Comparison of fish at reserve and control sites from Long Island-Kokomohua and Tonga Island Marine Reserves using baited underwater video (BUV), catch, measure, release (CMR) and underwater visual counts (UVC)

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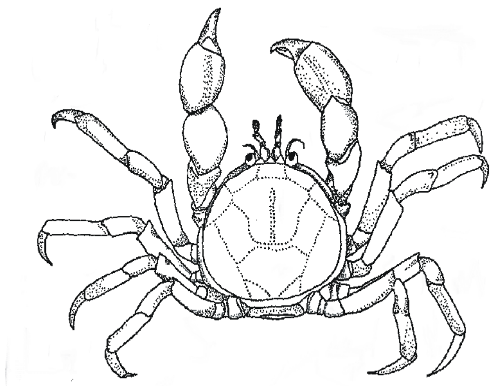

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1.0 Abstract

Thirty minute sequences of baited underwater video (BUV) were collected from two marine reserves and adjacent control areas in April 2004 from Tonga Island Marine Reserve (seven reserve and five control sites) and Long Island-Kokomohua Marine Reserve (eight reserve and eight control sites).

Abundance and size data for four reef fish species were compared between reserves and between each reserve and its associated controls.

The abundance of blue cod collected using BUV was compared with 12 years of underwater visual counts (UVC) at both reserves. Size data for blue cod collected by BUV were compared with 10 years of and UVC and catch, measure and release (CMR) data collected at Long Island-Kokomohua Marine Reserve.

A total of 12 species of reef fish excluding triplefins were observed using BUV along the Abel Tasman coast, while eight species were recorded from the Long Island-Kokomohua Marine Reserve and control sites. BUV footage was dominated by spotty, blue cod and tarakihi at both reserves. Leatherjackets were also common at Long Island.

At some Abel Tasman sites, blue cod arrived within the first minute of deployment, however the mean time for all control and reserve sites was greater overall due to first arrivals being in excesss of 5.5 minutes at many sites. Tarakihi and snapper were relatively slow to arrive at the Abel Tasman baited stations with most times in excess of 6.5 minutes. At Long Island-Kokomohua Marine Reserve and controls, blue cod arrived almost immediately apart from two control sites where they arrived 4.3 minutes from camera deployment. Tarakihi arrived at the baited stations considerably slower, with average times > 6.7 minutes at the reserve group and 11.4 minutes at the control group.

Blue cod were more abundant at Long Island-Kokomohua Marine Reserve than Tonga Island. The mean number of blue cod generally increased over the 30 minute sampling period at Tonga Island control and reserve sites. There was an increase at many sites at Long Island, but at some sites the numbers remained relatively high and stable over the 30 minute deployment. Along the Abel Tasman, blue cod were more abundant at control sites located north of the reserve compared to those situated south of the reserve boundaries. Highest numbers of blue cod were recorded from reserve sites dominated by rubble bank habitat along the north east side of Long and Kokomohua Islands and at the southern tip of Long Island.

Mean numbers of tarakihi were generally higher from the pooled reserve treatment compared to the control group, but this difference was relatively small as many sites had no tarakihi. The mean number of tarakihi generally increased over time at Tonga Island reserve sites, whereas control sites did not show this trend. At Long Island-Kokomohua Marine Reserve sites, the mean number of tarakihi recorded using BUV varied independent of duration, while two control sites exhibited a general increase in mean number of tarakihi over time. Snapper was recorded only from two Tonga Island reserve sites, with abundance increasing over time.

Although BUV did not appear to reflect differences in relative abundance of blue cod at individual sites where UVC methods had detected a consistent difference, this method did reflect the overall abundance differences between the two reserves (i.e. blue cod were considerably more abundant at Long Island using BUV and UVC methods).

At Tonga Island, tarakihi size was similar from both control and reserve sites. For Long Island-Kokomohua Marine Reserve and control sites, tarakihi size was could not be reliably determined as insufficient numbers of individuals could be reliably measured.

Blue cod were larger from both Tonga Island Marine Reserve and Long Island-Kokomohua Marine Reserve sites than from their respective control sites. The histogram shapes for blue cod obtained from the three sampling methodologies (BUV, CMR, and UVC) were comparable. It was concluded that catch, measure and release data for blue cod provided the best cost per effort regime to obtain size frequency data, but resulted in a small mortality of fish compared to BUV where no mortalities occured.

2.0 Introduction

Studies investigating the change in fish size and abundance in marine reserves have traditionally used diver estimates collected during underwater visual census (UVC) methods. This method has primarily been used due to its non-destructive nature. The limitations of UVC are well known (e.g. Thresher and Gunn 1986; Lincoln Smith 1988, 1989; St John *et al.* 1990, Thompson and Mapstone 1997, Davidson 2001a), but the method is still regularly used despite calls for methodological pilot studies to reduce observer error and enhance the accuracy and precision of data obtained (McCormick and Choat 1987; Cheal and Thompson 1997; Willis and Babcock 2000).

Most methods used by researchers fall into direct observation (UVC) and remote capture (e.g. angling, long-lining or gill-netting) techniques. The need for multiple methods relates to interspecific differences in body size, habitat association, aggregative behaviour, mobility, or responses of fish to the presence of divers (Willis and Babcock 2000). These authors also suggested that at times, these interspecific differences can be systematically biased by the very factor that is under investigation.

The potential for inaccurate fish measurements is high in marine reserves where fish behaviour can vary markedly among sites and between treatments (Cole 1994; Davidson 2001a). There is a distinct possibility that certain sizes of fish may avoid or positively react to the presence of divers. For example, snapper actively avoid divers in northern South Island areas, while large blue cod in marine reserves regularly follow and often bite divers. These variables combined with diver estimate variation lead to the possibility of large inaccuracies.

The concept that marine reserves provide conservation and fishery management benefits (Agardy 1994; Roberts 1997; Allison *et al.* 1998; Pauly *et al.* 1998) has generated considerable interest in the potential effects of marine reserves on the biota in them. In particular, environmental managers wish to know whether marine reserves protect those species most affected by human activity.

In the northern part of the South Island of New Zealand, fish species most likely to increase in size in marine reserves compared to unprotected areas are blue cod *Parapercis colias* (Pinguipedidae), tarakihi *Nemadactylus macropterus* (Cheilodactylidae), blue moki *Latridopsis ciliaris* (Latridae), and snapper *Pagrus auratus* (Sparidae). To date, the only fish species demonstrated to have increased in size within New Zealand marine reserves are snapper at Leigh (Willis and Babcock 2000; Willis *et al*. 2000; Willis *et al.* 2003), blue cod at Long Island, Marlborough Sounds (Davidson 1997, 2001a, 2004) and blue cod in the Tonga Island Marine Reserve (Davidson and Richards 2005).

In the present study we used a remotely-operated baited underwater video (BUV) in an attempt to describe the size and relative abundance of snapper, tarakihi and blue cod from two South Island marine reserves and their adjacent control areas. BUV was developed by Willis and Babcock (2000) in response to difficulties in accurately sampling a species whose behavioural reactions to divers vary markedly between sites (Cole 1994). The authors stated that fish feeding by visitors to the Leigh marine reserve has resulted in snapper exhibiting diver-positive behaviour at some sites, while elsewhere in the reserve they are wary of divers, and outside the reserve they actively avoid divers. Willis and Babcock (2000) stated that the use of a remotely deployed sampling method eliminated this source of bias.

During the present study we also compared BUV blue cod size data collected from Long Island-Kokomohua Marine Reserve with existing catch, measure and release (CMR) data collected in April 2004 by Davidson Environmental Ltd. CMR data were collected from four of the same reserve sites and six of the same control sites used in the BUV study (see Davidson 2004 for methods). Size estimates made by divers during underwater visual fish census (UVC) counts along the Abel Tasman coast in February 2004 were also compared with size data collected from BUV sites (Davidson and Richards 2005). UVC size data were collected from six of the same reserve sites and four of the same controls sites as the present BUV data.

3.0 Methods

BUV data were collected in April 2004 from Tonga Island Marine Reserve (Figure 1, Table 1) and Long Island-Kokomohua Marine Reserve (Figure 2, Table 2). At Tonga Island, seven reserve sites and five control sites were investigated, while BUV footage was collected from eight reserve and eight control sites at Long Island. Control and reserve sites at each reserve were selected in an effort to represent comparable environmental variables (erg. depth, substratum, shore aspect). For any reserve sites that were environmentally different to the majority of sites, comparable control sites were also sampled. At each site, GPS coordinates, water depth, time of day (NEST), and station number were filmed to identify the appropriate video sequence.

