less on only one or two days. In 2021-2022 the majority of the days were less than 10 meters (see *Table 1* for 2022 visibility during the shallow reef timed swim surveys). While surveying, this big variation in visibility proves a challenge for judging distance whilst counting fish. Despite trying to be consistent when judging distances and which fish to include in the survey, in practice this is very difficult between a 6 meter visibility day and a 15 meter visibility day. The error rate for our team regarding this big variation in visibility is not fully known.

As our observations grow we believe a pattern is becoming apparent in the shallow reef areas. In a strong La Niña pattern, the bigger and more frequent swells over summer are thought to have a large impact on the shallow reef habitats being observed as many of the fish temporarily, or for extended periods, move to deeper reef areas less affected by wave energy. The movement of fish on and off the reef has been uneven through the season and we think this is strongly affected by wave energy episodes and duration. It has been an unusually long La Niña pattern and we think this is causing variation in what we see on the reefs. To the extent that we are correct in this observation the seasonal differences in weather patterns and onshore increased wind and wave energy are difficult variables to assess in a monitoring program. However, it is important to record our observations as these records build towards understanding the unique movement of the reef life on these exposed shallow reefs in the context of rapid climate change.

Indicator Species

The chosen indicator species favour different feeding strategies and so their recovery rates will vary accordingly, which can already be seen in some of our results. Red moki and butterfish are mainly grazers and are dependent on kelp forest habitats for foraging. For these two species there has been no clear trend in their recovery, which makes sense until there is sufficient kelp forest recovery to support greater numbers of these species. By contrast, snapper are opportunistic feeders that mainly predate on invertebrates and small fish. They are versatile and vary their feeding strategy as needed. Their versatility as predators, habitat preferences, efficient breeding and fast growth rates allows their numbers to recover effectively after protection from fishing. Our findings support this suggestion with increasing abundance and biomass of snapper starting to show in the rāhui area.

Snapper Biomass

Fish weight does not increase linearly with an increase in its size. *Fig. 13* shows the theoretical relationship between the size and biomass of snapper, which is exponential. We can use this relationship to interpret the survey results. The BUV results (*Fig. 12*) indicate that although there are fewer snapper inside the rāhui, they are from larger size classes and make up the majority of the overall recorded biomass. This is further supported by the presence of larger snapper turning up in the recent shallow reef timed swim surveys (*Fig. 7*). It is worth noting that despite the relatively low number of these larger individuals they contribute significantly to the overall biomass in the area. We could attribute this difference to lower fishing pressure within the rāhui as the targeted larger fish are not being removed. Small or

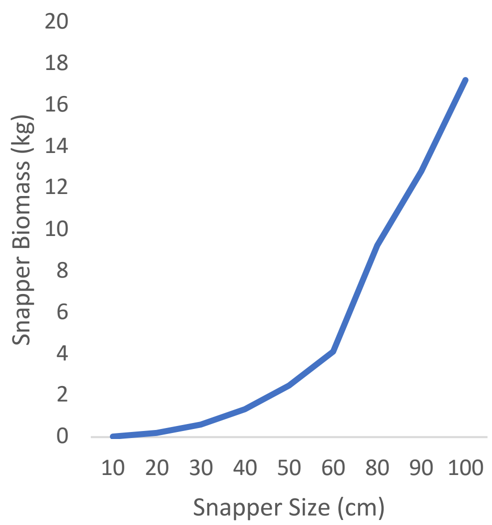

Figure 13. Relationship between size & weight in snapper

juvenile snapper were more abundant outside the rāhui. It is unknown if this is due to habitat differences, feeding preferences for small snapper, or perhaps the presence of larger fish within the protected area. These findings seem to fit with a number of other studies that found snapper within marine reserves were generally larger than in unprotected areas and the small snapper were more abundant outside (Willis *et al.,* 2003*;* Cole *et al.,* 1990).

