Maunganui Bay
Crypto-benthic Fish
Baseline Monitoring Programme

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Image cover page: Juvenile dwarf scorpion fish *Scorpaena papillosus* at Deep Water Cove, October 2016.

1. Introduction

1.1 MARINE MONITORING

Baseline-monitoring programmes involve the collection of environmental data over an extended time frame (Magurran et al., 2010), and despite having limited use when trying to answer specific research questions (Legg & Nagy, 2006), they can be useful in identifying natural variation and ecological changes over time.

As marine systems are put under increasing pressure from overfishing, pollution, climate change, invasive species and nutrient run-off; baseline monitoring programmes allow communities to document the ecological status and value of their Rohe Moana with an intrinsic and 'ecosystem goods and services' (benefits derived from ecosystems (Van den Belt & Cole, 2014)) perspective. Despite well publicised intentions to expand Oil and Gas operations such as deep sea drilling in New Zealand, the central government should not be relied on to show leadership in regulating industry or being responsible for effective environmental guardianship. This was illustrated by the grounding of the CV Rena, where up-to-date legislation increasing liability for polluters had not been implemented (Marten, 2011) and there was a deficiency in pre-impact baseline data on coastal ecosystems from which to gauge impacts. Communities and local government should ensure they have a scientifically robust long term monitoring programme collecting pre-impact state-of-the-environment datasets in-case a situation arises in which legal action is required to gain compensation from polluters.

Monitoring programmes should still be subject to scientific review and ideally started before the 'impact' so natural variation can be assessed (Willis, 2013). Marine monitoring projects can also provide a powerful educational tool and a good motive for people to work together and experience their local marine environment.

1.2 PROJECT AIM

This project aims to establish a long-term monitoring programme of crypto benthic reef fish (CBRF) assemblages in the Bay of Islands (BOI), and here we report on the first round of baseline sampling. This data will document the biodiversity and natural character of the BOI area and especially the Maunganui Bay Rahui area. Additionally, the data may be used to investigate habitat relationships and how changes in algal cover impact the diversity of benthic fish assemblages. This in turn could be used as supportive data for the aims and objectives of marine reserve promoters who are campaigning for a network of marine sanctuaries in the BOI.

1.3 CRYPTO BENTHIC REEF FISH

Crypto benthic reef fishes have been defined as 'small (<5cm adult) fish that are behaviourally cryptic and maintain close association with the benthos. These assemblages are not able to be sampled using Baited Underwater Video (BUV) techniques and have been understudied due to most investigations focussing on larger reef fish (Depczynski & Bellwood, 2003).

New Zealand has some of the most diverse cryptic reef fish assemblages in the world (Willis & Anderson, 2003) and the triplefins (family Tripterygiidae) reach their greatest diversity in our waters with 14 genera and 26 species (Feary & Clements, 2006). In addition to triplefin species, morays eels, slender roughy and bigeyes are some of the other groups of fish observed occupying cracks, crevices and caves beneath the *Ecklonia* canopy and counted in this survey.

1.4 STUDY AREA – BAY OF ISLANDS

The area of focus for this programme is the Cape Brett Peninsula in the Eastern BOI. The BOI is an embayment of 1800 square kilometres, located on the east coast of northern New Zealand. With the East Auckland Current (EAUC) flowing along the coast, the BOI forms part of the North-eastern biogeographic region with offshore currents influencing the BOI it forms part of a highly variable hemispheric system (NIWA, 2009). Sea temperature ranges from 14°C in winter to 21°C in the late summer. The BOI is made up of a diverse range of marine habitats from estuaries to exposed rocky reef. The focus habitats for this study are the shallow rocky reef systems providing substrate to sponges, bryozoans, ascidians, anemones, and encrusting algae.

1.5 RAHUI – MAUNGANUI BAY

A Rahui is a temporary restriction of access to a resource, in this case a fishery closure which is set down in law under the Fisheries Act 1996. Since 2012, Maunganui Bay has been closed to all fishing activities other than the gathering of kina (*Evechinus chloroticus* and *Centrostephanus rodgersii*). Both resident hapu, Ngati Kuta and Patukeha ki Te Rawhiti have maintained a Rahui in this area due to their concern about the depletion of fish stocks. Anecdotal reports from local dive operators indicate that some illegal fishing does continue within the Rahui.

