Motukaroro Island baseline marine investigations: BUV fish monitoring 2006, UVC fish and crayfish monitoring 2007, and brief assessment of invasive marine species.

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Clients Brief

- Design and carry out a monitoring programme utilizing standardized methodologies as much as possible incorporating UVC (Underwater visual count) and BUV (Baited underwater video) abundance surveys for crayfish and reef fish
- Provide a report for the project which includes an introduction, methodology, results and discussion of the baseline fish and crayfish abundance monitoring, and conclusions.
- Briefly assess the status of invasive marine species in the marine reserve.

Executive Summary

Baseline abundance data for fish and crayfish populations were collected in this initial investigation in order to support future study of changes to habitats and organisms arising from the introduction of the marine reserve designation at Motukaroro.

Sonar surveys, snorkelling and scuba diving techniques were used to design an experimental layout for baited underwater video (BUV) and underwater visual census (UVC) reef fish and crayfish monitoring. Difficulties were encountered in the design of the UVC survey due to the small scale of the reefs in this area, as well as the lack of comparable reference sites outside of the reserve area. With some modification we feel worthwhile UVC monitoring could be undertaken to examine long term trends.

UVC data for recreationally targeted fish showed low numbers generally in and outside the marine reserve. For snapper only sub-legal fish were present. Crayfish were found in small numbers and were all sub-legal size. Only a small proportion of transects had crayfish present, however this is typical for heavily fished areas. It was not possible to analyse this first set of survey data for differences between reserve areas and fished control areas due to the low numbers of fish, zero counts, small differences between in and outside the reserve and the modest number of replicates. Recommendations were made for future options to modify the UVC method for the conditions at Motukaroro.

BUV monitoring was successfully established and the results are analysed and presented in this report. The differences between reserve and reference sites are minimal and reflect that both are currently full access fishing areas. Fish levels overall are relatively low compared to studies completed in other areas. The design of the BUV survey sites attempted to establish sufficient replication in the reserve area and fished reference sites to allow for statistical analysis of change over time as the reserve is established. The small, diverse and dynamic nature of the site raises some challenges for using the standard BUV methodology at Motukaroro, however some of the remaining uncertainties can be tested statistically and practically with modifications of the monitoring design in the coming years.

It is recommended that this report and accompanying habits maps should be widely used to promote awareness within the community of the marine values of Motukaroro, and to foster involvement in the establishment of the Whangarei Harbour marine reserve.

Introduction

Motukaroro Island Marine Reserve was established and gazetted in October 2006. The Reserve covers just over 25 hectares, near the entrance to Whangarei Harbour, and is characterised by shallow rocky reefs dropping on to soft sediments. Strong tidal currents affect much of the Reserve as it is on the northern side of the narrow entrance channel to the Harbour.

Baseline fish monitoring using baited underwater video (BUV), and detailed marine habitat mapping was carried out in 2006, and reported in a progress report by Kerr and Grace (2006). The report reviewed previous work and described the methods used for both BUV and habitat mapping. BUV results were presented and analysed. The report included the final habitat map and descriptions of the habitats identified.

This report follows on from Kerr and Grace (2006), and completes the suite of subtidal baseline monitoring for the Reserve area and reference sites outside the Reserve. The main focus of this work was to carry out underwater visual counts (UVC) monitoring for fish and crayfish, but also to check for invasive marine species in or near the Marine Reserve. This report brings together the BUV and UVC work, separating monitoring from the habitat mapping work presented in Kerr and Grace (2006), and includes the invasive species assessment.

Whereas BUV produces information on relative abundance of a few predatory species which are attracted to baits, UVC monitoring assesses quantitatively the abundance of reef fish species visible by a scuba diver on a short measured swim over the seabed. The resulting counts are usually quite different because of behavioral differences in the fish. Neither method gives a “definitive result”, but together they give a reasonable picture of the fish population, and are standardised and repeatable procedures, lending themselves to assessment of long-term changes as a result of management differences inside and outside marine reserves.

Methods

Baited underwater video (BUV) reef fish monitoring

Seventeen stations were designed and positioned to carry out BUV monitoring for carnivorous fish species. The layout consisted of eight sites within the marine reserve area and nine sites outside the reserve area. The outside sites or ‘fished reference sites’ are intended to provide a means of comparison over time between the fished state and the reserve sites that ceased to be fished upon establishment of the reserve. Care was taken to locate reference sites with similar current, bottom substrate and depth to the reserve sites. Typically the sites selected are soft sediment bottoms immediately adjacent to rocky reefs. A location map of the BUV sites appears in Figure 1 below. GPS coordinates and notes of the BUV sites are included in Appendix 1.

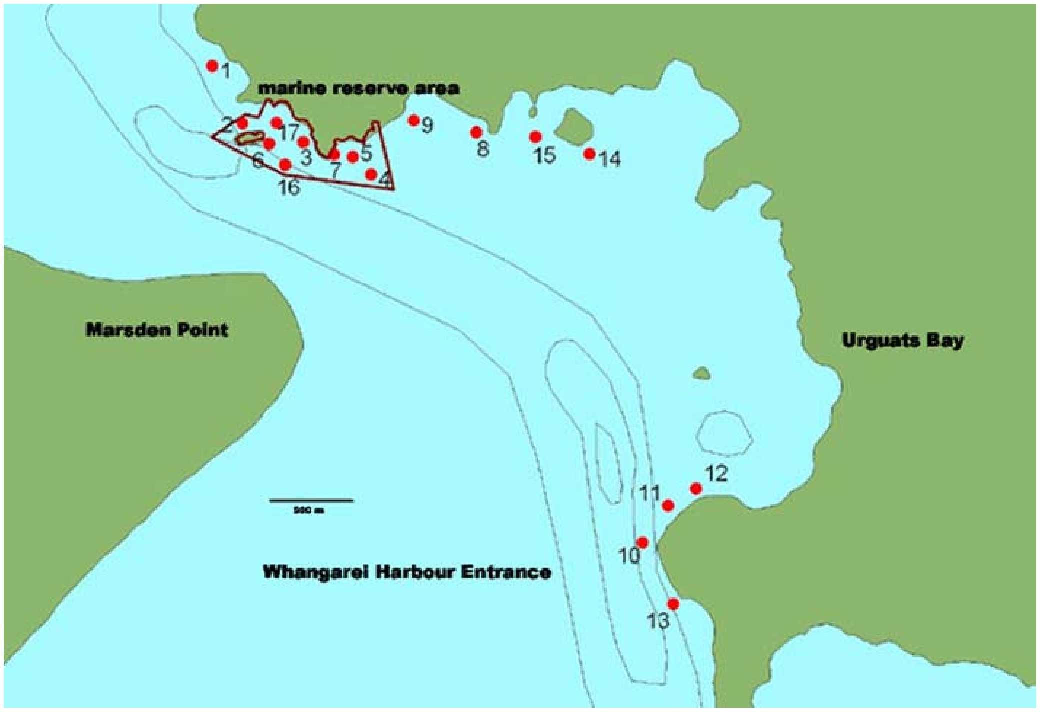

Figure 1 BUV monitoring sites

The BUV method used followed the protocols of Willis and Babcock (2000) with some modifications. The equipment used for this survey consists of a weighted steel bar forming the base of the unit, attached by ropes to a video camera contained in a waterproof underwater housing. The BUV video apparatus was a Sony TRV6e mini DV camera mounted in a simple, robust housing built from a recycled aluminum scuba cylinder and Plexiglass sheet material. As a result of a series of calibration tests, a Raynox .3X clip-on wide angle lens was added to the video camera lens to achieve the minimum vertical focal length which would result in a field of vision area of 1.43 sq.m. at the level of the base bar, that is at the seabed level. The video unit is tethered to the surface with a floating buoy. A bait jar containing approximately 4 pilchards (300g), *Sardinops neopilchardus* is attached to the base of the apparatus. The apparatus is pictured here in Figure 3 below. The BUV equipment was deployed from a 4.2m Mac boat powered with a 50 hp outboard motor. At each site the video was recorded for 30 minutes from the time the video assembly reached the bottom.

