Maitai Bay Rahui Monitoring Report – Summer 2019-20

December 2020

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Common species observed during timed swim fish surveys at Maitai Bay. Goatfish (Upeneichthys Lineatus), foreground and sandagers wrasse (Coris sandeyeri), background.

Report prepared for: Te Whānau Moana/Te Rorohuri

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Recommended Citation: Bone, O., Rutene, W., Krauss, I., Kerr, V.C., 2020. Maitai Bay Rahui Monitoring Report – summer 2019 - 2020. A report prepared for Te Whānau Moana/Te Rorohuri, Maitai Bay, Karikari Peninsula, Northland and the Mountains to Sea Conservation Trust.

Key Words: Rahui, kaitiakitanga, marine protection, snapper, crayfish, kina barren, Maitai Bay, Karikari Peninsula

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Executive Summary

Te Whānau Moana/Te Rorohuri established a rahui covering 384ha of Maitai Bay in 2017. An annual monitoring programme was established in 2018 to document the restoration process. The current report covers the third annual monitoring programme completed in the summer of 2019-2020.

The 2020 monitoring programme incorporated three complementary survey methods to capture a snapshot of the current status of fish populations within the rahui. The methods used were timed swim fish surveys, fish diversity dives and baited underwater video (BUV) surveys.

The main findings of the 2020 monitoring programme were:

- Fish diversity within the rahui remains similar to the previous two years;
- Red moki and butterfish numbers remain low, but appear to have increased steadily since inception of the rahui;
- The snapper population within the rahui remains skewed towards snapper less than 25cm length;
- Snapper biomass remains low at Maitai Bay relative to concurrent values recorded at the Leigh marine reserve. However, our data suggests some larger snapper are moving into the rahui;
- Abundance levels of juvenile snapper remains steady;
- Fish diversity and abundance were higher at sites adjacent to healthy kelp forest habitat.

Overall, the results of the 2020 monitoring programme are consistent with the early stages of recovery expected after three years of protection. There are positive signs of improvement of red moki, butterfish and snapper populations.

Ongoing monitoring of the rahui ensures effective documentation of the recovery process, which may be important in future management decisions. Tracking the recovery process also provides a check of the effectiveness of the rahui towards achieving the desired outcomes. Furthermore, it may also be important in galvanising wider community support and engagement.

Introduction

Te Whānau Moana/Te Rorohuri, a hapu of the Ngati Kahu Iwi, implemented a full no-take rahui at Maitai Bay covering 384 ha of the bay and exposed coast, effective from December 2017. The rahui is upheld under the traditional authority of Te Whānau Moana/Te Rorohuri as holding mana moana over their rohe, which includes the Maitai Bay area. Maitai Bay has been subject to heavy fishing pressure over the last several decades and there had been long-standing concern regarding degradation of the mauri of the area. Large predators (e.g. snapper and crayfish) were absent from many of the reefs and extensive kina barrens had taken hold in areas that were once rich kelp forests. The goals of the rahui, as stated by Te Whānau Moana/Te Rorohuri, are:

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

The rahui boundaries were set through an extensive consultation process taking into account a range of social, cultural and ecological factors. The rahui boundaries are presented in figure 1 below.

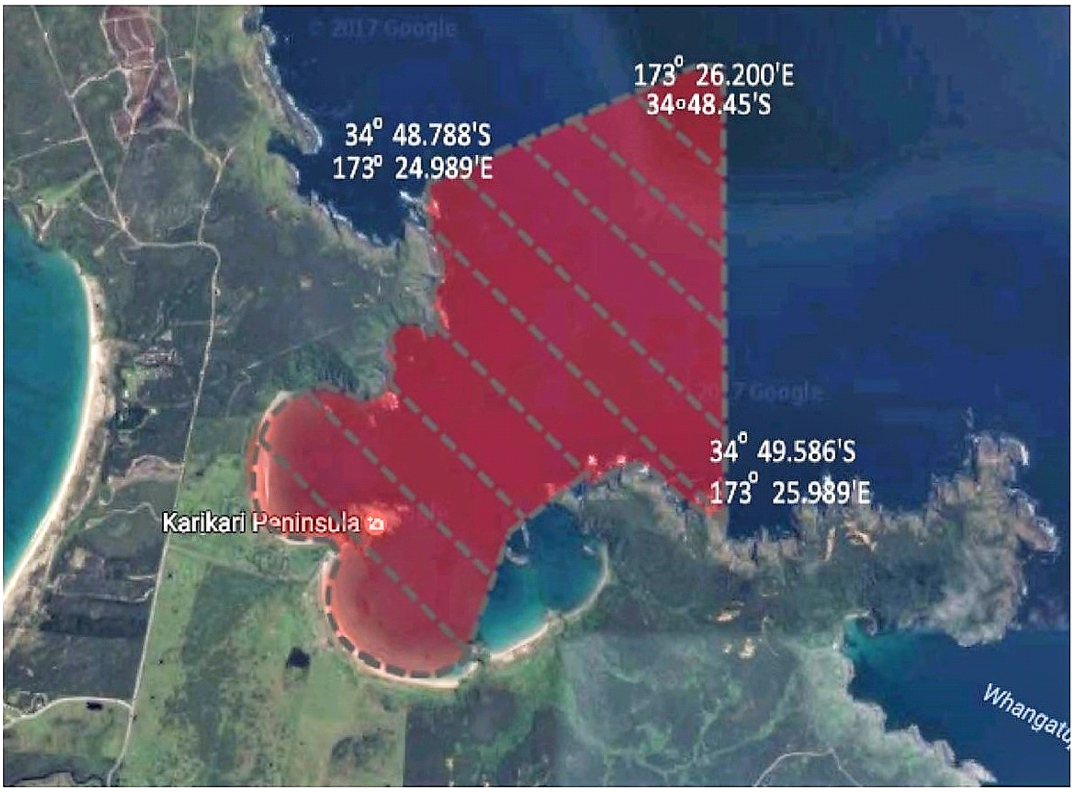

Figure 1: Maitai Bay rahui boundaries

The rahui was initially set for a duration of two years. This was reviewed in mid 2020 and the rahui was extended for an additional five years. The status of the rahui will be reviewed again at the end of this five year period.

The Mountains to Sea Conservation Trust (MTSCT) has provided ongoing support for the rahui since inception, including providing technical advice and assistance with determining rahui boundaries and the development and implementation of a monitoring programme. A range of survey methods were chosen to provide pertinent and robust information regarding ecological processes within the rahui. The selected methods include timed swim fish surveys, baited underwater video surveys and fish diversity dives. Crayfish den surveys were also trialled and have the potential to be further developed. The MTSCT has collaborated with Te Whānau Moana/Te Rorohuri to complete the annual monitoring of the rahui. The initial monitoring programmes were completed in 2018 (Kerr, 2018) and 2019 (Kerr, Rutene and Bone, 2019). The current report presents the findings of the third annual monitoring programme completed in the 2019 to 2020 monitoring season.

The initial monitoring programme, completed in the first year of rahui establishment, provides valuable baseline data against which the restoration of species and habitats can be tracked over time. The ongoing annual monitoring enables management decisions to be made based on up-to-date knowledge of ecological processes occurring within the rahui.

Methods

The 2020 monitoring programme incorporated three complementary survey methods to capture a snapshot of the current status of fish populations within the rahui. The three methods used were timed swim fish surveys, diversity dives and baited underwater video (BUV) surveys. A brief description of each method is provided below.

Timed Swim Fish Surveys

Monitoring was completed at both Maitai Bay and the Cape Rodney to Okakari Point (Leigh) marine reserve in the 2020 monitoring season. The Maitai Bay timed swim surveys were conducted on the same 13 transects defined by Kerr *et al.*, (2019) and presented in figure 2 below. These transects were chosen to cover a range of habitat types both within and outside the rahui. Four surveyors completed the monitoring in 2020 (Vince Kerr, Whetu Rutene, Isabel Krauss and Oliver Bone). In total each transect was surveyed approximately 5 times, resulting in 67 transects being surveyed at Maitai Bay this season.