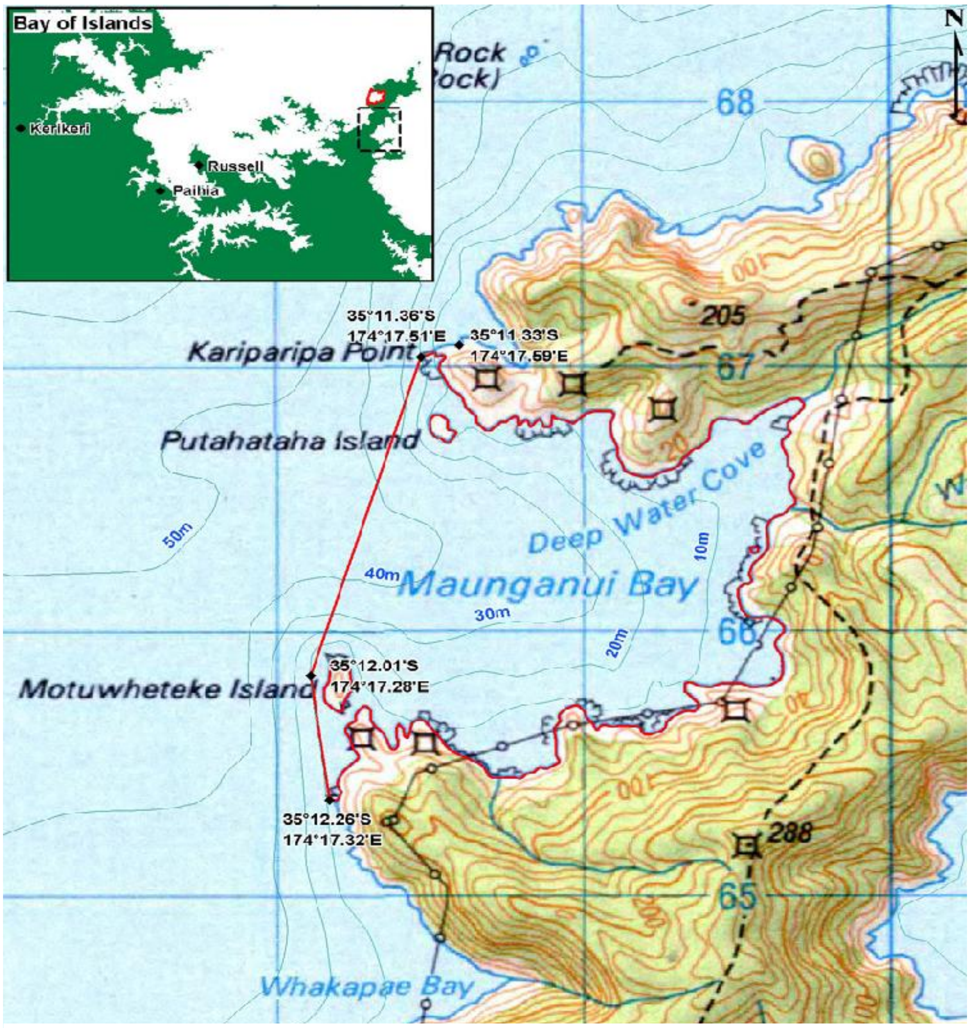

Figure 1: Maunganui Bay Rahui boundaries (red line) of no take area (image taken from www.Rahui.org.nz)

2. Methods

2.1 UNDERWATER VISUAL CENSUS

During Spring, this survey utilised an Underwater Visual Census (UVC) technique to collect baseline crypto-benthic fish species and habitat data. While UVC has been shown to underestimate crypto benthic fish abundance (Willis, 2001), non-destructive sampling must be used in a Rahui, and allows for comparison with similar studies. The methods used in this programme were developed by Dr. Adam Smith (Massey University) on crypto benthic reef fish and habitat relationships (Smith & Anderson, 2016).