Figure 2. BUV apparatus

Post field analysis of the video tapes was done on a PC with *ArcSoft Showbiz* video editing software and DVD backup discs were made of all drops. Video sequences for each site were played back on the PC with a real-time counter. The maximum number of each species of fish observed was recorded during each 30-minute sequence. Only fish visible at any one time were counted to avoid counting the same fish twice. For each species at the time in the tape where the maximum count was taken, the sizes of these individual fish were recorded. This was done from the still image at the maximum count point of the video, and in addition the tape was moved back and forth a few frames so that individual fish could be observed in slightly different positions which made estimation of size easier. Estimation of size was done by comparing two scales available in the image. One was the 10cm markers on the base bar of the apparatus, and the other was the 9cm width of the bait container. A judgment had to be made in each case as to where the fish was in the vertical dimension which affects the perception of length against a fixed point such as the bottom bar. i.e. the closer the fish is in the vertical dimension to the camera the longer it will appear in relation to the measured bottom bar. With a little practice it is possible to be certain that the fish being measured is at the 'bottom' position or the level of the bait container top or even higher. Measurements were only made of those fish present when the count of the maximum number of fish of a given species in a sequence was made. While this means that some fish moving in and out of the field of view may not have been measured, it also avoids repeated measurements of the same individuals. It is likely that this approach results in more conservative abundance estimates in high density areas than low density areas, and therefore observed relative differences between sites are also likely to be conservative.

Underwater visual counts (UVC) monitoring

Difficulties were encountered in the design of the UVC monitoring survey because of the small scale of rocky reefs both within the Marine Reserve and in reference sites outside the Reserve. Furthermore it was hard to find comparable reference sites as subtidal reef habitats similar to those within the Reserve are not common outside, within a reasonable distance to be a realistic comparison to the Reserve. Similar problems relating to the small scale of the Reserve were encountered with the BUV survey in 2006, and discussed in Kerr and Grace (2006).

The number of UVC sites, and the number of replicates at each site, was limited largely by availability of rocky reef habitat. Compromises had to be made to the desired "random" location of replicates at each site, simply because random placement would have resulted in many transects running off the reef and on to the sand.

Three sites were established inside the Marine Reserve, and three sites outside. At each site four replicate transects were worked, for both reef fish and for crayfish (rock lobster). Sites were predetermined with the help of aerial photographs and the existing habitat map (Kerr & Grace 2006) to ensure transects could be worked within the confines of the reef system at each site, and the boat was anchored at the GPS coordinates determined for a site.

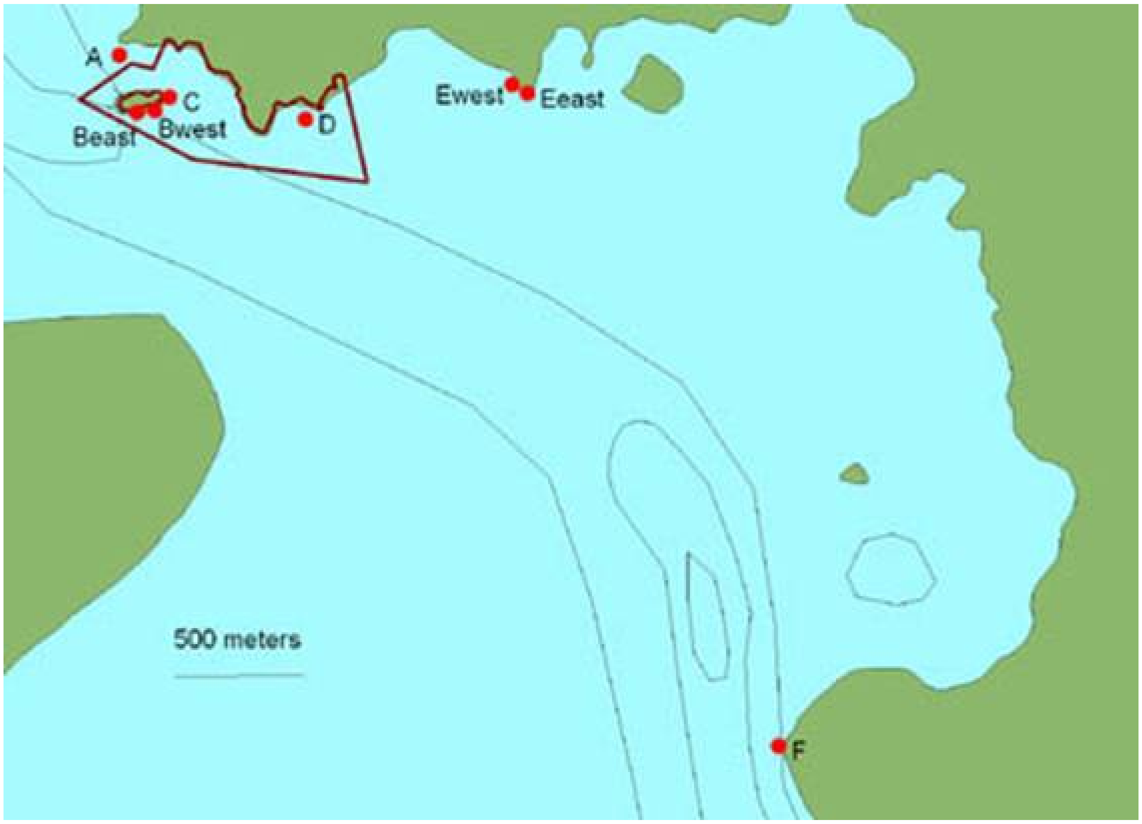

Figure 3. UVC fish and crayfish monitoring sites (site details included in appendix 6)

Fish survey

Two divers proceeded to the anchor, and tied off the zero end of a 30-metre tape either to the anchor or to a kelp plant or rock nearby. Each diver then headed off in a predetermined direction running out the tape to the 5 metre mark before beginning the fish count. This was to minimise any affect of the anchor and tying-off activity on fish behaviour. At the 5 metre mark the diver began identifying and counting fish seen within a 5-metre diameter tunnel immediately in front and ahead. Fish were noted down as tally marks, or if a larger group was seen an estimate of the number in the school, against a fish list on a pre-prepared underwater data sheet. In many cases the length of fish was also recorded, usually to the nearest 5cm. The diver continued to move slowly forward trying to avoid stopping during this process, until reaching the end of the tape at 30 metres. The diver then tied off the tape reel to a kelp plant or rock and proceeded to carry out the crayfish survey.

On completion of the crayfish transect the reel was wound up and another fish transect begun. In some cases this was from the same zero point, so that four transects radiated out from the anchor. In other cases where the reef was more linear in shape, and radiating transects would not "fit" in the available reef space, the zero point for the next two transects was shifted along the reef about 60 metres or a little more, so that four transects could be counted along the narrow reef structure.

The area covered by each transect was 25 x 5 metres, or 125 square metres.

Crayfish survey

The crayfish survey was started at the 30-metre end of the tape already tied off after the fish count described above. The diver commenced working back toward the zero end of the tape working within a 2.5 metre wide strip adjacent to one side of the tape. The presence of a short dense forest of kelp at most of the sites necessitated a laborious process of burrowing through the kelp in a zig-zag pattern along the transect, carefully searching under the kelp and around all rocks in order not to miss any crayfish or holes in which they could hide.

Once back at the 5-metre mark, the diver then proceeded along the other side of the tape working a zig-zag search pattern within a 2.5 metre strip as before out to the 30-metre mark. The tape was then wound back to zero and another fish/crayfish transect commenced.

Crayfish seen were counted and their carapace width estimated to the nearest 5mm interval, by comparison with a measured scale marked along the top of the data recording sheet. The area covered by each transect was the same as for the fish survey, that is 25 x 5 metres or 125 square metres.

Invasive species

No formal investigation was attempted for invasive species, but during the fish and crayfish counts a general watch was kept for anything unusual. The two field workers (Vince Kerr and Roger Grace) are both experienced divers familiar with the normal marine life of northeastern New Zealand, and are constantly on the lookout for anything unusual. Any obviously different non-cryptic or non-secretive macro-organism which was common or abundant in or near the marine reserve had a high chance of being detected within the vicinity of the fish and crayfish transects worked.