The maximum recorded snapper size was during this year's BUV survey from off the Pinnacle, one of the outer sites within the rāhui boundary (see map in *Fig. 4*). From the footage we estimated the fish to be 100cm in length and weighing around 17kg. The actual weight of snapper will have seasonal fluctuations around food availability and spawning so the equation we use is an estimate. However, the fact we are finding snapper of these sizes is exciting due to the roles they play in an ecosystem and the benefit they provide to its recovery.

The presence of larger fish can be considered a sign of success for the rāhui as they contribute huge value to an ecosystem through a number of means. *Fig. 13* shows the value of having larger individuals in an ecosystem as they contribute heavily to total biomass. Fish fecundity (number of eggs or spawn produced) also increases with size, meaning there is greater reproduction and recruitment. This can create a 'spill-over effect' in some cases, where many eggs are produced within a protected area and released into the water column, therefore increasing recruitment numbers of new fish in areas outside the reserve. Some species of fish, like snapper, can adopt different feeding strategies as they grow to larger sizes. Both snapper and crayfish as they get older and larger can catch and eat larger prey, meaning their ecological roles change as a result. This shows the impact these large players have on shallow reef environments and how important they are to the health of the ecosystem as a whole (Willis *et al.,* 2003).

Total Fish Biodiversity

Combining data from all three surveys we were able to create a measure of total fish diversity within Maitai Bay. There were 48 fish species in total recorded through the rāhui monitoring programme in 2022. A paper published by Andrew & Francis in 2003 found 103 species of fish inhabiting rocky reefs and kelp forest habitat in the northeast coast of Northland. Karikari Peninsula is regarded as one of the most diverse shallow reef fish communities in the region, alongside areas like Cape Brett, Bream Head and Poor Knights Islands (Brook, 2002). Therefore, as habitat recovers around Maitai Bay, we expect the number of fish species to rise significantly.

Looking to the Future

Fully no-take marine protected areas are considered the gold standard for marine protection and restoring ecosystems, biomass and fish communities to their natural states. This includes the recovery in abundance and size of exploited species, like snapper, red moki and butterfish, which can have flow-on effects on the overall ecosystem. In Northland, the biomass of snapper and crayfish is severely depleted. By some accounts the populations are considered functionally extinct, meaning they no longer play any role in the ecosystem. This severely highlights the urgency to act quickly to prevent further loss of our marine biodiversity and habitat. In New Zealand, there are currently 44 marine reserves. The number of rāhui in place at any given time is, by contrast, unknown. If granted the same respect and adhered to, there is no known reason why a fully protected rāhui should not yield the same benefits as a marine reserve.

The marine and coastal environment around Maitai Bay carries significant ecological, cultural and social value at regional and national scales. It is hoped this rāhui, as a fully no-take marine protected area, will allow for habitat and fish communities to fully recover. The effort from the monitoring programme so far provides an ecological baseline and annual trends to follow the restoration process. It has now been more than 5 years since this initial mahi began. Looking to the future it is an opportune time for further conservation efforts to be considered.

Crayfish play an important role in maintaining ecosystem balance, like snapper, so it would be valuable to establish an abundance survey to determine their population status within Maitai Bay. There is already good local knowledge of the general crayfish populations and where key sites are located. Crayfish numbers are considered to be at low levels currently but are expected to slowly increase under the rāhui. Monitoring this change would involve using local and traditional knowledge supported with Western science methods. This could be achieved with careful planning.

Protecting marine areas is a passive approach to restoring natural habitats. In today's current climate crisis there is more demand for active approaches to restoration to assist with the process. There is, for example, growing interest globally and nationally in kelp reforestation projects. With Maitai Bay under rāhui it makes an ideal place to pilot a regeneration project in the Far North. Hands-on restoration could also provide opportunities for rangatahi engagement, teaching them valuable skills and fostering kaitiakitanga within the next generation.

