Biological monitoring update for Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound: 1992 - 2009

Research, Survey and Monitoring Report Number 573

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1.0 EXECUTIVE SUMMARY

Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound was established in April 1993. Since March 1992, a biological monitoring programme coordinated by Davidson Environmental Ltd. under contract to the Department of Conservation has surveyed biological changes in relation to the establishment of the no-take marine reserve (Davidson 1995, 1997, 2004). This report provides a comprehensive update on the biological monitoring programme based on results of further sampling over the last six years.

1.1 Sampling

Biological monitoring of several key species has been undertaken at replicate reserve and control sites.

Line fishing (catch, measure and release)

- Fish were captured using baited hooks, measured and released in all years except for 2001. Sampling was bi-annual from 1993 to 1999 and annual from 2000 onwards. Only blue cod (*Parapercis colias*) catch measurement data have been presented in the present report.
- Catch per unit effort (CPUE) measurements were collected for fish caught on each sample occasion.

Underwater visual fish surveys (diver counts)

- Reef fish density and size from rubble and macroalgae habitats were sampled annually by divers from 1992 to 2009. Additional macroalgae control sites were sampled from March 2002 onwards.

Other sampling

- Spiny lobster (*Jasus edwardsii*) density, size and sex were sampled every 2-3 years from 1992 to 2001 and annually from 2001 to 2009.
- Black-foot paua (*Haliotis iris*) density and size data were collected on four and five occasions respectively between 1992 and 2009.
- Kina (*Evechinus chloroticus*) size and density, and cats eye (*Turbo smaragdus*) density, were initially sampled in 1992 and subsequently on two further occasions.

- Cats eye size and various shore profiles were surveyed 1992, but these data have not been re-sampled since the original baseline study.

1.2 Catch, measure and release

From 2004 to 2009, a total of 4830 fish (1917 individuals (5 species) from reserve and 2913 individuals (13 species) from control sites) were captured, measured and released during six annual sampling events. Blue cod dominated the total catch (4391 individuals or 90.9 % of the catch). Since April 2004, a total of 2522 blue cod was sampled at control sites, but only 40 individuals or 1.6 % were larger than 330 mm total length (TL). In contrast, of the 1815 blue cod measured from four reserve sites over the same period, a total of 534 or 29.4% were > 330 mm TL. Small blue cod (0 - 279 mm TL) always dominated the control population with proportions ranging from 55 % to 93 %. In contrast, since April 1996, large blue cod (330 – 650 mm TL) dominated the reserve population on four occasions and were second behind the smallest size class for the remaining 11 occasions.

Pooled mean blue cod length has increased in the reserve since the start of the study and was always higher than pooled data from areas open to fishing (control sites). Fluctuations in mean blue cod length values occurred both inside and outside the reserve, but were considerably larger at the control sites. These relatively large control site fluctuations were most likely influenced by changes to blue cod recreational size and bag limits.

Blue cod catch rates (catch per unit effort or CPUE) from experimental fishing in the reserve increased shortly after the reserve was established and remained high compared to control sites. At control sites where recreational fishing was permitted, catch rates remained consistently low.

1.3 Underwater visual fish surveys

Since April 1997, the density of reserve blue cod in rubble habitat remained significantly higher compared to control sites. This difference was primarily due to an increase in the density of large blue cod (> 300 mm TL) in the reserve. In May 2009, blue cod > 300 mm TL were 3.6 times more abundant from reserve rubble habitat compared to the same habitat outside the reserve. The different densities of large blue cod recorded between reserve and control sites was most likely due to the absence of fishing in the reserve.

No other reef fish on rubble habitat showed a trend that could be related to reservation. Spotty and banded wrasse were usually more abundant from the control group compared to the reserve treatment. Tarakihi were uncommon from rubble habitat and apart from 1994, showed no significant difference between treatments.

The density of blue cod, blue moki, tarakihi and butterfish from the macroalgae habitat were often, but not always, higher in the reserve. These differences were, however, seldom statistically significant. The density of butterfish from both treatments was usually very low with few individuals recorded at most sites. Tarakihi were patchily distributed and when seen, were often present in groups.

Since March 1994, the mean size of blue moki sampled from all sites was greater from the reserve compared to control sites. Divers regularly observed very large blue moki (>700 mm TL) from the reserve, whereas large individuals were rarely seen from control sites. Mean tarakihi size fluctuated dramatically during the study depending on the presence or absence of schools of juvenile fish.

1.4 Spiny lobster

Reserve spiny lobsters were more abundant than control lobsters from April 1999 onwards. In March 2009, lobsters were 3.3 times more abundant in the reserve (10.7 individuals per 100m^2) compared to outside (3.3 individuals per 100m^2) and 5.6 times more abundant than densities recorded at the start of the study.

In all years, large male and female lobsters were more abundant at reserve sites compared to control sites. In 2009, male lobsters were 3.1 times more abundant and females 3.6 times more abundant from the reserve compared to controls. Mean lobster carapace length was greater from the reserve compared to controls on all sample occasions from 1999 to 2009. It is concluded that the increase in lobster abundance and size within the reserve is directly related to their protection from fishing and will lead to greater reproductive output from the reserve compared to control areas.

1.5 Black-foot paua density and size

Black-foot paua density showed no clear changes in response to marine reserve protection. The mean size of paua was higher in the reserve compared to control sites on all sample occasions, with very large individuals being regularly encountered in the reserve and virtually absent from control sites, especially in 2007 and 2009. The mean size of paua in the reserve prior to reservation in 1992 was, however, greater than the average size recorded during the four subsequent sample events. The reason for the higher mean size in 1992 may be related to the small sample size in that year or larger numbers of smaller paua recruiting into the population since the reserve was established. Natural mortality, predation by lobsters and paua poaching may also have influenced the decline in mean paua size in the reserve.

1.6 Kina density and size

At both treatments, kina density initially declined and then increased to a high in 2008. These density changes were observed from both reserve and control treatments suggesting natural events rather than any reserve-related effect. Kina were larger at reserve sites compared to control sites; however, this difference existed prior to reservation and may therefore be a reflection of differences in habitat quality between sites rather than any reserve effect. The reasons for the increase in the mean size of kina at both treatments over the duration of the study is unknown, but in the reserve it will be partially related to the absence of small kina < 50 mm diameter in 2008. This size class was present at reserve sites in 1992 and 1999 and at control sites in all years including 2008. The absence of small kina from the reserve sites may be related to predation by the large numbers of large blue cod and/or lobsters. If this is the case, this represents the first structural community change indirectly related to reservation recorded for this marine reserve.

1.7 Behavioural change

Based on regular diver observations from the same areas before and after reservation and from between sites inside and outside the reserve, it was concluded that the behaviour of blue cod, blue moki and rock lobster changed during the course of the study. Individuals became diver neutral or positive. In the case of rock lobsters for example, individuals were regularly observed in the open or at the entrances to cracks and holes compared to control lobsters that were rarely seen in the open and were usually located well inside cracks and holes.

1.8 Recommendations for ongoing monitoring

Several recommendations regarding future ecological monitoring of Long Island-Kokomohua Marine Reserve are presented at the end of the report.

Table 1. Summary of sampling events for Long Island-Kokomohua Marine Reserve and control sites.

Sample	March 92	March 93	Sept 93	March 94	Aug 94	March 95	Sept 95	April 96	April 97	Sept 97	March 98	April 99	Sept 99	April 00	March 01	April 02	April 03
Catch, measure & release																	
Underwater visual (rubble)																	
Underwater visual (algae)																	
Lobster size, sex and density																	
Paua size																	
Paua density																	
Kina density and size																	
Cats eye snail density																	
Cats eye snail size																	
Shore profiles & video																	

Sample	March 04	April 05	April 06	April 07	April 08	March-May 09
Catch, measure & release						
Underwater visual (rubble)						
Underwater visual (algae)						
Lobster size, sex and density						
Paua size						
Paua density						
Kina density and size						
Cats eye snail density						
Cats eye snail size						
Shore profiles & video						

Note: Prior to April 2002, macroalgae habitats were sampled annually at three reserve and one control site. Due to the lack of sufficient control sites prior to 2002, these early data have not been presented in the present report.

2.0 INTRODUCTION

The establishment of a marine reserve often leads to an increase in the abundance and size of particular species (Bell, 1983; McCormick and Choat, 1987; Buxton and Smale, 1989; Garcia-Rubies and Zabala, 1990; Bennett and Attwood, 1991; MacDiarmid and Breen, 1993; Dufour *et al*., 1995; Edgar and Barrett, 1997; Babcock *et al*., 1999; Kelly *et al*., 2000; Willis *et al*., 2000; Davidson *et al.*, 2002; Halpern and Warner, 2002; Davidson *et al*., 2007; Pande *et al*., 2008). These changes have been documented for species traditionally targeted by fishers (Bennett and Attwood, 1993; Cole and Keuskamp, 1998; Kelly *et al*., 2000; Shears and Babcock, 2002; Denny *et al*., 2004; Freeman, 2006; Shears *et al*., 2006). However, for some species in marine reserves, little or no change has been documented (Cole *et al*., 1990; Freeman, 2005; Davidson *et al*., 2007). The reason for this has been a combination of several factors including: (i) most monitoring effort focusing on species targeted by fishers; (ii) limited funding to enable monitoring of other species; (iii) insufficient spatial or temporal sampling of non-fished species; and (iv) study duration being too short to detect longer term community changes.

In response to the pending establishment of Long Island-Kokomohua Marine Reserve, the Department of Conservation established a biological baseline in 1992 (Davidson, 1995). After the establishment of the reserve in 1993, particular aspects of the baseline have been monitored and the results presented in two subsequent reports (Davidson, 1997; 2004). The present report updates the overall data set by incorporating new monitoring data collected from March 2004 to May 2009.

Like most marine reserve studies, the present monitoring programme focuses on species traditionally targeted by fishers (i.e. blue cod and spiny lobster). Blue cod (*Parapercis colias*), for example, is one of the most important recreational fisheries in the Marlborough Sounds. Blue cod have been the focus of movement studies in the Marlborough Sounds (Mace and Johnson, 1983; Cole *et al*., 2000) and in southern New Zealand (Carbines, 1998, 1999). Blue cod have also been the focus of fisheries-related research in the Marlborough Sounds (Blackwell, 1997, 1998, 2002, 2006, 2008). Spiny lobster (*Jasus edwardsii*) was also selected as many studies within and outside New Zealand have shown that this species often responds to protection (MacDiarmid and Breen, 1993; Kelly *et al*., 2000; Davidson *et al*., 2002; Haggitt and Kelly, 2004; Shears *et al*., 2006). At less frequent intervals, data on paua, kina and cats eye were collected from the reserve and adjacent control sites in an effort to detect community or longer term changes due to reservation.

3.0 STUDY AREA

Long Island-Kokomohua Marine Reserve is a fully protected reserve extending a quarter nautical mile (463 metres) offshore around Long and Kokomohua Islands and an unnamed charted rock, north-east of Kokomohua Island (41 05.867 S, 174 18.750 E on Chart NZ 6153). The marine reserve is approximately 6.5 km in length and 619 ha in area (Figure 1). The marine reserve was formally established on 30 April 1993. For the four years prior to the formation of the marine reserve, local dive clubs had established a self-imposed voluntary ban on the taking of marine life from the area and had encouraged others to do the same.