Results

BUV reef fish monitoring

Thirty minute BUV drops were completed at 17 sites in and nearby to the Motukaroro reserve area. Maximum counts were made for each species for each site. The maximum count was defined as the greatest number of a species occurring in the field of vision of the camera during the 30 minute interval. The field of vision of the camera was 1.43 m^2 at the level of the bottom bar. Seven species were found in the 17 BUV drops: Spotty *Notolabrus celiodotus,* snapper P*agrus auratus,* trevally P*seudocarnyx dentex,* goatfish *Upeneichthys lineatus,* leatherjacket *Parika scaber,* blue cod *Parapercis colias* and john dory *Zues faber.* Results of these counts for each species are shown in Table 1 below.

Table 1. BUV fish counts Note: The sites inside the reserve area are shaded grey and are arranged from left to right in relation to their actual west to east position.

Fish/ Drop #	1	2	6	17	16	3	7	5	4	9	8	15	14	12	11	10	13
Spotty			4			1	1	3			1					3	
Snapper	3	3	3	2	2	5	5	3	2	3		2	2	9			
Trevally	3	13	19	18			11	9	1					3			
Goatfish								1								2	
Leatherjacket			1		1			2							2	4	1
Blue cod																2	
John Dory							1										
unidentified																3	
Total	6	16	27	20	3	6	18	18	3	3	1	2	2	12	2	14	1

One way to view this data is to calculate the number of sites that had each species present. Once this is done it is also possible to compare results from within the reserve area to the reference site areas. This result is depicted in Figure 4 below. (Note: Standard error calculations for the reserve and non-reserve replicate drops for spotty, snapper and trevally are indicated in Figure 8 below). For the three species that appear in the survey in the greatest numbers (spotty, trevally and snapper), there is an apparent difference between inside the reserve area and the outside reference sites. Spotty and snapper occur almost twice as frequently in the reserve as outside and trevally occurs three times as often. Snapper were present at 100% of the reserve sites and at only 56% of the reference sites. This aspect of the result suggests that the area around Motukaroro is in some way especially attractive to these species. Differences in frequency of presence/absence of the other four species, goatfish, blue cod, john dory and leatherjacket are hard to interpret and are unlikely to be significant. The actual numbers of these species observed were very low and the apparent differences between inside the reserve and outside are not great. There was only one legal size snapper counted in all the BUV drops making the separate analysis of legal and sub-legal size snapper impractical at this point.

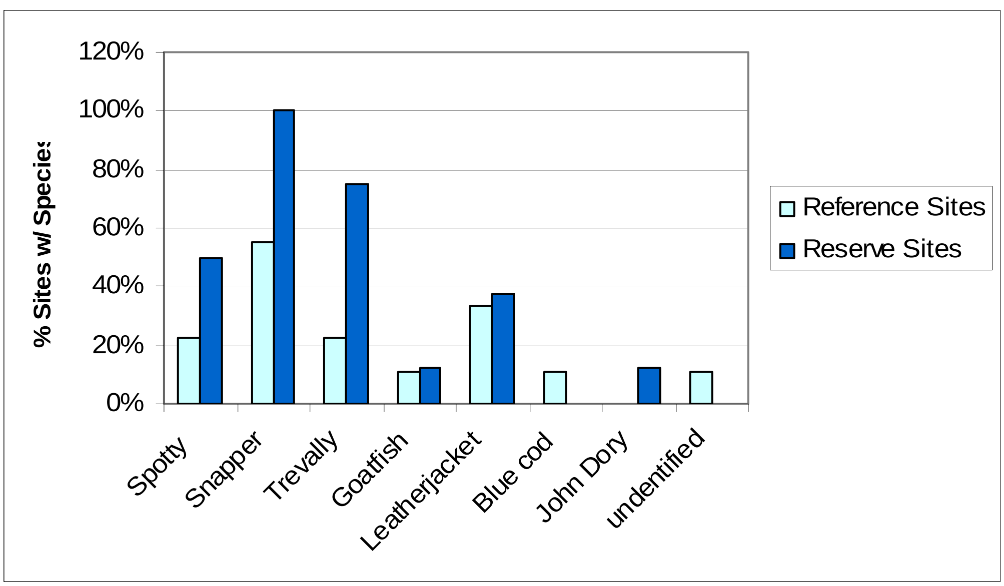

Figure 4 Frequency of species present at reserve and reference sites
Note: unidentified corresponds to a small fish on one BUV drop that could not be identified.

In another treatment of the data the total of the maximum counts for all species observed was calculated for each BUV site. The results of this treatment are presented in Figure 5. Two observations can be made. The total number of combined fish species shows that overall there are significantly more fish in the reserve area. However as can be seen from the graph there is considerable variation in numbers between the sites in the reserve and also between the reference sites. This variation will be explored further with evaluation of the results by species.

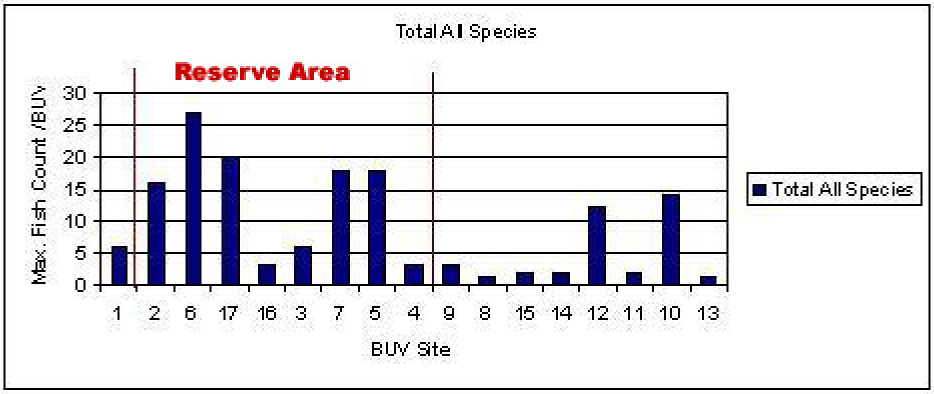

Figure 5 Maximum fish counts all species combined.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

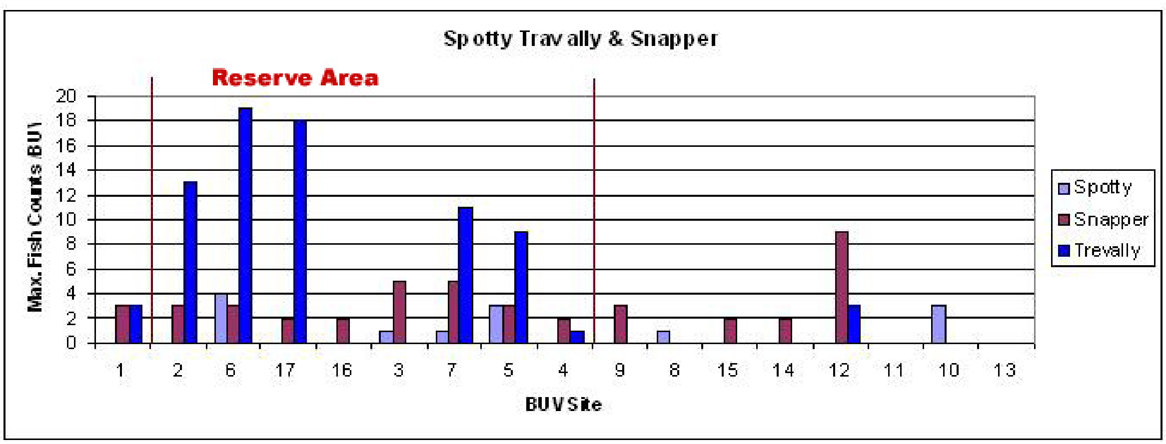

Figure 6 Maximum counts for spotty, trevally and snapper for all BUV sites.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

