Snapper (*Pagrus auratus*) abundance and size at Tūhua Marine Reserve as determined by baited underwater video (BUV) survey

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Technical report series 6

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Tuhua Marine Reserve was established in 1993 and protects an area off the northern coast of Tuhuā (Mayor Island) which itself lies approximately 26km north of Tauranga in the Bay of Plenty region. Since 1993, underwater visual surveys recorded no consistent increases in snapper (*Pagrus auratus*) abundance and size until 2008. This change appeared to be due to the Department of Conservation (DOC) increasing compliance efforts and an alteration in sampling methodology from 2004. In April 2011, a Baited Underwater Video (BUV) frame was dropped 23 times around Tuhuā Island; inside the no-take marine reserve and restricted fishing area, to record changes in fish abundance and size since the last BUV survey in 2004. The BUV survey in 2004 found a total of three snapper inside the reserve and seven outside the reserve giving a total of ten. In 2011 however, a total of 89 snapper were found inside the reserve and 31 outside the reserve giving a total of 120; showing a significant difference. From 2004 to 2011 the average sizes of snapper inside Tuhuā Marine Reserve increased by 10% and are 8% larger than the average size recorded at the Poor Knights in 2009. A number of factors relating to the methodology, equipment, choice of sites and footage must be taken into consideration when reviewing results, as difficulties were experienced in each of these areas. An increase has been recorded in abundance and size of snapper after 18 years of protection at Tuhuā, however, repeat BUV surveys will be required to confirm this trend.

Keywords: baited underwater video (BUV), snapper (*Pagrus auratus*), no-take marine reserve, restricted fishing, Tūhua (Mayor Island), Poor Knights Islands

1. Introduction

1.1 MARINE RESERVES

Marine reserves were first implemented in New Zealand in 1975, with the official opening of the first marine reserve at Leigh in 1977; thanks to the efforts of Auckland University researchers; Val Chapman and Bill Ballantine. They came up with the idea after noticing huge declines in fish and crayfish numbers in the area, and so pushed for legislation supporting reserve areas for scientific purposes after the Marine Research Laboratory in Leigh was built in 1963. Evidence suggests that marine reserves are positive for conservation and are useful tools for research, education, recreation and tourism. Benefits include species and ecosystem protection; they act as a species nursery and preserve biodiversity. It is also thought that they create a spillover effect where expanding fish populations increase and then move out of the reserve (Gell & Roberts 2003). This in turn benefits fisheries, however; evidence of this is still to be confirmed in New Zealand but has been well-documented overseas (Gell & Roberts 2003).

1.2 TŪHUA (MAYOR ISLAND) & MARINE RESERVE

Tūhua Marine Reserve is situated immediately north of Tūhua, a further 26km north off the coast from the city of Tauranga. The island is 1075ha in size, and roughly circular in shape. The island is the remains of a volcano that has gradually risen from the sea (Enderby & Enderby 2006). The Tūhua marine environs represent one of the southern-most extremes influenced by the sub-tropical East Auckland Current (Young & Smith 2007). The northern part of the island was declared a no-take marine reserve in 1993 under the Marine Reserves Act 1971. It covers three square nautical miles and extends one nautical mile out to sea, and is administered by the Tauranga Area Office, Department of Conservation (DOC). The western reserve boundary at Tumutu Point extends north-west and the eastern boundary at Turanganui Point extends north-east (Enderby & Enderby 2006). The remaining area of sea around the island is a restricted fishing zone that extends to 1 nautical mile offshore; set nets and long lines are prohibited (Enderby & Enderby 2006).

1.3 PAST SURVEYS

The marine area about Tūhua has been the site of many underwater surveys designed to document changes to the area and monitor progress of the reserve. The success of a marine reserve is generally gauged by monitoring the recovery of species that were previously targeted by fishermen in the area such as snapper (Shears & Usmar 2006). A preliminary intertidal and subtidal survey was conducted in February and May 1989 (Jones & Garrick 1991) and a baseline survey in March and April 1993 only three months after the reserve was established (Grange 1993). A baited underwater video (BUV) survey was last conducted by DOC in 2004 from which this is a continuation, while underwater visual surveys are conducted annually by DOC and the Bay of Plenty Polytechnic Marine Studies Department. This past data gathered on snapper has enabled comparison of abundance and sizes over time around Tuhuā. After the 2004 BUV survey, Shears & Usmar (2006) concluded that there appeared to have been no response of carnivorous reef fish in either management area (no-take or restricted fishing) after 10 years of protection. Therefore, another BUV survey was conducted in 2011 to assess if there has been a change in snapper abundance and size at Tuhuā since 2004. Studies have shown that there are many factors that affect the rate of recovery of targeted species including initial population size, size of reserve and annual variations in success of individual recruitment events (Babcock *et al.* 2010).

Data for 2011 was obtained using the same BUV techniques and GPS marked sites previously determined in 2004, inside and outside the reserve. BUV allows a frame with a camera and bait attached to be lowered down the water column and set on the bottom for a pre-determined amount of time. Footage captured is then analysed. This technique eliminates the bias of divers who may not be able to identify species or estimate numbers and sizes of fish correctly. It also ensures the fish don't behave differently as they often would with divers in the water. Of course, due to the bait, this technique only attracts carnivorous fish such as snapper. To conclude whether there is a difference or not in snapper abundance and size inside the no-take marine reserve, results are compared between the no-take and the restricted fishing management areas and to BUV results from 2004.

1.4 SNAPPER (*Pagrus auratus*)

Golden-pink to tones of red above, flecked with blue spots, with the colour paling to white on the belly (NZSIC 2007) snapper, from the family *Sparidae,* can reach 100cm in length and live at all depths down to around 200m (Doak 2003). They have a large head, strong teeth, moderately firm scales and semi-firm flesh with low oil content excellent for cooking; making them an important fish commercially. They are presently one of the largest and most valuable coast fisheries species (NZSIC 2007) in New Zealand. They extend over a wide variety of habitats including reefs as well as sand and mud bottoms. The young live inshore in summer, in shallow, sheltered habitats and move offshore in winter (NZSIC 2007). Roux De Buisson (2010) reiterated that increased abundances of fish have been shown to affect entire reef systems due to close links between fish, algae and invertebrates. Spawning can occur for four months from spring to early summer where sperm and eggs are released together into the water column. Snapper are frequent at Tuhuā and as a target species, are useful to monitor as they often give an indication of fishing pressure; especially as they are an extremely adaptable fish with a broad feeding niche including invertebrates and small fish (Doak 2003).

1.5 POOR KNIGHT'S ISLAND

The Poor Knights Islands are located some 24km off the east coast of Northland and are also influenced by the East Auckland Current. They were established as New Zealand's second marine reserve in 1981, however only 5% of the marine reserve was fully protected with limited recreational fishing and spear-fishing allowed in the other 95% (Enderby & Enderby 2006), similar to the current situation at Tuhuā. The islands became a full marine reserve in 1998, extending 800 metres out from the main islands and including all other rocky outcrops and islets above the low water mark (Enderby & Enderby 2006). The establishment of a full marine reserve was intended to ensure that populations of fish associated with the subtidal reefs at the islands would be protected (DOC 1995). Since full protection, the Poor Knights compared to Mimiwhangata Marine Park which has partial protection, have shown great increases in reef fish numbers including snapper. This has shown that partial protection mechanisms do not effectively protect some species of reef fish (Roux De Buisson 2010). The islands are considered one of the most important offshore nature reserves in New Zealand and are vital for scientific research, tourism and recreational diving and snorkelling.

BUV data from the Poor Knights Islands between 1981 and 1998 indicated that snapper populations did not recover under partial protection and were not significantly greater than at Cape Brett and the Mokohinau Islands which were open to recreational and commercial fishing (Roux De Buisson 2010). This is similar to trends seen after the BUV survey at Tuhuā in 2004. In 2009, after more than ten years of no-take protection at the Poor Knights the BUV survey found that snapper counts were 14 times greater than in 1998 before the marine reserve became fully no-take and estimated snapper biomass per baited video camera was 528% greater (Roux De Buisson 2010). In comparison, the numbers of snapper recorded in Tuhuā marine reserve in 2004 were very low compared to other reserves in northeastern New Zealand (Anon 2011). Further comparisons with the Poor Knights are made with this survey.

1.6 HYPOTHESIS

The success of a marine reserve is often shown by the population growth of a fish species in the area. So the main objective of this survey was to;

- Examine the abundance and sizes of snapper within and about the Tuhuā Marine Reserve and make comparisons with 2004 BUV data at Tuhuā and 2009 BUV data at the Poor Knights.
- The null hypothesis states; that there is no significant difference in abundance and size of snapper between the no-take marine reserve and restricted fishing area at Tuhuā Marine Reserve in 2011 or since the last BUV survey in 2004 and compared to the Poor Knights Islands Marine Reserve BUV survey in 2009.