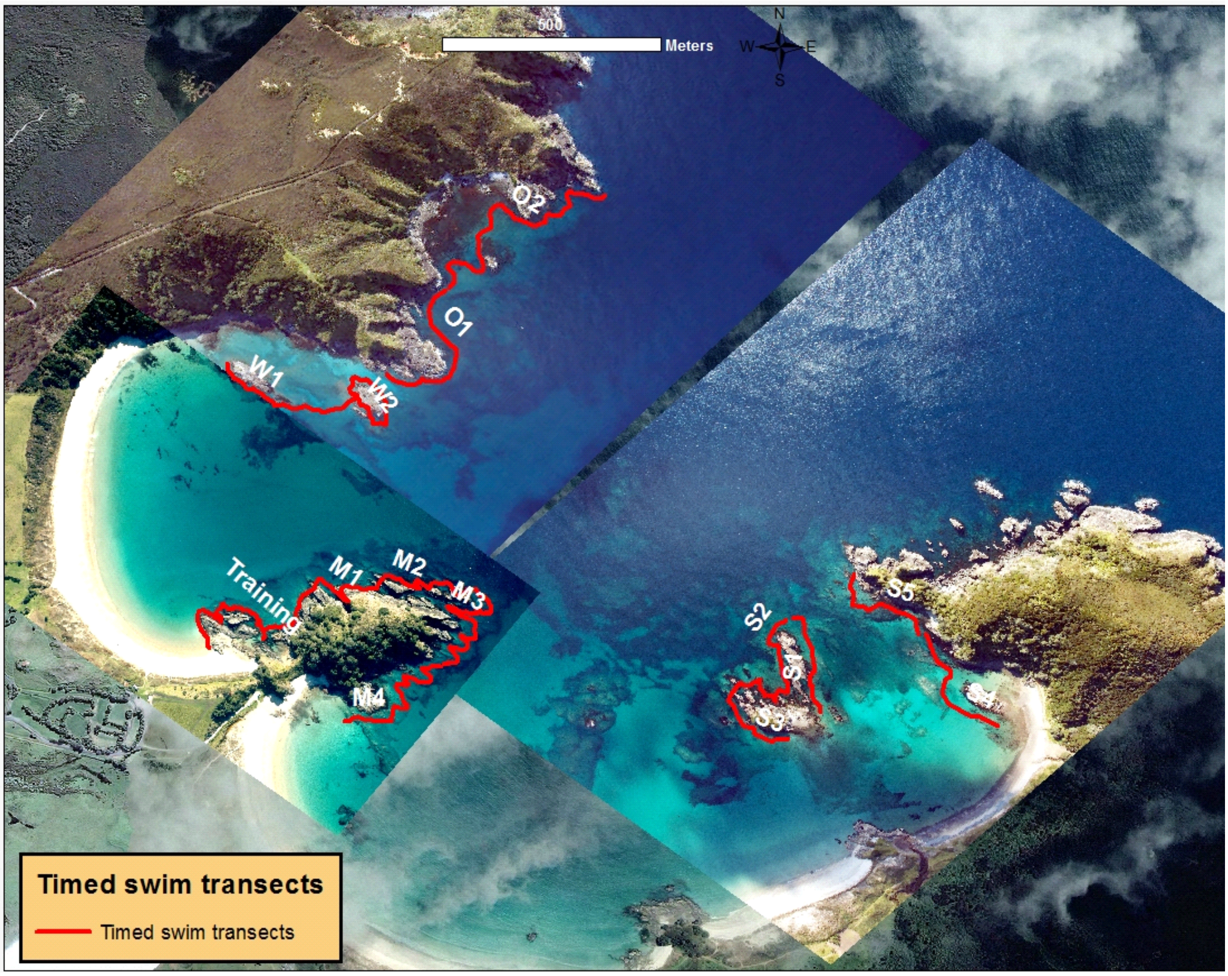

Figure 2: Timed swim fish survey transects surveyed as part of the 2020 monitoring programme.

The timed swim fish surveys at Leigh were completed on the same three transects originally defined by Kerr (2018). These are presented in figure 3 below. These three transects were surveyed once each by both Vince Kerr and Oliver Bone, resulting in six surveys being completed at Leigh marine reserve in the 2020 season.

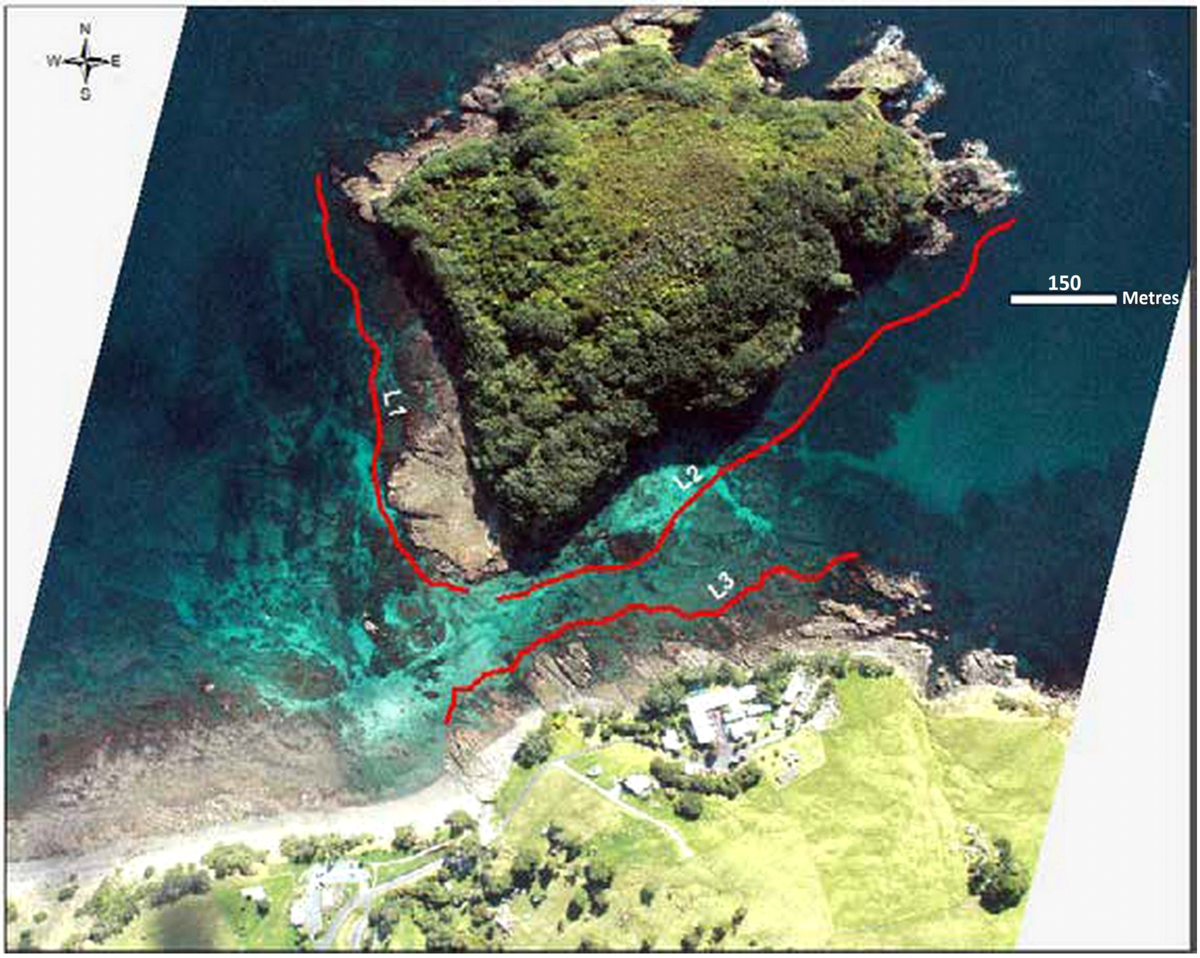

Figure 3: Timed swim survey transects at Leigh marine reserve surveyed as part of the 2020 monitoring programme to provide a comparison against data concurrently collected at Maitai Bay.

The timed swim fish survey methods were adapted from methods described by Kerr (2006) in the Phoenix Islands. Briefly, this involves a surveyor swimming the length of a pre-defined transect and recording all fish observed. A full description of the methodology is provided by Kerr *et al.*, (2019).

Size class categorisation of 'indicator' species

Red moki, butterfish and snapper were chosen as species of particular interest and hence, in addition to being counted, were also categorised into size classes. This gives us the ability to track trends in the population size distribution of each of these species over time (i.e. to determine whether the number of larger fish is increasing over time within the rahui). There were small differences in the size class categories used in 2020 compared to the categories used in the 2018 and 2019 surveys. For the purposes of analysis and graphical representation throughout this report we have standardised all pre-2020 timed swim data to the updated 2020 size class categories (5-15 cm, >15-25 cm, >25-35 cm, >35-45 cm and >45 cm). As the difference in size class categories is likely smaller than the existing survey error, we treat the 2018-19 and 2020 data as equivalent throughout this report.

Snapper biomass calculations

Snapper size estimates were also converted to estimates of biomass using the equation:

$W = aL^b$, where W is 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 also combined to determine the average total snapper biomass per transect. This enables us to track trends in snapper biomass in the rahui over time, as well as to compare the biomass within the rahui to the other areas surveyed using the same method (i.e. adjacent areas outside the rahui and our comparison site at Leigh marine reserve). The designated snapper length for each size class used for biomass calculation was updated in 2020. A summary of the different length designations used in the 2018-19 and 2020 surveys is provided in Appendix 1. The effect of this update is expected to fall within the typical methodological error. As such, the 2018-19 and 2020 snapper biomass data is treated as equivalent throughout this report.

Diversity Dive Surveys

The reef fish diversity dive surveys are an important method for documenting fish diversity. These diversity dives allow documentation of fish species that might otherwise be missed by the timed swim and BUV surveys; for instance, cryptic and herbivorous fish that spend most of their time at depths greater than 10 metres. As described by Kerr *et al.,* (2019) the diversity dives at Maitai Bay involve spending approximately 45 minutes following a pre-planned dive route and searching carefully for fish along this route. Each dive route traverses as many habitats within the site as possible at depths of 5-24 m. Diversity dives were conducted at the same five sites outlined by Kerr *et al.,* (2019) and presented in figure 4 below. These sites were originally selected on the basis of being representative of typical rocky reef habitats within Maitai Bay. Fish diversity for each site and a total for all sites has been determined and is tabulated for each year, allowing changes in fish diversity over time to be assessed.