The BUV system used in the present study consisted of an Ike lite EV-CAM Hz color camera mounted on a stainless steel tripod 115 cm above the substratum and faced straight down. A bait holder (containing 400g of canned cat food) was attached to the square base of a stand attached to the tripod so that it lay in the center of the camera’s field of view. The base was exactly 400 mm square allowing spatial calibration of digitized images, and allowed accurate estimation of the lengths of fish responding to the bait (Willis and Babcock 2000, 2001; Willis *et al.* 2000). Each 30 minute deployment was made on soft or combinations of soft and hard substrata. When deployed on soft substratum, the camera was placed immediately adjacent to or within 5 m of the reef habitat.

The BUV assembly was lowered to the sea floor from an aft- and stern-anchored vessel. The camera was deployed for 30 minutes from the time contact was made with the bottom. Digital video was monitored on a LCD screen and recorded onto tape on board the survey vessel using a Sony DC-TRV25E PAL 1-mega pixel fully digital colour camera. At the laboratory, video footage on tapes was digitised using Nero Vision Express 2.

Digitised video was then replayed on a PC. The elapsed times from the start of the deployment to the first arrival of blue cod, snapper, tarakihi and blue moki were recorded. Individual still photograph frames were grabbed approximately every 30 seconds using Nero Show Time software. Frame captures were often delayed from 1 to 4 seconds in an effort to photograph fish close to the benthos, or in an alignment that reduced measurement error. Individual lengths for snapper, blue cod, and tarakihi (FL) were measured using three point calibration on images imported into Sigma Scan Pro5 (image analysis software, Jandel Scientific). Measurement error using this method was typically < 20 mm (Willis and Babcock 2000). Not all fish in each photo frame could be measured as some fish were obscured by others while some were at oblique angles to the camera or were too high above the benthos. Only fish that were well presented to the camera and close to the benthos were measured. Presence or absence of other reef fish were recorded from frames (e.g. leatherjacket, hagfish, sweep, spotty) in relation to time elapsed from the start of deployment. These species were not counted or measured as they are not targeted by recreational fishers.

Photo frames were also analysed to determine the total number of blue cod, tarakihi, snapper and blue moki in the field of view. These data were then grouped into five minute intervals and mean count values calculated.

Table 1. Location of BUV sites along the Abel Tasman coast.

Site Name	Site No.	Treatment	GPS Lat	GPS Long
Separation Pt	1	Control	40 47.071	172 59.868
Totaranui north	2	Control	40 48.227	173 00.627
Totaranui reef	3	Control	40 48.895	173 01.044
Canoe Bay	4	Reserve	40 51.166	173 02.767
Abel Head south	5	Reserve	40 51.467	173 03.488
Cottage Loaf	6	Reserve	40 51.790	173 03.637
Reef Pt	8	Reserve	40 53.069	173.03.527
Tonga Island nth	7	Reserve	40 53.321	173 03.992
Foul Pt	9	Reserve	40 54.211	173 03.759
Mosquito Reef	10	Reserve	40 54.602	173 03.900
Bark Bay borth	11	Control	40 54.902	173 03.749
Bark Bay Reef	12	Control	40 55.193	173 04.318
Totara Rock	13	Control	40 56.368	173 03.657

Figure 1. Location of baited underwater video (BUV) sites along the Abel Tasman coast. Note the marine reserve extends south from Awaroa Head to immediately north of site 11 (see black lines on figures).

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Figure 2. Location of baited underwater sites (BUV) in outer Queen Charlotte Sound. Note: the marine reserve encompasses the entire circumference of Long Island and Kokomohua Islands.

Table 2. Coordinates for BUV stations around Long Island and adjacent control areas.

Site number	Coordinates	Location
1	41 07.51584,174 14.64311	Control
2	41 08.38494,174 13.30961	Control
3	41 09.48310,174 14.53877	Control
4	41 07.94880,174 18.49543	Control
5	41 08.20092,174 17.45452	Control
6	41 07.53447,174 18.28234	Control
7	41 06.81824,174 19.70937	Control
8	41 06.37143,174 19.53792	Control
9	41 05.87778,174 18.78638	Reserve
10	41 06.23982,174 18.42630	Reserve
11	41 06.43302,174 17.87914	Reserve
12	41 06.61642,174 17.24693	Reserve
13	41 06.71275,174 17.70801	Reserve
14	41 07.31284,174 16.59636	Reserve
15	41 07.56323,174 16.17727	Reserve
16	41 07.98802,174 15.93100	Reserve

4.0 Results

4.1 Species diversity

A total of 12 species of reef fish excluding triplefins were observed from the baited underwater videos collected from the Abel Tasman coast (Table 3). Nine species were recorded from control sites compared to eight species from reserve sites. Most species were recorded from < 2 sites with dominant species being blue cod, tarakihi and spotty. Blue cod were recorded from all reserve sites and all but one control site, while tarakihi were recorded from all but one reserve site and all but two control sites. Snapper were recorded from two reserve sites but no control sites (Table 3). Of special interest was the arrival of a rock lobster (*Jasus edwardsii*) at the Cottage Rock marine reserve site.

Table 3. Percentage presence / absence of fish species recorded from BUV sites inside and outside (controls) of the Tonga Island Marine Reserve.

Species	Control (%)	Reserve (%
Blue cod	80	100
Tarakihi	60	86
Spotty	80	100
Snapper	0	29
Blue moki	20	0
Scarlet wrasse	40	29
Rock cod	0	29
Jack mackerel	0	29
Goat fish	40	0
Rock cod	20	0
Sweep	20	29
Red cod	20	0

Eight species were recorded from BUV footage from both the Long Island-Kokomohua Marine Reserve sites and the control sites (Table 4). Blue cod, tarakihi, spotty and leatherjacket were the most regular visitors to the BUV stations. Blue cod were recorded from all reserve and control sites, while tarakihi were recorded from all but three reserve and three control sites. Other species were recorded from one to six sites.

Hagfish, carpet shark and leatherjacket were recorded from the Long Island area, but not the Abel Tasman. Snapper, blue moki, jack mackerel, goatfish, red cod, and rock cod were recorded from the Abel Tasman but not from Long Island sites.

Table 4. Percentage presence / absence of fish species recorded from BUV sites inside and outside (controls) of the Long Island-Kokomohua Marine Reserve.

Species	Control (%)	Reserve (%)
Blue cod	100	100
Tarakihi	62.5	75
Spotty	100	100
Leatherjacket	87.5	62.5
Scarlet wrasse	50	25
Hagfish	12.5	12.5
Carpet shark	0	12.5
Sweep	12.5	0

4.2 First arrivals

For the Abel Tasman samples, the quickest mean first arrival time from the four target reef fish species was blue moki from the control group (Table 5). However, this result is eroneous as only one individual blue moki was seen during the entire study.

Blue cod from the control sites along the Abel Tasman coast showed the second quickest mean first arrival time followed by blue cod from the reserve group. At some Abel Tasman sites, blue cod arrived within the first minute of camera deployment, however the mean time for all control and reserve sites was greater overall due to first arrivals in excess of 5.5 minutes. Tarakihi and snapper were relatively slow to arrive at the Abel Tasman baited stations with most times in excess of 6.5 minutes (Table 5).

The mean first arival time for blue cod in the Long Island- Kokomohua Marine Reserve was 1.5 seconds (Table 6). This was considerably fater than the mean first arival time for the control sites around Long Island and for reserve and control sites along the Abel Tasman coast. At most reserve sites and for many control sites around Long Island blue cod were immediately present at the station (Table 6). Where present tarakihi arived on average quicker at the reserve treatment at Long Island than at the control sites (Table 6). No snapper or blue moki were recorded from Long Island – Kokomohua Marine Reserve or control sites.

Table 5. Time for the first arrival (seconds) of four reef fish species at reserve and control BUV sites along the Abel Tasman coastline.