A target GPS position for each sampling location selected was produced from charts. At each sampling location eight 5x1m^2 replicate transects were completed, with a two-person dive team completing four transects each per dive. Transects were haphazardly placed in kelp forest habitat within the target depth range of 10±2m. Each transect was broken up into five 1m^2 quadrats surveyed individually with fine scale habitat data recorded for each quadrat. Each transect was spaced a minimum of 3m apart to ensure an independent sample.

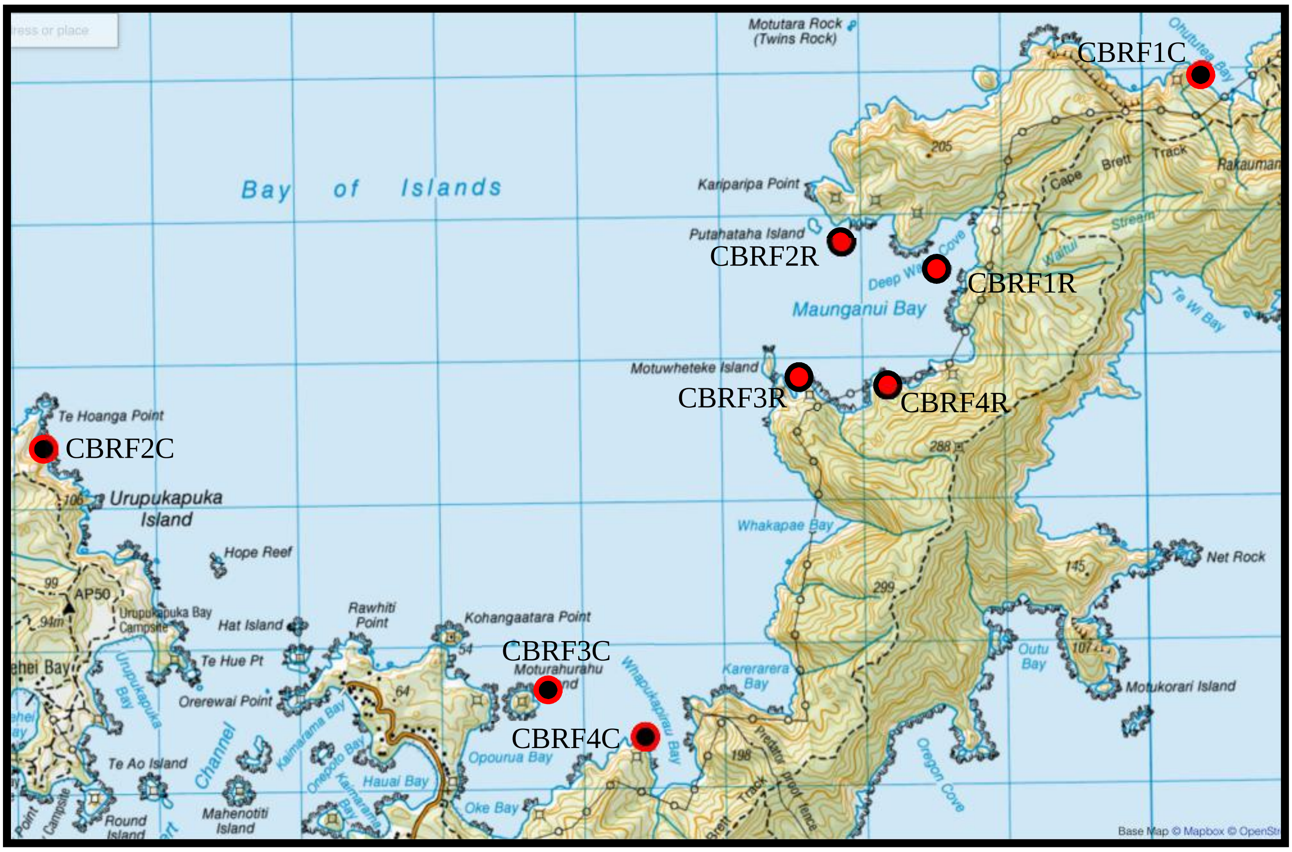

Figure 2: Sampling locations inside and outside Maunganui Bay Rahui in the outer Bay of Islands