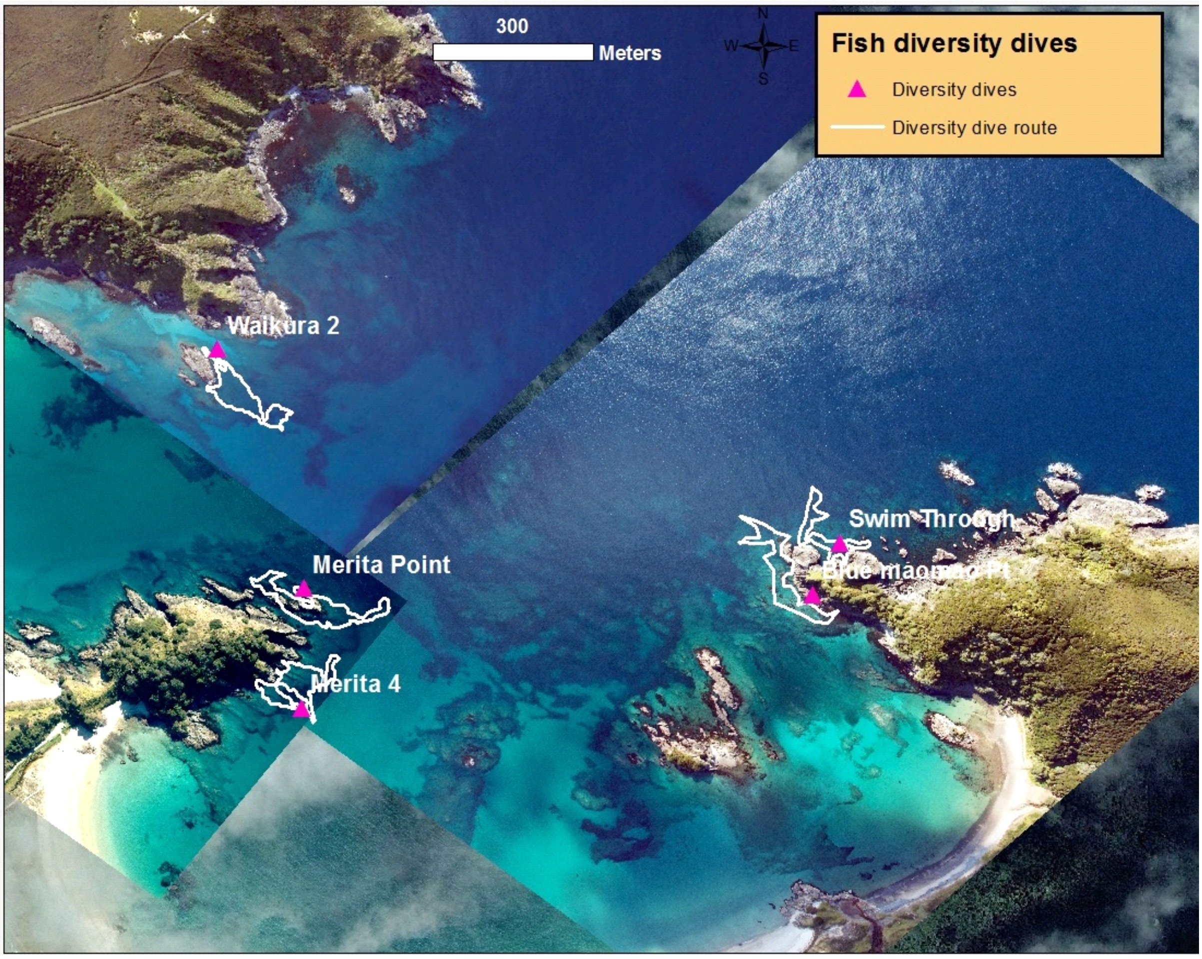

Figure 4: Diversity dive sites surveyed as part of the 2020 annual monitoring programme

Baited Underwater Video Surveys

Baited underwater video (BUV) surveys are an effective means of determining differences in the relative abundance of carnivorous fish species between protected and non-protected marine areas (Willis and Babcock, 2000). There is also a large body of existing BUV data for marine protected areas on the north east coast of the North Island of New Zealand (e.g. Buisson 2009). As such, data collected via BUV can be compared against existing datasets, which provides a gauge on the recovery process occurring at Maitai Bay.

In the 2020 survey we used the same BUV apparatus as originally described by Kerr *et al.*, (2019). The BUV apparatus consists of an aluminium frame made up of one horizontal bottom bar and one upright bar at an approximately 60 degree angle (Figure 5). A 9 cm long baitbox with holes drilled at 1 cm spacings is attached at the middle of the bottom bar. The bar is also marked with black tape bands at 10 cm intervals to assist subsequent sizing of fish. At the top of the upright bar a waterproof GoPro camera is mounted and faces directly down towards the centre of the bottom bar. The GoPro is mounted above the centre of the bottom bar and the camera field of view is greater than 1 m^2 in the plane of the bottom bar. In subsequent video analysis, using the 1 metre long bottom bar as a gauge, a 1 m^2 quadrat is delineated within which fish are recorded. The frame is connected to a nylon rope for deployment and a pressure resistant float is attached near the top of the frame to provide buoyancy, thus holding the frame upright when it is deployed.

Figure 5: Baited underwater video (BUV) apparatus with GoPro camera mounted at top facing the baitbox on the bottom bar. Also note the 10cm spaced scale along the bottom bar and the pressure resistant float attached at the top.

The BUV apparatus was deployed at the same 25 sites described by Kerr *et al.*, (2019) and presented below (Figure 6). The BUV surveys were completed during daylight hours on the 08th and 09th of June 2020. A suitable weather window with fine clear weather and less than one metre swell was selected to undertake the survey. The site layout includes 15 sites within the rahui boundaries and 10 sites outside the rahui boundaries. Of the 15 sites within the rahui, 10 are at 'sheltered' locations and 5 are at 'exposed' locations. Of the 10 sites outside the rahui, 3 are at 'sheltered' locations and 7 are at 'exposed' locations. This allows comparison of trends over time between both sheltered and exposed sites and sites within and outside the rahui. Six deployments (B6, B8, B9, B18, B20 and B22) were excluded from subsequent data analysis due to technical issues that unduly affected the resultant data. Overall, the final 2020 data set included nineteen BUV deployments. Ten of these were 'sheltered' sites (8 inside and 2 outside the rahui) and nine of these were 'exposed' sites (4 inside and 5 outside the rahui).

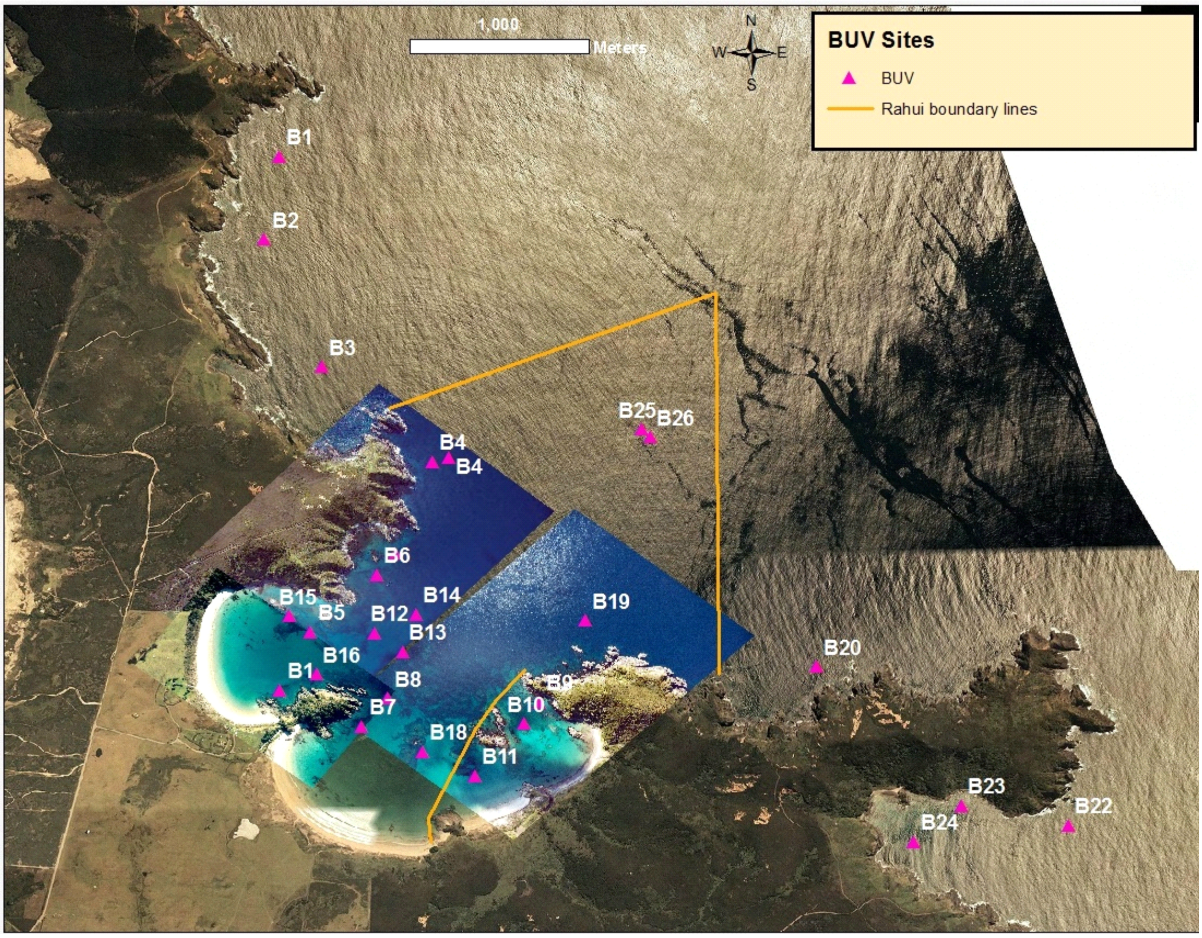

Figure 6: Baited underwater video (BUV) sites surveyed as part of the 2020 annual monitoring programme. Sites B6, B8, B9, B18, B20 and B22 were excluded from subsequent data analysis.