Site	No.	Treatment	Blue cod	Tarakihi	Snapper	Blue Moki
Separation Point	1	Control	30	122	Nil	102
Totaranui North	2	Control	50	Nil	Nil	Nil
Totaranui Reef	3	Control	330	1320	Nil	Nil
Turn Point	11	Control	Nil	Nil	Nil	Nil
Bark Bay Reef	12	Control	62	441	Nil	Nil
Canoe Bay	4	Reserve	5	302	Nil	Nil
Abel Head Sth	5	Reserve	460	418	Nil	Nil
Cottage Loaf Rock	6	Reserve	0	135	Nil	Nil
Reef Point	7	Reserve	143	1607	666	Nil
Tonga Island Nth	8	Reserve	49	450	Nil	Nil
Foul Point	9	Reserve	295	130	876	Nil
Mosquito Reef	10	Reserve	1114	Nil	Nil	Nil
Mean control (SE)			118 (63.18)	627.66 (277.47)	Nil	102.00
Mean reserve (SE)			295.14 (150.61)	507 (210.0)	771 (56.12)	Nil

Table 6. Time for the first arrival (seconds) of four reef fish species at reserve and control BUV sites around Long Island-Kokomohua Marine Reserve.

Location	Site No.	Treatment	Blue cod	Tarakihi
Bottle Rock	1	Control	7	1778
Scott Point	2	Control	0	120
Blumine north	3	Control	0	Nil
Anatohia Bay	4	Control	269	Nil
Clark Point	5	Control	0	448
Kotukutuku	6	Control	2	788
Motungarara	7	Control	255	Nil
The Twins	8	Control	0	297
Charted Rock	9	Reserve	0	11
Kokomohua	10	Reserve	0	984
Cliffs (east)	11	Reserve	0	644
Cliffs (west)	12	Reserve	12	2
North east	13	Reserve	0	Nil
South east	14	Reserve	0	Nil
South spit	15	Reserve	0	383
South tip	16	Reserve	0	Nil
Mean control (s.e.)			66.625 (42.66)	686.2 (306.88)
Mean reserve (s.e.)			1.5 (1.5)	404.8 (188.48)

4.3 Fish abundance

The mean number of blue cod recorded at the baited stations at Tonga Island control and reserve sites often initially increased in the first 20 minutes and then remained relatively stable in the second 10 minutes (Figure 3). Blue cod were more abundant at control sites located north of the reserve compared to those situated south of the reserve boundaries. No blue cod were recorded from one of the southern control sites (Turn Point). Mean numbers of blue cod were usually higher at reserve compared to control sites, except from Totaranui North and Totaranui Reef control sites which had comparable numbers of blue cod to reserve sites.

At Long Island-Kokomohua Marine Reserve and control sites, the mean number of blue cod recorded over time at the baited station increased at some sites over the 30 duration while at other sites their numbers remained relatively stable over the duration of camera deployment (Figure 4). High mean numbers of blue cod were often recorded from both reserve and control sites. In addition, low numbers of blue cod were recorded from both reserve and control sites (e.g. Cliffs west (reserve) and Motungarara, The Twins, and Anatohia Bay (controls)). Highest numbers of blue cod were recorded from reserve sites dominated by rubble bank habitat along the north east side of Long and Kokomohua Islands and at the southern tip of Long Island.

Pooled BUV data from all reserve and all control sites showed the mean number of blue cod present at the baited station was slightly higher at Tonga Island reserve sites compared to control sites, and their abundance at the BUV increased over time peaking in the last 10 minutes of deployment (Figure 5). At Long Island-Kokomohua, there were slightly but consistenly higher blue cod numbers recorded at reserve sites compared to the associated control sites and abundance reamined relatively high and only increased slightly over the duration of deployment. Blue cod dramatically more abundant at Long Island-Kokomohua Marine Reserve and control sites compared to Tonga Island Marine Reserve and controls (Figure 5).

The mean number of tarakihi at the BUV stations generally increased over time at most Tonga Island reserve sites, whereas control sites did not show this trend (Figure 6). Mean numbers of tarakihi were generally higher at reserve sites compared to control sites, but this difference was not large.

At Long Island-Kokomohua Marine Reserve sites, the mean number of tarakihi recorded at the baited stations varied independent of duration, while two control sites (Clark Pt and The Twins) did exhibit a general increase in mean number of tarakihi over time (Figure 7). Mean numbers of tarakihi was highest from two Long Island-Kokomohua Marine Reserve sites. At the remaining reserve and control sites little or no tarakihi were recorded.

After the BUV sites were pooled (Figure 8), the mean number of tarakihi present at the baited stations from Tonga Island sites were slightly higher than those recorded from control sites, and abundance increased over time. At Long Island-Kokomohua Marine Reserve, there were slightly higher tarakihi numbers compared to the control treatment but this was promarily due to two marine reserve sites. Comparison of the relative abundance of tarakihi between the two reserves and their associated controls showed little difference (Figure 8).

Snapper was recorded only from two Tonga Island reserve sites, with abundance increasing over time (Figures 9 and 10).

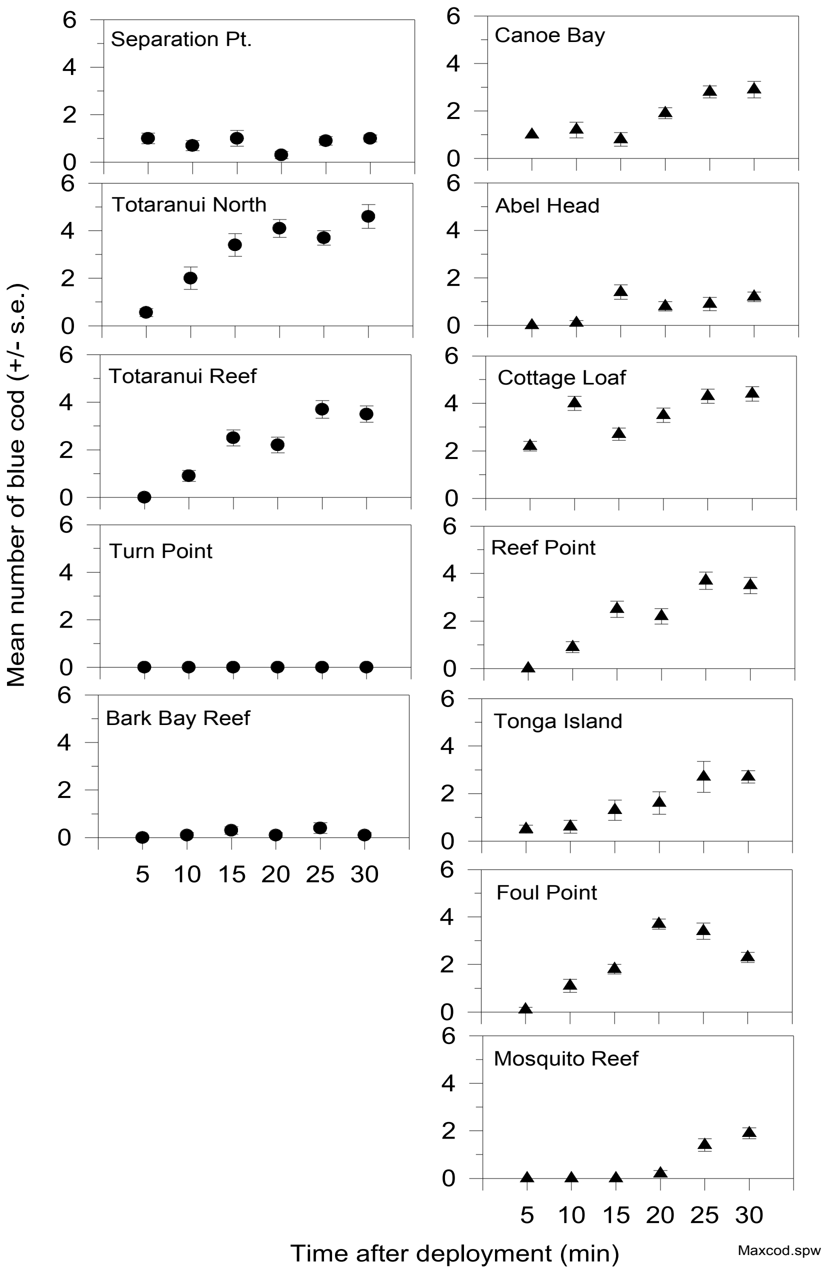

Figure 3. Mean number of blue cod observed in photos sampled from five minute video sequence lengths at control (circles) and reserve (triangles) sites in Tonga Island Marine Reserve.