All benthic fish species in the quadrat were identified to species level, counted and recorded on a slate. Any species that could not be identified by the diver were photographed, with descriptive notes taken to allow for identification post-dive. Conspicuous species were counted first, then a torch used to search crevices for more secretive species. Supplementary information recorded was diver name, date, location, site, depth of each quadrat and underwater visibility.

Habitat Assessment

The range of habitat features (Table 1) observed in each quadrat sampled was recorded. As this programme accrues more data, the assessment of habitat complexity and algal cover in relation to crypto benthic fish species abundance and diversity can be investigated.

Table 1: Habitat categories and definitions

Habitat feature category	**Definition**
Platform	Flat rock platform
Wall	Vertical rock wall
Overhang	Overhanging rock face
Gravel	Rocks less than 5cm
Cobble	Rocks 5 - 20 cm
Boulder	Rocks over 20cm
Crack	Fissure more than 5cm wide
Crevice	Opening 5 - 20 cm wide
Cave	More than 20cm wide
Ecklonia ‘C’	Closed *Ecklonia* canopy
Ecklonia ‘O’	Significant gaps in *Ecklonia* canopy
Ecklonia ‘X’	*Ecklonia* canopy absent
Carpophylum	*Carpophylum* sp. present
Red turf	Red algal turf present
Other	Presence of other habitat/shelter providing species such as sponges

2.2 BIODIVERSITY ANALYSIS

Biodiversity indices are commonly used to characterise the biodiversity of ecosystems. Species diversity is used to compare CBRF assemblages to indicate areas of high biodiversity, worthy of marine protection. We applied the Shannon Weiner Index (H value) to each site to compare the biodiversity between the Rahui and control sites. This is simply to compare the natural quality of the Rahui to the wider BOI sites. As more data becomes available, Rahui effects may be investigated with more advanced statistical analysis. The species diversity (H) of each sampling site will be calculated with the equation set out below where p_i is the proportion of individuals found for each species in the sample or $p_i = n_i/N$, where n_1 is the number of individuals per species for each sample and N is the total number of individuals in the sample.

$$H' = -\sum p_i \ln p_i$$

H_{max} is the best measure of H possible for that site and is used to give H some context. When H is divided by H_{max} the result is equitability and is the proportion of H to H_{max}.

$H_{max} = \ln s$ where *s* is the number of species in the community.

3. Results

Over three days from 19 October 2016 to 4 November 2016, eights sites where surveyed with a total of 320 quadrats sampled, 160 inside the Rahui and 160 outside the Rahui. The average depth of transects was 10m inside and outside the Rahui area. The most common fish species observed were the Blue-eyed triplefin (*Notoclinops segmentatus)* followed by the Common triplefin (*Forsterygion lapillum).*

Table 2: Number of each CBRF species observed

		TOTALS		
Common Name	**Scientific Name**	**Inside Rahui**	**Outside Rahui**	**Total**
Blue-eyed triplefin	*Notoclinops segmentatus*	338	404	742
Variable triplefin	*Forsterygion varium*	80	97	177
Spectacled triplefin	*Ruanoho whero*	97	25	122
Banded triplefin	*Forsterygion malcolmi*	16	0	16
Oblique-swimming triplefin	*Obliquichthys maryannae*	388	77	465
Mottled triplefin	*Grahamina capito*	2	0	2
Yellow-black triplefin	*Forsterygion flavonigrum*	21	0	21
Common triplefin	*Forsterygion lapillum*	57	92	149
Blue dot triplefin	*Notoclinops caerulepunctus*	2	0	2
Scaly-headed triplefin	*Karalepis stewarti*	0	1	1
Crested blenny	*Parablennius laticlavius*	39	0	39
Slender roughy	*Optivus elongatus*	45	16	61
Bigeye	*Pempheris adspersa*	105	2	107
Dwarf scorpionfish	*Scorpaena papillosus*	0	1	1
Northern scorpionfish	*Scorpaena cardinalis*	1	0	1
Two spot demoiselle	*Chromis dispilus*	10	0	10
Yellow moray	*Gymnothorax prasinus*	1	1	2
	TOTALS	**1202**	**716**	**1918**