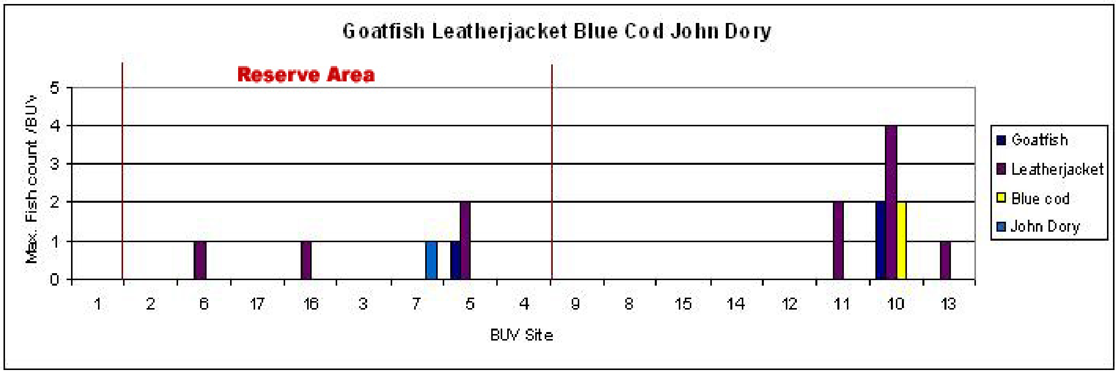

Figure 7 Maximum counts for goatfish, leatherjacket, blue cod and john dory for all BUV sites.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

In order to test the usefulness of this data and the degree to which the reserve area and the reference site area can be compared we pooled the maximum count data for each species into two groups: the reserve group and the reference site group. Grouped in this way the BUV site become two sets of replicates with n=8 for the reserve area and n=9 for the reference sites. We then calculated a mean value for the maximum counts for snapper, trevally and spotty. This is presented in Figure 8 below along with standard error bars which indicate the variation between the replicate BUV drops within the two groups.

When the data is viewed in this way for spotty and snapper, while the means are higher in the reserve than outside, the difference is less than the standard error. This can be taken to mean that either the difference between in and out is not significant or there is too much variation between the replicate BUVs to indicate difference between in and out, i.e. more replicates are required. For trevally the absolute mean values are quite divergent. However the apparent difference between inside and outside must be considered along with the variation error between samples, expressed as error bars (standard error or 95 % confidence level), which are large in this case. This means that the variation between sites within each group is nearly as large as the overall difference between inside and outside groups. Accordingly much of the difference between the two groups can be accounted for as sampling variation. The results do however suggest there is a difference between inside and outside for trevally, but again the large error bar especially for the reserve group suggests that there is a tendency towards a patchy distribution of trevally and that the number of replicates used is minimal for this species.

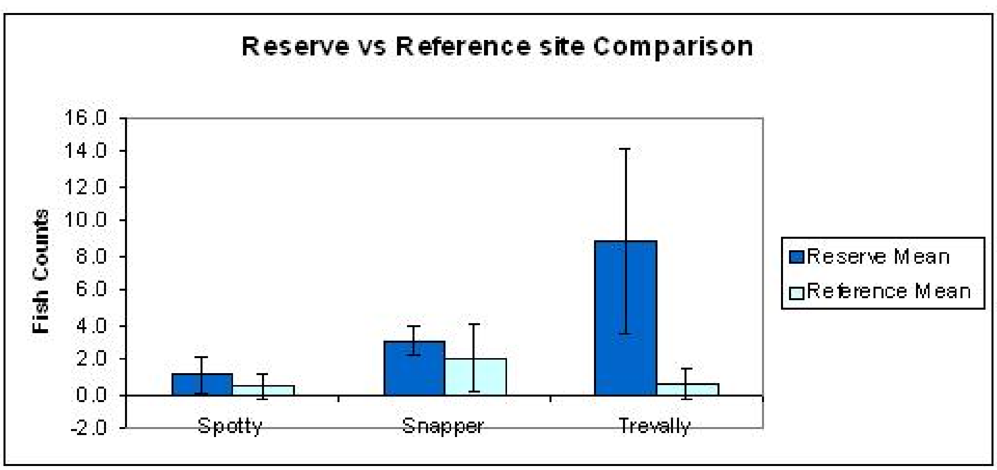

Figure 8 Comparison of mean maximum counts snapper, trevally and grouped as reserve verses reference sites

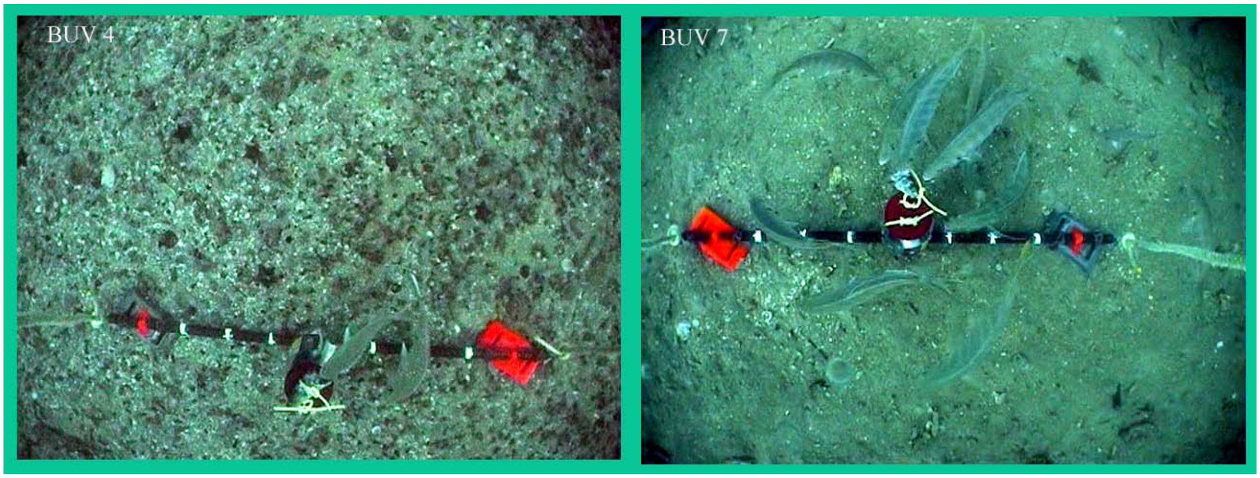

Figure 9 Representative photos from BUV monitoring

For the four species occurring in small numbers, goatfish, leatherjacket, blue cod and john dory, the distribution is too patchy and numbers too low to allow for the calculation of sensible mean values in and out of the reserve, or to measure variation within the two groups. At these low levels of occurrence more replicate BUV drops would be required to assess difference between inside and outside.

Returning to Figure 8 it is worth examining the results of snapper in the context of the longer term purpose of this monitoring program. It is possible based on previous studies, that in the years to come following the establishment of the reserve, density of exploited species will increase over time in relation to densities in nearby ‘fished’ reference sites. While there is some question about this at the Motukaroro reserve because of the very small size, this possibly remains the most important monitoring question. It is also clear that changes in snapper abundance will potentially be one of the best indicators of the reserve effect and thus should be a central focus of the monitoring. In our BUV design snapper occurred at all reserve BUV sites. The standard error calculated for the reserve mean of 3.1 fish/BUV was 0.9. This degree of variation is acceptable for statistical treatments of the data, indicating that the BUV design should be workable for assessment of change over time for this species. For the reference sites the mean of 2.1 fish/BUV and standard error of 1.9 is not as encouraging. Snapper were present in only 56% of reference area BUV drops. If snapper numbers appearing at the reference sites remains this low it is logical to conclude that more replicates will be required to calculate mean values for the reference group sites with sufficiently low variation error to allow for meaningful comparison to the reserve group of BUV sites.

BUV fish size data

Size data was collected for all species at the time in each BUV of the maximum count for each species. The size data by species for each BUV drop is detailed in Appendix 2 of this report. Overall the size of the fish is small with the vast majority of fish appearing falling into size classes that would be considered juveniles for that species. Snapper ranged in size between 9 and 28cm with only three fish in total being estimated to equal to or exceeding 27cm, the size for legal take. Trevally ranged from 19 to 37cm in size and spotty ranged from 11 to 27cm. The other four species leatherjacket, blue cod, goatfish and john dory exhibited a similar pattern of predominately small fish and no large individuals present. This pattern of young fish dominating the population is typical of fished areas, and is also a typical feature of harbour habitats known for their importance as nurseries and refuges for juvenile stages of these species (Morrison 2005). Comparison of size data following reserve establishment is expected to produce a key indicator of reserve effect change over time. As a general rule, in reserves studied to date, the increase in biomass over time after reserve establishment is greater than the increase in abundance. For this purpose then it would appear that this data will form a worthwhile baseline to measure changes in biomass of these species, at the least for snapper.