For each deployment the baitbox was filled with approximately 100g of frozen chopped pilchard. The video recording was then started and an image of the site number was recorded. The apparatus was then lowered to the seafloor at the pre-defined GPS location attached to a line and float. The entire set-up was then left undisturbed for 30 minutes before being retrieved and the video recording stopped. Videos were subsequently analysed according to the protocols described by Willis and Babcock (2000). In brief, the maximum number of snapper occurring within the 1 m^2 quadrat over the 30 minute recording (MAXsna) was determined. The length of each snapper contributing to the MAXsna count was then calculated by comparing against the marked scale bar on the BUV apparatus. Snapper length was then converted to estimated biomass according to the length to biomass conversion of Taylor & Willis (1998), provided above.

The diversity and abundance of other fish species occurring within the 1 m^2 quadrat over the 30 minute time frame was also recorded according to the same protocol used for MAXsna. Results of snapper size, abundance and biomass determined via BUV surveys at Maitai bay in 2019 and 2020 are presented in the results section below. To help with gauging the dynamics of the recovery process within the rahui we have also compared this data against typical values recorded from BUV surveys over the period 1997-99 at the Leigh marine reserve. Results of overall fish diversity and abundance recorded via BUV are also presented.

Results and Discussion

The results of each survey methodology are presented below. An interpretation of the findings and discussion of key points follows the presentation of results for each method used.

Timed Swim Fish Surveys

Overview

Results

A summary of the timed swim fish survey results from the 2018, 2019 and 2020 monitoring programmes is presented in table 1 below. In the Maitai Bay 2020 survey the total number of fish counted was 22,912. The average number of species recorded per transect (species richness) was 11.1. The lowest number of species recorded on any transect was 5 at transects M1, M2 and M4; and the highest number of species recorded on any transect was 20 at transect M4 (refer to figure 2 in the methods section for a map of the transect locations).

Table 1: Data from timed swim fish surveys completed at Maitia Bay from 2018 to 2020. Data from the Leigh 2020 survey are also included.

Timed Swim summary table	Maitai 2018	Maitai 2019	Maitai 2020	Leigh 2020
Number of transects in survey	8	13	13	3
Total transects surveyed	16	45	67	6
Hours surveying	4	15	17	2
Total fish counted	2,239	17,550	22,912	759
Average No. fish per transect	140	352	342	126.5
Average No. species per transect	9.5	10.4	11.1	8.5
Highest No. species per transect	14	20	20	10
Lowest No. species per transect	7	5	5	6

The values recorded in the 2020 survey are similar to the values that were recorded in the 2018 and 2019 surveys. There has been a slight increase in overall species richness from 9.5 in 2018 to 10.4 in 2019, and 11.1 in 2020.

In addition to overall species richness, the maximum and minimum number of species recorded per transect were the same for both the 2019 and 2020 surveys. The transect with with the lowest recorded number of species in 2019 (M4) was also one of the transects with the lowest recorded species counts in 2020, along with the nearby M1 and M2 transects (see Appendix 2 for a full summary of the 2020 timed swim data). Interestingly, one survey completed on the M4 transect also returned the highest species richness of all transects in the 2020 survey (Appendix 2). The other transects with high species richness in the 2020 survey were O1 and O2. The O1 and O2 transects are the same transects that also returned the highest counts in the 2019 survey.

In comparison to Maitai Bay, the number of species recorded per transect was generally lower in the Leigh 2020 survey. The average species richness in the Leigh 2020 survey was 8.5. The maximum number of species recorded on any transect was 10 and the lowest number was 6.

Discussion

The slight increase in overall species richness from 2018 to 2020 is not necessarily a result of the rahui, as other factors such as seasonal fish migration, methodological error or behaviour patterns may have influenced the data.

The low species richness recorded on the M1, M2 and M4 transects is likely driven by poor habitat quality at these sites. As stated in the 2019 monitoring report (Kerr *et al.*, 2019) and reinforced by the recently completed habitat mapping (Kerr *et al.*, 2020), the M4 transect and to some extent the M1 and M2 transects, are located in areas that have some of the most extensive and long standing kina barrens in Maitai Bay. The long term absence of kelp habitat is likely a major factor driving the low species richness recorded at these sites.

The higher species richness recorded on the O1 and O2 transects may reflect higher quality habitat at these sites. These transects are in exposed locations and, as recent habitat mapping shows (Kerr *et al.*, 2020), they are adjacent to large areas of *Ecklonia radiata* kelp forest. The singular high species count recorded on the M4 transect is not consistent with the rest of the data set. It's not clear what could have caused this, but this particular recording was taken late in the season (6th July 2020), so it is possible this observation may be an anomaly resulting from certain fish behaviour at that time of year.

The lower species richness recorded at Leigh is likely due to the different environmental characteristics of the Leigh marine reserve compared to Maitai Bay. While we know Leigh has large areas of high quality kelp habitat, other broad scale environmental factors are likely limiting species richness at Leigh. For instance, Leigh is approximately 170 km further south than Maitai Bay, is less likely to be exposed to tropical species dispersed on the East Auckland Current, has a different range and extent of habitat availability, and is subject to different patterns of wind and wave exposure. On that basis, the fish diversity counts recorded at Leigh are not necessarily a direct indication of the fish diversity counts that would be expected at Maitai Bay after the same duration of protection.

Size and biomass of selected 'indicator' species

Results

During the timed swim surveys the size of snapper, red moki and butterfish were estimated to the nearest 10 cm. These species are all commonly targeted by fishers, and were identified by Te Whānau Moana/Te Rorohuri as being of particular importance. It is hoped that the rahui will support the restoration of these species. As stated by Kerr *et al.*, (2019) red moki and butterfish are grazers, reliant on the kelp forest for food, and as such, their population is not expected to increase significantly until there is sufficient healthy kelp forest to support larger populations. Preliminary assessment indicates that while total numbers remain low, from 2018 – 2020 there has been a steady increase in the size and abundance of both red moki (Figure 7) and butterfish (Figure 8) within the rahui.

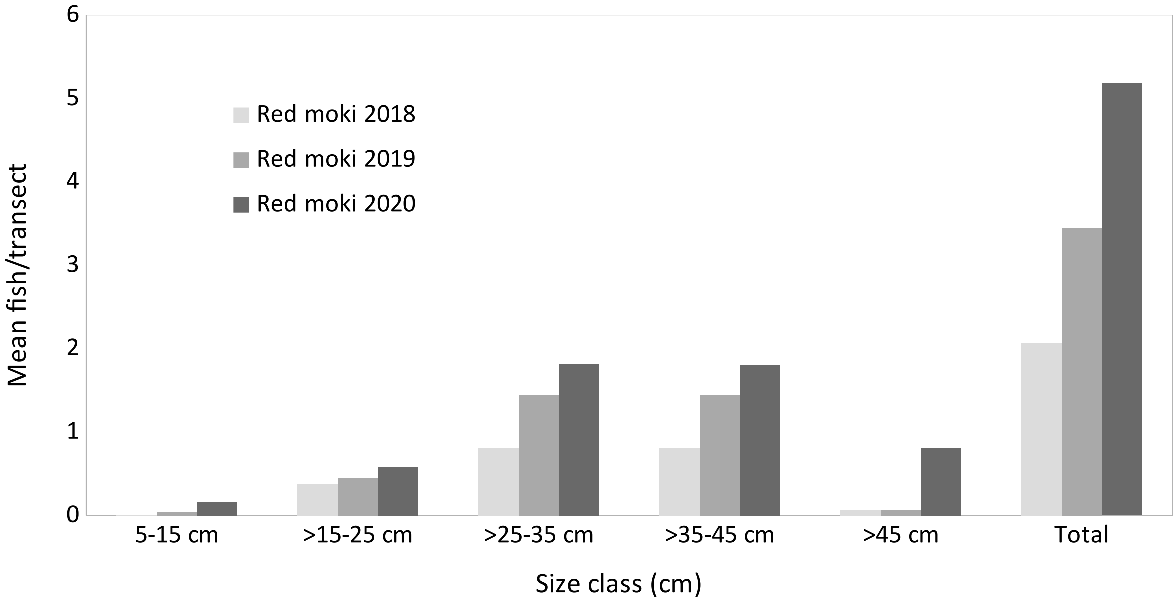

Figure 7: Average number of red moki per transect for each size class in the 2018, 2019 and 2020 timed swim surveys