Long Island and the adjacent Kokomohua Island are located in outer Queen Charlotte Sound, Marlborough Sounds (Figure 1). Long Island is approximately 4 km in length and between 300 m and 500 m wide. Kokomohua Island is subtidally connected to Long Island by a reef at the north-east tip of Long Island and contributes a further one km to the total length of both islands. Long Island is 1.9 km from the nearest point on the mainland, 1.5 km from Arapawa Island, 3.5 km from Blumine Island, and 1.4 km from Motuara Island, all of which were used to situate control sites in the present study.

The selection of study sites was based on habitat type that, in turn, related to shore aspect and topography. On south, east and west-facing shores of the outer Queen Charlotte Sound, a sublittoral fringe of macroalgae extending to approximately 1 m depth was recorded by Davidson (1995). On north-facing aspects of Long and Kokomohua Islands, the macroalgae habitat extended down to between 7 – 10 m depths. *Macrocystis pyrifera* habitat was located on the reef extending north-east of Long Island, in the gap between Long and Kokomohua Islands and around much of Motuara, The Twins and Motungarara Islands (excluding the southern shores). Shallow sand bottoms (< 14 m depth) were located between Long, Kokomohua, and Motuara Islands. Rubble habitat was distributed around most of the outer Sound and was often colonised by a relatively narrow sublittoral fringe of macroalgae. Bedrock habitat was restricted to headlands and northerly aspects where the macroalgae habitat extended beyond the sublittoral fringe.

Long Island is located in a transition zone between habitats common within sheltered parts of Queen Charlotte Sound and habitats common in the outer Sound. The outer Sound habitats include macroalgae stands of *M. pyrifera*, *Ecklonia radiata*, *Landsburgia quercifolia*, *Zonaria angustata* and *Marginariella urvilleana*, present along the northern parts of Long Island. Southern Long Island was dominated by typical inner Queen Charlotte Sound rubble banks supporting a narrow sublittoral fringe of macroalgae. McKnight and Grange (1991) also recorded a transition zone in the Long Island area from soft sediment biological community characteristic of the inner Marlborough Sounds to those more representative of the outer Sounds.

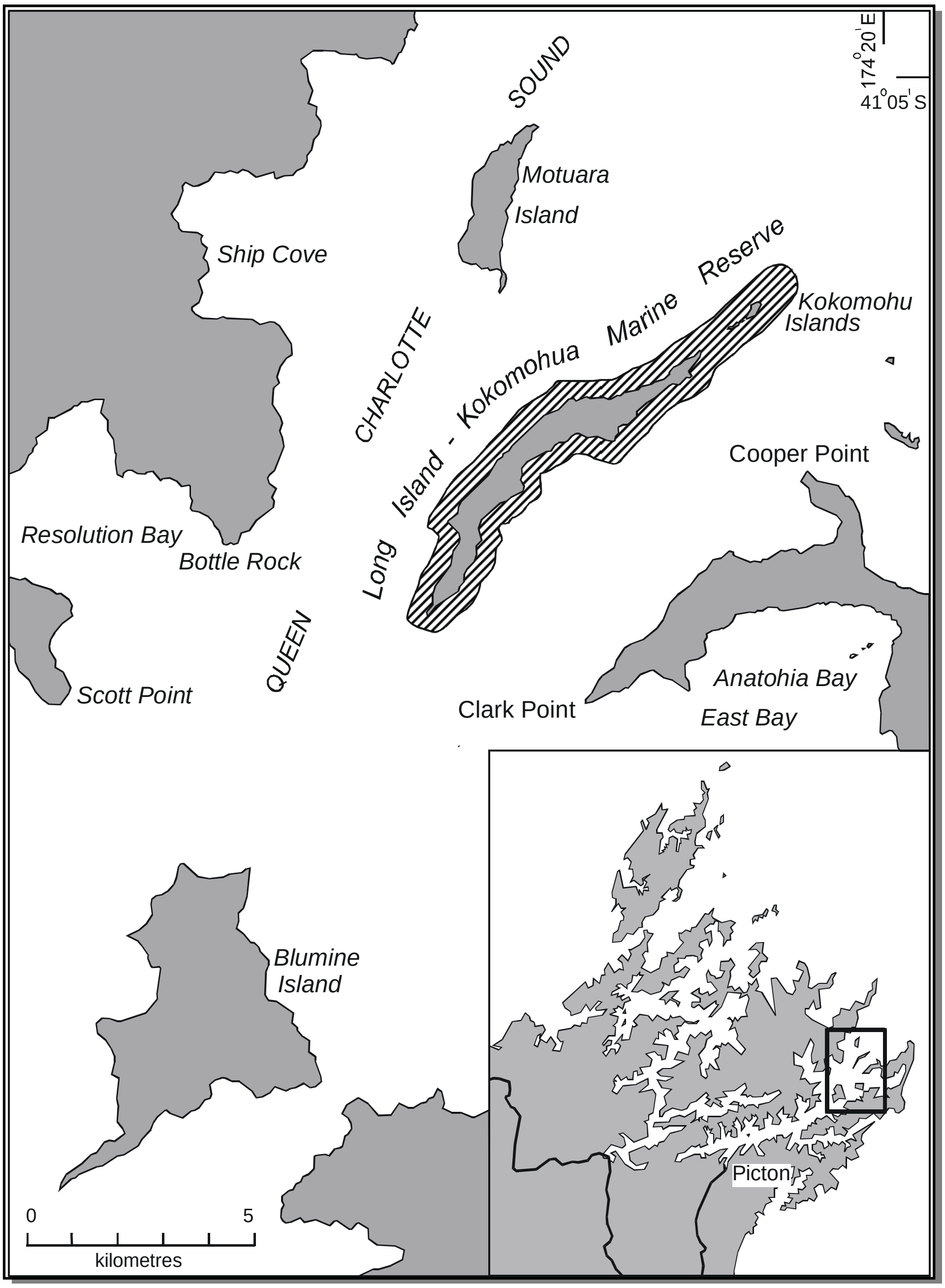


Figure 1. Location of Long Island-Kokomohua Marine Reserve in outer Queen Charlotte Sound.

4.0 MATERIALS AND METHODS

4.1 Fishing surveys (catch, measure and release)

Fish (predominantly blue cod) size and catch rates were investigated at six control sites and three (1993-2003) or four (2004-2009) reserve sites (Figure 2, Table 2). A maximum of 60 blue cod were sampled from each site, increasing to a maximum of 80 individuals from 2007 onwards. For the first several years up until and including 1999, line fishing was annual or biannual in either autumn (March or April) or spring (August or September). From 2000 onwards, sampling was carried out annually each autumn (predominantly in April).

Table 2. Catch, measure and release sample sites located within the marine reserve and at control sites.

Site no.	Area	Sample site	Habitat	Coordinates
R 1	Reserve	Long Island (east)	Rubble	41° 06.678'S 174° 17.793'E
R 2	Reserve	Kokomohua (east)	Rubble	41° 06.239'S 174° 18.397'E
R 3	Reserve	Long Island (south-west)	Rubble	41° 07.546'S 174° 16.182'E
R4	Reserve	Long Island (south-east)	Rubble	41 07.299'S 174° 16.597'E
C 1	Control	Bottle Rock	Rubble	41° 07.506'S 174° 14.628'E
C 2	Control	Clark Point	Rubble	41° 08.388'S 174° 17.281'E
C 3	Control	Blumine Island (north)	Rubble	41° 09.489'S 174° 14.523'E
C 4	Control	Anatohia Bay	Rubble	41° 08.005'S 174° 18.384'E
C 5	Control	Scott Point	Rubble	41° 08.567'S 174° 13.163'E
C 6	Control	Blumine Island (south-west)	Rubble	41° 10.580'S 174° 13.603'E

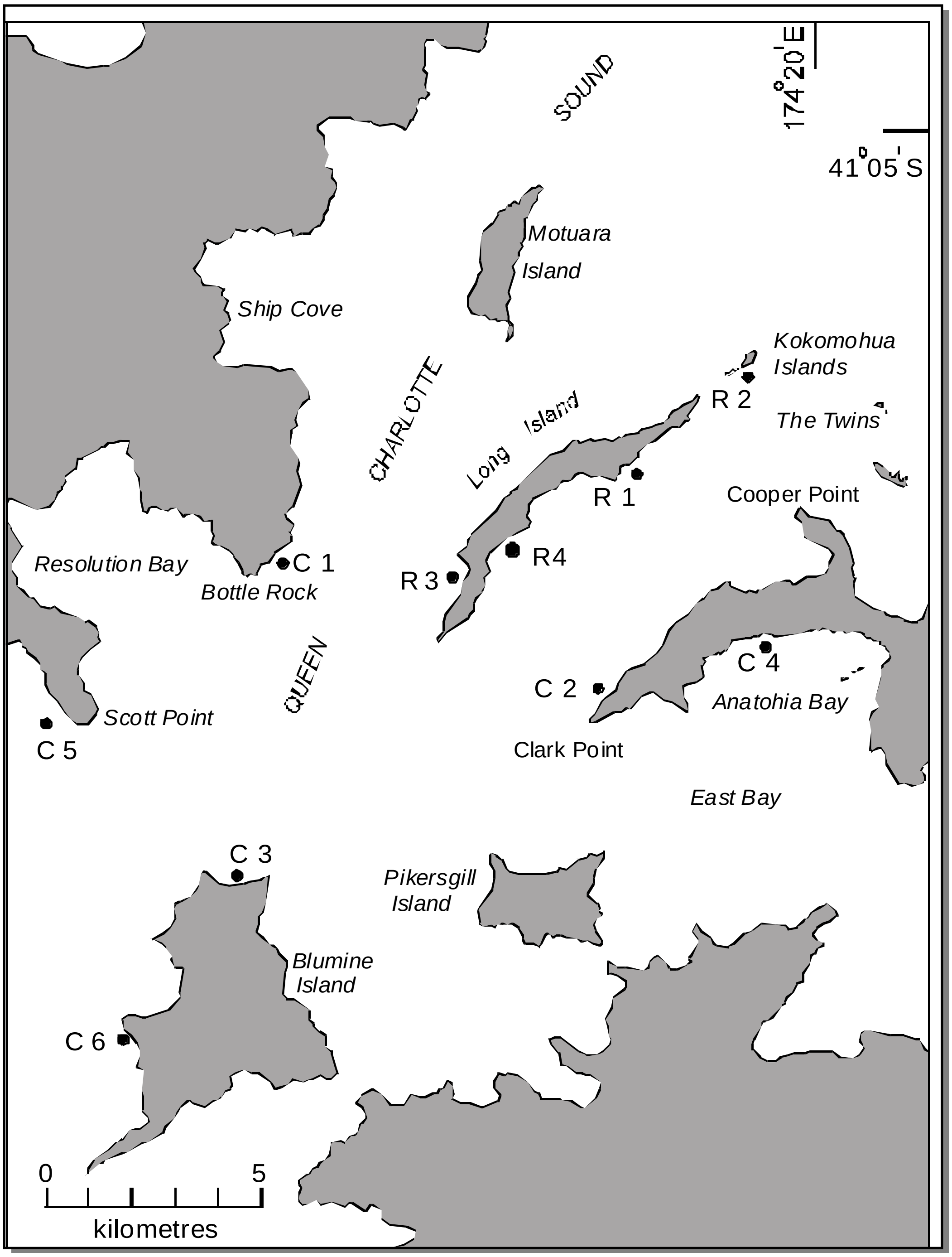


Figure 2. Location of catch, measure and release sites (R1 - R4 = marine reserve sites, C1 - C6 = control sites).