Underwater Visual Counts (UVC) fish survey

Fish counts

Counts of fish seen on the transects are presented in Table 2. In the table sites are arranged from west to east, with sites B, C and D inside the marine reserve, and sites A, E and F outside the reserve. At each site four replicate 25 x 5 metre transects were worked, covering a total area of 1500 square metres inside and 1500 square metres outside the marine reserve.

Table2 Fish Counts UVC fish counts. Sites and replicates inside the reserve area are shaded grey, and arranged from left to right in relation to their actual west east position.

Site and replic.	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2	F3	F4
Species																								
Banded wrasse	5	1					1		1	1	1	1							2				1	
Black angelfish																								
Blue maomao				10		3			10								15	40		15				
Butterfish					2																			1
Butterfly perch																			2					
Conger eel																								
Demoiselle																				1				
Dwarf scorpion																								
Eagleray																								
Goatfish	42	13	11	55	1		33	34		7	1	4	16	15	12	40	15	70	14	10				1
Jack mackerel					55	20	15		10			150	100					100	30	20				100
John dory																	1	1	1					
Kahawai																							1	
Kelpfish	1	2																						
Kingfish																								
Koheru									3														50	20
Leatherjacket			2	1		1													3				1	
Longtail stingray																								
Longnose pipefish																								
Marblefish																								
Parore	10	6	20	25	9	2	5	2	31	10	13	6	10	3			9	3	2	2	1	8	4	6
Piper																								
Red moki	2	1	2	1			6			1	1		1	1				3	7	3				
Scarlet wrasse							1																	
Shorttail stingray																								
Silver drummer																			1					
Snapper				14			16													2				
Spotty	55	5	7	35	45	57	50	51	70	31	300	125	80	350	8	9	402	120	178	90	12	20	15	60
Sweep	18	15	3	35	6	6			70		2							150	65	80				
Trevally																								
Yellow moray																								
No. of spp.	7	7	6	8	6	6	8	3	7	5	6	5	5	4	2	2	5	8	11	9	2	2	6	6

A total of 19 species were counted on the transects. Thirteen species were counted on transects inside, and 18 species on transects outside the reserve across all replicates. A mean of 4.9 species/transect occurred on reserve transects (95% confidence value = 1.1), and a mean of 6.4 species/transect occurred on transects at the reference sites (95% confidence level value =1.5).

The spotty was the only species counted on all transects inside and outside the reserve.

Parore occurred on all transects outside the reserve, and on 10 of the 12 transects inside the reserve. Goatfish were also widespread, occurring on 9 of 12 transects outside, and 10 of 12 transects inside the reserve.

Five species occurred frequently on transects and in reasonable numbers and were distributed more or less equally between reserve and reference sites, although there was considerable variation in actual counts. These species include goatfish, jack mackerel, parore, and spotty. Spotty, the most abundant fish in the area, reached numbers of 300 to 400 on individual transects, both inside and outside the reserve. Table 3 and Figure 10 below show these results in graphic form. Based on the standard error (95% confidence levels) calculated for these species it is reasonable to conclude that spotty densities were similar between the reserve and reference sites. For the other species its is not possible to reliably infer a conclusion because of the high variability across the transects as demonstrated by the high standard error values that are exceeding mean values. It possible that there are similar densities for these species overall in and outside the reserve, but our data based on the limited number of replicates does no statistically support this conclusion.

Table 3 Mean fish counts and standard error values

Species	Reserve transects Mean	Reserve transects Standard Error	Reference transects Mean	Reference transects Standard Error
goatfish	13.6	8.2	19.3	13.3
jack mackeral	29.2	27.5	20.8	21.6
parore	7.6	4.8	8.0	4.2
spotty	98.0	62.8	83.3	64.1
sweep	7.0	11.3	30.5	26.3

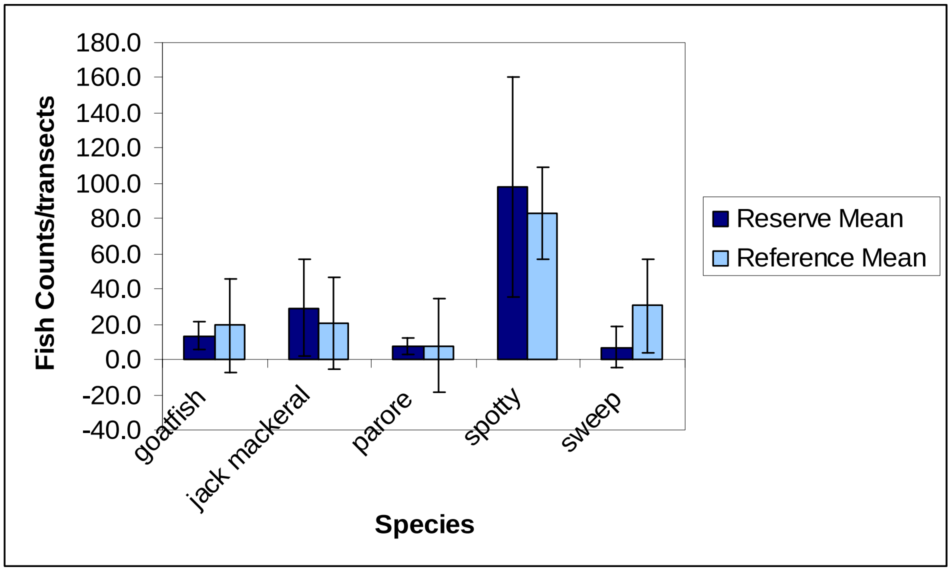

Figure 10 Mean fish counts/transect with error bars indicating standard error at 95% confidence level

All the other species were either not found frequently on transects or were only found in very small numbers. For these species the data does not support statistical comparison between reserve densities and reference site densities at this stage. Calculation of mean fish density values are also not statistically valid for the same reason.

Red moki, an important reef fish in the area, occurred in small numbers at several sites both within and outside the marine reserve. Although there were almost twice as many counted outside the reserve than inside, this difference is probably not statistically significant based on standard error values and the low absolute counts.

Snapper occurred as juveniles only, on one transect inside and two transects outside the reserve.
A further nine species were seen either on the transects but not during the counts, or at places away from the transects. These include big eyes, conger eel, dwarf scorpionfish, kingfish, long-snouted pipefish, marblefish, short-tail stingray, slender roughy and yellow moray. Several species of triplefin and blennies were also seen but not recorded.

Fish sizes

The length of individual fish was usually estimated to the nearest 5cm for several species; red moki, snapper, and parore, and the results presented in Appendix 3.

Parore were recorded on all transects except two in the reserve. Mean length inside the reserve was 32cm, whereas in reference areas the mean was 21.6cm. There were high numbers of juvenile parore seen at reference site A outside the reserve.

Red moki counts produced seven zeros out of 12 in the reserve, and five zeros out of 12 reference transects. Mean lengths were 39.4cm in the reserve, and 28.4cm in reference areas.

Snapper counts and sizes are very low, only juvenile snapper being seen at one of 12 reserve transects, and two of 12 reference transects. They are included here because it is expected numbers and sizes may increase within the reserve.

Crayfish survey (UVC)

No green or packhorse crayfish (Sagmasarius verreauxi) were seen during this survey.

Counts and size estimates of red crayfish (Jasus edwardsii or red rock lobster) on each transect are presented below in Table 4.

Table 4 UVC Crayfish counts and size data. Note: The sites inside the reserve are shaded grey and are arranged from left to right in relation to their actual west to east position.

Site and replicate	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**	**D3**	**D4**	**E1**	**E2**	**E3**	**E4**	**F1**	**F2**	**F3**	**F4**	**Site and replicate**
Red crayfish #																									**Red crayfish #**
Sublegal shell width (mm)																									**Sublegal shell width (mm)**
10					1																				10
15																									15
20																									20
25																									25
30													1												30
35																									35
40												3	1					2							40
45												2												1	45
50							1	2				1					2								50
55												1							1					1	55
Legal shell width (mm)																									**Legal shell width (mm)**
60																									60
70																									70
80																									80
90																									90
100																									100
110																									110
120																									120
130																									130
140																									140
150																									150
Total sublegal size	0	0	0	0	1	0	1	2	0	0	0	7	2	0	0	0	2	2	1	0	0	0	0	2	
Total legal size	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

All red crayfish seen were of a sublegal size.