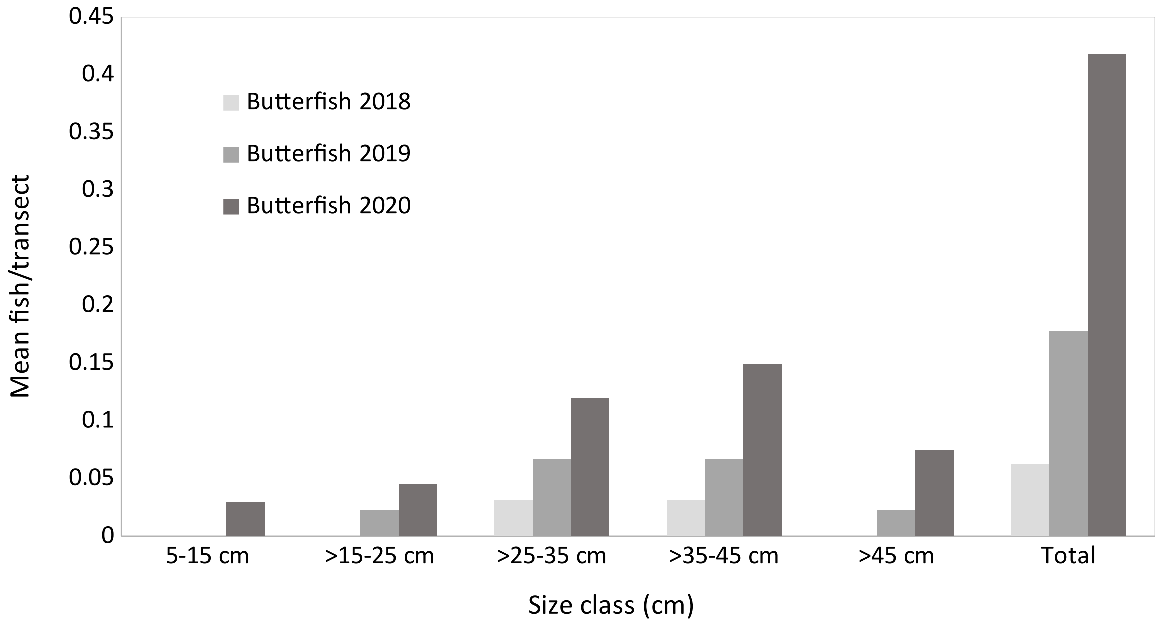

Figure 8: Average number of butterfish per transect for each size class in the 2018, 2019 and 2020 timed swim surveys

In contrast to butterfish and red moki, the snapper abundance data indicates a more rapid increase in the abundance of small snapper (less than 25cm) within the rahui (Figure 9). However, the data also reveals a lack of large snapper (greater than 25cm) at Maitai Bay compared to Leigh.

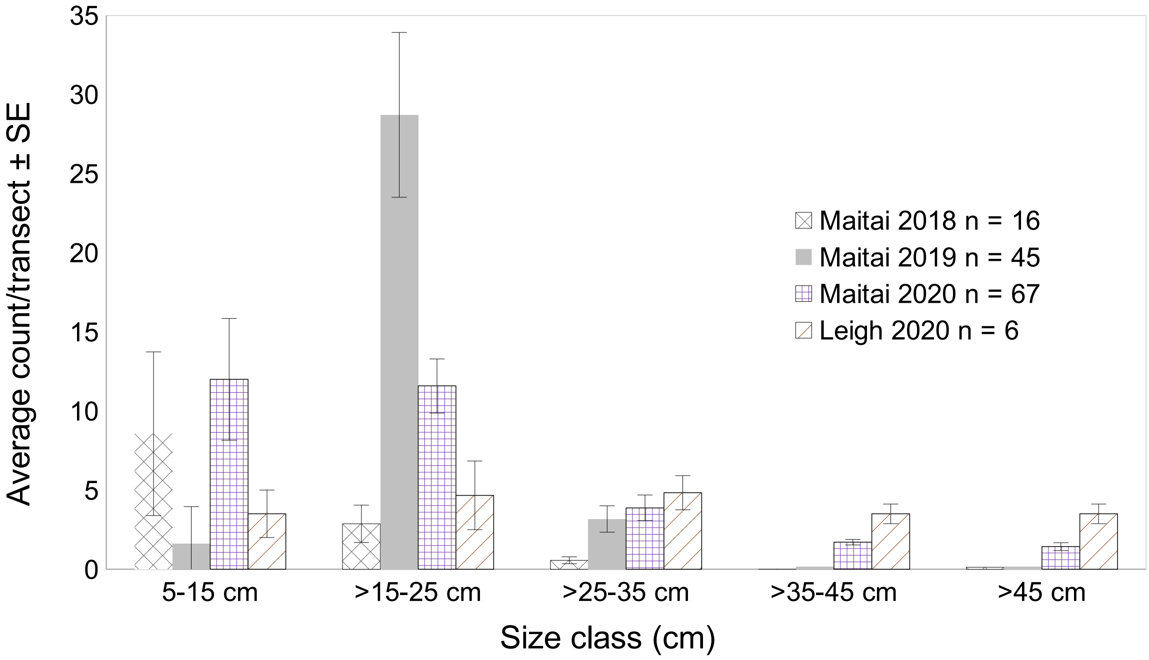

Figure 9: Average snapper count per transect ± SE in each size class comparing survey data from Maitai Bay 2018-2020 and Leigh 2020 surveys.

The 2020 results also indicate that there were similar numbers of snapper in the smaller size categories (i.e. less than 25 cm) in 2020 compared to 2019. In addition, the results show a slight increase in the abundance of snapper in the >35-45 cm and >45 cm size categories at Maitai Bay in 2020.

Snapper size was also converted to biomass using the equation of Taylor and Willis (1998), as described in the methods section above. Fish biomass does not increase linearly with fish size, but follows a more exponential trend. This trend is clear when comparing the Maitai Bay and Leigh 2018-2019 data. While there was slightly more large snapper at Leigh (Figure 9), there was a much greater biomass in each of the large (greater than 25cm) size class categories at Leigh compared to Maitai Bay (Figure 10). This means that overall there was a much greater total biomass of snapper at Leigh compared to Maitai Bay.

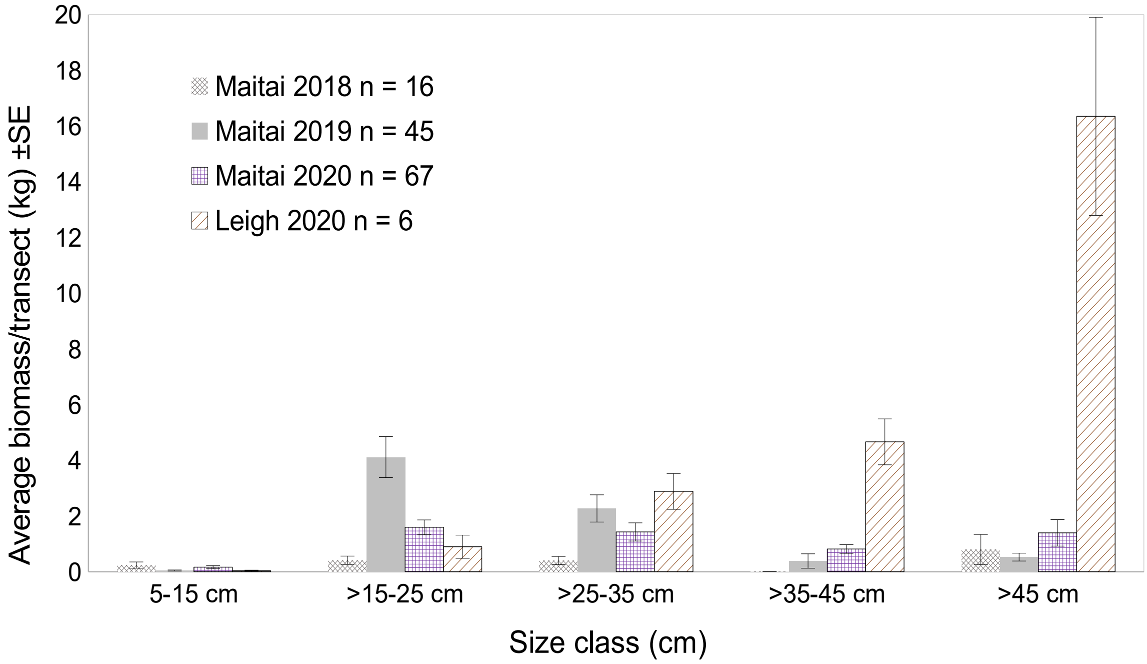

Figure 10: Average snapper biomass per transect ± SE in each size class based on timed swim surveys at Maitai Bay from 2018 – 2020 and at Leigh in 2020.

The patterns of snapper biomass at Maitai Bay and Leigh were similar in 2020 compared to the values recorded in the 2018 and 2019 surveys (Figure 10). The trend across all these surveys was for a higher biomass of large snapper (greater than 25 cm) at Leigh compared to Maitai Bay. For example, in 2020 the average biomass of snapper per transect in the >45 cm category was 16.34 kg ± 3.56 (SE) at Leigh, while the corresponding biomass of >45 cm snapper at Maitai Bay was 1.4 kg ± 0.47 (SE).

A comparison of the average biomass of snapper per transect, summed across all size classes for the Maitai Bay and Leigh 2020 surveys is presented in figure 11, below.