2. Methods

2.1 BAITED UNDERWATER VIDEO

There were 37 drop sites around Tuhuā all with fixed GPS waypoints surveyed in 2004. This survey used the same GPS waypoints, but not all drop sites were surveyed due to rough weather conditions and some drop sites footage was unusable. Therefore, 22 existing waypoints and one new waypoint (#38)[1] are used for the results of this survey (Appendix 1). To assess differences between no-take and partial protection, the marine reserve was divided into four management areas, which were compared with five adjacent management areas in the restricted fishing zone (two at the western end of the reserve and three at the eastern end that encompassed Tuhuā Reef) (Anon 2011), see Figure 1. Shears & Usmar (2006) used this sampling design because it had been used in numerous other studies of fish in New Zealand marine reserves with dual advantages. These included ensuring that the reference areas were similar to the reserve areas, and it enabled the detection of any edge effects such as fishing impacts on the reserve or cross-boundary movements into or out of the marine reserve (Shears & Usmar 2006). In each of the nine management areas, between one and four drops were completed. Sampling occurred between the 5th and 7th April 2011 from the Department of Conservation vessel 'Rewa'.

[1] The additional site (waypoint #38) was chosen by Paul Buisson as the weather was not conducive for sampling at certain sites and he wanted a location on the sand (without issues with *Ecklonia* sp.) in the general sampling area.

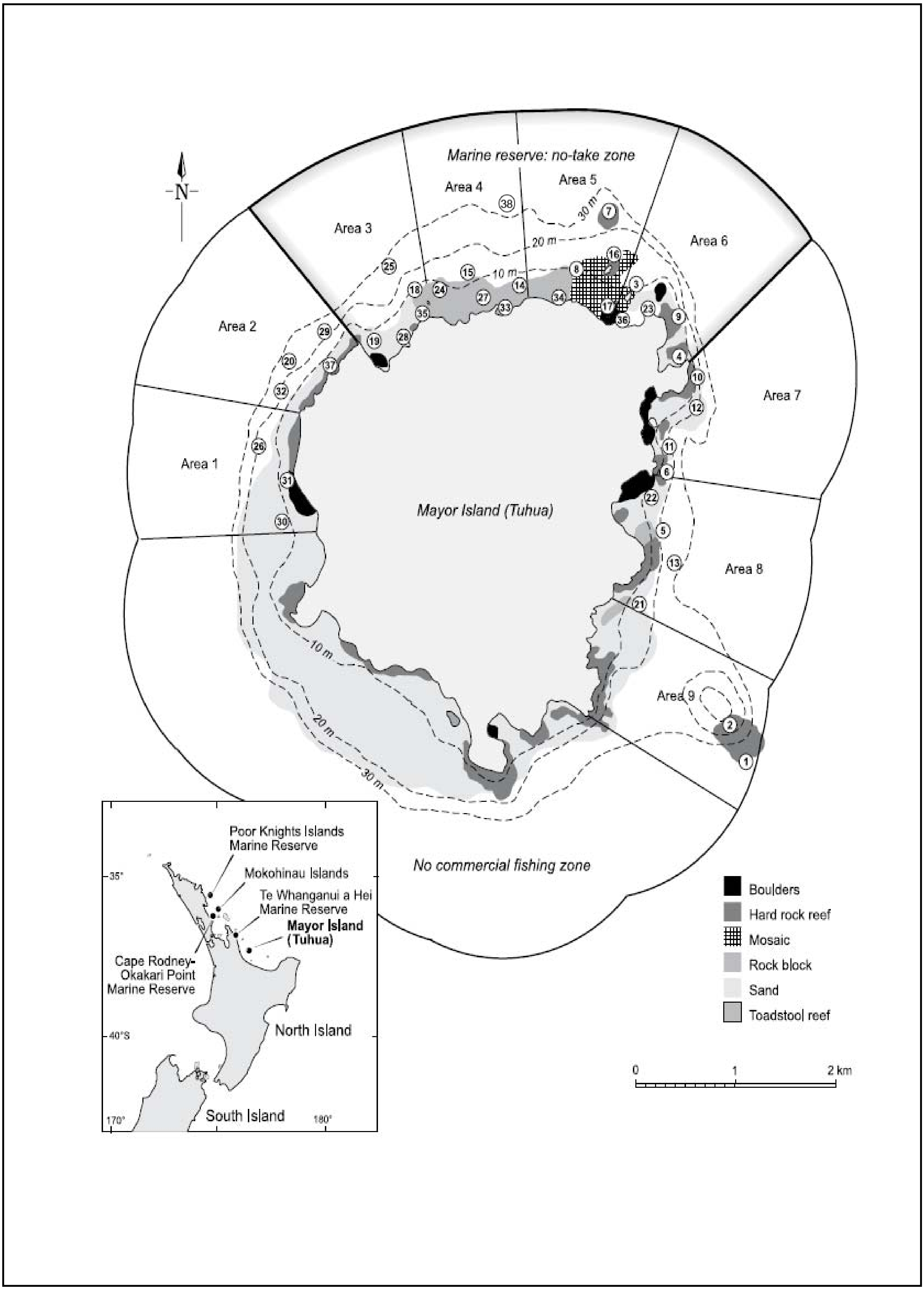

Figure 1: Map of Tuhuā (Mayor Island) showing drop sites for the baited underwater video (1-38) in April 2011. Insert map shows location of Tuhuā and Poor Knights Islands marine reserves in New Zealand (from Shears & Usmar 2006) – repeated with permission.

Baited underwater video (BUV) was used to assess the abundance and size distribution of predatory reef fish such as snapper (Roux De Buisson 2010). It provides most effective comparative results when used inside and outside marine reserves in New Zealand. This technique allowed the sampling of carnivorous species, which can be difficult to sample for divers conducting underwater visual surveys. It has the ability to go to greater depths and for longer amounts of time than divers can.

The BUV unit consisted of a two-sided triangular stainless steel frame with a video camera in a housing attached to it, directly above a bait pot, which filmed fish attracted to it when dropped into the water from the vessel (Figure 2). The unit was attached to a rope and a surface buoy so it could be relocated and in order to stay upright on the sea bed, the frame had a pressure buoy attached to it. The bottom frame of the unit was taped in black and white in 100mm blocks for visual reference. The bait pot of known length (94mm) was used as a fish size indicator during analysis and was half filled with fresh bait (cut up pilchards) then a whole pilchard attached with rubber bands to the outside before each deployment. Each drop was placed a minimum distance of 50m away from another deployment location, to avoid potential effects on fish behaviour due to interference between baited videos (Roux De Buisson 2010).

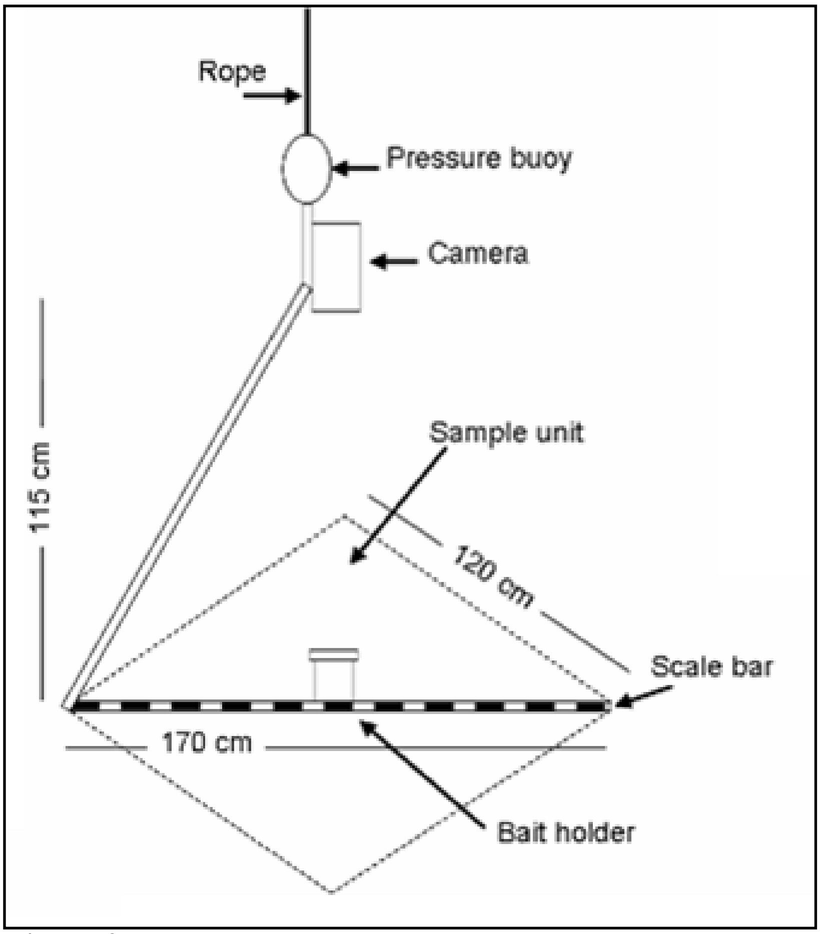

Figure 2: Baited underwater video system (adapted from Roux De Buisson 2010).

On each deployment, a live feed camera on a reel was attached to the BUV unit to ensure that the frame was placed correctly and not dropped in an *Ecklonia* sp. forest, which could block the view of the camera (Figure 3). This feed was viewed on a monitor at the surface and the umbilical camera removed by a quick release once the frame was in place. The BUV unit was left filming on the sea bed for 30 minutes then pulled back up. Each drop had the site number, weather conditions, lat-long coordinates, time in, depth, substrate, habitat type, time out and any field comments recorded.