The six catch, measure and release control sites were established at sites subject to a perceived wide range of recreational fishing pressures. Two sites known to be regularly visited by recreational fishers were selected close to the marine reserve (Bottle Rock and Clark Point), one site was chosen that represented an area seldom fished (Anatohia Bay), and a further three sites were selected representing fishing pressure between these two extremes.

All fishing surveys were located over rubble habitat (i.e. cobbles and small boulders), as close to 12 m depth as possible. At each site, the survey vessel was positioned perpendicular to the shore using bow and stern anchors, thereby ensuring minimal boat movement. Ground-bait (berley) was secured inside a weighted plastic mesh container and lowered to the sea floor directly below the boat. Fishers used Kilwell scarab boat rods, set-up with two barbless 'surf-master' flasher rig hooks (size 2/0) and a lead sinker. Small hooks were used in an effort to catch as wide a range of fish sizes as possible. Hooks were baited using small pieces of squid. In order to minimise fish mortality, fishers were instructed to maintain direct contact between the rod and the sinker (tight lines) to help ensure fish did not swallow the hooks.

At each site, fishing effort (number of fishers and time fished) was recorded. Captured fish were transferred to a holding tank continuously supplied with fresh seawater. At the end of the fishing period, all fish were measured and transferred to a second holding tank secured over the side of the boat and supplied with fresh circulating seawater. All fish were handled using clean cotton gloves to minimise damage and risk of infection to fish. No fish were released while sampling continued, eliminating the chance of their recapture. This also allowed the sampling coordinator to assess any fish mortality during the period prior to fish release. All fish were released together to minimise mortality from predators, principally shags and barracouta (*Thyrsites atun*).

The maximum period fished at any site was set at two hours due to low catch rates at some sites. The target number of captured blue cod was always reached at reserve sites while the number of blue cod captured at control sites varied. Fishing ceased at two hours or when the target number of blue cod individuals were captured (i.e. up to 60 blue cod through to 2006 and up to 80 blue cod from 2007 onwards).

Davidson (2004) used two methods to confirm that the catch was representative of the reserve and control site blue cod populations. The author reported that in March 1994, and again in April 2000, divers descended to the sea floor under the catching boat at one reserve and one control site and visually assessed the sizes of fish in the populations around the ground bait and compared these to those sizes in the catch. In September 1995, the sizes of blue cod were recorded in the order they were captured at two control sites (i.e. Bottle Rock and Clark Point) and all three reserve sites.

4.2 Underwater visual fish surveys

Blue cod and other reef fish abundance were investigated using established underwater visual transect methods (Bell, 1983; McCormick and Choat, 1987; Choat *et al*., 1988; Buxton and Smale, 1989; Cole *et al*., 1990; Cole, 1994; Willis *et al*., 2000).

For rubble habitats, five reserve and four control sites were sampled annually from March 1992 to March 2009 (Figure 3, Table 3). For macroalgae habitats, three control and three reserve sites were sampled annually from April 2002 to May 2009 (Figure 4, Table 4). Prior to April 2002, algae habitats were sampled each year from three reserve and one control site (C3). Due to the lack of sufficient control sites prior to 2002, these early data have not been presented in the present report.

All transects were established parallel to the shore at depths from 7 m to 12 m. Blue cod sizes were estimated by divers and allocated to three size groups (juvenile < 100 mm, sub-adult 100 mm to 299 mm, and adult > 300 mm total length). Divers also recorded the presence of other reef fish, excluding triplefins and cave and crevice-dwelling species. The same three divers were used to estimate blue cod sizes and numbers from 1992 to 1999 and 2001 to 2009, while two additional divers were used in April 2000. All divers were trained at estimating fish size using a calibrated fish measuring pole.

At each site, a lead weight at the start of the transect line was dropped onto the substrate within the designated depth range. The line was automatically reeled off a spool as the diver holding the spool swam away from the lead weight. At a distance of 5 m from the weight (as indicated by a marker on the line), the diver started counting fish present within an estimated 2 m wide x 2 m high x 30 m long “tunnel”. A total of 12 replicates were collected on each occasion, apart from during March 1992 when six replicates per site were collected. Transects were swum at a constant slow speed, but fast enough to ensure that swimming blue cod did not overtake the divers. Underwater visibility was ≥ 4 m horizontal distance for all fish counts.

Table 3. Diver visual fish sites (rubble) in Long Island-Kokomohua Marine Reserve and at control sites (note: more sites were initially sampled by Davidson (1995)).

Site no.	Area	Sample site	Habitat	Coordinates
R 1	Reserve	Long Island (south-east)	Rubble	41° 07.299'S 174° 16.586'E
R 2	Reserve	Long Island (east)	Rubble	41° 06.678'S 174° 17.793'E
R 3	Reserve	Long Island (north-east)	Rubble	41° 06.447'S 174° 18.056'E
R 4	Reserve	Kokomohua (east)	Rubble	41° 06.239'S 174° 18.397'E
R 5	Reserve	Long Island (south-west)	Rubble	41° 07.546'S 174° 16.182'E
C 1	Control	Bottle Rock	Rubble	41° 07.506'S 174° 14.628'E
C 2	Control	Motuara Island	Rubble	41° 05.869'S 174° 16.354'E
C 3	Control	Kotukutuku	Rock/Rubble	41° 07.574'S 174° 18.198'E
C 4	Control	Clark Point	Rubble	41° 08.388'S 174° 17.281'E

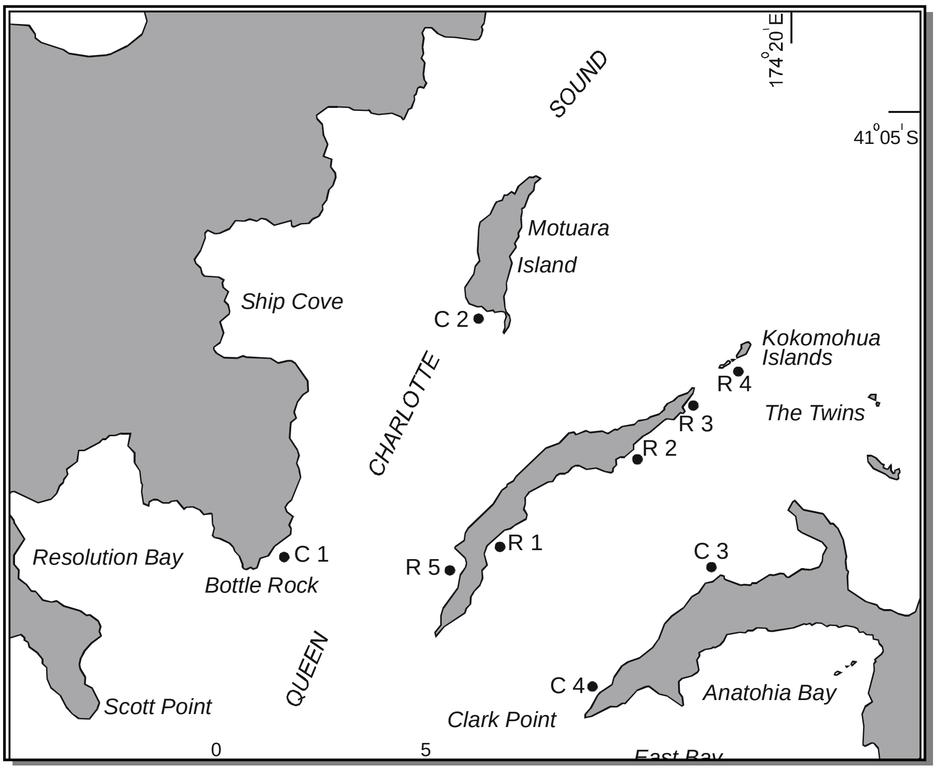


Figure 3. Location of rubble habitat underwater visual fish transects (R1 - R5 = marine reserve, C1 – C4 = control sites).

Table 4. Diver visual fish transect sample sites from algae habitat in Long Island-Kokomohua Marine Reserve and at control sites.

Site no.	Area	Sample site	Habitat	Depth (m)	Coordinates
R 1	Reserve	Charted Rock	Algae	4-15 m	41° 05.896'S 174° 18.809'E
R 2	Reserve	Long Island (north)	Algae	4-8 m	41° 06.419'S 174° 17.855'E
R 3	Reserve	Long Island (north-west)	Algae	4-8 m	41° 06.614'S 174° 17.198'E
C 1	Control	Motungarara Island	Algae	4-8 m	41° 06.828'S 174° 19.740'E
C2	Control	The Twins	Algae	4-10 m	41° 06.358'S 174° 19.577'E
C 3	Control	Motuara (west)	Algae	3-5 m	41° 05.539'S 174° 16.296'E

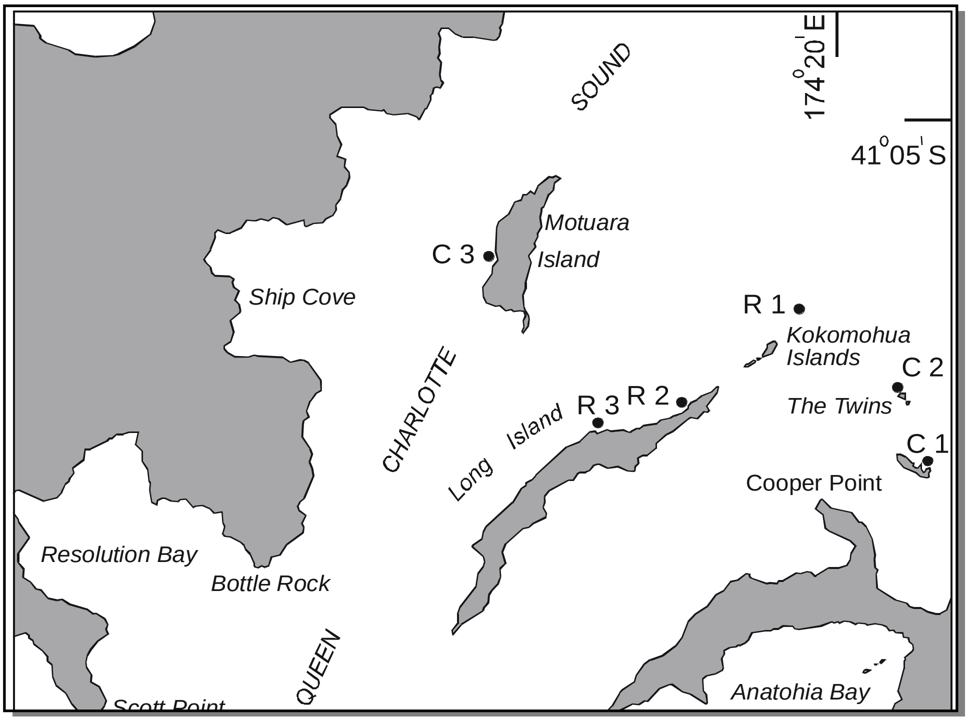


Figure 4. Location of algae habitat underwater visual fish transects (R1 - R3 = marine reserve, C1 – C3 = control sites).