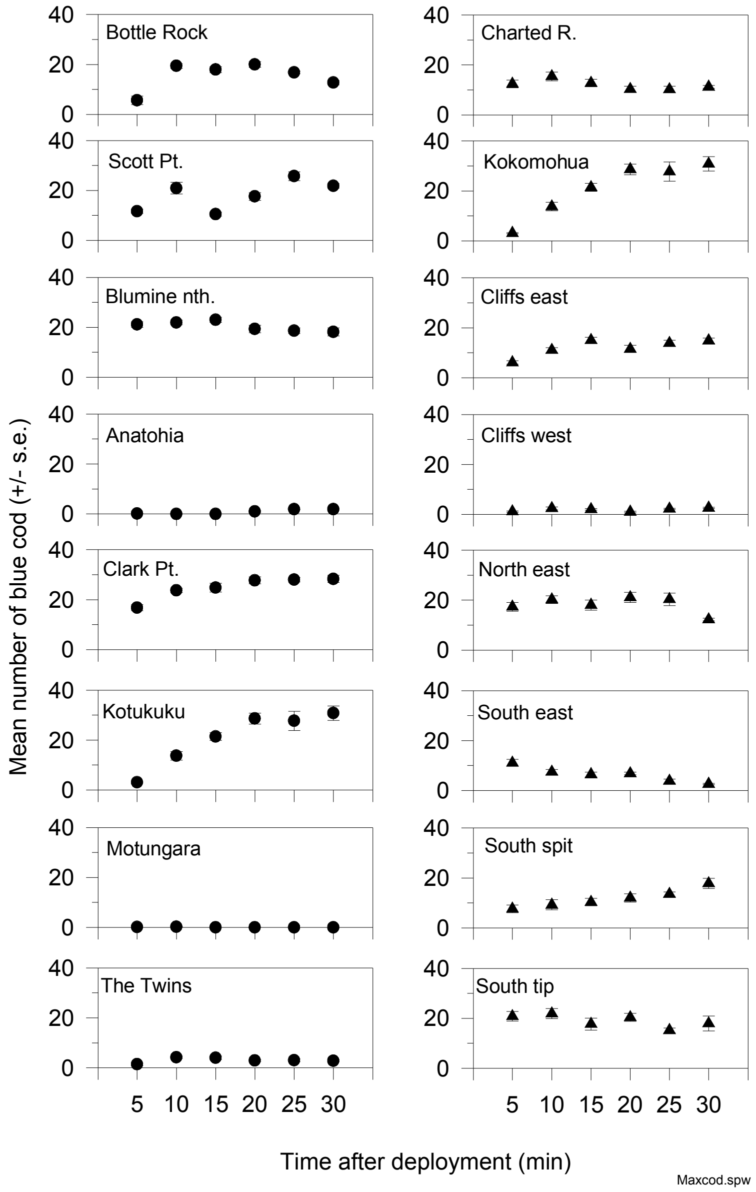

Figure 4. Mean number of blue cod observed in photos sampled from five minute video sequence lengths at control (circles) and reserve (triangles) sites from Long Island-Kokomohua Marine Reserve.

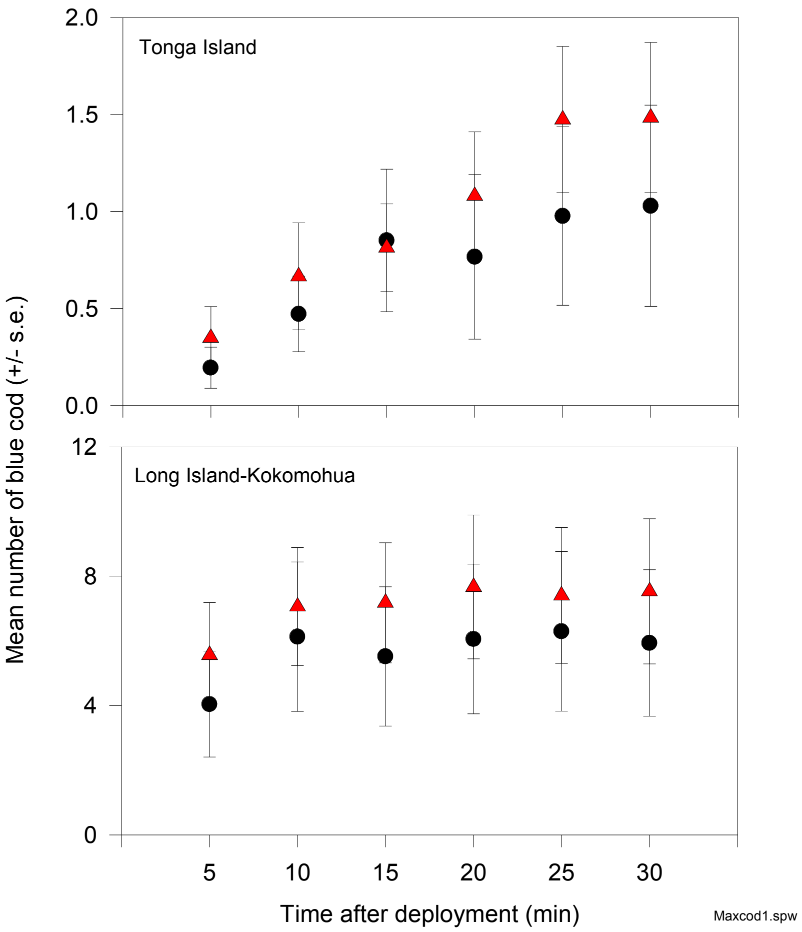

Figure 5. Mean number of blue cod detected in photos sampled from five minute video sequence lengths pooled from all control (circles) and reserve (triangles) sites at two marine reserves. Error bars are +/- s.e.

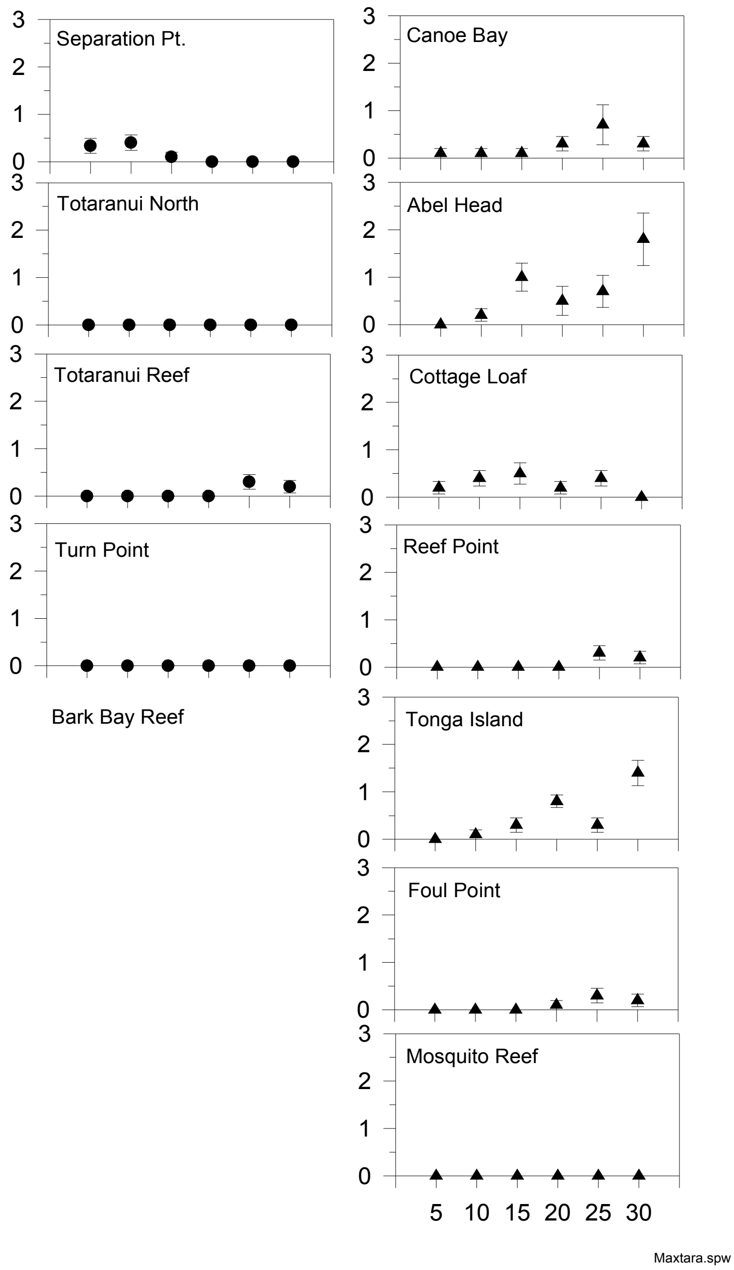

Figure 6. Mean number of tarakihi observed in photos sampled from five minute video sequence lengths at control (circles) and reserve (triangles) sites from Tonga Island Marine Reserve.