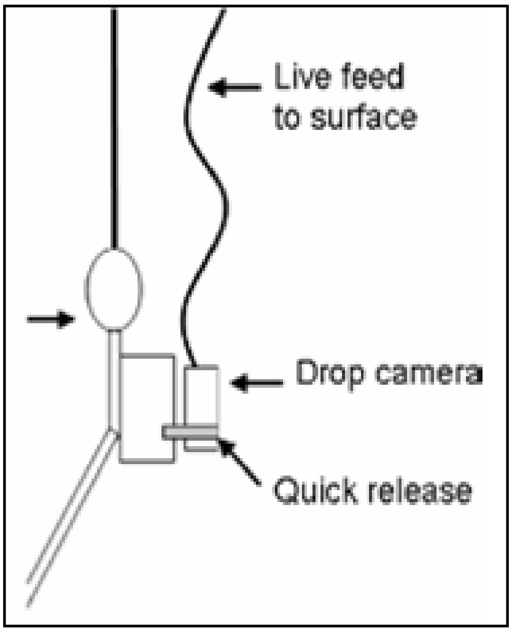

Figure 3: Live feed to surface (adapted from Roux De Buisson 2010).

2.2 FOOTAGE ANALYSIS

The BUV footage was copied onto a hard drive from the video camera for analysis and archiving. It was analysed during the months of June to August 2011 and for each 30 minute drop sequence, the footage was judged to ensure each drop fell into the same criteria as the others. Because of this some footage was deemed unsuitable for a number of reasons including, *Ecklonia* sp. blocking the camera therefore the view; the pressure buoy came loose causing the frame to lay flat on the sea bed instead of upright, or the bait pot was lost. Watched in real time, for each video, the frame containing the maximum number of snapper was recorded detailing the time and quantity, for example time and quantity (Figure 4).

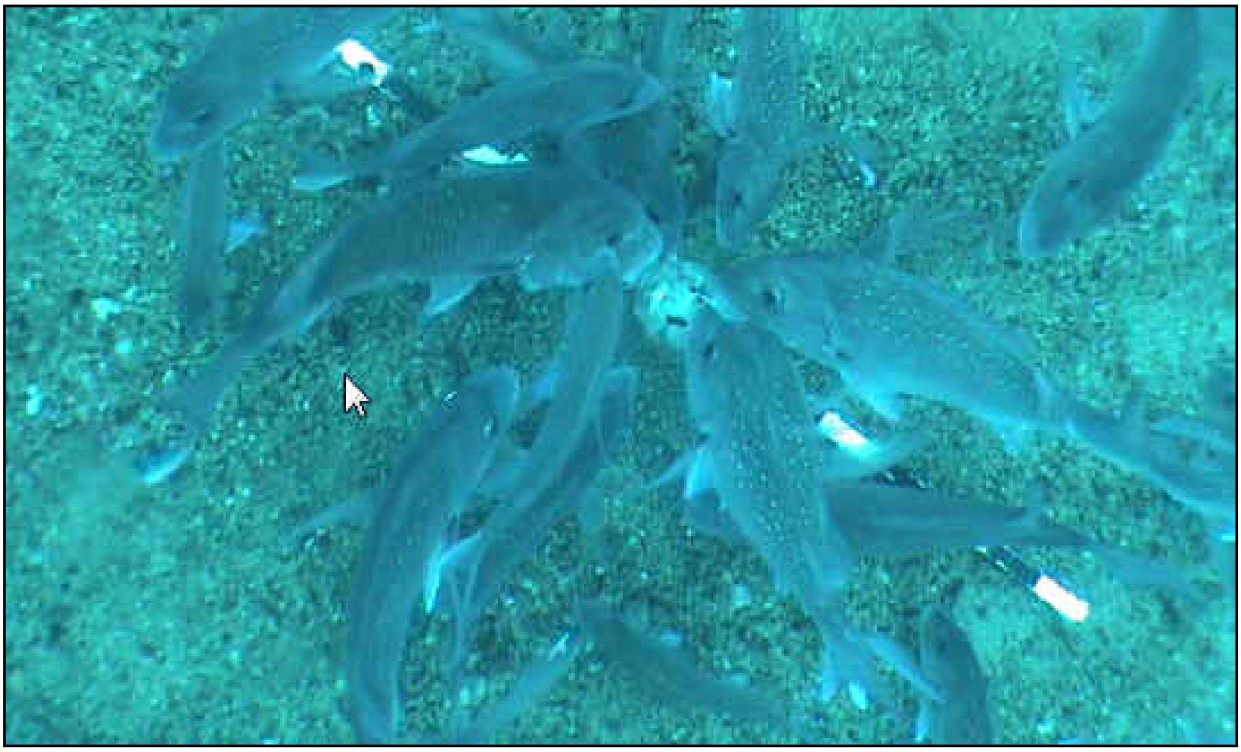

Figure 4: Still from BUV footage, site MI-38.

Utilising the UTHSCSA ImageTool, pictures of these frames were saved from the video sequence and used to measure the length of each snapper. The fish length was calibrated against the bait container of known length within the baited video's field of view (Roux De Buisson 2010). Because the video camera was not bi-focal, care was taken to accurately measure fish length. Fish were measured using three point calibration and were only measured when they were at the same level as the calibration point of known length; the bait container (Roux De Buisson 2010). Measurements were taken from the tip of the mouth to the fork of the tail for each snapper and care was taken to ensure fish were measured accurately and not measured twice.

2.3 STATISTICAL ANALYSIS

Statistically the BUV data was first analysed using descriptive statistics producing means, standard deviation, standard error and confidence intervals. Tables (Appendices) and graphs were arranged showing comparisons and error bars. Abundance and size data was further analysed using a one way ANOVA and then a two-sample t-Test assuming equal variances comparing each drop, area, inside and outside the reserve and each year. The Chi-Square test was then used to establish a test of independence for each comparison. Mean snapper length from the video frame with the maximum number of snapper was converted to wet weight biomass using the following formulae from (Taylor and Willis, 1998) from (Roux De Buisson 2010);

$W = aL^b$, where; W is weight (g),
a is 7.194×10^{-5},
L is length (mm) and,
^{b} is 2.793.

2.4 COMPARISON

This data compared snapper abundance and sizes between the no-take and restricted fishing areas, the nine management areas and each drop site. This was also compared to the data sets from the last BUV surveys at Tuhuā in 2004 as well as the Poor Knights Islands in 2009 and compared maximum numbers seen and average sizes overall.

3. Results

A total of 30 out of 38 waypoints had the BUV deployed at Tuhuā in April 2011. Eight waypoints were not surveyed due to difficulties dealing with adverse weather conditions. The footage from 30 waypoints was analysed and of these 23 were judged suitable for data collection as the others did not fit within the criteria required for the survey. Of these, eight were inside the no-take reserve and 15 were inside the restricted fishing area. Comparisons with the BUV data from 2004 were made with the same 23 drop sites surveyed here in 2011.

3.1 SNAPPER ABUNDANCE

In 2011, a total of 120 snapper were seen, 25 of which were at the new site MI-38. In 2004, all comparative sites except three had a result of zero snapper seen however, seven snapper were seen at site MI-20 outside the marine reserve whereas in 2011 the number dropped to two (Figure 5). Although, numbers of snapper for most drops in 2011 increased greatly since 2004. A total of 24 more snapper were seen outside the reserve than in 2004. One drop inside the reserve and seven outside saw no snapper at all in 2011. The spread of each drop data in 2011 is wider inside the reserve (s.d. = 7.2) compared to outside the reserve (s.d. = 3.4).