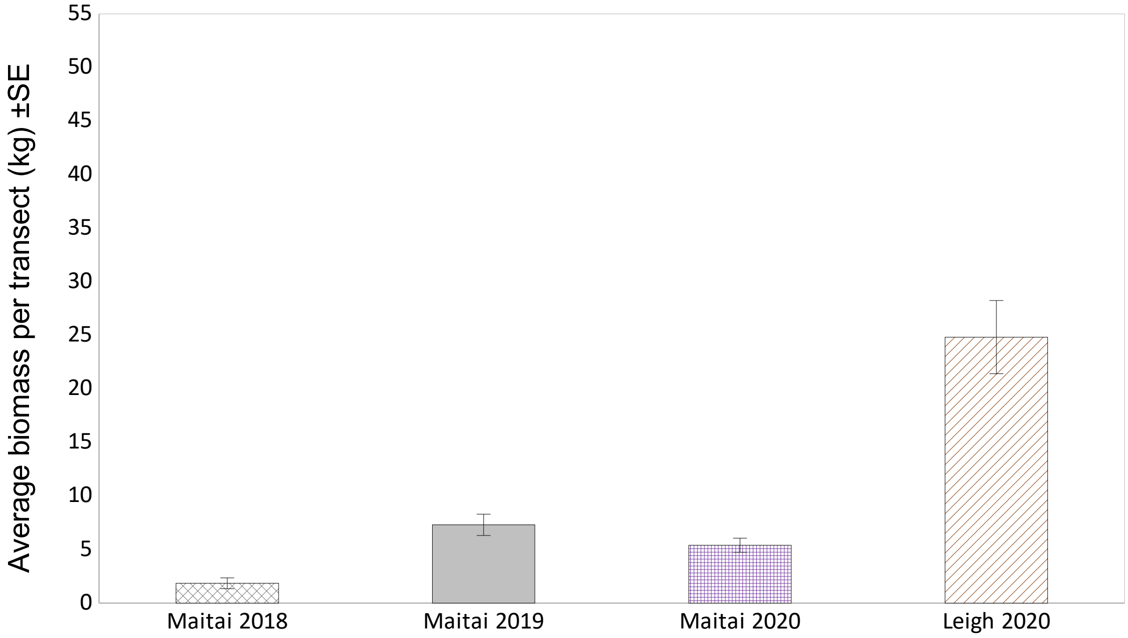

Figure 11: Average snapper biomass per transect ± SE based on timed swim surveys at Maitai Bay from 2018 – 2020 and at Leigh in 2020

This shows that in all three years that surveys have been completed there has been a much lower average snapper biomass per transect at Maitai Bay compared to the values recorded at Leigh in 2020.

Another way to visualise the patterns of snapper abundance at Maitai Bay relative to Leigh is to determine the snapper biomass at Maitai Bay relative to the snapper biomass at Leigh each year. As this value approaches one the biomass at Maitai Bay is approaching the same biomass as Leigh. A value above one would indicate that the biomass at Maitai Bay is greater than the biomass at Leigh. Performing this calculation based on the survey data to date indicates that there has been a steady increase in the average snapper biomass per transect at Maitai Bay relative to the corresponding snapper biomass at Leigh since the rahui was established in 2017 (Figure 12).

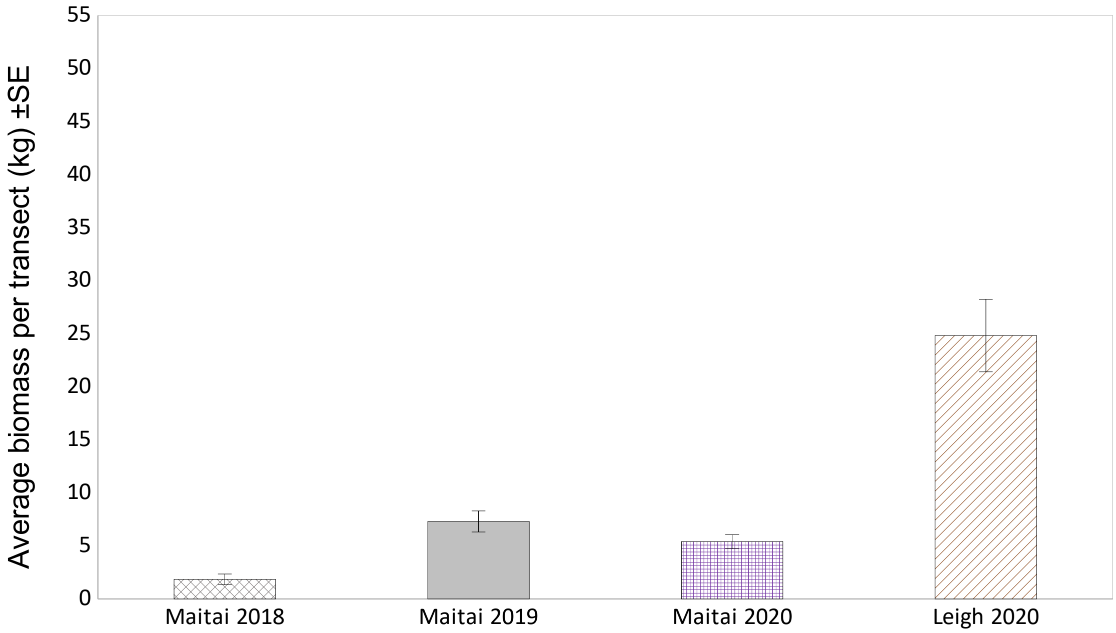

Figure 12: Proportion of average snapper biomass per transect at Maitai Bay relative to the corresponding value at Leigh (there was no 2019 Leigh annual survey, so Maitai 2019 data is compared against Leigh 2018 data).

Discussion

It is encouraging to note the recorded increase in the size and abundance of red moki and butterfish within the rahui. While it is too early to say for sure, this result does suggest that the rahui is having it's intended effect and allowing the restoration of the populations of these species. Both red moki and buterfish are commonly targeted by spear fishers. Taken together, this indicates the rahui effectively reducing spearfishing pressure within the bay.

The low numbers of large snapper at Maitai Bay relative to Leigh are consistent with the initial observations of Te Whānau Moana/Te Rorohuri that lead to the establishment of the rahui. The relationship between length and biomass of snapper was particularly clear in this data set. While there is good numbers of small (less than 25 cm) snapper in Maitai Bay, the overall biomass of the snapper population is still very low relative to the snapper biomass at Leigh (Figure 11). As stated by Kerr *et al.,* (2019), large snapper are more capable of feeding on kina compared to the smaller snapper, and due to their 'exponentially' greater biomass compared to small snapper, they also require more food. Thus, large snapper play an important role in mediating kina density and kelp forest dynamics on the reef.

There did appear to be a slight increase in the abundance and biomass of snapper larger than 25cm within the rahui in the 2020 survey. This suggests larger snapper from outside the rahui are moving into the protected area. Our current understanding of marine protected areas suggests the abundance of large snapper at Leigh is a result of the full no-take protection that has been in place since 1975. With the return of healthy populations of snapper at Leigh the kina barrens also returned to healthy kelp forest. Based on this understanding, it is plausible to expect a similar abundance of large snapper would eventuate at Maitai Bay along with the associated restoration of kelp forest habitats after a similar duration of protection.

Diversity Dive Surveys

Results

The diversity dive survey methodology provides a means of identifying fish species that may be missed by the timed swim and BUV surveys. For example, cryptic and herbivorous species that predominantly inhabit depths below 10 m. Diversity dives were conducted at all five diversity dive sites in 2020 and the results are presented in table 2 below. A total of 31 species were identified across all sites. The lowest species count was recorded at Waikura 2, with 17 species identified. The highest species count was recorded at Blue maomao west, with 23 species identified.

Table 2: *Diversity dive summary*

Dive site	Species count - 2019	Species count - 2020
Waikura 2	18	17
Merita 4	15	14
Merita Point	20	20
Blue maomao east	23	21
Blue maomao west	22	23
TOTAL	**40**	**31**

Discussion

Species counts were similar, albeit slightly lower, in the 2020 survey compared to the 2019 survey. The two highest species counts in the 2020 survey were both at the blue maomao site. These sites also had the highest species counts in the 2019 survey. As stated by Kerr *et al.*, (2019), this site encompasses a diverse array of habitats such as pinnacles, boulder fields, large crevices and an archway, as well as being subject to regular currents. It is likely that this site is able to sustain a more biodiverse fish population as a result of these diverse habitat features. Species counts are expected to increase at all sites as the habitats and fish communities recover in response to the rahui.

Baited Underwater Video Surveys

Results

A summary of the Maitai Bay 2020 Baited Underwater Video (BUV) surveys is presented in table 3. Overall, 20 species were recorded across the nineteen BUV deployments. The most abundant species (totalled across the nineteen deployments) was snapper, with the sum of 'MAXsna' counts coming to a total of 85. The next most abundant species (totalled across the nineteen deployments) were bigeye (49), demoiselle (36), trevally (22), pigfish (12) and leatherjacket (12). A full summary of BUV diversity data is presented in (Appendix 3).