Sublegal crayfish appeared on five transects inside and four transects outside the marine reserve. A total of 13 crayfish occurred on transects inside the reserve, and seven on reference transects. Sizes were generally between 30 and 55mm carapace width, with one very small crayfish of 10mm carapace width seen inside the reserve.

Zero counts occurred on 7 of 12 transects inside the reserve, and 8 of 12 transects at reference sites.

Invasive species

The only clearly foreign species seen on the transects was the oriental file shell Limaria orientalis. One was seen under a rock on transect A4.

The parchment worm Chaetopteris sp. has behaved like an invasive species in recent years, by undergoing an explosive spread and infestation then reducing in abundance, but apparently it has not yet been determined if it is a native or imported species (Karen Tricklebank, pers.comm.). It was found at sites A, B, C, and E, and was noted as common at C1, C2, and E2.

The Pacific oyster Crassostrea gigas is common on sheltered rocky shores in the reserve and reference areas.

Occasional shells of the zebra mussel Musculista senhousia are seen washed up on the shore, but no mats of these mud-binding invasive were seen during this survey.

Site data

Physical and biological site data are presented in Appendix 3. This includes GPS fixes for the zero ends of the transects, depth at start and end of each transect, and a note of the habitat. The direction each transect runs from the zero is also noted, as well as date, approximate time, visibility and other notes.

Discussion

BUV fish monitoring

Overall the results of the BUV monitoring appear to fulfill the objectives set down for the study with some concerns that can be addressed in subsequent years of monitoring which we will further discuss here. For the most significant carnivorous fish species snapper, the results indicate that the number of replicates and placement inside the reserve should provide the ability to do change over time statistical analysis and yield worthwhile results. This is assuming that there is significant change over time as a result of the establishment of the marine reserve. However the layout and number of replicates in the ‘reference’ site areas is not as clearly sufficient even though there were nine sites compared to the eight within the reserve. The main problem is that the various habitat characteristics of the Motukaroro area are not easily replicated by moving either up or down the harbour. We tried to pay particular attention to current and depth and proximate reef structures in this regard, but the choice of sites is limited. In one sense this supports the argument to have more replicates in the reference areas. The other aspect of this problem is that the fish numbers we measured at the reference sites were quite low with a number of zero counts affecting the analysis of results. This is a chronic problem in marine reserve studies as the organism that is studied may be so depleted outside the reserve area that ‘fished reference sites’ become difficult to identify. Reviewing the initial data with these two considerations in mind it seems sensible to expand the number of replicate BUV drops of the reference sites. In the layout of reference sites it is possible to view them as two distinct groups: one group described as the shore to the East - around High Island and between High Island and the reserve, the other group described as the shoreline of Home Point. If expanded it would probably be necessary to have 8-10 replicates for each reference area. This approach would afford the possibility of using more powerful statistical analysis on the data. The current number of replicates for the reserve area should be regarded as the bare minimum to be practically useful. Increasing the number of replicates from 8 to 12 or 15 would greatly increase the statistical power of the analysis based on the data in this years monitoring. While future efforts are most likely to be focused on snapper, increasing the number of replicate BUV drops as described here would also solve some of the problems of assessing change in the other species that appear in smaller numbers and/or appear in a more patchy distribution.

There are two other limitations of this BUV study which warrant discussion. Previous to this study the BUV methodology has been used for open coast applications. It is possible that in the estuarine situation, the time of tide when the BUV drop is deployed is a more important factor in influencing the number of fish present than it would be in an open coast situation where typically tide stage has been ignored. There are two possible ways to deal with this added uncertainty. The first is to test the method for changes over a tide cycle. This is a specific research project on its own and would be valuable to this study and other estuarine BUV studies. The second is to set a standard tide stage to do the BUV drops - say 1 hour either side of high tide and do all drops in this way. In the current study we carried out the survey over three days and did not standardise the tide stage. The second limitation is the spatial proximity of drop sites. In previous studies an effort was made to have a minimum of 500m between BUV drop sites. This spatial separation is designed to eliminate possible interactions between fish attracted in numbers to one BUV drop simply shifting en masse to the next proximate BUV drop and thus skewing the data. In this study because of the extremely small scale of the reserve and the non-fished reference sites this degree of spatial separation is not achievable. No sites were less than 100m from one another but about a third are between 100-200m apart with the others being 200-300m from the next closest site. The degree to which this spatial limitation affected the current survey data is unknown. Given that it would be very difficult to quantify this effect the practical solution appears to be to adopt a protocol which requires that sites with less than 500m spatial separation must be done with a certain amount of time lag or possibly on different days. The exact rule to use here needs to be determined and tested in a practical manner alongside the protocol adopted to deal with the stage of tide factor and is therefore appropriate to resolve as part of the next round of monitoring. It needs to be noted that adoption of the protocols discussed above will increase the time and therefore the cost of this work.

One of the distinct advantages of using a standardised method like BUV monitoring is to have the ability to compare results with other locations, management treatments and research programs. Table 5 below is a summary of mean snapper densities in BUV surveys conducted by the Auckland University research team. The comparable result for our study is indicated in Figure 8. In our study there were not enough legal-size snapper to calculate a mean so we can take this value as zero, and the mean for sub-legal sized snapper was just over 2 fish/BUV drop. Taken in a straight forward comparison our result is at a similar level as Mimiwhangata, but well below the other study sites. While this comparison is interesting caution must be taken in interpreting what it means because as a harbour site Motukaroro differs substantially from the Auckland University study sites which are coastal or offshore island sites. Taking this into account the snapper densities at Motukaroro appear to be comparatively low. This comparison will be useful over time if not in terms of absolute values then in terms of relative change over time in relation to differing management treatments of the sites, especially if we see large changes in the monitoring data over time.

Table 5 Mean snapper densities in BUV surveys at Poor Knights, Cape Brett, Mokohinau Islands and Mimiwhangata from: (Denny & Babcock 2004)

Mean number of snapper, *Pagrus auratus*, per BUV (+/- s.e. in brackets) at the Poor Knights, Cape Brett, Mokohinau Islands, and Mimiwhangata. The first 3 areas show data from autumn 2001; Mimiwhangata data is from autumn 2002.

	2001(autumn)			2002 (autumn)
Snapper	Poor Knights	Cape Brett	Mokes	Mimiwhangata
all	19.6 (2)	10.53 (3.7)	6.6 (0.8)	4.4 (0.9)
legal (>270mm)	13.5 (1.3)	0.9 (0.3)	0.7 (0.2)	0.3 (0.1)
sublegal (<270mm)	3.9 (0.5)	9.13 (1.2)	5.86 (0.8)	3.83 (0.9)

A bit of good news for future work has arisen from the field work this year. As part of our work this year we re-designed the BUV apparatus as pictured in Figure 3. Previous systems were designed around large steel tripod frames. The new design worked extremely well, even in some rather difficult current and visibility situations encountered in this study. While these are simple changes the new arrangement is a lot easier to use and cheaper to build than previous versions of the BUV apparatus. Some of the improvement was made possible by the use of a wide angle lens on the video camera which allowed us to shorten the vertical dimension of the apparatus considerably. This in turn allows for faster handling and a better result in reduced visibility conditions. The present system lends itself to a method where two BUVs are deployed simultaneously tethered to buoys allowing the boat and crew to move alternately between BUV units, reducing the field time by a significant factor. Another advantage of the new system is that we can use the same camera and housing that we use for the drop video habitat ground truthing work. Also the cost of building a second unit with this design would be low. We have recent built two new housings from recycled 2kg CO_2 cylinders, which are considerably lighter and easier to handle than the scuba-cylinder version. All other features are the same.