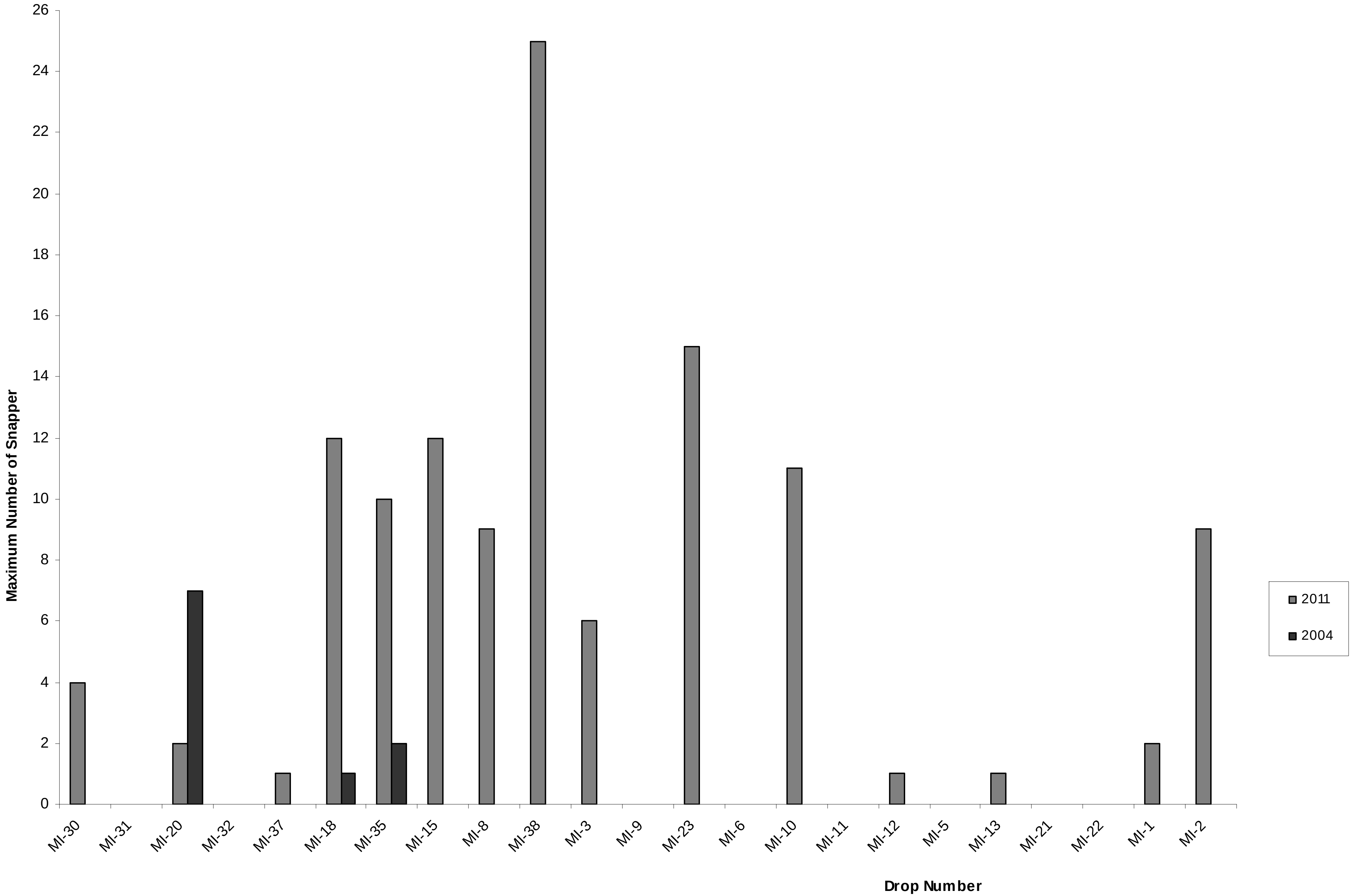

Figure 5: Maximum number of snapper per drop no. recorded from 23 BUV drops inside and outside Tuhuā Marine Reserve April 2011 and March 2004.

In 2011 the highest number of snapper was seen in area 5 (n=34) inside the reserve with a mean and confidence interval of 17 ± 15.68 whereas, in 2004 the highest was seen in area 2 (n=7) outside the reserve with a mean and confidence interval of 2.33 ± 4.57 (Figure 6). All areas inside the reserve had higher means than outside in 2011. The highest number of snapper outside the reserve in 2011 was in area 9 at Tuhuā Reef (n=11) with a mean and confidence interval of 5.5 ± 6.86. The error bars for area 2 and area 3 do not overlap showing that there is a significant difference in mean numbers of snapper between 2011 and 2004 in these areas.

For 2011, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.04212 where $p<0.05$; so we can accept the alternate hypothesis that the abundance is different between the nine areas. However, for 2004 the p-value was 0.56285 where $p>0.05$; so we can accept the null hypothesis that the abundance was the same between the nine areas.

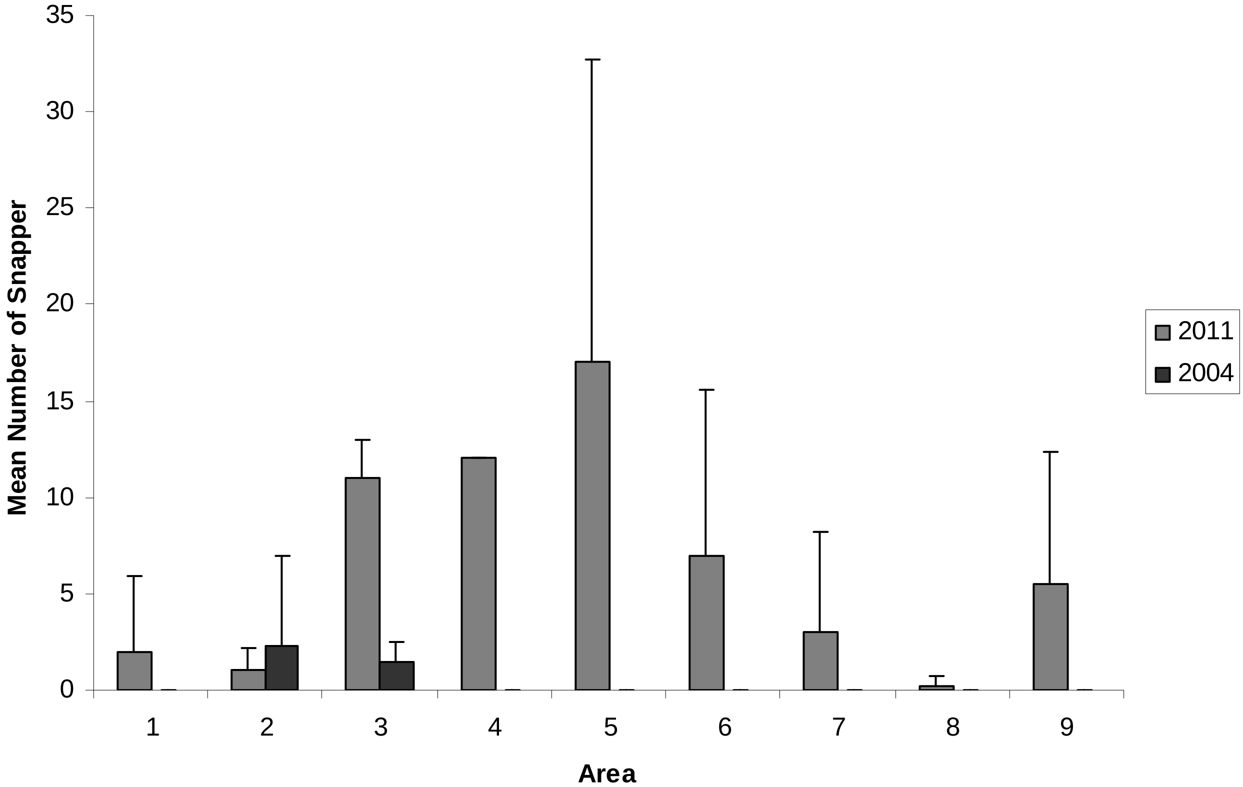

Figure 6: Mean number of snapper per Area recorded from 23 BUV drops inside and outside Tuhuā Marine Reserve April 2011 and March 2004.

In 2011; from 120 total snapper seen; 89 were seen inside the no-take reserve and 31 inside the restricted fishing area. This is 12 times more snapper than the total seen in 2004; a 2,867% increase inside the reserve and 343% increase outside the reserve. There was a mean number of 11.125 ± 5.003 snapper inside the no-take reserve and 2.067 ± 1.737 inside the restricted fishing area (Figure 7). The error bars do not overlap inside or outside the reserve showing that there is a significant difference in mean numbers of snapper between each area and each year.

For 2011, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.000488491 where $p<0.05$; so we can accept the alternate hypothesis that the abundance is significantly different inside and outside the reserve. This was also seen in the chi-square test of independence where $p=1.19244E^{-}7$. However, for 2004 the p-value was 0.893 where $p>0.05$; so we can accept the null hypothesis that the abundance was the same inside and outside the reserve. This was also seen in the chi-square test of independence where p=0.205903321.

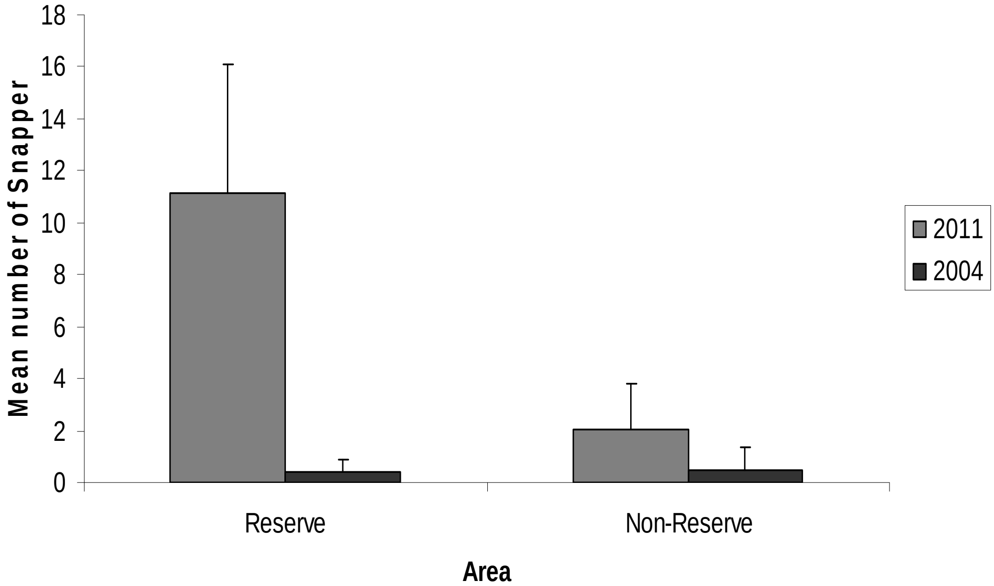

Figure 7: Mean number of snapper inside and outside Tuhuā Marine Reserve recorded from 23 BUV drops April 2011 and March 2004.

The mean number of snapper seen in 2011 was 5.2 ± 2.7; this is compared to a mean of 0.43 ± 0.61 snapper seen in 2004 (Figure 8). The error bars do not overlap showing that there is a significant difference in mean numbers of snapper between 2011 and 2004.