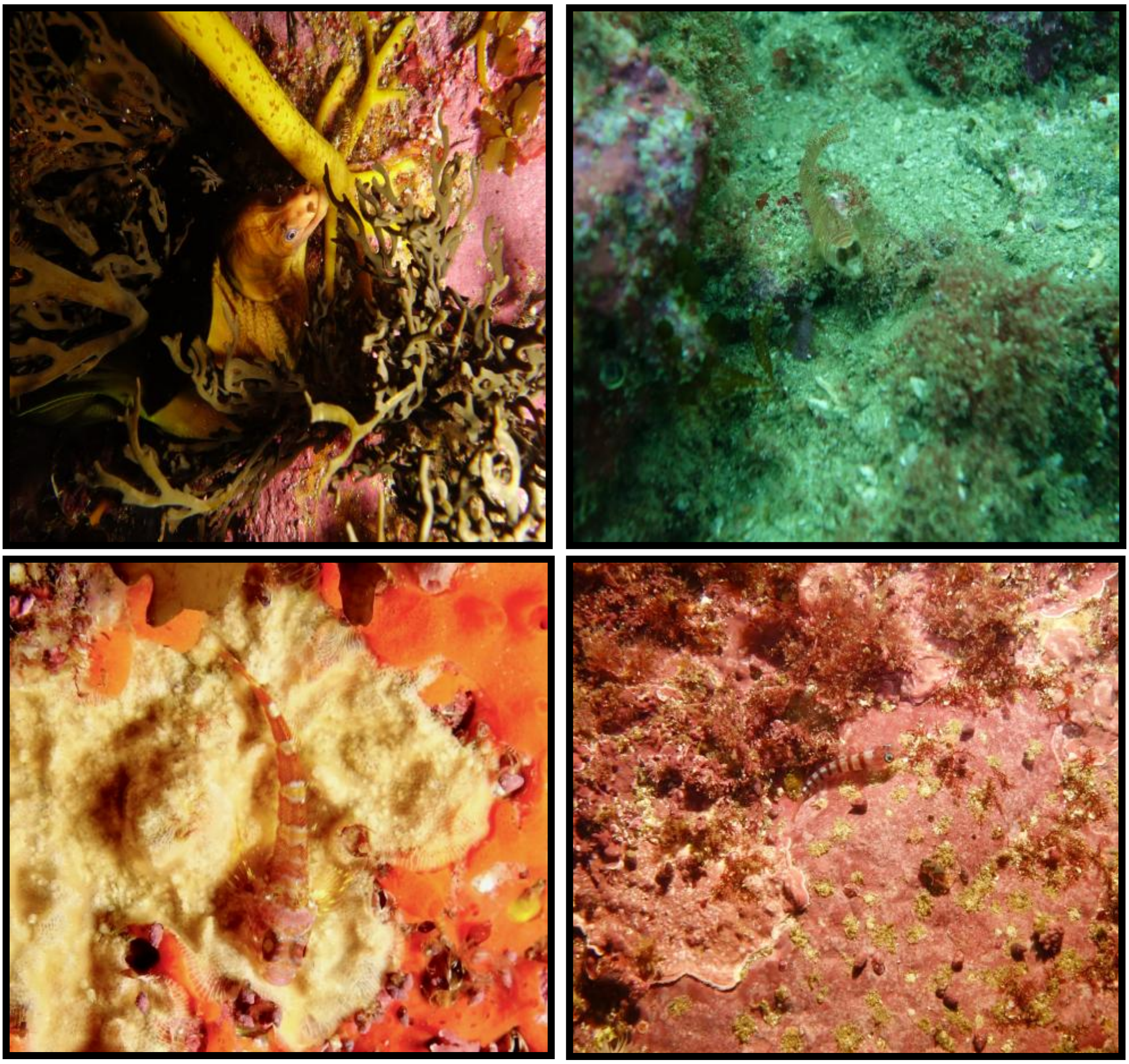

Figure 3: Clockwise from top left - Yellow moray (Gymnothorax prasinus), Spectacled triplefin (Ruanoho whero), Blue eyed triplefin (Notoclinops segmentatus) and a Juvenile dwarf scorpionfish (Scorpaena papillosus)

3.1 SPECIES DIVERSITY, HABITAT COMPLEXITY AND ALGAL COVER

The Rahui sites had higher species richness with three Rahui sites having eleven species observed and one having twelve species observed. Species diversity appeared higher in Rahui sites when at the Shannon Weiner Index scores, but when considering the equitability figure (H/H_{max}) there is no significant difference between Rahui and control site groups. Two control sites had five species observed and one each had eight and nine species observed.

Algal cover was also overall higher in the Rahui with three control sites having 60% or higher quadrats with the algal canopy described as closed. Habitat complexity was generally higher in Rahui sites with three Rahui sites having the highest average number of habitat features present overall.

Table 3: Species richness, diversity (H), habitat features and algae cover

Site	Species Richness	Shannon Wiener Index (H)	H_{max} (Ln SR)	Equitability (H/H_{max})	Total no. habitat features observed at site.	Mean no. of habitat features encountered at site	Algal canopy cover %
RAHUI							
CBRF1R	12	1.54	2.48	0.62	170	4.25	97%
CBRF2R	11	1.82	2.4	0.76	162	9.95	60%
CBRF3R	11	1.66	2.2	0.76	279	6.98	7%
CBRF4R	11	1.45	2.4	0.61	305	7.62	65%
CONTROL							
CBRF1C	5	1.03	1.61	0.64	168	4.2	25%
CBRF2C	8	0.98	2.07	0.47	206	5.1	50%
CBRF3C	9	1.37	1.79	0.76	168	4.2	55%
CBRF4C	5	1.31	1.60	0.81	204	5.1	2.5%

There was a weak positive correlation between species diversity and algal cover (R^2 = 0.16) (Fig. 4) and a slightly stronger one between species diversity and habitat complexity (R^2= 0.48) (Fig. 5).