4.3 Spiny lobster density, sex and size

Spiny lobster density and sex were sampled in March 1992, March 1995, April 1997, April 1999, and annually from April 2001 to March 2009 from four reserve and four control sites (Table 5, Figure 5). Lobster size (carapace length, CL, in 5 mm intervals) was recorded on slates with rulers used to estimate and, when possible, measure lobster size.

Prior to April 2001, between three to eight 60 m^2 quadrats were sampled per site. Starting in April 2001, the methodology was altered to reflect survey methodologies used elsewhere in New Zealand with between three and eight 100 m^2 quadrats sampled per site. Since March 2003, a total of six 100 m^2 quadrats was sampled. The method used to measure lobster size was also altered to using carapace length (CL) instead of total length (TL) from April 1999 onwards. Lobster quadrats were located in variable depths depending on the local topography at each sample site (i.e. sample depths corresponded to the location of suitable reef habitat) (Table 5).

Each lobster quadrat was haphazardly placed within the depth stratum. Two divers independently searched all crevices, caves and cracks within each quadrat using a dive torch. The size (CL) and sex of lobsters encountered were recorded. A core group of three divers was involved in most of the surveys. The size and sex of some lobsters could not be measured because they were deeply concealed beneath boulders or within caves. As a result, lobster density and size data do not correspond (i.e. all lobsters are included in density calculations, but some lobsters which could not be sexed do not appear under the male, female or juvenile categories). Underwater visibility was > 2 m horizontal distance during all counts.

4.4 Black-foot paua density and size

Black-foot paua (*Haliotis iris*) were sampled at eight reserve and three control sites in 1992. Since 1992, the number of sites was standardised to seven reserve sites and six control sites (Figure 6, Table 6). Paua were sampled from sublittoral bedrock or boulder habitats. In all cases, paua data came from the "mixed algae" habitat or from a macroalgal (*C. maschalocarpum*) sublittoral strip growing on bedrock located from 0 to 2 m depth.

Paua density was sampled in March 1992, April 1999, April 2007 and March 2009 from 30 to 60 1 m^2 quadrats within a predetermined depth range (Table 6). Quadrats were haphazardly placed on bedrock and boulder substrata and all visible black-foot paua were counted.

Between 15 and 115 individual black-foot paua were measured *in situ* (maximum length) using callipers in March 1992, April 1999, March 2004, April 2007 and March 2009 from the same sites used to sample paua density (Table 6). The minimum number measured varied depending on the availability of paua. All paua within the quadrats used for density sampling were measured. In some cases additional paua were measured outside quadrats to increase the sample size and in 2004, quadrats were not used. When quadrats were not used, divers searched methodically within the depth range to sample all sizes present. Divers did not, however, look under boulders or cobbles for cryptic paua in either the quadrats or during measuring searches.

4.5 Kina density and size

Kina or sea urchin (*E. chloroticus*) density and size data were collected in March 1992, April 1999 and April 2008. Eleven reserve and five control sites were sampled in 1992, but sites were reduced to six reserve and five control sites in April 1999 onwards (Figure 7). Analysis of size data used only the 1999 and 2008 sample sites, with data from additional sites collected in 1992 being excluded from the analysis. At each site, numbers of kina were counted from 34 to 66 haphazard 1 m^2 quadrats sampled at a predetermined depth range from rock or rubble substrata not covered by foliose macroalgae (Table 7). All surface-dwelling kina within quadrats were measured *in situ* using callipers to the nearest 1 mm length. When insufficient kina were measured from quadrats, additional kina were measured from adjacent areas within the predetermined depth range by divers thoroughly and methodically searching rocky habitats.

4.6 Cats eye density

Cats eye snail (*T. smaragdus*) density was sampled from five reserve and five control sites in March 1992, April 1999 and April 2008 (Figure 7). Cats eyes were counted in 21 to 60 haphazard 1 m^2 quadrats sampled from a predetermined depth range on rock or rubble habitat free of foliose macroalgae (Table 7).

Table 5. Spiny lobster sites in the reserve and at control sites.

Site	Area	Sample site	Habitat	Depth (m)	Coordinates
R1	Reserve	Charted Rock	Bedrock	4-15 m	41° 05.896'S 174° 18.809'E
R 2	Reserve	Long Island (north-east)	Rubble/bedrock	2-5 m	41° 06.352'S 174° 18.109'E
R 3	Reserve	Long Island (north-west)	Bedrock	4-10 m	41° 06.419'S 174° 17.855'E
R 4	Reserve	Long Island (north-west)	Bedrock	4-10 m	41° 06.614'S 174° 17.198'E
C 1	Control	Motungarara Island	Bedrock	3-12 m	41° 06.678'S 174° 17.793'E
C 2	Control	The Twins	Bedrock	3-12 m	41° 06.358'S 174° 19.577'E
C3	Control	Kotukutuku	Rock	2-6 m	41° 07.509'S 174° 18.332'E
C4	Control	Motuara (west)	Bedrock/rubble	2-7 m	41° 05.539'S 174° 16.296'E

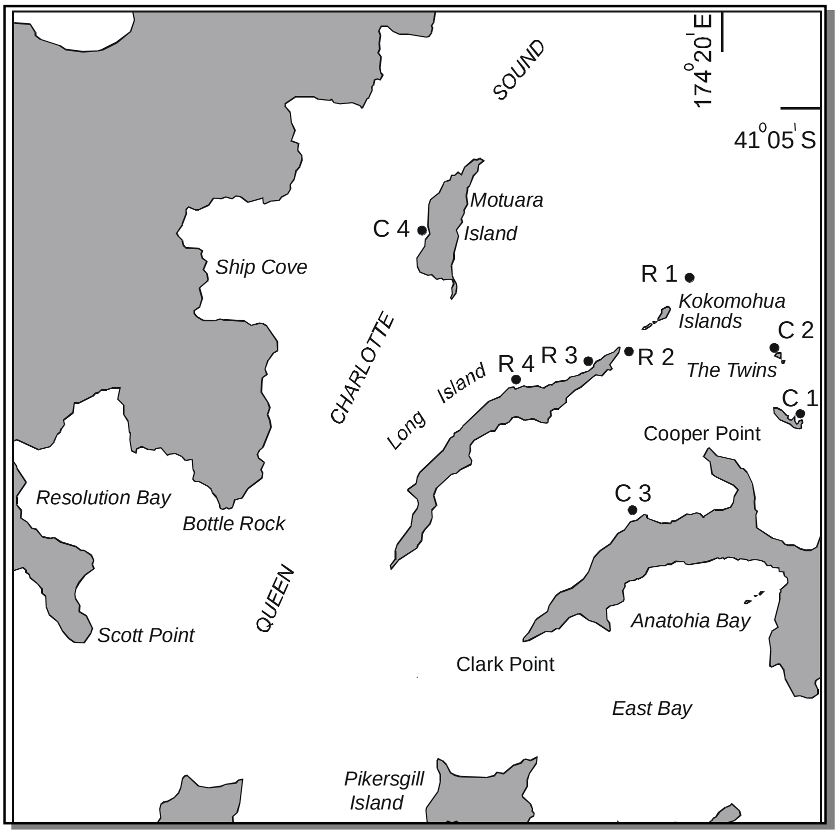


Figure 5. Location of spiny lobster sample sites in Queen Charlotte Sound (R1 – R4 = marine reserve sites, C1 - C4 = control sites).

Table 6. Black-foot paua sample sites in the Long Island-Kokomohua Marine Reserve and control sites.

Site no.	Area	Sample site	Habitat	Depth (m)	Coordinates
R1	Reserve	Eduardo Rock	Bedrock, cobble	0-2 m	41 06.77379,174 17.57974
R2	Reserve	North-east Long Is.	Bedrock	0-2 m	41 06.37738,174 18.08845
R3	Reserve	Kokomohua Is.	Bedrock, cobble	0-2 m	41 06.19322,174 18.40408
R4	Reserve	Long Is. (NW)	Bedrock	0-2 m	41 06.47505,174 17.87018
R5	Reserve	Long Is. cliffs	Bedrock	0-2 m	41 06.63415,174 17.23677
R6	Reserve	Long Is. west	Boulder, cobble	0-2 m	41 07.15759,174 16.41064
R7	Reserve	Long Is. south Spit	Bedrock, cobble	0-2 m	41 07.55120,174 16.23871
C1	Control	Te Ruatarore	Bedrock	0-2 m	41 06.94826,174 14.92066
C2	Control	Motuara Is. south	Bedrock, cobble	0-2 m	41 05.86498,174 16.34414
C3	Control	Motuara Is. west	Bedrock, cobble	0-2 m	41 05.55268,174 16.32606
C4	Control	Motungarara Is.	Bedrock, cobble	0-2 m	41 06.86422,174 19.76224
C5	Control	Kotukutuku	Bedrock	0-2 m	41 07.59032,174 18.24171
C6	Control	Clark Point	Boulder, cobble	0-2 m	41 08.15534,174 17.54890

Figure 6. Location of black-foot paua sample sites (R1 - R7 = marine reserve sites, C1 – C6 = control sites).

Table 7. Kina and cats eye sample sites from Long Island-Kokomohua Marine Reserve and control sites (note: no cats eye samples were collected from R4).

Site no.	Area	Sample site	Habitat	Depth (m)	Coordinates
R1	Reserve	Long Is (SE)	Cobble	2-8 m	41 07.298, 174 16.589
R2	Reserve	Eduardo Rock	Cobble	2-8 m	41 06.783, 174 17.586
R3	Reserve	Kokomohua Is.	Cobble	2-8 m	41 06.220, 174 18.382
R4	Reserve	Charted Rock	Rock	2-8 m	41 05.896, 174 18.809
R5	Reserve	Long Is. (west)	Cobble-bedrock	2-8 m	41 07.160, 174 16.379
R6	Reserve	Long Is. (south Spit)	Cobble	2-8 m	41 07.567, 174 16.212
C1	Control	Bottle Rock	Cobble	2-8 m	41 07.491, 174 14.609
C2	Control	Motuara Is. (south)	Cobble	2-8 m	41 05.888, 174 16.275
C3	Control	Motuara Is. (west)	Cobble	2-4 m	41 05.539, 174 16.296
C4	Control	Kotukutuku	Cobble-bedrock	2-8 m	41 08.221, 174 17.469
C5	Control	Clark Point	Cobble	2-8 m	41 07.492, 174 18.299

Figure 7. Location of kina and cats-eye sample sites (R1 - R6 = marine reserve sites, C1 – C5 = control sites) (note: no cats-eye sample from R4).

5.0 RESULTS

This report updates monitoring data collected from Long Island-Kokomohua Marine Reserve and nearby control sites from March 1992 to May 2009 and adds to the existing data sets reported previously by Davidson (1995, 1997, and 2004).