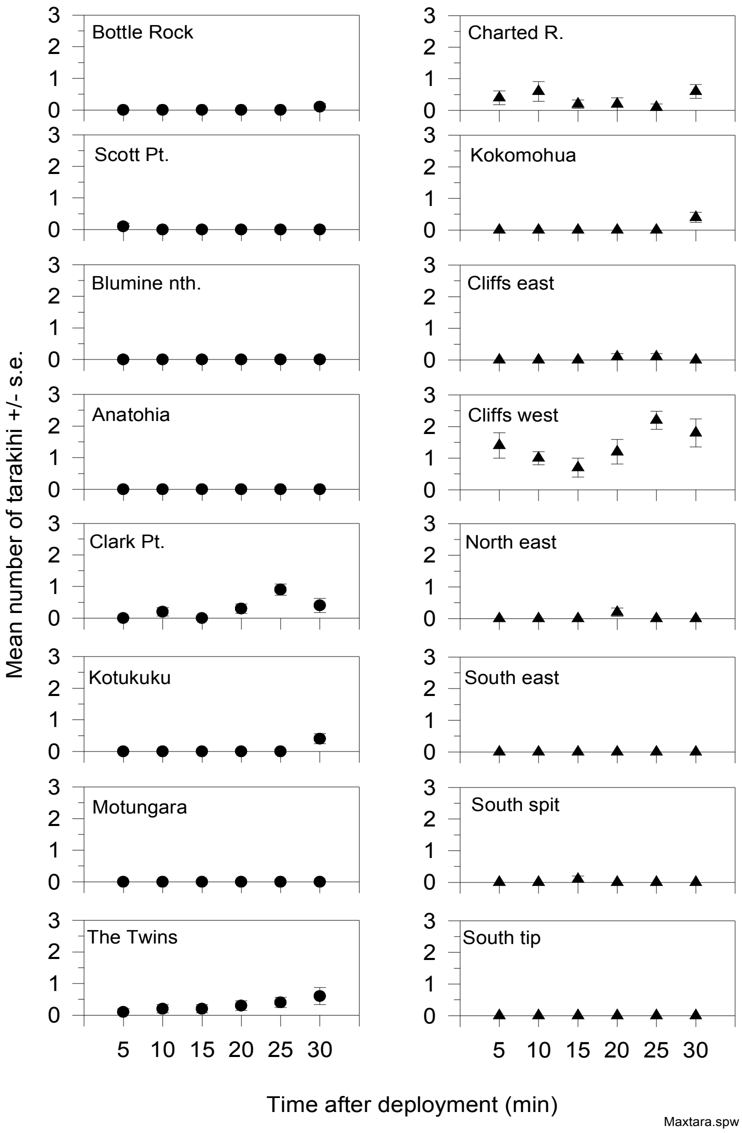

Figure 7. Mean number of tarakihi observed in photos sampled from five minute video sequence lengths at control (circles) and reserve (triangles) sites from Long Island-Kokomohua Marine Reserve.

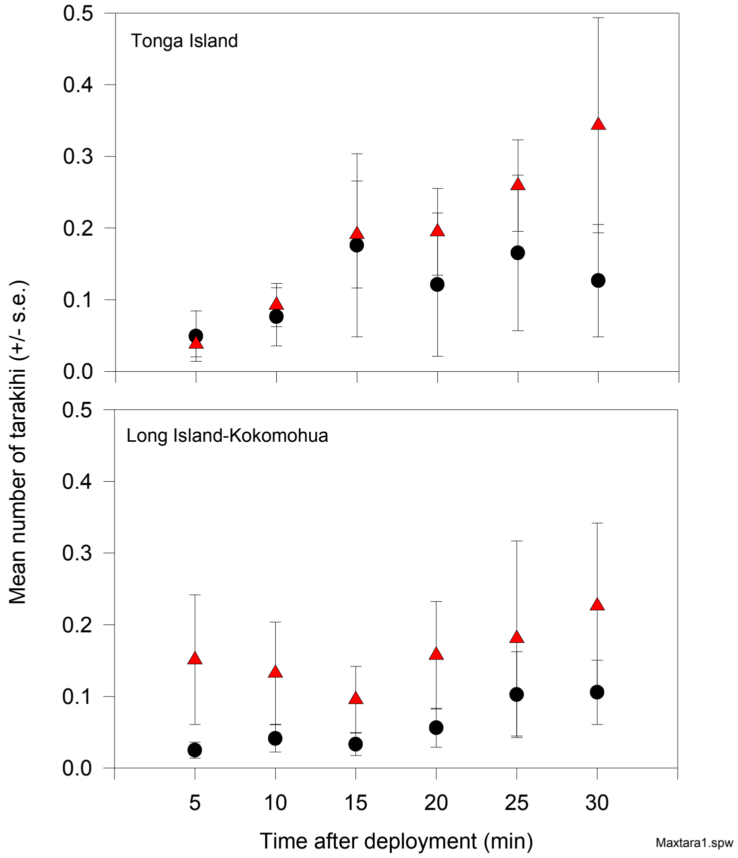

Figure 8. Mean number of tarakihi detected in photos sampled from five minute video sequence lengths pooled from all control (circles) and reserve (triangles) sites at two marine reserves.

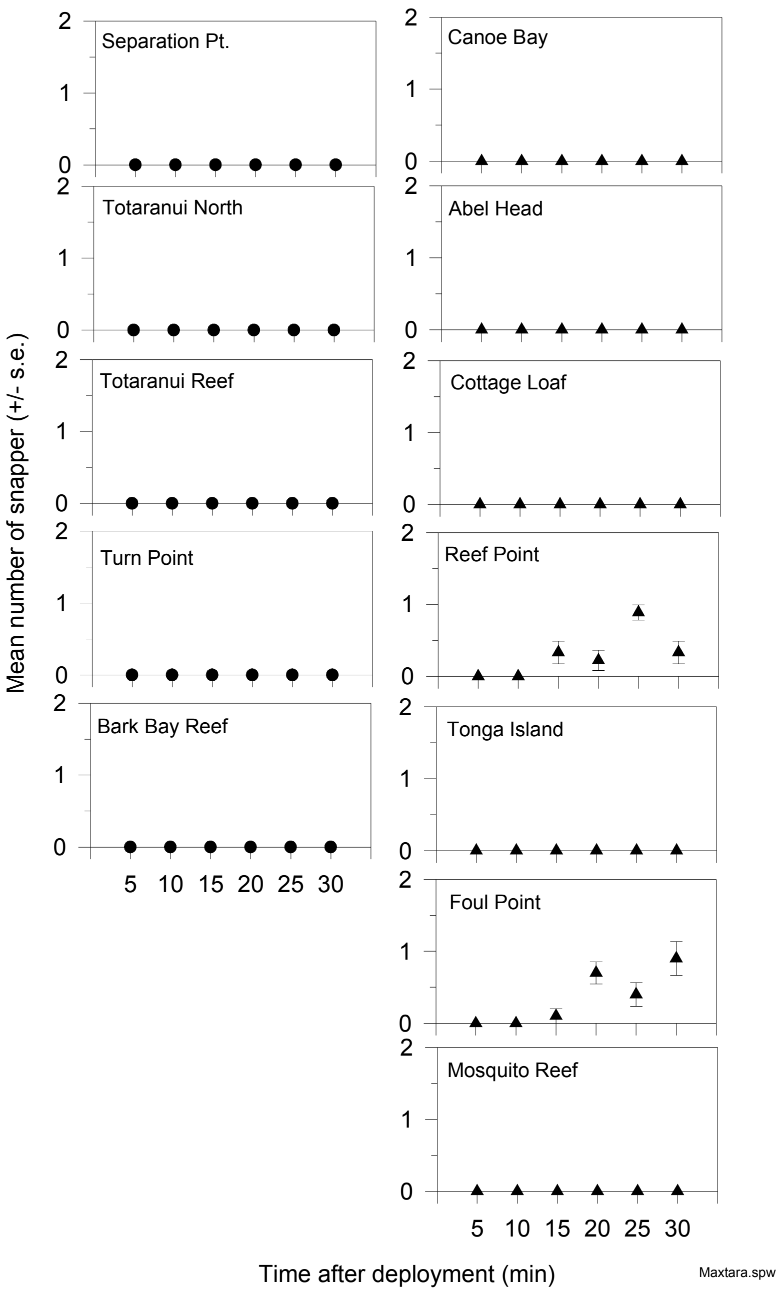

Figure 9. Mean number of snapper observed in photos sampled from five minute video sequence lengths at control (circles) and reserve (triangles) sites from Tonga Island Marine Reserve.