Table 3: Summary of Baited Underwater Video (BUV) surveys completed at Maitai Bay over the 2020 survey season

Site	Exposed/ sheltered	Inside/ outside rahui	Diversity (No. of species)	Total fish count (including all species)	MAXsna count	Mean Length (mm)	Mean biomass (kg)	Total Biomass (kg)
B5	Sheltered	In	7	9	2	25	0.36	0.72
B7	Sheltered	In	1	4	4	38	1.54	5.97
B12	Sheltered	In	2	11	10	18	0.20	1.30
B13	Sheltered	In	1	3	3	25	0.38	1.15
B14	Sheltered	In	4	11	4	25	0.41	1.55
B15	Sheltered	In	2	12	9	23	0.30	1.55
B16	Sheltered	In	1	3	3	10	0.03	0.08
B17	Sheltered	In	5	10	5	24	0.34	1.31
B10	Sheltered	Out	3	10	4	11	0.04	0.14
B11	Sheltered	Out	1	0	0	0	0.00	0.00
Mean 2020			**2.70**	**7.30**	**4.40**	**19.85**	**0.36**	**1.38**
SE			**0.65**	**1.37**	**0.96**	**3.31**	**0.14**	**0.55**
B4	Exposed	In	2	1	0	0	0.00	0.00
B19	Exposed	In	10	19	4	24	0.39	1.47
B25	Exposed	In	14	43	3	28	0.51	1.52
B26	Exposed	In	5	12	3	40	1.33	4.00
B1	Exposed	Out	3	9	6	24	0.39	1.87
B2	Exposed	Out	5	16	4	23	0.29	0.98
B3	Exposed	Out	10	66	5	23	0.34	1.31
B23	Exposed	Out	8	17	3	25	0.38	1.15
B24	Exposed	Out	2	22	13	21	0.25	1.27
Mean 2020			**6.56**	**22.78**	**4.56**	**23.09**	**0.43**	**1.51**
SE			**1.40**	**6.62**	**1.19**	**3.44**	**0.12**	**0.36**

Mean fish count and diversity were considerably lower at the sheltered sites compared to the exposed sites (Table 3). The mean MAXsna count was similar at both the sheltered and exposed sites; however, mean snapper length and mean snapper mass were slightly higher at the exposed sites (Table 3). Mean total snapper biomass was also similar at both sheltered and exposed sites.

A summary of overall mean MAXsna, mean snapper length and mean total biomass at Maitai Bay for 2019 and 2020 is presented in table 4 below. The mean MAXsna recorded in 2020 was approximately half the value of what was recorded in 2019. Mean snapper length has increased slightly in 2020 compared to 2019 and mean total biomass has dropped slightly in 2020 compared to 2019.

Table 4: *Summary of mean MAXsna, snapper length and total biomass at Maitai Bay for 2019 and 2020 survey seasons*

	Maitai2019	**Maitai 2020**
Mean 'MAXsna'	8.6	4.2
Mean snapper length (mm)	20.5	23.3
Mean total biomass/site (kg)	2.2	1.7

Discussion

BUV has been widely used to document fish population dynamics over the last several decades at a number of marine protected areas close to Maitai Bay (e.g. the Poor Knights Islands and Leigh marine reserve). This enables us to compare the progress at Maitai Bay against the processes that were recorded at these nearby protected areas. A summary of fish diversity, size and biomass determined via BUV at Maitai Bay in 2019 and 2020, and at Leigh marine reserve over the period 1997-99 is provided below (Table 5). This enables us to track the progress of the restoration of snapper populations at Maitai Bay and also compare how Maitai Bay is tracking against typical values seen at Leigh after approximately 25 years of protection.

Table 5: *Fish Diversity, size and biomass at Maitai Bay versus typical values recorded at Leigh marine reserve*

	Maitai 2019 – Sheltered	**Maitai 2019 – Exposed**	**Maitai 2020 – Sheltered**	**Maitai 2020 – Exposed**	**Leigh 'typical' 1997-99**
Mean Total fish count (including all species)	**10.5**	**23.4**	**7.3**	**22.78**	
Mean diversity (No. of species)	**2.3**	**5.9**	**2.70**	**6.56**	
Max 'MAXsna'	19	20	10	13	
Min 'MAXsna'	1	0	0	0	
Mean 'MAXsna'	7.8	9.4	4.4	4.56	14
Mean length (mm)	21	20	19.85	23.09	30
Mean snapper biomass(kg)	0.27	0.286	0.36	0.43	
Mean total biomass/site (kg)	1.70	2.60	1.38	1.51	17.00

Mean MAXsna counts at both sheltered and exposed sites at Maitai Bay were slightly lower in 2020 compared to 2019. However, mean snapper biomass was higher at both exposed and sheltered sites in 2020 compared to 2019. This data is consistent with the timed swim survey data, which indicated counts of small snapper (less than 25cm) were lower in 2020 compared to 2019, whereas counts of snapper larger than 25cm were notably higher (Figure 9).

Comparing mean MAXsna counts, mean snapper length and mean total biomass per site between Maitai Bay in 2019 and 2020 and typical values recorded at Leigh between 1997-99 (Figure 13) indicates that the Maitai Bay snapper population has a long way to recover before it is similar to what was seen at Leigh after 25 years of protection. For example, in comparison to the Leigh 1997-99 values, MAXsna counts at Maitai Bay are currently around half, while mean snapper length is around two thirds. Of most significance, the mean total snapper biomass per site at Maitai Bay in 2019 and 2020 was an entire order of magnitude (10 times) lower at Maitai Bay in 2020 compared to what was recorded at Leigh in 1997-99. This large discrepancy in biomass between Maitai Bay and Leigh was also clear in the timed swim data, further reinforcing the conclusion that restoration is only at the early stages at Maitai Bay.

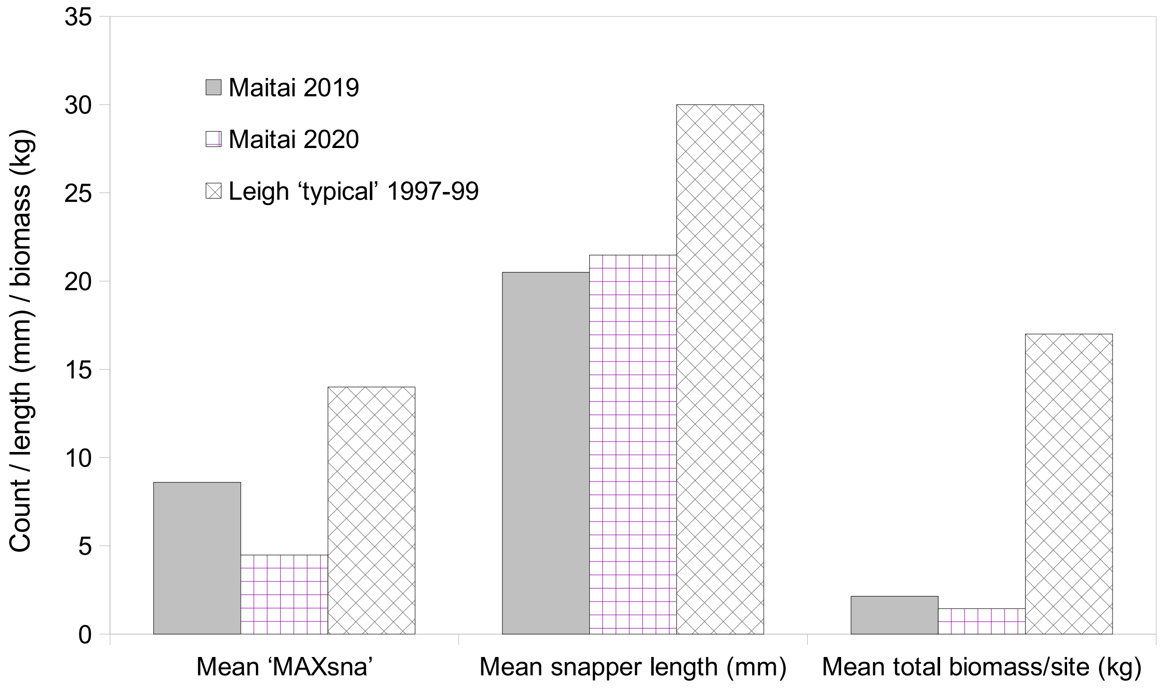

Figure 13: Snapper abundance, length and biomass based on BUV surveys at Maitai Bay in 2020 compared to typical values recorded using BUV at Leigh over the period 1997-99.

Looking at this in a positive light, it is likely that Maitai Bay has the potential to support a much higher abundance of much larger snapper than is currently present. With this restored snapper population we hope that the diverse kelp forests and taonga species associated with these kelp forests will return to the bay.

Summary

Overall, the results of the 2020 monitoring programme indicate that positive changes are beginning to occur within the rahui with regards to the restoration of fish populations. A summary of key results is provided below:

- Although numbers remain low, the size and abundance of both red moki and butterfish have both increased steadily each year since inception of the rahui.
- While the snapper population remains skewed to fish less than 25cm length and the overall snapper biomass remains low relative to Leigh marine reserve, it does appear that some larger snapper are starting to move into the rahui.
- Fish diversity remains similar to what was observed immediately following establishment of the rahui. However, this is to be expected, as new species require quality habitat to support their populations. We expect these quality habitats (e.g. kelp forests) to return over time as ecological balance is restored to the bay (i.e. when the snapper and crayfish populations are large enough to control kina densities, thus allowing kelp forest habitat to regenerate).
- Fish diversity and abundance were higher at sites adjacent to healthy kelp forest habitat.

The changes in size and abundance of fish populations occurring within the rahui are still relatively small at this point. However, this is consistent with the rahui having been in place for three years, which is still early days in comparison to the restoration processes that have been recorded at the Leigh marine reserve and the Poor Knights Islands.

Future possibilities

Trialling a kelp forest gardening programme has been discussed as a potential means of engaging the community in the restoration process. This would involve controlling kina densities in a specified area and introducing young kelp fronds to establish a new kelp forest. The whole community could be involved in the project from kina control through to kelp translocation and follow-up monitoring. If the trial is successful the project could be scaled up to support a larger area of the rahui. Kelp forest gardening has the potential to have both direct and indirect positive effects on the regeneration process through community engagement and education opportunities, as well as direct regeneration of important kelp habitat.