UVC fish survey

One of the biggest limitations to this UVC set is the small extent of rocky reefs within and particularly outside the marine reserve. Only three sites were set up inside and three outside the reserve. There is only room for perhaps two or maybe three more sites within the reserve, and probably only one additional reference site outside without getting an unreasonable distance away from the reserve. These additional sites suffer from the same problems as those already established, in that the small area of the reef and often lineal nature of the reefs certainly compromises any attempt at random placement. Often transects have to be carefully positioned to stay within the confines of the reef system, and this was not always achieved.

In the cases of sites A, B and D the four replicate transects radiated out from a point, but at sites C, E and F the reef was a narrow strip parallel to the shoreline. In these cases the four replicate transects effectively ran in a line parallel to the shore, with a gap of a few metres between the transect ends. It would be desirable to establish more sites, and probably use more replicates at each site, but finding sufficient reef space may not be achievable. It is not clear how this situation might effect interpretation of results, but the pattern of sampling certainly does not comply with a "random" placement required for some statistical treatments.

Because of the strong tidal currents experienced in some parts of the reserve and reference areas, the time sampling can be carried out is severely restricted at some sites. Particularly at site A west of the reserve, strong currents were experienced despite beginning well before high tide when we expected slack water. It is not known what effect sampling during a current may have on results, but it certainly makes the sampling activity a lot more difficult. With further experience it should be possible to predict times of slack water at each of the sampling sites. It is not straightforward due to the development of eddies and sometimes counter-eddies, which may be different at spring compared to neap tides, as well as changing between flood and ebb tides.

UVC and BUV fish survey methods produce very different results because of differing behaviour between species. In the Motukaroro BUV study reported in Kerr and Grace (2006), key species were spotty, snapper and trevally, with trevally numbers the highest. In this UVC study key species were spotty, goatfish, parore, and red moki, with only a few juvenile snapper seen. Particularly surprising was the lack of trevally seen, not only during the counts but also while not actually working on the transects.

It appears that the UVC survey method adopted probably produces an underestimate of the diversity and abundance of fish on the transects in the habitats encountered at Motukaroro and reference sites. Algal cover (Ecklonia and/or Carpophyllum flexuosum) is quite dense on most transects, and swimming relatively fast over the top of the kelp as required by the method means that most fish beneath the kelp canopy are missed. This was crudely tested at Motukaroro as we carried out the crayfish survey on each transect immediately after completing the fish count. The crayfish survey method involved burrowing through and under the algal cover to find all potential crayfish habitat, during which survey usually several species and more individual fish were seen which were missed during the fish survey. This problem may not occur to an important degree in open habitat areas like kina barrens or sediment areas, but in the dense algal cover at Motukaroro our crude estimate suggested that only 60 – 70% of species and individual fish on the transects were detected by the fish counting method.

UVC crayfish survey

The complete lack of legal-sized red crayfish both inside and outside the reserve was not surprising at this early stage in the history of the marine reserve, given the high level of exploitation and the corresponding low densities of crayfish generally on the Northland east coast (Shears et.al. 2006, Kerr and Grace 2007).

Sublegal crays were present on 5 transects inside, and 4 transects outside the reserve, with approximately twice the number of individuals at reserve sites compared to reference sites. This difference probably means very little at this stage, but is a good baseline for future comparison. Zero counts occurred at 7 of 12 sites inside, and 8 of 12 sites outside the reserve. It is likely the prevalence of zero counts will change as the reserve matures.

Crayfish are very patchy in their distribution, particularly in exploited populations, and in this survey area it was apparent that crayfish tended to occur in groups in specific lairs.

The design of the survey does not allow precise relocation of the transects in future, and it may be that future samplings do not count exactly the same lairs. Notes on field data sheets for this area in several sites indicated lairs of small crayfish just outside the counted areas, and it would be an accident of the method if these lairs were included or missed in future counts.

One way around this problem is to have permanently marked fixed transects, as in the historic transects worked at Mimiwhangata and Tawharanui since the mid 1970's (Shears et.al. 2006). Another way would be to work sufficient replicate transects to deal with this variation on a statistical basis, but we have already indicated there is not sufficient reef habitat available to accommodate many more transects. Consideration should be given to establishing accurately fixed transects for UVC crayfish surveys if a more precise survey is to be achieved.

Invasive species

The four invasive species noted during this survey (Limaria orientalis, Chaetopteris sp., Crassostrea gigas, and shells of Musculista senhousia) are widespread through northern New Zealand and were no surprise at Motukaroro. Future potential invaders identified by Biosecurity NZ (2005) include the kelp Undaria pinnatifida, clubbed seasquirt Styela clava, fanworm Sabella spallanzanni, seastar Asterias amurensis, green crab Carcinus maenas, another crab Eriocheir sinensis, the Asian clam Potamocorbula amurensis, and a green alga Caulerpa taxifolia.

Undaria, which is widespread in southern New Zealand, has already made it as far north as the Firth of Thames, Westhaven in Auckland, and Kawau Bay, so it seems likely it will appear in the general Whangarei area in the next few years. Styela has already been identified in several marinas in the north. One of the authors (RVG) observed populations of the fan worm Sabella spallanzanni, seastar Asterias amurensis, and the green alga Caulerpa taxifolia in the Mediterranean Sea in 2006, and recently photographed the seasquirt Styela clava in Long Bay marine reserve, so should readily recognise these species if they appear at Motukaroro.

Conclusions

Recommendations

1 Design layout of the BUV monitoring should be reviewed in the context of the discussion above regarding the increase in the number of replicates and the protocols addressing the issues around the stage of tide and spatial separation of the BUV sites.

2 Consideration should be given to increasing the number of UVC fish and crayfish sites, up to the maximum which can be accommodated within the reef areas. Perhaps 2 or 3 more sites could be fitted within the reserve, and one or maybe two in reference areas.

3 Consideration should be given to establishing existing and future UVC transects in fixed permanent locations, by installing permanent markers or finding a way to be more precise about the end points of each transect. This would avoid variations in data caused by sampling different lairs, or missing lairs included in earlier counts, of crayfish. The use of fixed permanent transects is probably of greater benefit to the crayfish survey than to the fish survey.

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Appendices

Appendix 1. BUV Data Points

Appendix 2. BUV Size Data

Appendix 3 UVC Fish Lengths Sonar Data Points

Appendix 4. UVC Site Data Drop Video Data Points

Appendix 1 BUV data points

Marsden Point Tide Note: 31/5 H 10:22am 2.4, L 4:28pm .6   1/6 H 11:08 2.3 L 5:13pm .7   2/6 H11:52am 2.3 L 5:58 .8

Wpt	Lat	Long	Eastings	Northings	Time	Uncorrected depth m.	Habitat	Date	Notes
1	-35.8264	174.4949	2645723	6596044	1407	8.1	s	31.5.06	Seechi disk (SD)4.8m. Current 1 kn. Fine sand.
2	-35.82941	174.497	2645901	6595706	1500	5.2	s	31.5.06	Too much current for SD. Current c.1.5kn. Coarse sand.
3	-35.83033	174.501	2646259	6595598	1545	6.7	s	31.5.06	SD 3.8m. Current 0.5kn. Coarse sand.
4	-35.832	174.5054	2646656	6595406	1109	17.6	s	1.6.06	end of rising tide. Current c. 0.5kn at start. SD 7.9m.
5	-35.83109	174.5042	2646548	6595509	1150	9.0	s	1.6.06	Sand with rocks nearby. First of falling tide.Current c.0.5-1 kn. Temp c. 15.1C.
6	-35.83046	174.4987	2646057	6595588	1230	9.0	s	1.6.06	Sand. Falling tide. Current c. 0.5kn.
7	-35.83098	174.503	2646440	6595523	1400	6.0	s	1.6.06	Sand. 1/2 Falling tide. Current < 0.5kn.SD 6.0m
8	-35.82967	174.5122	2647275	6595653	1440	9.0	s	1.6.06	Sand. 1/2 Falling tide. Current < 0.5kn.SD 7.4m. Temp 15.3C
9	-35.8291	174.5081	2646906	6595723	1025	4.1	s	2.6.06	Current < 0.5kn. Viz greater than 4.0m. Approaching HW.Sand/ Temp 15.0C
10	-35.85127	174.5235	2648252	6593238	1112	15.5	s	2.6.06	Current C.0.5kn. Close to HW.Viz c.6+m. Coarse sand.Photo of *Ecklonia* brought up.
11	-35.84929	174.5251	2648402	6593455	1202	9.5	s	2.6.06	Current c.0.5kn.First of dropping tide. Sand.Viz c. 6+m.
12	-35.84836	174.5269	2648566	6593556	1238	7.0	s	2.6.06	Current c. 1.0kn. Tide dropping. Viz 6+m.Coarse sand.
13	-35.85449	174.5255	2648432	6592877	1322	6.5	s	2.6.06	Current nil. Coarse sand. 15.2C. Viz greater than 6m.
14	-35.8307	174.5196	2647941	6595527	1411	9.5	s	2.6.06	Current less than 0.5kn.Viz c, 6+m.Probably coarse sand.
15	-35.82984	174.5161	2647624	6595628	1455	7.5	s	2.6.06	Probably coarse sand. Current less than 0.5m. Viz c. 6m.
16	-35.83157	174.4998	2646150	6595463	1536	16.1	s	2.6.06	Viz c.3m? Current c.1kn. Sand. Heading toward low tide.
17	-35.82934	174.4992	2646100	6595711	1616	7.0	s	2.6.06	Coarse sand. Viz c.6m. Current c.1.0kn. Toward low water.