5.1 Fishing surveys (catch, measure and release)

A total of 4830 fish, (1917 from the reserve (five species) and 2913 from the control sites (13 species)) were captured, measured and released during six separate fishing surveys conducted annually between April 2004 and May 2009 (Tables 8 and 9). Blue cod dominated the catch with 4391 fish (90.9% of the total catch), comprising 1898 from the four reserve sites and 2493 from six control sites. Blue cod represented 99% of the total reserve catch (Table 8) and 85.6% of the total catch at control sites (Table 9). Spotty (*N. celidotus*) were the next most common fish caught in the reserve, followed by barracouta (*T. atun)* (0.5% and 0.26% respectively). At the control sites, spotty dominated the by-catch, with 330 fish representing 11.3% of the total control catch, followed by leatherjacket (*Parika scaber*) at 1%.

5.1.1 Size structure of blue cod

Total length (TL) of blue cod varied between reserve and control treatments throughout the catch, measure and release study (Figure 9). The median for reserve sites always exceeded that of the control sites.

Mean blue cod TL within the pooled reserve treatment increased between the start of the study and September 1999 (Figure 9). Since then, the pooled mean has varied from lows in 2002, 2003, 2005, 2007 and 2009 to highs in 2004, 2006 and 2008 (Figure 9). Pooled mean TL in the reserve ranged from 276 mm (+/- 6.6 s.e., n = 189) in September 1995 to a high of 318 mm (+/- 8.2 s.e., n = 206) in September 1999. T-test of means for the two treatments showed reserve means were significantly higher than those recorded for the control treatment (T = -11.2, P < 0.00001, df = 36).

Mean blue cod TL for the pooled control group was more variable than the pooled reserve means (Figure 9). Mean TL in the control group increased from September 1993 to August 1994, but declined dramatically by September 1995. Mean blue cod TL gradually increased in the following four sample events to March 1998, but declined again to an all-time low in April 2000. For the next two samples, mean TL for the control treatment increased peaking in April 2003, only to decline in March 2004. Since March 2004, there has been a gradual but consistent increase in the mean size of blue cod for the control treatment (Figure 9).

The proportion of four blue cod size classes showed relatively large-scale differences between reserve and control treatments (Figures 10 and 11, Table 10). For most of the study, the largest size class (330 – 650 mm TL) has represented a small part of the population outside the reserve. Since April 2004, a total of 2522 blue cod were sampled at control sites, but only 40 individuals or 1.6 % were larger than 330 mm TL. In contrast, of the 1815 blue cod measured from the four reserve sites over the same period, a total of 534 or 29.4% were > 330 mm TL (Figure 11). Small blue cod (0 - 279 mm TL) always dominated the control population with values ranging from 55 % to 93 % (Figure 10, Table 10). In the reserve, small blue cod usually dominated the population; however, large blue cod 330 – 650 mm TL were dominant on two occasions and were always second behind the smallest size class (Figure 10). The proportion of blue cod between 300 mm to 329 mm TL was usually higher from the reserve treatment; however, the 280 to 299 mm size class was comparable between the reserve and the control groups.

Comparison of blue cod size-frequency distributions throughout the study showed population size structure was different in the reserve compared to the control treatment (Figures 12 - 16). Comparison of blue cod size structure between March 1994 and April 2008 showed that large individuals (> 300 mm TL) were common in the reserve but comparatively few were recorded from control sites, especially in 2008 (Figure 17). The size-frequency distribution for the pooled April 2008 reserve sample spanned a greater size range of cod compared to the reserve in March 1994 (Figure 17). Blue cod size-frequency from pooled control sites in March 1994 and April 2008 generally showed a smaller size range compared to the reserve. This narrow size range was particularly apparent in the control April 2008 sample where very few cod were recorded above 320 mm and no cod were above 350 mm TL (Figure 17). In particular years, the reserve blue cod population showed a bi-modal structure, a phenomenon that was not recorded from the control treatment (for example, April 2003 in Figure 15 and April 2006 in Figure 16).

5.1.2 Blue cod catch per unit effort

Pooled catch per unit effort (CPUE) values were significantly higher in the reserve compared to the control sites ($T = -10.02$, $P<0.00001$, $df = 36$). For the pooled control sites, CPUE values remained consistently low and never exceeded 0.39 blue cod per rod per minute (Figure 18). In contrast, CPUE in the reserve increased by over 100% within a year and continued to increase over the next four years. From September 1997 onwards, the reserve CPUE mostly remained above one blue cod per rod per minute compared to < 0.4 blue cod per minute in the control group (Figure 18).

Table 8. List of fish species recorded from catch, measure and release samples collected annually from pooled reserve sites from April 2004 to May 2009.

Species name	Common name	4-2004	4-2005	4-2006	4-2007	4-2008	5-2009	Total
Parapercis colias	Blue cod	251	320	330	339	331	327	1898
Nemadactylus macropterus	Tarakihi	0	0	0	1	0	2	3
Notolabrus celidotus	Spotty	0	0	6	1	1	2	10
Thyrsites atun	Barracouta	1	1	0	0	2	1	5
Cephaloscyllium isabellum	Carpet shark	0	0	0	0	0	0	0
Chelidonichthys kumu	Gurnard	0	0	0	0	0	0	0
Parika scaber	Leatherjacket	0	0	1	0	0	0	1
Arripis trutta	Kahawhai	0	0	0	0	0	0	0
Helicolenus papillosus	Sea perch	0	0	0	0	0	0	0
Pseudolabrus miles	Scarlet wrasse	0	0	0	0	0	0	0
Notolabrus fucicola	Banded wrasse	0	0	0	0	0	0	0
Caesioperca lepidoptera	Butterfly perch	0	0	0	0	0	0	0
Caranx georgianus	Trevally	0	0	0	0	0	0	0
Total catch (n)		252	321	337	341	334	332	1917
Total no. species		2	2	3	3	3	4	5

Table 9. List of fish species recorded from catch, measure and release samples collected annually from pooled control sites from April 2004 to May 2009.

Species name	Common name	4-2004	4-2005	4-2006	4-2007	4-2008	5-2009	Total
Parapercis colias	Blue cod	227	481	456	492	355	482	2493
Nemadactylus macropterus	Tarakihi	1	3	2	1	1	1	9
Notolabrus celidotus	Spotty	45	42	37	97	81	28	330
Thyrsites atun	Barracouta	4	1	1	1	0	1	8
Cephaloscyllium isabellum	Carpet shark	0	2	1	0	0	4	7
Chelidonichthys kumu	Gurnard	0	0	0	0	3	0	3
Parika scaber	Leatherjacket	5	5	3	6	9	2	30
Arripis trutta	Kahawhai	0	1	0	0	3	4	8
Helicolenus papillosus	Sea perch	0	0	0	2	1	0	3
Pseudolabrus miles	Scarlet wrasse	0	3	1	2	8	2	16
Notolabrus fucicola	Banded wrasse	0	0	1	0	1	0	2
Caesioperca lepidoptera	Butterfly perch	0	2	0	0	0	0	2
Caranx georgianus	Trevally	0	0	0	0	2	0	2
Total catch (n)		282	540	502	601	464	524	2913
Total no. species		5	9	8	7	10	8	13

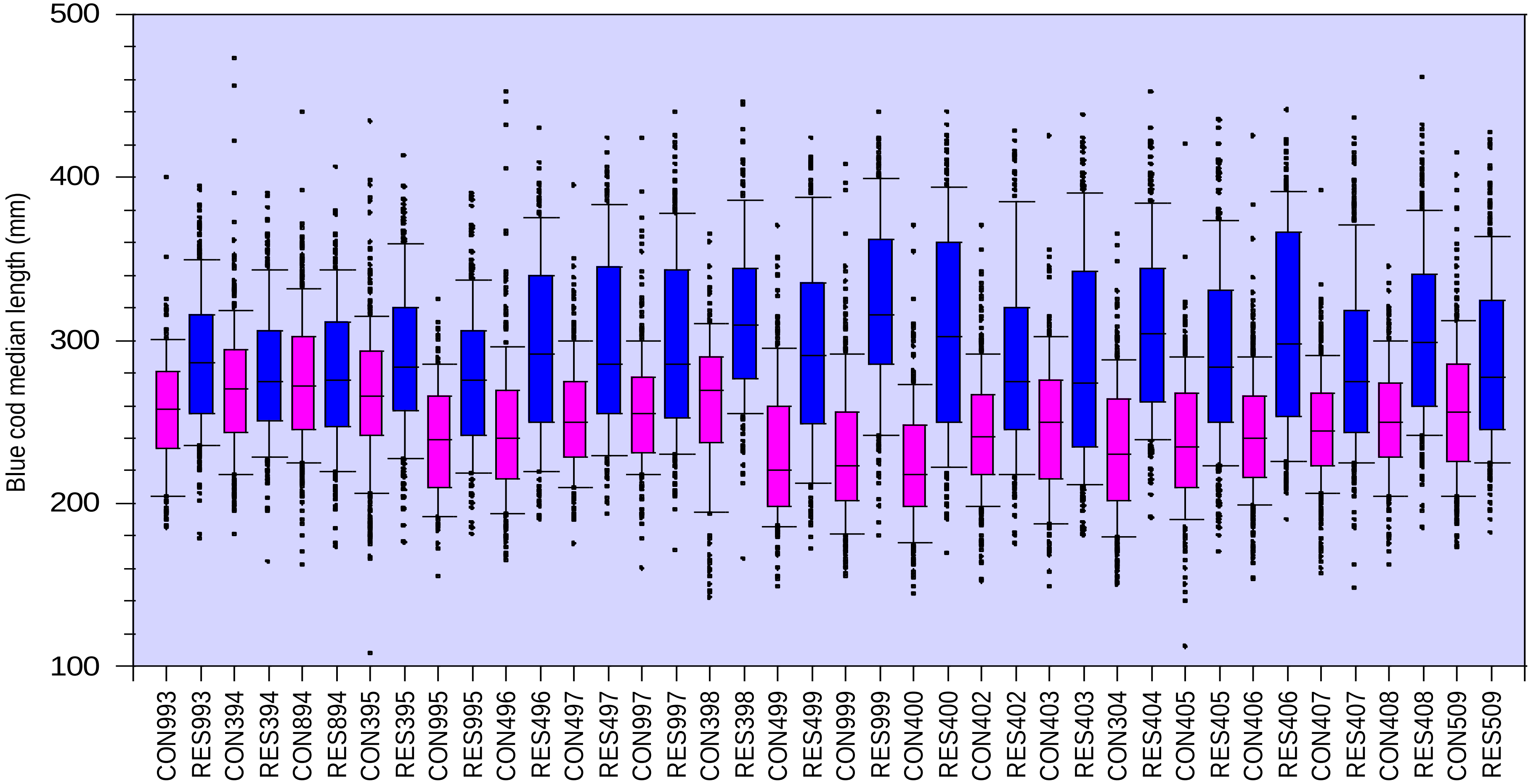


Figure 8. Box plot of blue cod length from pooled catch, measure and release reserve (blue) and control (pink) treatments. Enclosed boxes represent 25th and 75th percentiles and the horizontal line the median. Error bars are 10th and 90th percentiles. X axis labels are: CON = control, RES = reserve, three numbers = month and then the year.