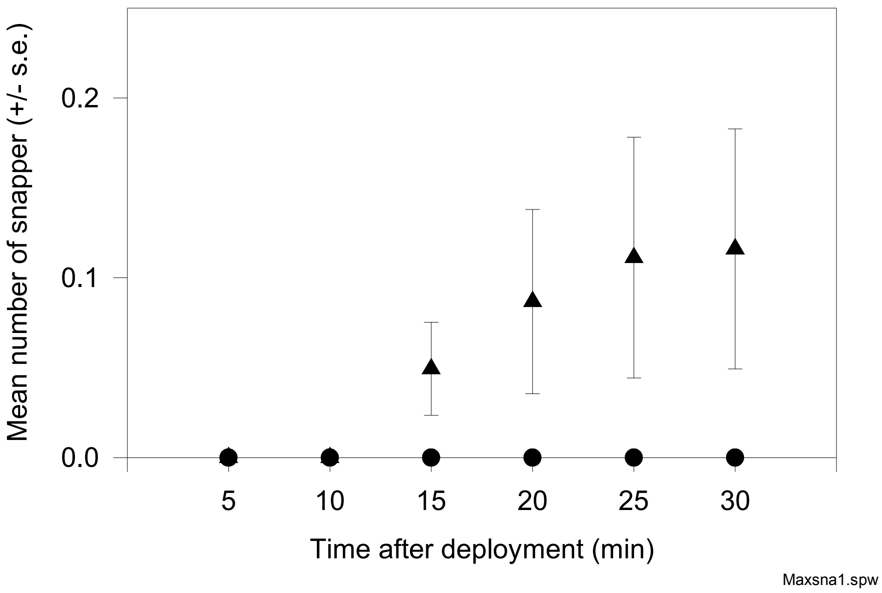

Figure 10. Mean number of snapper detected in photos sampled from five minute video sequence lengths pooled from all control (circles) and reserve (triangles) sites along the Abel Tasman coastline.

4.4 Fish size

Tarakihi size was similar (approximately 200 mm mean length) from both control and reserve sites for Tonga Island (Figure 11). For Long Island-Kokomohua reserve and control sites, tarakihi size could not be reliably determined as insufficient numbers of individuals could be reliably measured.

Blue cod were larger from both Tonga Island Marine Reserve and Long Island-Kokomohua Marine Reserve sites than from their respective control sites (Figure 11). Mean length values were generally greater for blue cod at Tonga Island Marine Reserve sites (i.e. ≥ 300 mm mean length) compared to Long Island-Kokomohua Reserve sites (i.e. usually < 300 mm mean length). The largest mean values for blue cod at Long Island-Kokomohua Marine Reserve were recorded from sites located along the northern cliffs (i.e. cliffs east, cliffs west) and from the Charted Rock located approximately 460m north of Kokomohua Island. At Tonga Island marine Reserve the largest mean blue cod sizes were recorded from mainland sites in the southern half of the reserve (i.e. Mosquito Reef, Reef Point and Foul Point).

A greater number of blue cod length measurements were obtained from a comparable effort in the field (5 days) using the baited underwater video (BUV) methodology compared to length-frequency plots obtained from underwater visual counts (UVC) and catch, measure and release (CMR) methods (Figure 12). The histogram shapes for blue cod obtained from the three methodologies were comparable (Figure 12). Most noticeable from these plots were the greater number of larger blue cod (> 300 mm length, i.e. minimum legal size) inside the two marine reserves compared to their respective control sites. This result was independent of survey method.

At Tonga Island Marine Reserve sites, BUV identified more large blue cod (400 to 500 mm length) than the UVC method, however the UVC method was better at detecting smaller blue cod (100 to 200 mm length) than BUV (Figure 12). At Long Island-Kokomohua, comparisons between BUV and CMR methods showed the two methods provided comparable blue cod size-frequency distributions. The only notable difference between the two methods was that BUV sampled smaller blue cod than the CMR methodology (Figure 12).

Tarakihi length-frequency distributions from Tonga Island sites using BUV and UVC methods were not comparable Figure 13). UVC methodology recorded more tarakihithan BUV with a large 'spike' of small individuals (approximately 100 mm length), while BUV did not record any individuals < 120 mm total length (Figure 13). Small schools of tarakihi < 100 mm length were regularly recorded by divers during counts, however these small fish did not appear to be attracted to the BUV camera. BUV recorded many more individual tarakihi in the range of 120 to 250 mm length compared to UVC methodology that rarly recorded fish of this size. BUV showed that legal size tarakihi (> 250 mm length) were equally rare inside and outside the reserve. No difference between the mean size of tarakihi between the reserve and control treatments was obvious using the two sampling methodologies (Figure 13).

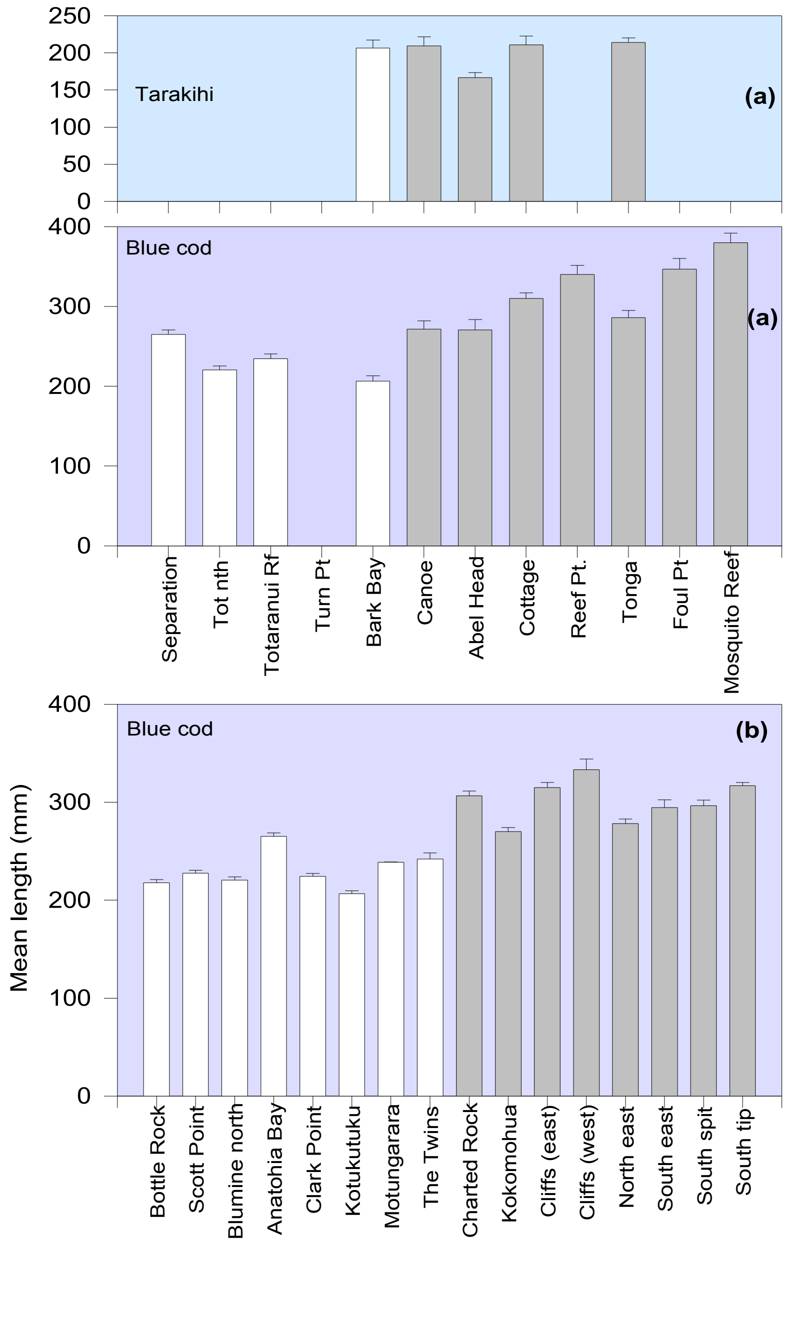

Figure 11. Mean length of tarakihi (a) and blue cod (a) from Tonga Island Marine Reserve and controls and (b) blue cod from Long Island-Kokomohua Marine Reserve. Control (open) and reserve (shaded) sites. Errors are +/-1 standard error.