The Maramataka is the traditional Māori lunar calendar and is used to guide planting, harvesting, fishing, and hunting. These guides vary depending on region and iwi. Over the course of the monitoring program we have kept a record of the days that were surveyed on. This record can be found in *Appendix 2*. We hope that at some stage in the future we may be able to use the maramataka teachings to help interpret and draw further conclusions from our results. We believe this is an area that will continue to evolve and that the program may help foster the restoration and growth of traditional knowledge alongside Western science.

In summary, following on from 5 years of successful rāhui, there is positive momentum to begin future planning and restoration for the greater rohe.

Acknowledgements

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 a number of 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, 2022

#	Family	Genus	Species	Common name	Maori name	Timed Swim	Diversity Dive	BUV
1	**Acanthuridae**	*Acanthurus*	*dussumeiri*	Eyestripe Surgeon fish		✓	▪	▪
2	**Aplodactylidae**	*Aplodactylus*	*meandratus*	Marblefish	Kehe	✓	✓	▪
3	**Arripidae**	*Arripis*	*trutta*	Kahawai	Kahawai	✓	✓	▪
4	**Berycidae**	*Centroberyx*	*affinis*	Golden Snapper	Hauture	▪	▪	✓
5	**Carangidae**	*Trachurus*	*novaezelandiae*	Jack Mackerel		✓	✓	▪
6	**Carangidae**	*Seriola*	*lalandi*	Yellowtail Kingfish	Haku	✓	✓	▪
7	**Carangidae**	*Decapterus*	*koheru*	Koheru	Koheru	✓	✓	▪
8	**Carangidae**	*Caranx*	*lutescens*	Trevally	Araara	✓	✓	✓
9	**Cheilodactylidae**	*Cheilodactylus*	*ephippium*	Painted Moki		▪	✓	▪
10	**Cheilodactylidae**	*Cheilodactylus*	*douglasi*	Porae	Porae	✓	▪	▪
11	**Cheilodactylidae**	*Cheilodactylus*	*spectabilis*	Red Moki	Nanua	✓	✓	✓
12	**Chironemidae**	*Chironemus*	*marmoratus*	Hiwihiwi	Hiwihiwi	✓	✓	▪
13	**Dasyatidae**	*Dasyatis*	*brevicaudata*	Shortailed Stingray	Whai	▪	▪	✓
14	**Diodontidae**	*Allomycterus*	*jaculiferus*	Porcupine Fish		✓	▪	▪
15	**Engraulidae**	*Engraulis*	*australis*	Anchovy	Kokowhaawhaa	✓	▪	▪
16	**Hemiramphidae**	*Hyporhamphus*	*ihi*	Piper		✓	✓	▪
17	**Kyphosidae**	*Scorpis*	*violaceus*	Blue Maomao	Maomao	✓	✓	▪
18	**Kyphosidae**	*Girella*	*tricuspidata*	Parore	Parore	✓	✓	▪
19	**Kyphosidae**	*Kyphosus*	*sydneyanus*	Silver drummer		✓	✓	✓
20	**Labridae**	*Suezichthys*	*aylingi*	Crimson Cleaner Fish		▪	✓	✓
21	**Labridae**	*Bodianus*	*unimaculatus*	Red Pigfish		✓	✓	✓
22	**Labridae**	*Notolabrus*	*celidotus*	Spotty	Paketi, Paekirikiri	✓	✓	✓
23	**Labridae**	*Notolabrus*	*fucicola*	Banded Wrasse	Tāngahangaha	✓	✓	✓
24	**Labridae**	*Notolabrus*	*inscriptus*	Green Wrasse		✓	✓	▪
25	**Labridae**	*Pseudolabrus*	*luculentus*	Orange Wrasse		▪	✓	▪
26	**Labridae**	*Coris*	*sandageri*	Sandaggers Wrasse		✓	✓	✓
27	**Labridae**	*Pseudolabrus*	*miles*	Scarlet Wrasse		▪	▪	✓
28	**Monacanthidae**	*Parika*	*scaber*	Leather Jacket	Kokiri	✓	✓	✓
29	**Mullidae**	*Parupeneus*	*fraterculus*	Goatfish (tropical)	Āhuruhuru	✓	✓	▪
30	**Mullidae**	*Upeneichthys*	*lineatus*	Goatfish bar-tailed	Āhuruhuru	✓	✓	✓
31	**Muraenidae**	*Gymnothorax*	*nubilus*	Moray Gray		▪	▪	✓
32	**Muraenidae**	*Gymnothorax*	*obsesus*	Moray Speckled		▪	▪	✓
33	**Muraenidae**	*Gymnothorax*	*prasinus*	Moray Yellow		▪	✓	✓
34	**Myliobatidae**	*Myliobatus*	*tenuicaudatus*	Eagle Ray	Whai keo	▪	✓	✓
35	**Odacidae**	*Coridodax*	*pullus*	Butterfish	Mararii	✓	✓	▪
36	**Pempheridae**	*Pempheris*	*adspersus*	Big Eye		✓	✓	✓
37	**Pomacentridae**	*Parma*	*alboscapularis*	Black Angelfish		✓	✓	▪
38	**Pomacentridae**	*Chromis*	*dispilis*	Two-spot Demoiselle		✓	✓	✓
39	**Scorpaenidae**	*Scorpaena*	*papillosa*	Dwarf Scorpian Fish		▪	✓	▪
40	**Scorpidae**	*Scorpis*	*lineolatus*	Sweep	Hui	✓	✓	✓
41	**Serranidae**	*Caesioperca*	*lepidoptera*	Butterfly Perch	Oia	▪	▪	✓
42	**Serranidae**	*Epinephelus*	*daemelii*	Black Spotted Grouper		▪	✓	▪
43	**Serranidae**	*Hypoplectrodes*	*sp.*	Half banded perch		▪	▪	✓
44	**Sparidae**	*Pagrus*	*auratus*	Pink Snapper	Taamure	✓	✓	✓
45	**Tetraodontidae**	*Canthigaster*	*callisterna*	Sharp nosed puffer		✓	▪	✓
46	**Tripterygiidae**		*sp.*	Common Triplefin		▪	▪	▪
47	**Tripterygiidae**	*Obliquichthys*	*maryannae*	Swimming Blennie		✓	✓	▪
48	**Zeidae**	*Zeus*	*japonicus*	John Dory	Kuparu	▪	▪	✓
						32	***34***	***26***