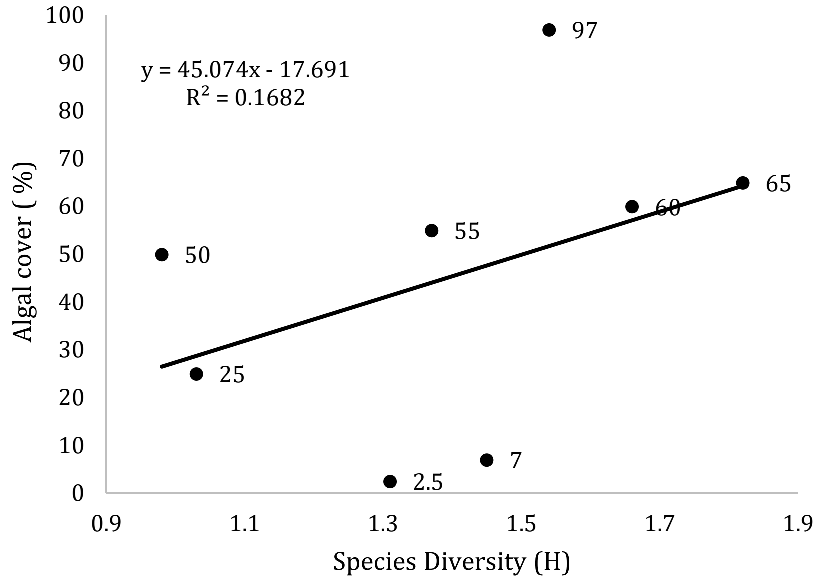

Figure 4: Species diversity (Shannon Weiner Index) and algal cover correlation

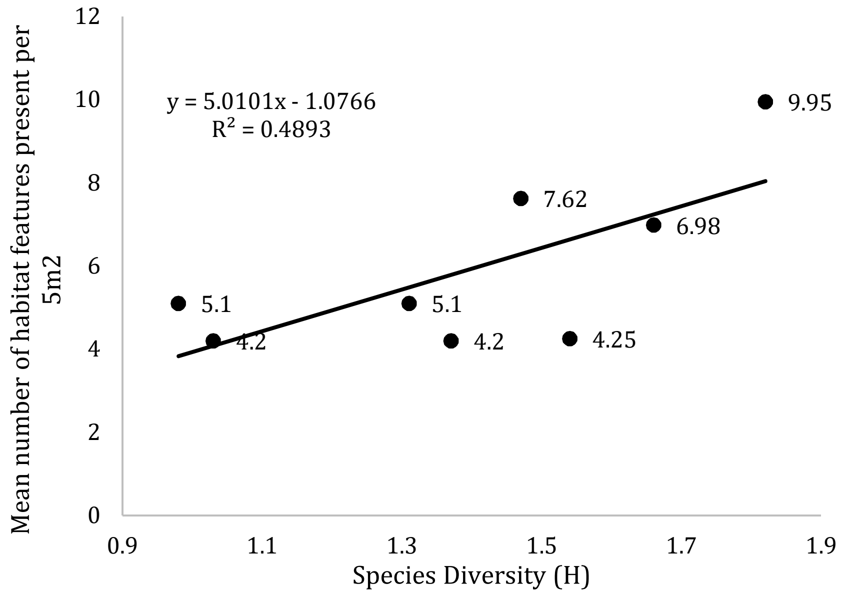

Figure 5: Species diversity (Shannon Weiner Index) and habitat complexity correlation

4. Discussion

Investigating the effects of protection on fish assemblages is challenging due to the natural variation that marine systems exhibit on temporal and spatial scales. Monitoring programmes should be replicated appropriately. Therefore, practicality and cost effectiveness are crucial to ongoing monitoring being maintained. We believe the method employed on this round of sampling produced results of an acceptable standard regarding characterising biodiversity of crypto benthic reef fish assemblages, and was practical to apply in the field with two divers.

A strong correlation between habitat structural complexity and triplefin diversity has been found in a previous study (Willis & Anderson, 2003) which also found higher numbers in urchin barren habitats, possibly due to the absence of predators from fishing effects. Triplefin species have also been found to have overlap between habitat use, with a preference for nesting in shelters such as cracks and crevices (Feary & Clements, 2006). Interestingly, no reserve effects were found on diversity and density, but strong correlation with two species and habitat complexity were found for *Ruanoho whero* and *Forsterygion flavonigrum* in the latest study (Smith & Anderson, 2016).
This BOI study found a weak positive correlation with algal cover and a slightly higher one with habitat complexity, but this may become stronger with more sampling effort and is worth further investigation.

Depth was also a main factor identified in the 2006 (Feary & Clements, 2006) study, with two distinct groupings of triplefin taxa, a shallow (<5m) and deep group (>10m). Different depth investigations were outside the scope of this work but in future, to get a clearer picture of habitat biodiversity, a depth stratified set of transects could be added. This would also benefit from a species area curve to indicate the rate at which and when new species are being detected as sampling is increased.

This programme has potential to be developed with further sampling repetition and additional sites to produce more robust data for future marine reserve planning and investigating the effects of fishing on the poorly studied crypto benthic reef fish communities of the BOI. Additionally, there is potential to have the dataset undergo more advanced statistical analysis not possible with the current time and resource constraints, or form part of a spatial planning programme for the BOI. We propose that a summer sampling effort may detect tropical species not present in the spring surveys, an important aspect to document when characterising the natural character of the BOI.