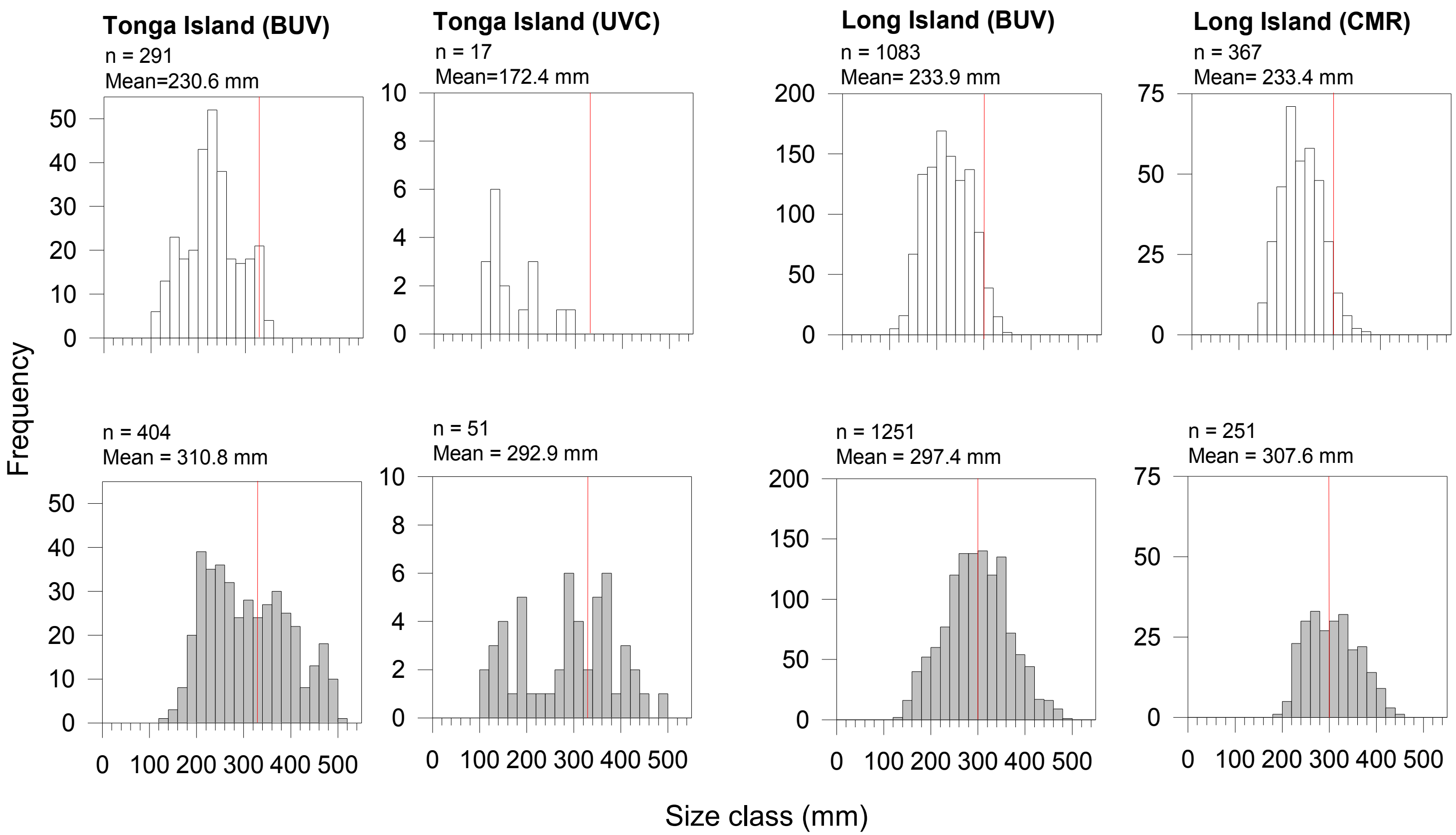

Figure 12. Length frequency distributions of blue cod according to survey method at both Tonga Island and Long Island-Kokomohua control (open) and reserve (shaded) sites. BUV = baited underwater video, UVC = underwater visual census, and CMR = catch, measure and release. Reference line is the minimum legal size limit for the Marlborough Sounds 300 mm and Tasman and Golden Bays 300 mm length.

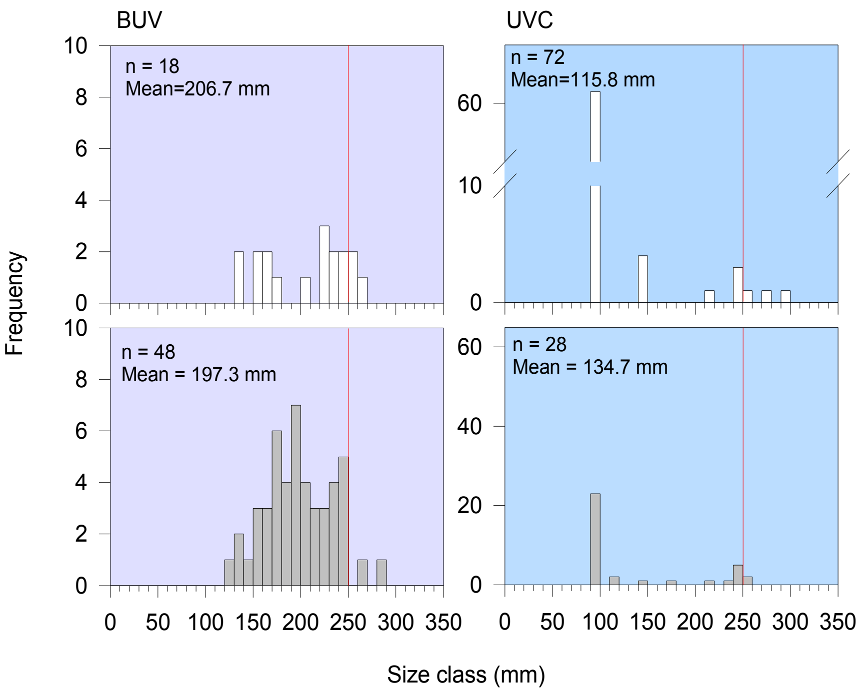

Figure 13. Length frequency distributions of tarakihi according to survey method at Tonga Island control (open) and reserve (shaded) sites. BUV = baited underwater video and UVC = underwater visual counts. Reference line is the minimum legal size limit.

5.0 Discussion

The present study used baited underwater camera methodology to compare relative abundance and size of particular fish species at two South Island marine reserves. Size data collected using BUV methodology were compared with two other sampling techniques.

5.1 BUV methodology

Willis and Babcock (2001) stated that baited underwater video surveys were an effective (and sometimes superior) alternative to UVC methods for estimating relative densities of predatory reef fish. The authors stated that remote-sampling methods could be used in low-visibility conditions and at greater depths than the capabilities of SCUBA divers. They also stated that it required fewer personnel, removed bias caused by spatial variability in fish behaviour, and was less likely to return low (or zero) abundance estimates for large carnivorous species, meaning that the statistical power of comparisons was likely to be greater with lower field costs than diving operations. Willis and Babcock (2000) did however warn that the system had operational limitations, including substrata with high vertical relief or high current conditions causing the camera stand to become unstable, frightening away fish responding to the bait. Additionally, the field of view may be obscured by kelp on shallow reefs, inhibiting the accuracy of counts and length measurements.

During the present study, BUV was successfully deployed at two marine reserves and their associated control sites (28 sites in total). Based on our experience using the traditional BUV techniques outlined by Willis and Babcock (2000), we encountered particular difficulties and have recommended modifications to the technique.

BUV methodology has visibility limitations at the data analysis stage. Although the camera can record at any visibility, the reliability of fish measurements during computer analysis declined at low levels of water clarity. During the present survey, Abel Tasman water clarity was <3 m horizontal distance. Under these conditions, many fish could not be measured as their body limits could not be reliability detected on the computer screen. It is therefore recommended that BUV samples be collected when water visibility is relatively high (>5 m horizontal distance). This distance is approximately the minimum distance used to collect UVC data (Davidson and Richards 2005).