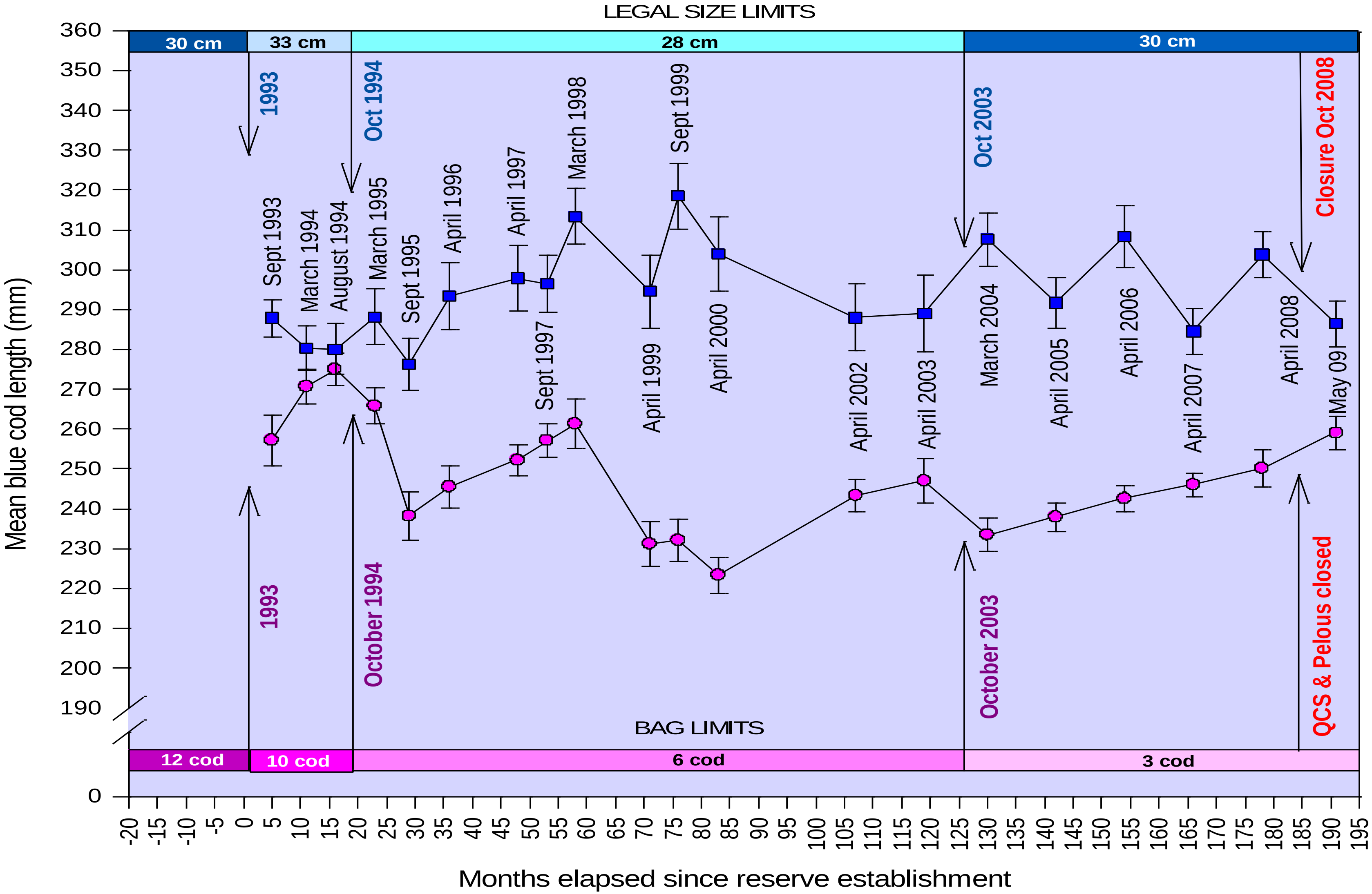


Figure 9. Mean blue cod length from pooled catch, measure and release reserve (blue squares) and control (pink circles). Error bars represent 95% confidence intervals. Changes to blue cod fishing regulations are indicated over the study period. QCS & Pelorus closed = Queen Charlotte and Pelorus Sound closed to blue cod fishing.

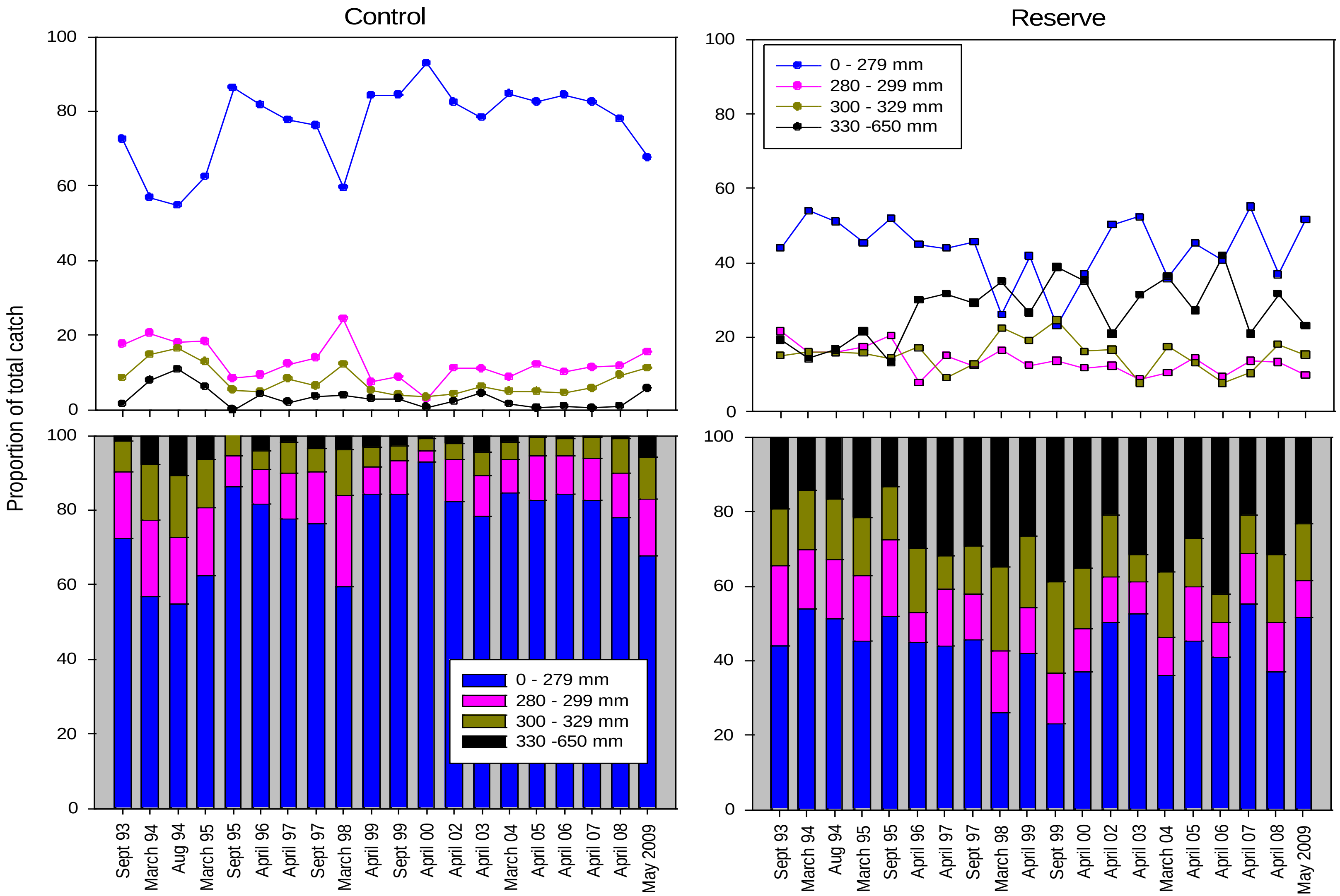
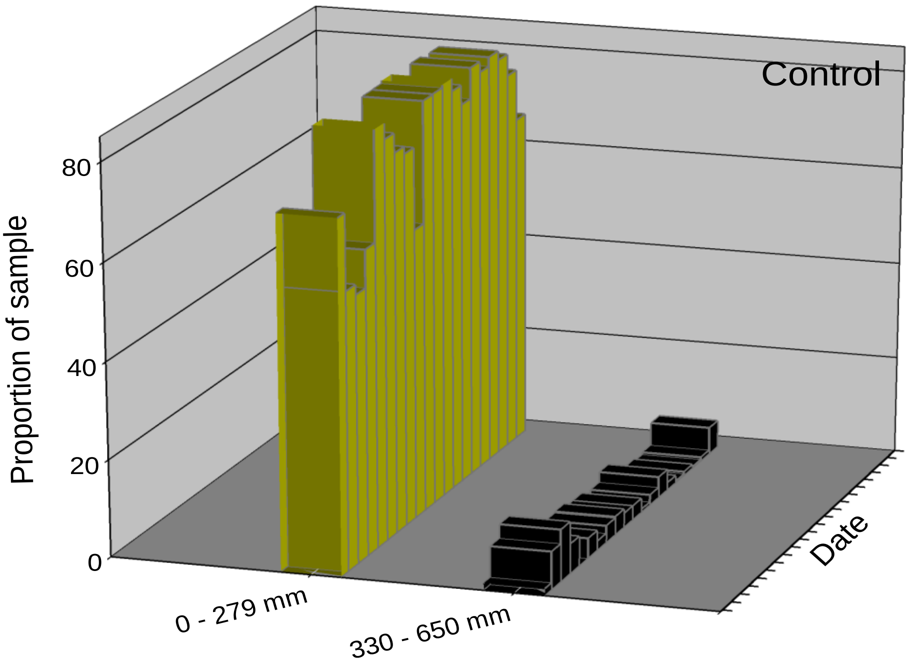


Figure 10. Proportion of blue cod captured (catch, measure and release) during each sample event from pooled reserve and control treatments separated into four size categories (September 1993 to May 2009). Line (top) and bar (bottom) graphs display the same data for control (left) and reserve (right) pooled samples.