For the survey years, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.001488226 where $p<0.05$; so we can accept the alternate hypothesis that the abundance is significantly different between the years 2011 and 2004. This was also seen in the chi-square test of independence where $p=5.03008E^{-22}$.

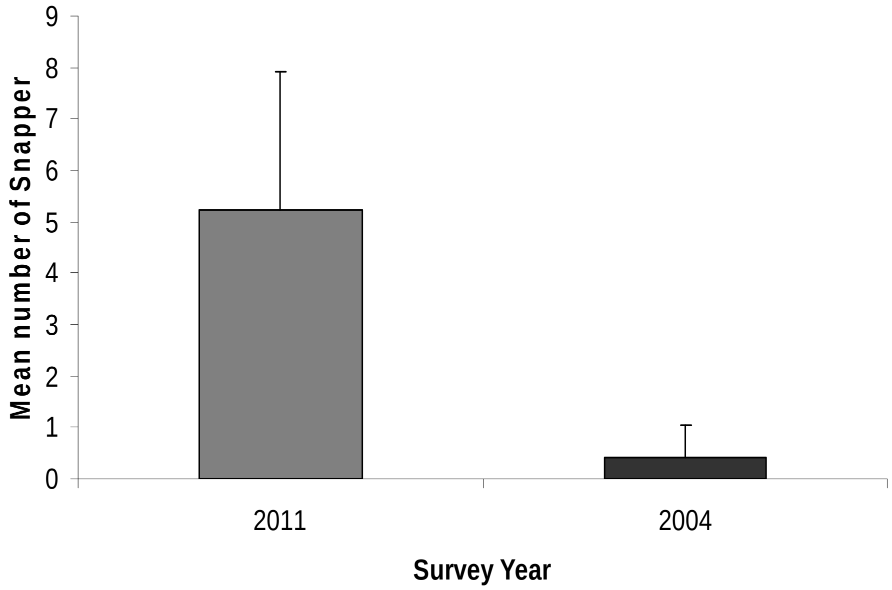

Figure 8: Mean number of snapper recorded from 23 BUV drops inside and outside Tuhuā Marine Reserve April 2011 and March 2004.

3.2 SNAPPER SIZE

Of the 120 snapper seen in 2011, only 115 were able to be measured but all 10 snapper from 2004 were measured. In 2011, the highest mean size of snapper were seen at site MI-23 inside the marine reserve (464.41mm ± 71.81) whereas the highest mean size of snapper in 2004 was seen at site MI-18 also inside the marine reserve (386mm ± 0 (only one sample fish)) (Figure 8). The smallest mean sizes for both years were seen outside the marine reserve. All means were above the legal recreational catch size limit of 270mm. The mean size of snapper seen per drop in 2011 (without taking into account drops with zero fish) was 371.69mm ± 27.83 compared to 341.36mm ± 60.92 in 2004. The spread of each drop data in 2011 (s.d. = 51.19mm) is less than that when compared to 2004 (s.d. = 53.83mm). Also in 2011, the largest individual size overall was seen in site MI-23 inside the reserve with 714.81mm (a 66% increase in largest size compared to 2004) and the smallest in site MI-2 at Tuhuā Reef outside the reserve with 211.47mm. These are similar findings to those in 2004 where the largest individual size overall was seen in site MI-35 inside the reserve with 430mm and the smallest in site MI-20 outside the reserve with 213mm.

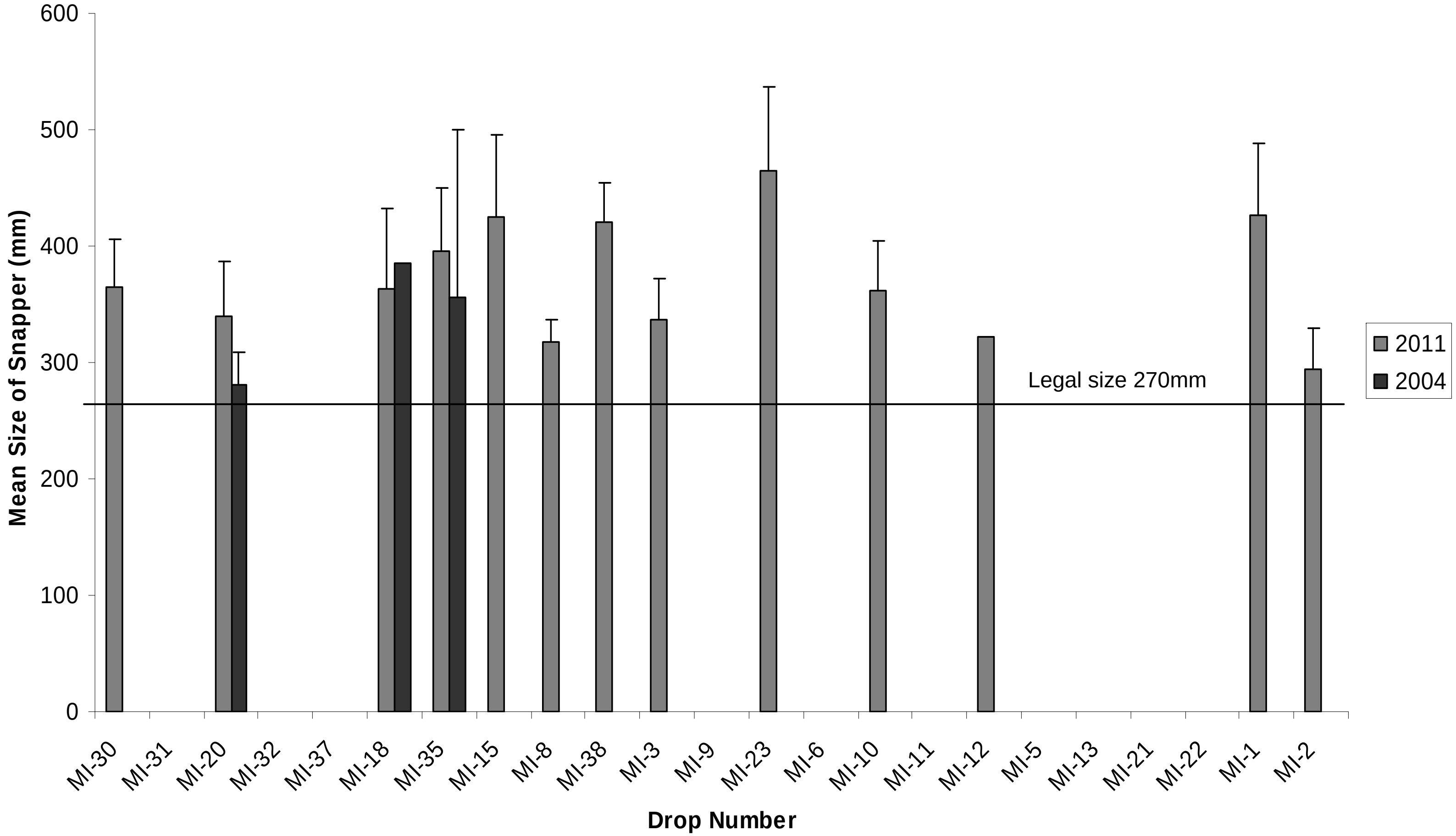

Figure 9: Mean size of snapper per drop no. recorded from 23 BUV drops inside and outside Tuhuā Marine reserve April 2001 and March 2004.

All areas inside the reserve in 2011 had higher mean sizes of snapper than the areas outside the reserve and all areas in 2004 (Figure 9). The highest mean size of snapper was seen in area six inside the reserve (427.99mm ± 57.46) in 2011. In 2004, area three also inside the reserve saw the highest mean size of (366.33mm ± 85.38). The error bars for area two do not overlap showing that there is a significant difference in sizes of snapper between 2011 and 2004 whereas the error bars overlap in area three showing no significant difference in mean sizes of snapper between years in this area.

For 2011, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.14843 and for 2004 the p-value was 0.9875 where p>0.05 for both; so we can accept the null hypothesis that the mean sizes are the same between the nine areas for both years.