Sampling of the 30 minute sequence onto video, followed by video capture, and video rendering resulted in reduced digital image quality. This is particularly evident when still images used to measure fish lengths were “frame grabbed” from the video footage. The quality of still photos “grabbed” from video was dramatically lower than still frames collected directly from the BUV camera. It is therefore recommended that video footage be collected for first fish arrival times and to generate a species list for each site, but still photos should also be collected directly from the BUV camera for fish measurement purposes. It is suggested that a series of 3-4 still photos be collected at 30 second intervals and the best of each photograph series should be used to measure and count fish. Counting fish numbers at each 30 second interval was preferred during the present study rather than counting the maximum number in each 30 second sequence. Large numbers of blue cod were often present meaning detection of the maximum in each sequence became impracticable and not commercially cost-effect.

BUV had some very positive attributes including ease of data collection, low staff numbers, no damage to fish, no need for divers, and the detection of species present not previously recorded by divers. For example, BUV detected snapper at two sites in the Tonga Island Marine Reserve, while UVC methods have detected no snapper over a period of 12 years (Davidson and Richards 2005). Furthermore, greater numbers of fish could be measured using BUV footage collected over the same duration of field time compared to UVC and

CMR methods. The down side was the dramatically longer computer analysis time required to process BUV images and to undertake fish measurements. It was estimated that two and a half times the effort was required to process BUV data than was needed to collect it, compared to 20% for UVC data processing.

The number of fish seen for each 30 second interval over the duration of the 30 minute video sequence was used as an index of relative abundance. Willis and Babcock (2000) stated that there was an upper limit to the number of fish that were visible in the field of view at a given moment, which may cause BUV to underestimate abundance where densities are very high. The authors stated that this would produce conservative contrasts between areas with high and low fish density and may result in failure to detect a difference between two areas where densities were different but high enough to saturate the field of view in both places. During the present study, this did not occur for tarakihi, blue moki or snapper, but could potentially reduce the difference in blue cod abundance calculations between reserve and control sites as blue cod were very abundant, especially around the bait where fish were frequently on top of each other.

Prior to the start of sampling in the present study, a trial of two bait holder types was conducted in the Tonga Island Marine Reserve and control sites. The two bait holder types were trialed together on the same frame and separately to assess which attracted more numbers of fish. Results were clear that the bait holder providing better access to the bait with larger holes attracted fish and maintained that attraction over a more prolonged period than the bait holder that was more enclosed and provided limited access to the bait. Ellis and DeMartini (1995) suggested that a major cause of the discrepancy between their results and those of workers in abyssal depths was due to bait availability for the fish. Willis and Babcock (2000) considered that removal of baits by the deep sea fish *Coryphaenoides* (*N.*) *armatus* in a study by Armstrong *et al.* (1992) may well have affected the accumulation of fish under the camera thereby resulting in a poor correlation between abundance of fish from BUV compared to the abundance determined from trawl surveys. Different species may also respond to bait in different ways. In the course of the present study it was noted that tarakihi and snapper moved in and out of the field of view far more often than blue cod that remained around the bait for prolonged periods.

Willis and Babcock (2000) used MAX indices obtained from continuous monitoring of the sequence. The authors stated that maxima rarely coincided with predetermined sampling intervals and concluded that non-continuous monitoring results potentially lost important information. We conclude that this may be the case at Long Island-Kokomohua and Tonga Island Marine Reserves for species such as tarakihi and snapper that are present sporadically and in relatively low numbers compared with the numbers. In contrast, blue cod were present during many 30 minute sequences during the present study. Determination of the maximum number of blue cod recorded from each 30 second sequence was impracticable, if not impossible, due to the very large numbers of fish. Sampling of blue cod numbers at set time intervals is unlikely to result in a loss of information at Long Island-Kokomohua and Tonga Island Marine Reserves. The methods adopted in the present study are also likely to reduce the possibility of over-estimation of blue cod numbers compared to selecting the maximum number of fish in each timed sequence that may lead to over-estimation.

5.2 Methodology comparisons

Detailed comparison of the fish abundance between the different sampling methods was not attemped during the present study as insufficient ground truthing of BUV has been historically undertaken in order to make such calcuations reliable. It was noted however, that the relative densities of blue cod recorded using BUV methods between the two marine reserves in the present study were similar to the relative differences recorded using UVC methods. Clearly, further study of the use of BUV for calcuation of fish densities is required and may lead to reliable density measurements.

Comparison of fish sizes was considered reliable after comparison between CMR, UVC and BUV measurements . Small variations in the size frequencies for blue cod and tarakihi for the two marine reserves for the three sampling methods were apparent, but the size frequency histograms and mean fish sizes were similar. CMR methods used at Long Island-Kokomohua Marine Reserve did not sample the very small blue cod that were detected using the BUV methodology. This is probably due to larger fish getting to baited hooks quicker than the very small fish that tended to either not come to the baited station or "stood off". This was combined with the size of hooks perhaps being too large for the very small blue cod. Overall, CMR provided blue cod size-frequency data at the lowest cost per unit effort followed by UVC methods. CMR does however, result in a small mortality of fish compared to BUV and UVC methods where no mortalities occur. CMR does not sample juvenile blue cod, however, these fish were not recorded by BUV and are seldom seem by divers as they are relatively secretive at this size (< 10 cm length).

Very small tarakihi (<100 mm total length) were sampled by UVC but not the BUV. Very small tarakihi appear to feed from the surface of rocks on the Abel Tasman coastline and do not appear to respond to a baited station. No other notable differences in size frequencies were recorded between the methods at each reserve.

5.3 Fish abundance comparisons between reserves

The relatiove abundance of blue cod at reserve and control sites between Long Island-Kokomohua Marine Reserve and Tonga Island Marine Reserve suggested that cod were dramatically less abundant along the Abel Tasman coastline. This was supported by UVC data collected between 1992 and 2004 (Davidson 2001a, Davidson and Richards 2005). Both reserves have been in place for approximately the same time span (12 years) and support blue cod habitat and food. It is probable that the difference in blue cod abundance is related to the proximity to other blue cod populations. The Abel Tasman coast is an isolated rocky coastline separated from other rocky coastline by large expanses of soft bottom habitats (i.e. Tasman and Golden Bays). This large physical separation (50 - 60 km) may mean that the abundance of blue cod along the Abel Tasman coast may recover from fishing at a much slower rate than reserve areas such as Long Island-Kokomohua Marine Reserve where blue cod populations are widespread and abundant in close proximity to the reserve.

Using UVC techniques from 1992 to 2001, Davidson (2001a) showed that blue cod were more abundant from within Long Island-Kokomohua Marine Reserve compared to outside the reserve. Results from the present study showed that BUV methodology for blue cod did not detect significant differences in abundance between Long Island-Kokomohua Marine Reserve and controls. This suggests that BUV may not always be an appropriate method for comparing blue cod abundance between reserve and control areas. This problem is primarily due to cod being attracted from a wide area and entering the camera field and with many remaining there rather than swimming in and out like snapper and tarakihi behave. For areas where blue cod are relatively abundant, cod numbers build up under the camera invluding control areas where blue cod may be less common thereby masking any differences in abundance between reserve and control areas.

Blue cod and tarakihi were more numerous from reserve BUV samples than from control samples, but these differences were relatively small and would unlikely be statistically significant. Snapper were recorded from two sites in Tonga Island Marine Reserve, with no other snapper being recorded from the control sites along the Abel Tasman coast or from any sites associated with the Long Island-Kokomohua Marine Reserve.

The size frequency data collected for tarakihi showed no difference between reserve and control areas; however, blue cod were larger from within both reserves compared to their associated control areas. Differences in blue cod size between the two marine reserves were relatively small with Tonga Island Marine Reserve fish being slightly larger on average than those at Long Island-Kokomohua Marine Reserve. This difference may be due to the relatively low numbers of juvenile and small blue cod along the Abel Tasman coast compared to the Long Island area. Juvenile blue cod often inhabit sandy shelly habitat surrounded by cobble and small boulder substratum in the Long Island area (authors pers. Obs. Cole *et al.* 2000). This habitat is relatively uncommon from the Abel Tasman coastline (Davidson 1992). This lack of juvenile habitat along the Abel Tasman coast may also contribute to the slow recovery of this species in the Tonga Island Marine Reserve.

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