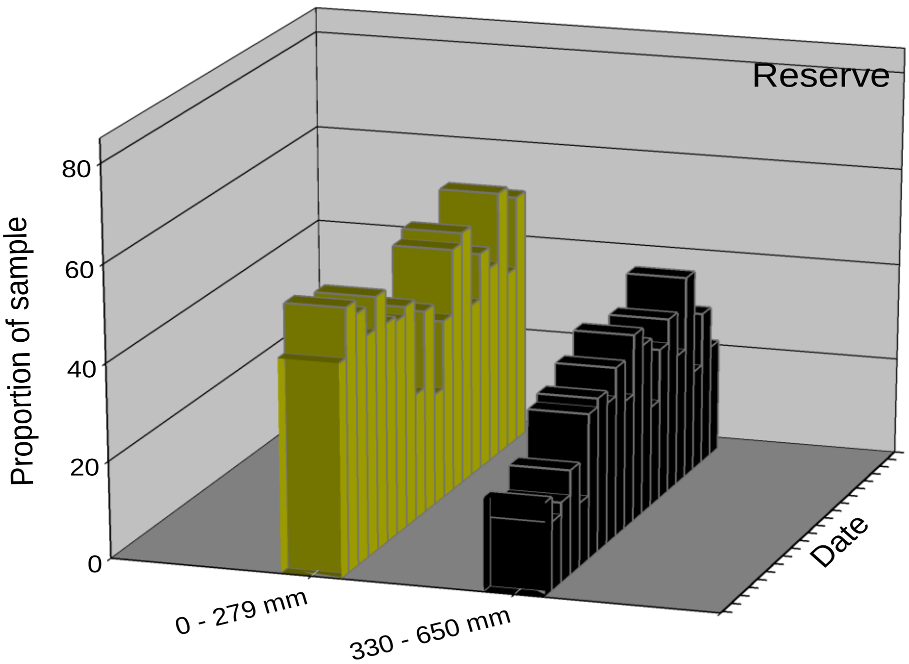


Figure 11. Proportion (%) of small 0 – 279 mm (yellow bars) and large 330 – 650 mm (black bars) blue cod from the total catch per each sample event from pooled control (top) and pooled reserve (bottom) treatments. Bars display data from September 1993 in the foreground to May 2009 in the background. Note: 300 mm to 329 mm size classes are not displayed.

Table 10. Average size, number and proportion of blue cod in four size categories (0-279 mm, 280 - 299 mm, 300-329, and 330-650 mm length) for pooled catch, measure and release sites inside and outside the reserve.

Date	Treatment (sites)	N	Mean (mm)	0 - 279 mm N	0 - 279 mm %	280 – 299 mm N	280 – 299 mm %	300 – 329 mm N	300 – 329 mm %	330 - 650 mm N	330 - 650 mm %	Size range (mm)
Sep-93	Marine reserve (3)	305	287.9	134	43.9	66	21.6	46	15.1	59	19.3	178-394
	Control sites (2)	131	257.2	95	72.5	23	17.6	11	8.5	2	1.5	185-400
Mar-94	Marine reserve (3)	226	279.9	122	54	36	15.9	36	15.9	32	14.2	164-390
	Control sites (6)	336	270.7	206	56.9	78	20.5	56	14.8	30	7.9	181-473
Aug-94	Marine reserve (3)	193	280.1	99	51.2	31	16	31	16	32	16.6	173-406
	Control sites (6)	372	275.0	204	54.8	67	18	61	16.4	40	10.8	162-440
Mar-95	Marine reserve (3)	185	288.2	84	45.4	32	17.3	29	15.7	40	21.6	176-413
	Control sites (6)	372	265.8	232	62.5	68	18.3	48	12.9	23	6.2	166-434
Sep-95	Marine reserve (3)	181	276.3	94	51.9	37	20.4	26	14.4	24	13.3	181-390
	Control sites (6)	131	238.2	113	86.3	11	8.4	7	5.3	0	0	155-325
Apr-96	Marine reserve (3)	181	293.4	81	45	14	7.8	31	17.2	54	30	190-430
	Control sites (5)	289	245.5	236	81.7	27	9.3	14	4.8	12	4.2	165-452
Apr-97	Marine reserve (3)	186	297.9	82	44	28	15.1	17	9.1	59	31.7	193-424
	Control sites (6)	302	252.2	234	77.7	37	12.3	25	8.3	6	2	175-395
Sep-97	Marine reserve (3)	240	296.5	114	45.6	31	12.4	32	12.8	73	29.2	171-440
	Control sites (6)	281	257.1	214	76.2	39	13.9	18	6.4	10	3.6	160-424
Mar-98	Marine reserve (3)	200	313.4	52	26	33	16.5	45	22.5	70	35	166-446
	Control sites (6)	205	261.3	122	59.5	50	24.4	25	12.2	8	3.9	142-365
Apr-99	Marine reserve (3)	177	294.5	74	41.8	22	12.4	34	19.2	47	26.2	172-424
	Control sites (6)	230	231.2	194	84.3	17	7.4	12	5.2	7	3	149-370
Sep-99	Marine reserve (3)	183	318.5	42	23	25	13.7	45	24.6	71	38.8	180-440
	Control sites (6)	275	232.1	232	84.4	24	8.7	11	4	8	3	155-408
Apr-00	Marine reserve (3)	179	304	66	36.9	21	11.7	29	16.2	63	35.2	169-440
	Control sites (6)	268	223.3	249	92.9	8	3	9	3.4	2	0.7	144-370
Apr-02	Marine reserve (3)	187	287.5	94	50.3	23	12.3	31	16.6	39	20.9	175-428
	Control sites (6)	313	243.3	258	82.4	35	11.2	13	4.2	7	2.2	152-370
Apr-03	Marine reserve (3)	185	289.0	97	52.4	16	8.6	14	7.6	58	31.4	180-438
	Control sites (6)	227	247.0	178	78.4	25	11	14	6.2	10	4.4	149-425
Mar-04	Marine reserve (4)	251	307.6	90	35.9	26	10.4	44	17.5	91	36.3	191-452
	Control sites (6)	367	233.4	311	84.7	32	8.7	18	4.9	6	1.6	150-365
Apr-05	Marine reserve (4)	320	291.7	145	45.3	46	14.4	42	13.1	87	27.2	170-435
	Control sites (6)	451	238.0	372	82.5	55	12.2	22	4.9	2	0.44	112-420
Apr-06	Marine reserve (4)	247	308.3	101	40.9	23	9.3	19	7.7	104	42.1	190-441
	Control sites (6)	456	242.5	385	84.4	46	10	21	4.6	4	0.9	153-425
Apr-07	Marine reserve (4)	339	284.5	187	52.2	46	13.6	35	10.3	71	20.9	148-436
	Control sites (6)	492	246.0	406	82.5	56	11.4	28	5.7	2	0.4	157-392
Apr-08	Marine reserve (4)	331	303.8	122	36.9	44	13.3	60	18.1	105	31.7	185-461
	Control sites (6)	355	250.2	277	78	42	11.8	33	9.3	3	0.9	162-345
May-09	Marine reserve (4)	327	286.5	169	51.7	32	9.8	50	15.3	76	23.2	182-415
	Control sites (5)	401	259.0	271	67.6	62	15.5	45	11.2	23	5.7	173-345

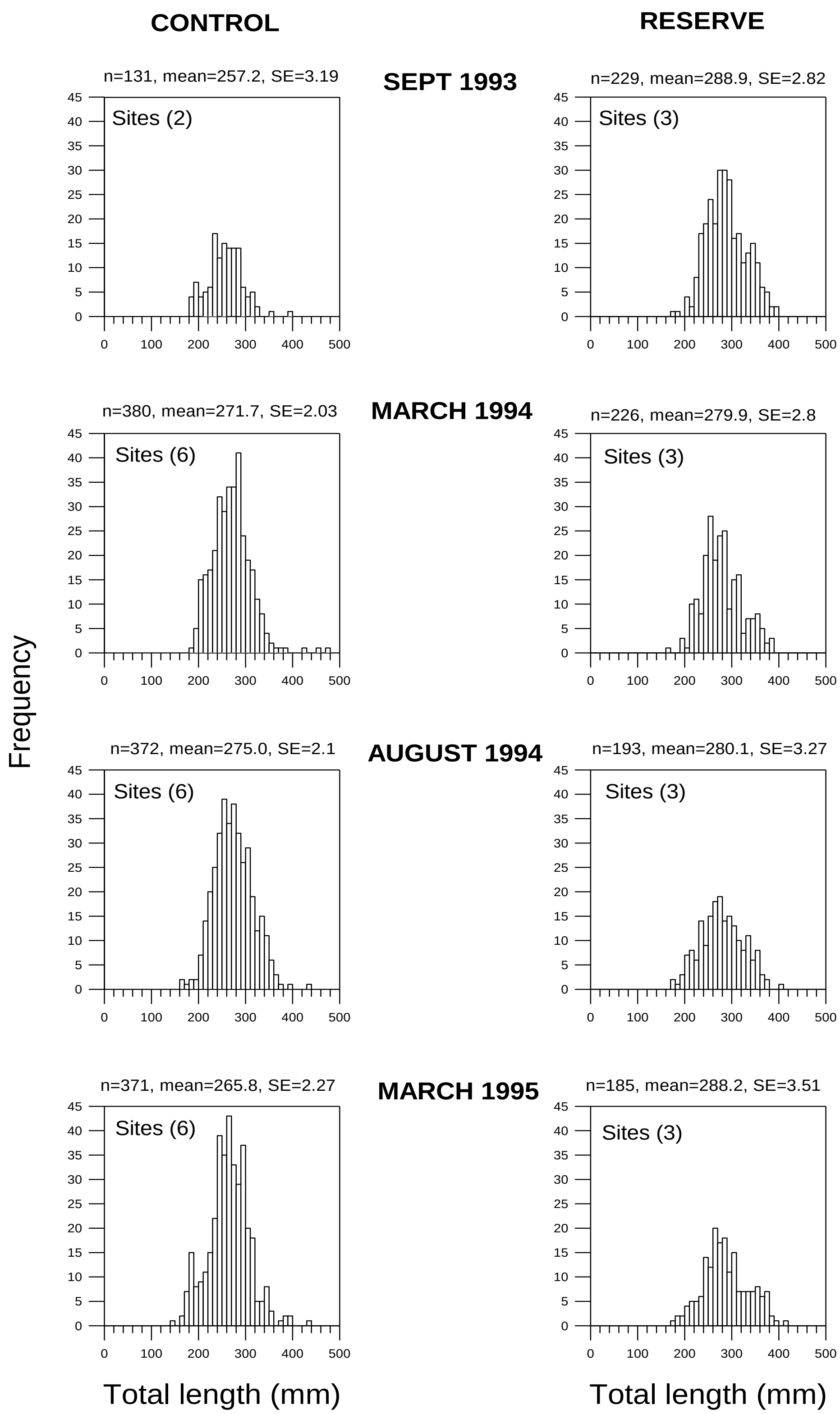


Figure 12. Length-frequency of blue cod from pooled Long Island-Kokomohua Marine Reserve and control sites from September 1993 to March 1995.