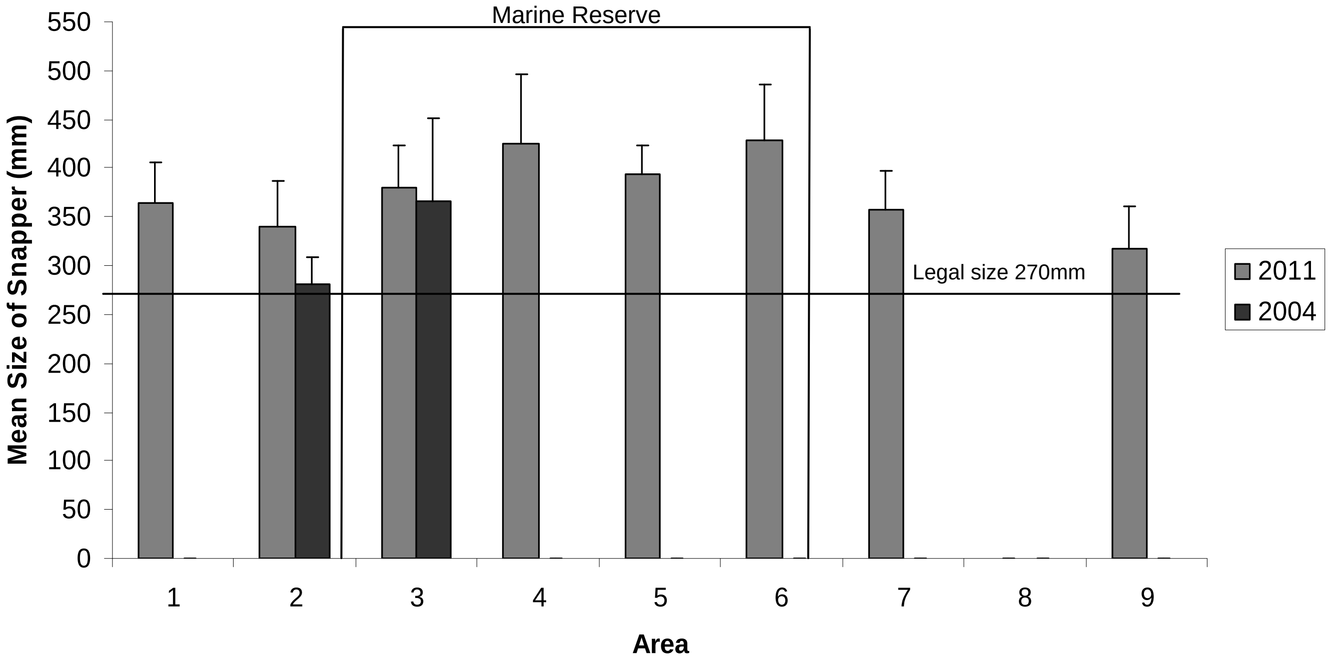

Figure 10: Mean size of snapper per Area recorded from 23 BUV drops inside and outside Tuhuā Marine Reserve April 2011 and March 2004.

All areas inside the reserve in 2011 had higher mean sizes of snapper than the areas outside the reserve and all areas in 2004 (Figure 10). The highest mean size of snapper was seen in area six inside the reserve (427.99mm ± 57.46) in 2011. In 2004, area three also inside the reserve saw the highest mean size of (366.33mm ± 85.38). The error bars for area two do not overlap showing that there is a significant difference in sizes of snapper between 2011 and 2004 whereas the error bars overlap in area three showing no significant difference in mean sizes of snapper between years in this area.

For 2011, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.14843 and for 2004 the p-value was 0.9875 where p>0.05 for both; so we can accept the null hypothesis that the mean sizes are the same between the nine areas for both years.

In 2011, the mean snapper size inside the reserve was 403.6mm ± 22.7 whereas in 2004 it was 366.33mm ± 85.38; a 10.17% increase. The larger confidence interval in 2004 indicates a less reliable dataset however. Outside the reserve, snapper sizes increased by 21.56% from 2004 with 281.57mm ± 27.05 to 342.32mm ± 24.29 in 2011 (Figure 11).

For 2011, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.004713689 where $p<0.05$; so we can accept the alternate hypothesis that the sizes are different inside and outside the reserve. The chi-square test of independence produced the same outcome; $p=0.024850279$ where $p<0.05$. For 2004, the p-value was 0.03721885 where $p<0.05$; so we can also accept the alternate hypothesis that the sizes were different inside and outside the reserve. This was also seen in the chi-square test of independence where $p=0.000868764$. The error bars for 2011 and 2004 inside the reserve overlap indicating no significant difference between the years inside the reserve however, they do not overlap outside the reserve showing a difference in mean sizes of snapper between the years outside the reserve.

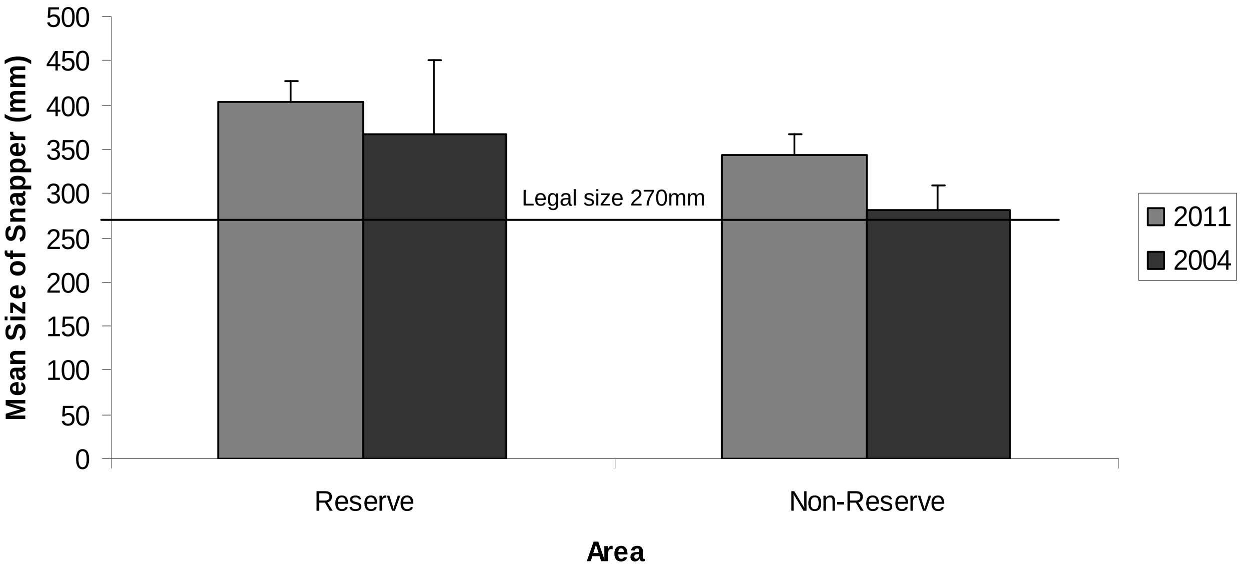

Figure 11: Mean size of snapper inside and outside Tuhuā Marine reserve recorded from 23 BUV drops April 2011 and March 2004.

Overall, the mean size for snapper in 2011 was 388.147mm ± 18.6616, whereas in 2004 the mean size was 307mm ± 38.36 (Figure 12), an increase of 26.43%. For the survey years, a single factor ANOVA and t-test two sample assuming equal variances gave a p-value of 0.014945025 where $p<0.05$; so we can accept the alternate hypothesis that the mean sizes are different between the years 2011 and 2004. This agrees with the chi-square test of independence where $p=0.002085626$ and is also emphasised by the error bars not overlapping.

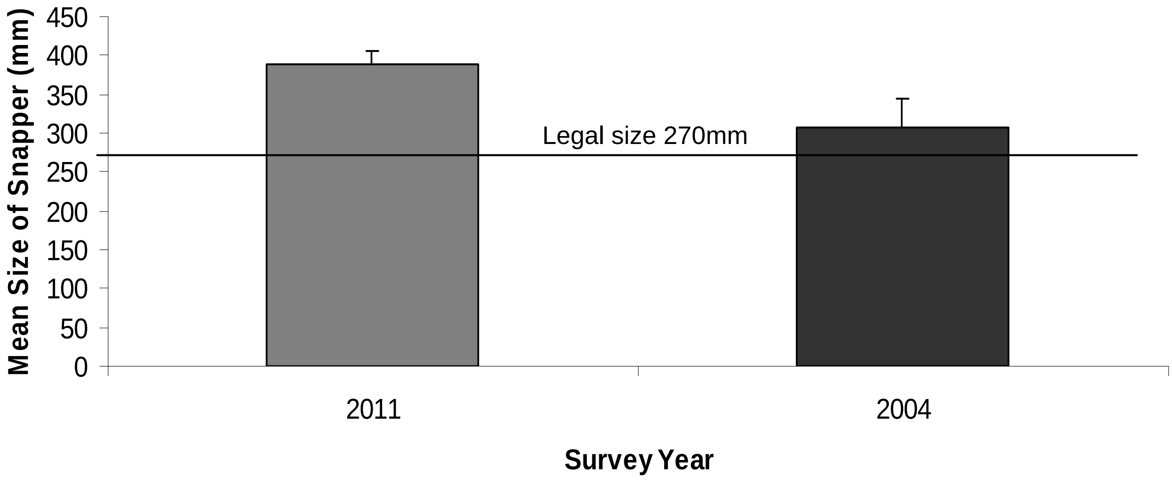

Figure 12: Mean number of snapper recorded from 23 BUV drops inside and outside Tuhuā Marine Reserve April 2011 and March 2004.

For 2011, the mean wet weight biomass per snapper was 1225grams (1.2kg) compared to 636grams (0.6kg) in 2004. Inside the reserve was 1366grams (1.4kg) compared to 862grams (0.9kg) outside in 2011 and 1042grams (1kg) inside the reserve compared to 500grams (0.5kg) outside in 2004. This shows a clear increase in mean wet weight biomass per snapper between the no-take marine reserve and restricted fishing zone as well as between the two survey years.

Taking into account the variances of temperature, ranging from 18.9ºC to 19.4º; habitats, ranging from sand to reef with *Ecklonia* sp.; and times of drops, ranging from 0900 to 1700; there seems to be no correlation between these factors and number of snapper seen or sizes for either 2011 or 2004.

3.3 THE POOR KNIGHTS

The BUV survey from 2009 at the Poor Knights found an ever increasing abundance of snapper over the years. In 2009, the maximum number seen at one drop was 36 with an average seen per drop being 20 snapper. Compare this to the maximum number seen at one drop at Tuhuā in 2011 with 25 and an average seen per drop of 11 snapper inside the reserve only. These Poor Knights figures however were sampled in summer and it has been noted that summer recorded counts were consistently significantly higher than winter counts (Roux De Buisson 2010). Tuhuā sampling in 2011 occurred in autumn. Prior to implementation of no-take status in October 1998 at the Poor Knights, the average maximum snapper count from winter baited video samples in 1998 was 1.5 (Roux De Buisson 2010).