Appendix 2 BUV size data

Note: Fish size, head to fork of tail estimate, in cm

BUV Drop Number	**1**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	22	20																
Trevally	22	22	22																
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**2**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	20	18	19																
Trevally	32	32	24	24	27	26	26	20	26	26	20	28	25						
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**3**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	23																		
Snapper	28	27	22	18	19														
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**4**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	21	27																	
Trevally	37																		
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**5**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	12	20	17																
Snapper	20	22	17																
Trevally	30	30	33	25	21	21	20	22	19										
Goatfish	23																		
Leatherjacket	29	22																	
Blue cod																			

BUV Drop Number	**6**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	27	18	20	22															
Snapper	25	25	22																
Trevally	32	36	32	32	33	34	34	36	29	33	34	30	31	30	32	27	27	29	33
Goatfish																			
Leatherjacket	32																		
Blue cod																			

BUV Drop Number	**7**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	14																		
Snapper	25	20	24	20	18														
Trevally	35	28	30	33	32	28	27	30	28	29	29								
Goatfish																			
Leatherjacket																			
Blue cod																			
John Dory	36																		

BUV Drop Number	**8**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	11																		
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**9**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	10	12																
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**10**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	24	26	20																
Snapper																			
Trevally																			
Goatfish	22	17																	
Leatherjacket	29	27	28	28															
Blue cod	27	18																	
unidentified	10	10	10																

BUV Drop Number	**11**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket	29	27																	
Blue cod																			

BUV Drop Number	**12**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	23	23	23	22	24	21	21	20										
Trevally	20	20	19																
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	13																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket	30																		
Blue cod																			

BUV Drop Number	14																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	9																	
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	15																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	12																	
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	16																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	15	18																	
Trevally																			
Goatfish																			
Leatherjacket	30																		
Blue cod																			

BUV Drop Number	17																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	20																	
Trevally	32	32	32	34	30	33	28	27	28	34	37	37	36	32	24	35	33	29	
Goatfish																			
Leatherjacket																			
Blue cod																			

Appendix 3 UVC fish lengths in centimetres. Sites and replicates inside the reserve area are shaded grey, and arranged from left to right in relation to their actual west east position.

Site & rep.		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2	F3	F4	mean, res.	mean, ref.
Species																											
Parore	cm																									32	21.6
	50												1														
	45																										
	40				3	2		2		8	5		4	4					1		1						
	35							1		10	1			1					2								
	30					5		2	1	4	4		1	1													
	25	2				2	1		1					4													
	20	2		20	20		1			1								1			1						
	15	6			2					7																	
	10									1																	
	5																										
Not recorded	NR		6									13			3			8		2		1	8	4	6		
	Tot	10	6	20	25	9	2	5	2	31	10	13	6	10	3	0	0	9	3	2	2	1	8	4	6		
Red moki	cm																									39.4	28.4
	50							1																			
	45																										
	40			1	1			3			1										2						
	35							2						1					3								
	30																				1						
	25	1	1																								
	20	1																		4							
	15																										
	10			1																							
	5																										
Not recorded	NR											1			1					3							
	Tot	2	1	2	1	0	0	6	0	0	1	1	0	1	1	0	0	0	3	7	3	0	0	0	0		
Snapper	cm																									15	12.5
	15				6			16													2						
	10				8																						
Not recorded	NR																										
	Tot	0	0	0	14	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0		

Appendix 4 UVC Site data

(a) **Reserve sites**

Site and replicate	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**	**D3**	**D4**
Zero point E	2645934	2645934	2645998	2645998	2646055	2646055	2646055	2646055	2646558	2646558	2646558	2646558
Zero point N	6595577	6595577	6595587	6595587	6595635	6595635	6595635	6595635	6595552	6595552	6595552	6595552
Direction from zero	WSW	ENE	WSW	ENE	NNW	NE	SE	S	NE	E	SE	S
Depth at zero	2.8	2.8	8.7	8.7	4	4	4	4	7.5	7.5	7.5	7.2
Depth at 30m	6.6	?	9.4	5.5	5	11.1	?	6	4.1	?	?	6.6
Habitat at zero	eck	eck	eck	eck	eck	eck	eck	eck	sand	sand	sand	sand
Habitat at 30m	eck	eck	eck	eck	eck	sand	eck	eck	eck/sand	?	?	sand
Sampling date	8.3.07	8.3.07	8.3.07	8.3.07	5.3.07	6.3.07	6.3.07	6.3.07	6.3.07	6.3.07	6.3.07	6.3.07
Approximate time	1600	1600	1500	1500	1300	1300	1200	1200	1500	1500	1530	1530
Tide state	late falling	late falling	late falling	late falling	late falling	early falling	early falling	early falling	late falling	late falling	late falling	late falling
Current	slight	slight	slight	slight	slight	slight	slight	slight	slight	slight	slight	sight
Visibility (metres)	5 to 3	5	5	5	6 to 4	5	5	6	5	5	5	5 to 6
Observer	Grace	Kerr	Grace	Kerr	Grace	Grace	Buisson	Grace	Grace	Buisson	Buisson	Grace

(b) **Reference sites**

Site and replicate	**A1**	**A2**	**A3**	**A4**	**E1**	**E2**	**E3**	**E4**	**F1**	**F2**	**F3**	**F4**
Zero point E	2645867	2645867	2645867	2645867	2647324	2647324	2647383	2647383	2648328	2648328	2648328	2648302
Zero point N	6595792	6595792	6595792	6595792	6595681	6595681	6595648	6595648	6593221	6593221	6593221	6593204
Direction from zero	WNW	NNW	ENE	E	NNW	SSE	W	NNE	NNW	NE	SW	SE
Depth at zero	6	6	7	8.7	7.8	7.8	8.4	8.4	4	3	5.7	4.8
Depth at 30m	?	8.5	7.5	10.2	3.4	9	?	6.3	?	4	4.8	3.8
Habitat at zero	eck/sand	eck/sand	eck/sand	eck/sand	eck/sand	eck/sand	eck/sand	eck/sand	eck	eck	eck	eck
Habitat at 30m	eck	eck/sand	eck/sand	eck/sand	C.flex	eck	?	eck	eck	eck	eck	eck
Sampling date	12.3.07	7.4.07	7.4.07	12.3.07	12.3.07	12.3.07	12.3.07	12.3.07	25.4.07	25.4.07	25.4.07	25.4.07
Approximate time	1415	1045	1045	1415	1615	1615	1730	1730	1400	1445	1400	1445
Tide state	early falling	early falling	early falling	early falling	mid falling	mid falling	late falling	late falling	before HW	after HW	before HW	after HW
Current	strong	strong	strong	strong	slight	slight	nil	nil	nil	nil	nil	nil
Visibility (metres)	5	4	4	5	5	5	5	4 to 5	6	6	6 to 7	6 to 7
Observer	Kerr	Kerr	Grace	Grace	Kerr	Grace	Kerr	Grace	Kerr	Kerr	Grace	Grace