5. Conclusions and Recommendations

While the results indicate a weak correlation between species diversity and algal cover, additional sampling is required to investigate further. Advanced statistical analysis with a greater dataset would be beneficial as a long-term dataset would more accurately identify any relationships and changes to habitat and CBRF abundance due to Rahui protection. With more understanding of crypto benthic fish relationships and their habitat, there is the potential to develop this study to become part of a rapid ecosystem assessment or system of measuring how far systems have moved from a natural state.

The addition of depth stratified sampling to investigate depth effects, and summer sampling to detect tropical visitor species would aid in gaining a better understanding of CBRF seasonal behaviours. While UVC has been shown to underestimate cryptic species, rotenone is not an option and so getting a team of trained divers is important to this study in order to collect a valuable, consistent dataset.

Overall, due to the tried and tested sampling method, we recommend that this survey be repeated during different seasons and over several years in order to grasp the effect the Rahui at Maunganui Bay is having on CBRF. This data would be comparable to Dr. Adam Smith's work around other protected areas along the east coast of the North Island. Beneficially, an ongoing habitat assessment including algal cover inside and outside the Rahui would provide valuable data to marine reserve promoters and the local community to ascertain the effects of over-fishing in the BOI.

6. Citations

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7. Appendices

Raw data available on request.

Table 4: Site information

Site Code	Survey Date	Site Location	Status	Latitude	Longitude	Depth (m)
CBRF1R	19/10/2016	Maunganui Bay	Rahui	174.30026	-35.19345	8-10
CBRF2R	19/10/2016	Maunganui Bay	Rahui	174.29481	-35.19195	8-11
CBRF3R	21/10/2016	Maunganui Bay	Rahui	174.290457	-35.201410	11-12
CBRF4R	21/10/2016	Maunganui Bay	Rahui	174.29810	-35.20134	10-12
CBRF1C	4/11/2016	Ohututea Bay	Control	174.32173	-35.18250	8-10
CBRF2C	4/11/2016	Urupukapuka	Non-Rahui	174.23353	-35.20720	8-12
CBRF3C	4/11/2016	Moturahurahu Island/Oke Bay	Non-Rahui	174.27977	-35.22401	8-12
CBRF4C	4/11/2016	Whapukapirau Bay/Oke Bay	Non-Rahui	174.27084	-35.22145	8-12

Table 5: Number of each species observed at each site

	Site							
Species	CBRF1R	CBRF2R	CBRF3R	CBRF4R	CBRF1C	CBRF2C	CBRF3C	CBRF4C
Blue-eyed triplefin *Notoclinops segmentatus*	113	17	82	126	40	187	111	66
Variable triplefin *Forsterygion varium*	26	16	20	18	7	19	32	39
Spectacled triplefin *Ruanoho whero*	65	7	11	18	0	10	7	8
Banded triplefin *Forsterygion malcolmi*	6	9	0	1	0	0	0	0
Oblique-swimming triplefin *Obliquichthys maryannae*	273	61	53	1	0	17	60	0
Mottled triplefin *Grahamina capito*	0	1	0	1	0	0	0	0
Yellow-black triplefin *Forsterygion flavonigrum*	12	6	0	4	0	0	0	0
Common triplefin *Forsterygion lapillum*	5	18	18	16	23	5	30	34
Blue dot triplefin *Notoclinops caerulepunctus*	2	0	0	0	0	0	0	0
Scaly-headed triplefin *Karalepis stewarti*	0	0	0	0	0	1	0	0
Crested blenny *Parablennius laticlavius*	20	5	9	6	0	0	0	0
Slender roughy *Optivus elongatus*	7	0	1	37	0	9	2	5
Bigeye *Pempheris adspersa*	5	0	100	0	0	2	0	0
Dwarf scorpionfish *Scorpaena papillosus*	0	0	0	0	1	0	0	0
Northern scorpionfish *Scorpaena cardinalis*	0	1	0	0	0	0	0	0
Two spot demoiselle *Chromis dispilus*	6	2	2	0	0	0	0	0
Yellow moray *Gymnothorax prasinus*	0	0	0	1	1	0	0	0