Another project that has been considered as a means to increase community engagement and compliance is the establishment of a kaitiaki rangers programme. This could involve a team of rangers spending time at the beach or on the water monitoring compliance and educating people who are unaware of the rahui or the importance and purpose of this protection. As there has been some non-compliance noted over recent months it seems a kaitiaki ranger programme has strong merit.

The possibility of creating an educational video sharing success stories of the work that Te Whānau Moana/Te Rorohuri is doing throughout the rohe has also been raised. This could then be linked to a QR code placed at strategic locations for members of the public to view. This seems like a great way to share the kaupapa of the hapu with a wider audience and garner wider public support and awareness of these important projects.

Recommendations

All three survey methods used in the monitoring programme (timed swims, diversity dives and baited underwater video) have produced high quality, relevant and complementary data over the past three years. The data produced from these methods enables us to confidently track restoration of fish populations within the rahui over time. We can also benchmark progress against other sites such as the Leigh marine reserve. On this basis, it is recommended that these survey methods all continue to be used in annual monitoring going forwards.

It would also be useful to incorporate a method to document the effect of the rahui on crayfish populations. A method that generates relative size and abundance data and provides Te Whānau Moana/Te Rorohuri with data that is relevant and of interest would be ideal. It is recommended that methods for crayfish monitoring are explored and incorporated into future monitoring programmes where possible.

Kelp forest cover is expected to increase as snapper and crayfish populations recover within Maitai Bay. In turn, the increase in kelp forest is expected to support more productive and diverse fish communities. As such, it seems the status of kelp forest cover within the rahui is a pertinent indicator of the health of the ecosystems within the bay. A thorough baseline of the marine habitats of Maitai Bay, including kelp forest cover, has been generated by Kerr *et al.,* (2020). It is recommended that the status of kelp forest cover is regularly monitored and the change in kelp forest cover tracked over time.

Finally, Te Whānau Moana/Te Rorohuri have expressed a desire to incorporate the use of maramataka and traditional ecological knowledge (TEK) into the monitoring programme. The Mountains to Sea Conservation Trust is in full support of this. It is recommended that all avenues to achieve this are explored, perhaps through dedicated hui and/or the development of a maramataka and TEK working group.

Acknowledgments

First and foremost, we would like to acknowledge the vision of Te Whānau Moana/Te Rorohuri, not only in establishing the rahui at Maitai Bay, but also in their work of regenerating the social, cultural and ecological health of their entire rohe. We extend particular gratitude to the dedicated rahui komiti for everything they do to make this the successful project it is. We are also grateful to the wider MTSCT team who have wholeheartedly supported this project and always offered a helping hand when needed. Finally, we would like to thank Foundation North, who have made this vital work possible through their generous financial support.

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Appendices

Appendix 1
Snapper length designations used in the 2018-19 and 2020 surveys

2018-19 size class and length designation	2020 size class and length designation
1-10 cm = 100 mm	5-15 cm = 100 mm
11-24 cm = 180 mm	>15-25 cm = 200 mm
25-39 cm = 320 mm	>25-35 cm = 300 mm
40-59 cm = 500 mm	>35-45 cm = 400 mm
60+ cm = 700 mm	>45 cm = estimated size to nearest 50 mm

Appendix 2
Summary of Maitai Bay and Leigh 2020 timed swim data

Transect	Surveyor	Date	Start time (24hr)	Average visibility (m)	Total fish counted	No. species recorded
M1	VK	2019-11-02	16:55	6	25	6
M1	VK	2019-11-23	16:35	5	50	10
M1	VK	2019-11-24	10:20	5	21	5
M1	OB	2020-02-27	07:30	4	35	10
M1	OB	2020-03-20	14:00	5	117	9
M1	OB	2020-03-21	16:10	6	297	11
M1	OB	2020-05-30	13:45	6.5	248	9
M1	OB	2020-07-06	15:10	5	260	11
M2	VK	2019-11-02	17:10	6	219	7
M2	VK	2019-11-23	16:50	5	14	5
M2	VK	2019-11-24	10:40	5	110	8
M2	OB	2020-02-27	07:15	3	247	7
M2	OB	2020-03-20	13:45	6	140	11
M2	OB	2020-03-21	15:57	7	586	11
M2	OB	2020-07-06	14:50	7	200	14
M2	IK	2020-05-30	13:50	6.5	126	14
M3	VK	2019-11-02	17:25	6	129	9
M3	VK	2019-11-23	17:15	5	67	9
M3	VK	2019-11-24	11:00	5	35	9
M3	VK	2020-03-21	15:15	6	139	11
M3	VK	2020-05-30	14:15	6.5	522	14
M3	OB	2020-02-27	07:00	2.5	47	7
M3	OB	2020-03-20	13:30	7	329	13
M3	OB	2020-03-21	15:30	6	189	13
M3	IK	2020-07-06	14:50	7	214	13
M4	VK	2019-11-02	17:40	6	161	5
M4	VK	2019-11-23	17:30	5	29	8
M4	VK	2019-11-24	11:20	5	17	5
M4	VK	2020-03-20	13:30	8	417	9
M4	VK	2020-03-21	15:30	6	183	7
M4	VK	2020-05-30	14:35	6.5	224	8
M4	OB	2020-02-27	06:45	4	167	9
M4	OB	2020-03-21	15:10	6	303	12
M4	IK	2020-07-06	15:19	5	3277	20
O1	WR	2020-03-21	12:30	9	247	13
O1	VK	2020-07-06	13:25	10	905	19
O1	OB	2020-03-20	12:10	7	390	12
O1	IK	2020-05-30	12:13	5.5	330	14
O2	VK	2020-03-21	12:30	12.5	597	16
O2	VK	2020-07-06	13:05	10	1221	17
O2	OB	2020-03-20	11:45	7	1455	16
O2	IK	2020-05-30	11:53	5.5	397	18
S1	VK	2020-05-30	10:45	8	125	11
S1	OB	2020-03-21	11:15	5	189	12
S1	IK	2020-07-06	10:50	9	615	17
S2	VK	2020-05-30	11:10	8	143	14
S2	VK	2020-07-06	11:08	12	869	11

S2	OB	2020-03-21	11:30	5	381	10
S3	VK	2020-07-06	11:25	11	202	12
S3	OB	2020-03-21	11:45	5	21	2
S3	OB	2020-05-30	11:00	5.5	181	12
S4	VK	2020-03-21	11:30	4	41	8
S4	OB	2020-03-20	12:35	5	269	9
S4	OB	2020-07-06	10:54	8	183	12
S4	IK	2020-05-30	10:32	6.5	321	9
S5	WR	2020-03-21	11:45	7	403	15
S5	OB	2020-03-20	12:50	5	264	14
S5	OB	2020-07-06	11:15	8	1405	16
S5	IK	2020-05-30	10:50	6.5	574	12
W1	VK	2020-03-20	11:45	4.5	181	8
W1	OB	2020-03-21	13:40	5	605	17
W1	OB	2020-05-30	12:00	5	292	10
W1	IK	2020-07-06	13:11	7.5	320	10
W2	VK	2020-03-20	12:05	4.5	81	8
W2	VK	2020-03-21	13:40	7	71	6
W2	VK	2020-05-30	12:00	8	192	9
W2	OB	2020-07-06	13:20	8	298	17

Transect	Surveyor	Date	Start time (24hr)	Average visibility (m)	Total fish counted	No. species recorded
Leigh 1	VK	2020-05-16	14:06	5	188	10
Leigh 1	OB	2020-05-16	12:31	4	354	10
Leigh 2	VK	2020-05-16	13:46	4.5	42	6
Leigh 2	OB	2020-05-16	11:35	3.5	40	7
Leigh 3	VK	2020-05-16	13:16	4	71	10
Leigh 3	OB	2020-05-16	12:00	4	64	8

Appendix 3

Full summary of Maitai Bay 2020 BUV diversity data

BUV No.	**B1**	**B2**	**B3**	**B4**	**B5**	**B7**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	**B19**	**B23**	**B24**	**B25**	**B26**
Spotty																1			
Snapper	6	4	5	0	2	4	4	0	10	3	4	9	3	5	4	3	13	3	3
Trevally							5		1							7	9		
Goatfish			3		1										1			1	
Leatherjacket	1	1	1		1		1				1			2	1	1		1	1
Blue cod																		2	
Pigfish		1	2	1	1						1			1	1	1		2	1
Porae	2																		
Scarlet Wrasse															1			2	
John Dory																			
Short tail stingray																			
Tarakihi																			
Red moki					1										1	1			
Kingfish																			
Orange wrasse																			
Speckled moray																		1	
Grey moray			1																
Yellow moray			1		2									1	1	2			
Eagle ray																			
Sandagers wrasse			1		1									1		1			
Mottled moray																			
Half banded perch			1																
Butterfly perch		1	2												4			2	
Demoiselle		9	10												3			9	5
Pink maomao																		1	
Sweep																		1	
Kahawai												3							
Mado																			
Roughy																		10	
Bigeye			40												2			7	
Silver drummer																			
Blue maomao											5							1	2
Marble fish																			
Jack mackerel																			
Koheru																			
Total	**9**	**16**	**67**	**1**	**9**	**4**	**10**	**0**	**11**	**3**	**11**	**12**	**3**	**10**	**19**	**17**	**22**	**43**	**12**
Richness	**3**	**5**	**11**	**2**	**7**	**1**	**3**	**1**	**2**	**1**	**4**	**2**	**1**	**5**	**10**	**8**	**2**	**14**	**5**