Appendix 2: *Maramataka*

The intention here is to simply keep a record of the days we surveyed so that in time we might be able to apply the teachings of the maramataka to interpreting our results. For now, we are not yet properly educated in the ways of Ngati Kahu regarding applying the maramataka to things in the ocean and our work. We welcome any and all interpretations, comments, questions and observations. We believe this learning has no beginning and end; it is something we do.

2022 Survey Calendar:

- *16th Feb* – First Shallow Reef Timed Swims completed

- *17th Feb* – First kina trials.
  Notes: Feb 17th was *Rākaunui – full moon shining, a powerful time for all things and time to reap rewards, time to chase what is close, closer to achieve. Sleep is short.*
  The conditions were very settled after a long stretch of onshore winds steady swells and some big swell periods in the last 3 weeks and also in January. Visibility was average at about 6m, winds were light with a small swell creating a small surge in our diving area. Fish life on the reef over the two days was pretty quiet with the exception of snapper which continue the trend of increasing through the various sizes and a change to them being happier to be around humans. It was partially cloudy with some sunny periods.
  Vince comment: I think this is a good time to tackle our work on the water from the human point of view, but I am not so clear on what this means to the things of the sea. Often full moon is meant to be a time when fishing in the daytime is poor because things are settled and the sun is bright and many fish that normally take the night off can be active all night long under the shining moon. So maybe it is a good time to do the kina culling work but a bad time to count the reef fish, who may be laying low at deeper levels resting before a busy night of the full moon.