The average size of snapper at the Poor Knights in 2009 was 373mm ± 16 (Roux De Buisson 2010). However, the average size of snapper inside Tuhuā Marine Reserve in 2011 was larger at 403.60mm ± 22.33; an 8% difference.

4. Discussion

Marine Reserves are an important ecological haven for marine flora and fauna (Babcock et al. 2010). In 1993 the Tuhuā Marine Reserve was established. Since then, many surveys including the Baited Underwater Video (BUV) technique have been conducted to monitor changes in the Tūhua marine environment. This survey was conducted in 2011 and focused on the abundance and size of snapper (*Pagrus auratus*) then compared findings to 2004 data and information from the Poor Knights survey in 2009.

4.1 RESULTS

The results are generally clear for all variables making conclusions sound. However, some discrepancies could be due to the general lack of snapper seen in 2004 to compare to. It is however clear that there is a significant difference between the abundance of snapper in 2011 and 2004 with much more seen in 2011. There is also a significant difference between the management areas and inside and outside the reserve in 2011 however, the abundance was regarded the same in these areas in 2004. This could also be due to the small numbers of snapper seen in 2004.

The sizes of snapper is interesting as the management areas for both years saw no significant difference however overall there was a difference between sizes seen in 2011 and 2004 but this was not significant. There was a difference between the reserve and non-reserve in 2011 with the larger snapper generally found inside the reserve. In 2004 also, there was a difference in sizes inside and outside the reserve perhaps again due to the lack of snapper actually seen.

There is also a significant difference in abundance and sizes of snapper inside Tuhuā Marine Reserve and inside the Poor Knights Islands Marine Reserve where much more on average are seen at the Poor Knights however, the average sizes are larger at Tuhuā. Therefore, there is a small basis to recommend expanding the Tuhuā Marine Reserve to the whole coastline of Tuhuā in order to encourage more recovery of snapper numbers. To resolve the effects of no take protection on reef fish through time at the Poor Knights, summer and winter counts have been analysed and graphed separately to remove the influence of seasonality among years (Roux De Buisson 2010). We recommend that the BUV sampling should occur more often and during different seasons at Tuhuā to see if this trend also exists.

Some reasons for the lack of snapper seen in 2004 or even outside the marine reserve in 2011 could be depth and water temperature. Snapper occupy shallow sheltered habitats during their first summer, moving to deeper coastal water in winter; these seasonal inshore-offshore movements continue through life (Paul 2000). These local movements also occur in response to tides, weather and seasonal food supplies (Paul 2000). When the surface water reaches 18ºC in summer, schools aggregate in open water (Doak 2003).

The direct effects of fishing have indirect effects on the structure and function of marine ecosystems (Moore & Jennings 2000). Marine reserves can be used as control grounds for comparisons with fished areas (Moore & Jennings 2000). Fishing alters the age and size structure of populations as older and larger fish are often removed first, eventually the fishery is supported by the small newly recruited individuals (Hart & Reynolds 2002). The length of a fish can be measured more easily and accurately than weight under field conditions, so length measurements are the most convenient method of growth expression (Hart & Reynolds 2002). The increase in abundance and sizes at Tuhuā Marine Reserve has given a positive outlook for these factors.

Syntheses of research from around the world have shown that the creation of reserves closed to fishing does yield rapid increases in abundance, body size and diversity of marine communities. Reserves can therefore provide an important fishery management tool by putting back refuges that fishing has eroded away during the last century (Hart & Reynolds 2002). Current understanding of marine reserves suggests they will deliver maximum benefits when they cover between 20-50% of every habitat and biogeographic region of the oceans (Hart & Reynolds 2002).

4.2 METHODS

Due to adverse weather conditions and equipment issues not all sites surveyed in 2004 were surveyed in 2011. This was unfortunate as comparative data was then limited especially inside the reserve but provides discussion for improvement.

4.2.1 Equipment

Certain factors in regards to the equipment often proved difficult for the survey. A major issue was keeping the gear consistent. The angle of the frame was a factor as well as the positioning of the camera inside the case. Sometimes the camera could see past the frames end while others not. This could be due to the placing of the camera housing onto the frame where there was a choice of holes to screw into, some higher and some lower.

It is important to secure the bait pot properly as on site MI-29 the pot came loose on the way down so there was nothing on the frame to attract the fish when the frame was settled on the seabed, a complete waste of a drop. It was also often difficult to identify some species due to depth and not being able to make out true colours; perhaps a light needs to be attached so colours can be easily seen.

The quick release used for the live feed camera were rubber bands that were broken off when the feed was brought back to the surface and left to litter the seabed. We consider that this is a pollutant as by the end of the survey, a whole jar of rubber bands ended up in the sea. This is also harmful to fish as on site MI-31 a Trevally (*Pseudocaranx dentex*) ate the rubber band and throughout other drops, fish would often nibble on the rubber bands. Rubber band alternatives could include string (attached to the rubber bands and the frame), Velcro or magnets that come apart when pulled.

There were many issues with the frame moving from its site due to the swell and surgy weather which may have skewed results. The frame often continuously dragged along the seabed, jolted up and down or swayed side to side (sometimes banging against a rock) perhaps frightening away fish and leaving the GPS marked waypoint. Boat noise was often heard and could also be a contributing factor to lack of fish. Other consequences of this include damage to flora and fauna for example; an eel got squashed by the frame as it dragged on site MI-8 and many other sites destroyed some *Ecklonia* sp. and benthic/encrusting organisms when pulled up or dragged.

Associate Professor Euan Harvey from the School of Plant Biology/Oceans Institute at the University of Western Australia places his BUV frame flat on the seabed rather than upright (Euan Harvey *pers comm* 2011). Perhaps it is better this way to reduce movement of the frame and to get a broader view of the surrounding fish. This was seen at site MI-26 when the pressure buoy came loose and was seen to be quiet effective.

It was also noted that perhaps a sand habitat has more pelagic fish swimming above the frame out of view. It appeared that a lot of the restricted fishing sites were on sand whereas the sites inside the reserve were often near *Ecklonia* sp. The frame was more likely to move along the sand in the surge instead of stay in the same position. Perhaps the survey should have been delayed until there were calmer conditions.

This sampling design however has been proven to provide adequate data in fish abundance studies at the Poor Knights. The design has the dual advantages of ensuring that reference areas are similar to reserve areas, and enabling the detection of any edge effects that might be related to the encroachment of fishing effects into the reserve or cross-boundary movements into or out of the marine reserve (Anon 2011).

4.2.2 *Footage*

All drops footage was viewed but not all selected for the data collection due to not fitting inside the survey criteria. Such problems as the video camera battery dying before the 30 minutes was up, the movement and positioning of the frame and losing the bait pot occurred. Site MI-7 had lots of snapper for example but the footage was deemed unsuitable as there was heaps of *Ecklonia* sp. in the way of the camera blocking the view. Some sites had no fish at all which could be due to positioning of the frame either next to a boulder or there were simply no fish on a deep sand flat outside the reserve such as site MI-6. When pulling up the frame there were still no fish in sight. It was interesting to see that the fish tended to go for the chopped bait inside the pot first rather than the whole pilchard on top. The common trend was that it took a while for the snapper to show up, but then for numbers to snowball when they do. Perhaps the amount of bait restricts the numbers coming or the time frame is too short.

4.2.3 *Size Measurements*

Occasionally small patches of *Ecklonia* sp. would cover a portion of the frame which made it difficult when measuring the fish. Other problems included the shape of the bait pot, as the edges were hard to define on video to pin-point the known length. We recommend a different straight edged container be used or have the pot positioned the other way round with the base, not the lid, attached to frame. This way it is more accurate to measure and easier to load the bait. The angle of the bait pot caused by a tilting frame also made it difficult to measure consistently, if no changes to the pot were made perhaps simply using a vivid to outline the shape would provide a clearer known length.

There may also be some bias in measuring. There were times when more than one frame had to be used to measure the fish due to their positioning. When this happened it was possible to accidentally measure the same fish more than once or you could loose track of a fish swimming in and out of view.

5. Conclusion:

Marine ecosystems throughout the world have been degraded as a result of human activities (Norse & Crowder, 2005) especially through over-fishing. We consider that networks of marine reserves which protect a range of habitats including those which fully encompass offshore islands or reefs will be a key tool in the recovery of these delicate ecosystems.

It is positive to see the change in snapper numbers since the initial study in 1993; where Grange (1993) found two snapper inside the reserve and two outside the reserve, compared to 2011, where a total of 89 snapper were found inside the reserve and 31 outside. This is a 3000% increase in total numbers over the last 14 years. From 2004 to 2011 the average size of snapper inside Tuhuā Marine Reserve has increased by 10% and they are now 8% larger than the average size recorded at the Poor Knights in 2009. After 10 years of no-take marine reserve protection at Tuhuā, Shears & Usmar (2006) found little evidence to suggest snapper populations had recovered. However, in 2011, we are now seeing an increase in abundance and size of snapper which may be due to a change in sampling technique in 2004 and/or increased compliance enforcement by DOC.

Other offshore marine reserves in the north eastern marine bioregion of New Zealand have demonstrated dramatic increases in key predatory fish subsequent to boundary extensions through enhanced protection and the simplification of fishing rules around these (Denny & Willis 2004). There are clear signs of recovery of key species in Tuhua marine reserve and it is timely to consider ways to enhance marine protection here in an attempt to mirror the conservation gains that have been achieved through protection on the island itself. Further marine protection could be achieved through increasing the extent of the reserve or by adopting other forms of less stringent protection. Boundary increases would confer immediately benefits to marine life though increased availability of more diverse habitat free of human disturbance and decreased edge effects created by fishing ‘on the line’ (Willis et al. 2000). Marine reserves confer the highest form of protection to marine environments but the adoption of other forms of protection, which may garner more support from the fishing community, could be considered to achieve broader conservation goals.

We recommend that BUV monitoring be repeated at regular intervals to quantify the ongoing response of predatory reef fish and that active compliance enforcement continues in and around the marine reserve at Tuhuā Island. The equipment and analysis limitations should be addressed as outlined in section 4.2 and improved by DOC prior to the next BUV survey. We also encourage ongoing dialogue on ways to extend and enhance protection of marine habitats in the Tuhua environs.

Tuhuā Marine Reserve's current success should continue to be closely monitored. The next BUV survey will establish the direction of the trends reported herein and links well with the regular annual underwater visual census surveys. Tuhuā is an important offshore island for conservation and continued enhancement of marine protection will confer both short and long term benefits to marine ecosystems.

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8. Appendices

8.1 SITE POSITIONS AND DETAILS OF BAITED UNDERWATER VIDEO DROPS INCLUDING SITES FROM 2004 NOT SURVEYED IN 2011

Area	Drop No.	Date	Site Location	Status*	Latitude	Longitude	Depth (m)	Habitat
1	26†	6 Apr	Awatukoro Point	NR	3716722	17613801	20	Sand off Reef
1	30	6 Apr	Moewai Bay	NR	3717131	17613745	19	Sand off Reef
1	31	6 Apr	Centre NW Bay	NR	3717525	17613865	9	Sand off Reef
2	20	6 Apr	Herbies hole	NR	3716447	17613982	29	Sand
2	29†	6 Apr	Outside West Reserve Boundary	NR	3716266	17614215	24	Reef/ecklonia
2	32	6 Apr	West end of Moewai Bay	NR	3717025	17613667	22	Sand
2	37	6 Apr	NW Awatukoro Point	NR	3716559	17614021	27	Sand off reef
3	18	6 Apr	SW Maori Chief	R	3716095	17614803	20	Sand/Small cobbles
3	19†	6 Apr	Cathedral Bay	R	3716310	17614496	14.1	Sand off Reef
3	25†	7 Apr	SW Maori Chief Mid Bay	R	3715970	17614583	31	Sand
3	28	Not Surveyed	North Cathedral Cove	R	3716344	17614620	9	Fine sand
3	35	6 Apr	East end Opupoto Bay	R	3716227	17614729	16	Rocky-Reef/Ecklonia
4	14	Not Surveyed	Te Ananui Cave	R	3715975	17615266	23	Reef/ecklonia/sand
4	15	7 Apr	NW Maori Chief	R	3715764	17614810	32	Reef/Sand/Cobbles/*Ecklonia*
4	24	Not Surveyed	East Maori Chief	R	3716048	17614922	14	Sand off Reef
4	27	Not Surveyed	Close in to Te Ananui Cave	R	3716069	17615183	11	Reef/sand
4	33	Not Surveyed	East Motunaki Rock	R	3716159	17615156	8.5	Sand off Reef
5	7†	7 Apr	Two Fathom Reef	R	3715566	17616119	47	Reef/*Ecklonia*
5	8	7 Apr	Hurihurianga Bay	R	3715683	17615168	34	Sand/*Ecklonia*

Area	Drop No.	Date	Site Location	Status*	Latitude	Longitude	Depth (m)	Habitat
5	16†	7 Apr	Btwn Tabletop & Two Fathom Reef	R	3715769	17616233	34	Reef
5	17	Not Surveyed	SW The Queen	R	3715961	17616092	11	Reef/mixed algae
5	34	Not Surveyed	In close Hurihurianga Bay	R	3716095	17615435	8	Reef
5	38	7 Apr	New waypoint	R	3715908	17615712	38	reef/sand
6	3	7 Apr	The Queen	R	3715870	17616522	37	Reef/sand/mixed algae
6	4†	5 Apr	East Turanganui Bay	R	3716359	17616755	28	Reef/mixed algae
6	9	5 Apr	Wharenui Pt	R	3716121	17616765	41	Reef/ecklonia
6	23	7 Apr	East The Queen	R	3716045	17616445	14	Reef/ecklonia
6	36	Not Surveyed	South The Queen	R	3716122	17616484	5	Reef
7	6	5 Apr	Taumo Point	NR	3716941	17616745	26	Sand/boulder/mixed algae
7	10	5 Apr	Right of East Reserve Boundary	NR	3716428	17616931	28	Cobbled-rocky reef/ecklonia
7	11	5 Apr	Motuoneone Island	NR	3716775	17616763	26	Sand
7	12	5 Apr	North Motuoneone Island	NR	3716632	17616633	21	Reef/ecklonia/sand
8	5	5 Apr	North Te Roto Point	NR	3717321	17616677	22	Sand/Reef/*Ecklonia*
8	13	5 Apr	Te Horo	NR	3717867	17616478	21	Sand off Reef
8	21	5 Apr	SE Te Horo	NR	3717716	17616459	18	Sand
8	22	5 Apr	North Te Roto Pt	NR	3717248	17616542	16	Reef/mixed algae/sand
9	1	6 Apr	South Crown Tuhua Reef	NR	3718461	17617246	27	Sand/Reef/some *Ecklonia*
9	2	6 Apr	North Crown Tuhua Reef	NR	3718259	17617118	33	Sand some algae

* Reserve (R) or no reserve (NR).
† Footage no good, not used in results.

8.2 COUNT DATA FOR SNAPPER FROM BAITED UNDERWATER VIDEO SAMPLING AT TUHUĀ (MAYOR ISLAND) APRIL 2011 AND MARCH 2004

Area	Drop No.	Site Location	Status*	Max Snapper (2004)	Legal Snapper (2004)	Max Snapper (2011)	Legal Snapper (2011)
1	30	Moewai Bay	NR	0	0	4	4
1	31	Centre NW Bay	NR	0	0	0	0
2	20	Herbies hole	NR	7	5	2	2
2	32	West end of Moewai Bay	NR	0	0	0	0
2	37	NW Awatukoro Point	NR	0	0	1	0
3	18	SW Maori Chief	R	1	1	12	9
3	35	East end Opupoto Bay	R	2	2	10	10
4	15	NW Maori Chief	R	0	0	12	12
5	8	Hurihurianga Bay	R	0	0	9	9
5	38	New site	R	-	-	25	25
6	3	The Queen	R	0	0	6	6
6	9	Wharenui Point	R	0	0	0	0
6	23	East The Queen	R	0	0	15	14
7	6	Taumo Point	NR	0	0	0	0
7	10	Right of East Reserve Boundary	NR	0	0	11	10
7	11	Motuoneone Island	NR	0	0	0	0
7	12	North Motuoneone Island	NR	0	0	1	1
8	5	North Te Roto Point	NR	0	0	0	0
8	13	Te Horo	NR	0	0	1	0
8	21	SE Te Horo	NR	0	0	0	0
8	22	North Te Roto Point	NR	0	0	0	0
9	1	South Crown Tuhua Reef	NR	0	0	2	2
9	2	North Crown Tuhua Reef	NR	0	0	9	6

* Reserve (R) or no reserve (NR). Note*: only includes sites with footage fitting into survey criteria*

8.3 AVERAGE LENGTH DATA FOR SNAPPER FROM BAITED UNDERWATER VIDEO SAMPLING AT TUHUĀ (MAYOR ISLAND) APRIL 2011 AND MARCH 2004

Area	Drop No.	Site Location	Status*	Average Length (mm) (2011)	Average Length (mm) (2004)
1	30	Moewai Bay	NR	364.39	-
1	31	Centre NW Bay	NR	-	-
2	20	Herbies hole	NR	339.24	281.57
2	32	West end of Moewai Bay	NR	-	-
2	37	NW Awatukoro Point	NR	-	-
3	18	SW Maori Chief	R	362.84	386.00
3	35	East end Opupoto Bay	R	395.77	356.50
4	15	NW Maori Chief	R	425.15	-
5	8	Hurihurianga Bay	R	318.38	-
5	38	New site	R	421.25	-
6	3	The Queen	R	336.95	-
6	9	Wharenui Point	R	-	-
6	23	East The Queen	R	464.41	-
7	6	Taumo Point	NR	-	-
7	10	Right of East Reserve Boundary	NR	361.23	-
7	11	Motuoneone Island	NR	-	-
7	12	North Motuoneone Island	NR	321.89	-
8	5	North Te Roto Point	NR	-	-
8	13	Te Horo	NR	-	-
8	21	SE Te Horo	NR	-	-
8	22	North Te Roto Point	NR	-	-
9	1	South Crown Tuhua Reef	NR	426.84	-
9	2	North Crown Tuhua Reef	NR	293.57	-

* Reserve (R) or no reserve (NR). Note*: no snapper to measure or could not measure snapper, and only includes sites with footage fitting into survey criteria*