- *15th March* – Second round of Shallow Reef Timed Swims completed

- *31st March* – Third round of Shallow Reef Timed Swims completed

- *1st April* – Reef Fish Diversity Dives completed for Merita and Blue Maomao sites

- *25th April* – Reef Fish Diversity Dive at Waikura 2 site completed

Appendix 3: Juvenile Snapper / Manta Board Tow Survey

Trial Description

To date, our focus with the monitoring program has been on rocky reefs and kelp forests and fish species. We have not yet investigated the soft-bottom habitats in the Bay or offshore other than through the collection of habitat mapping data. In the summer months, we have often recorded large numbers of small snapper ranging down to 100mm length. The presence of these small snapper along the reef/sand fringes where we have many observations led us to ask the question to what extent the Maitai Bay soft sediment areas are acting as a nursery and feeding area for these small fish. Based on the numbers that we have seen on or near the reefs it is suggested that Maitai Bay could be a very significant snapper nursery area.

Trial Method

We towed a scuba diver on a manta board along a route that transversed four soft bottom areas in the Bay. The tows were done on May 24th. As with every monitoring visit to Maitai Bay this year, there had previously been strong easterly wind and swell in the past week to 10 days but conditions were settled on the day we did the tows. The tows took from 10-15mins to run and were between 700 – 850m in length. A GoPro video camera was mounted on the manta board.

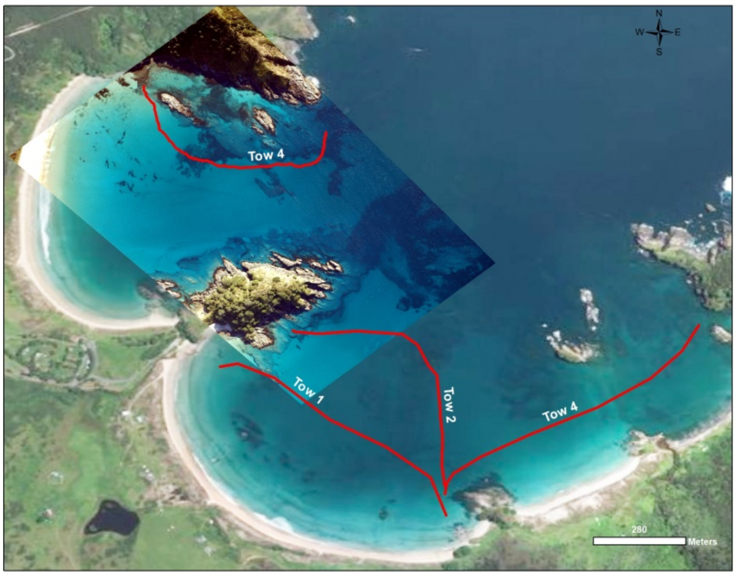

Figure 14. A map of the four completed manta tows.

Results:

On this day there were very few snapper of any size on the soft bottom (mainly sand) habitats. We saw no more than one or two fish on any of the transects. There was also very few larger snapper present. We did see snapper as soon as we were towed over reef areas. Most of these fish were in the just under legal size or just legal at around 25cm. Other reef species were seen over the reefs as well.

Comments:

This method is a good method for carrying out this sort of survey. The video can be analysed in a semi-quantitative manner to arrive at a relative abundance method that could be monitored over time. The manta tow has the advantage of covering a lot of ground quickly and producing a good video recording at the same time.

We were surprised to see the young snapper not present in the Bay in this late May period. This result begs the question, what are the times of year that the young snapper are in the Bay in large numbers and how important is this feature of Maitai Bay? And a second question: where have all these small snapper we see in the middle of summer gone in May? Our generally accepted model of snapper development is that following their first summer on a reef or in shallow water they begin schooling and spending time moving and in deeper waters.

Further Work:

We suggest that if it is decided we want to continue this investigation, we use a similar method in the future and repeat this trial every month starting in January or December. This could give us a very good picture of snapper movements in and out of the Bay. There is also the question of the weather patterns which could only be answered by doing surveys over several years with differing weather patterns.