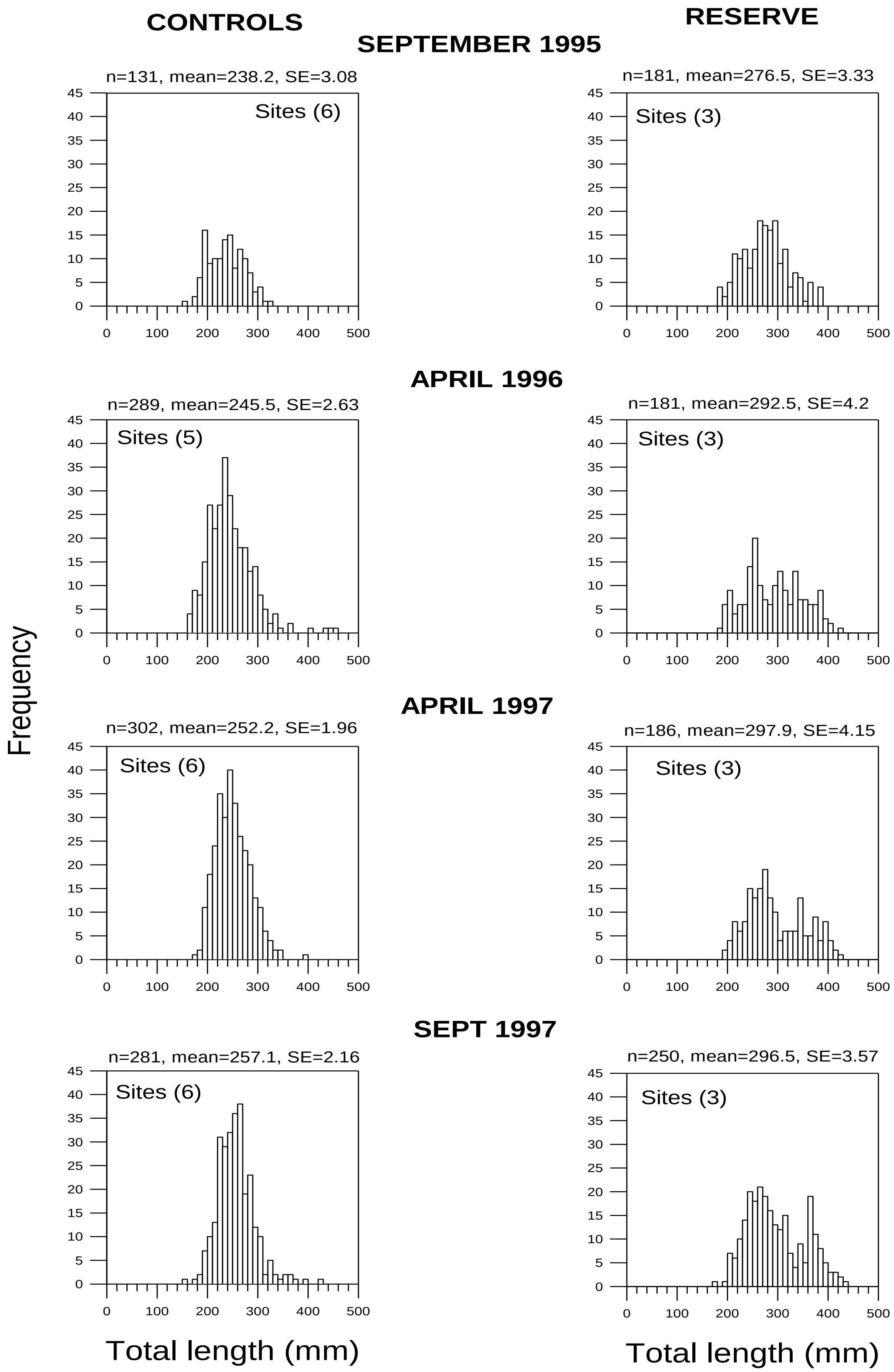


Figure 13. Length-frequency of blue cod from pooled Long Island-Kokomohua Marine Reserve and control sites from September 1995 to September 1997.

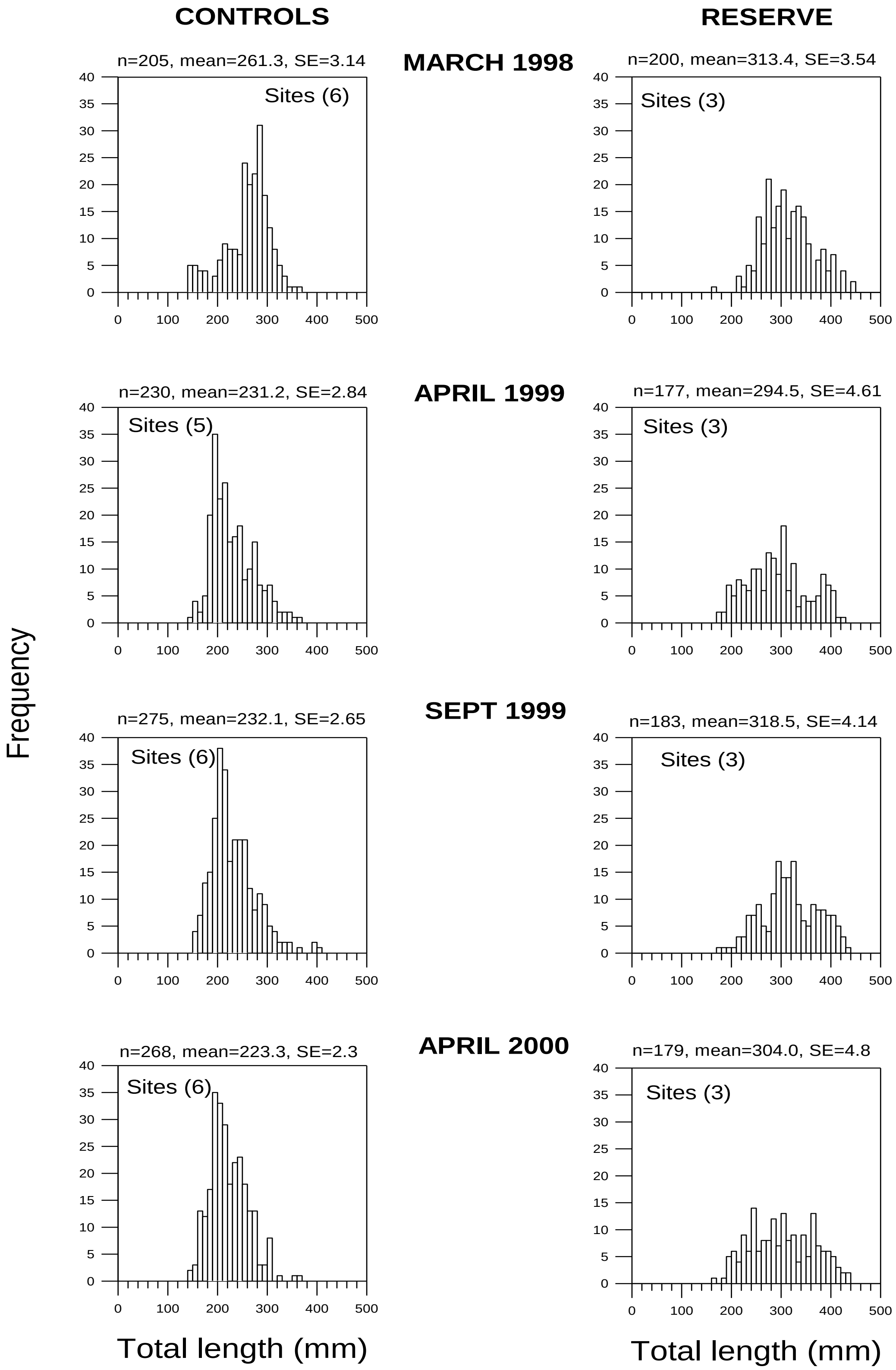


Figure 14. Length-frequency of blue cod from pooled Long Island-Kokomohua Marine Reserve and control sites from March 1998 to April 2000.

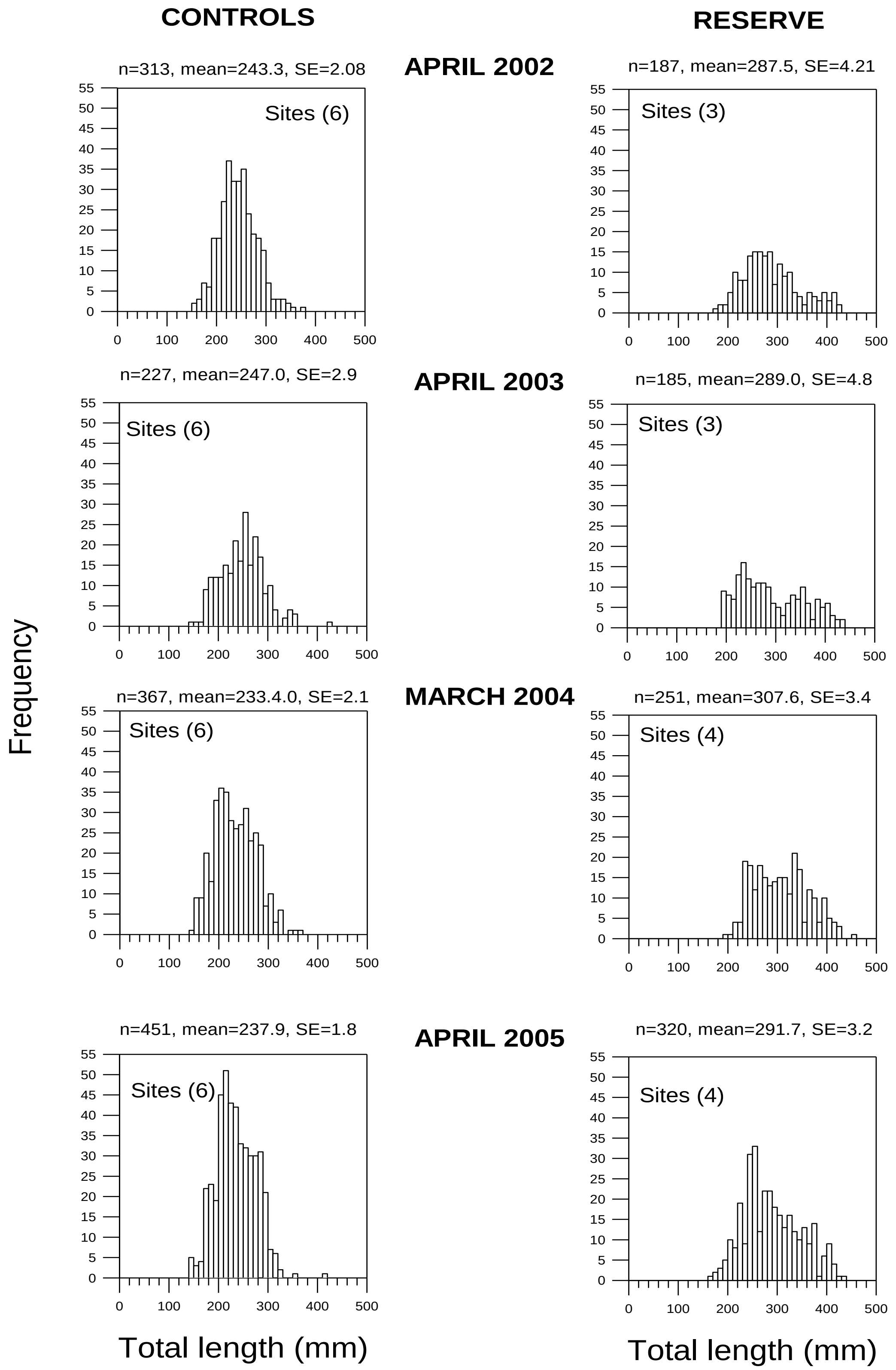


Figure 15. Length-frequency of blue cod from pooled Long Island-Kokomohua Marine Reserve and control sites from April 2002 to April 2005.

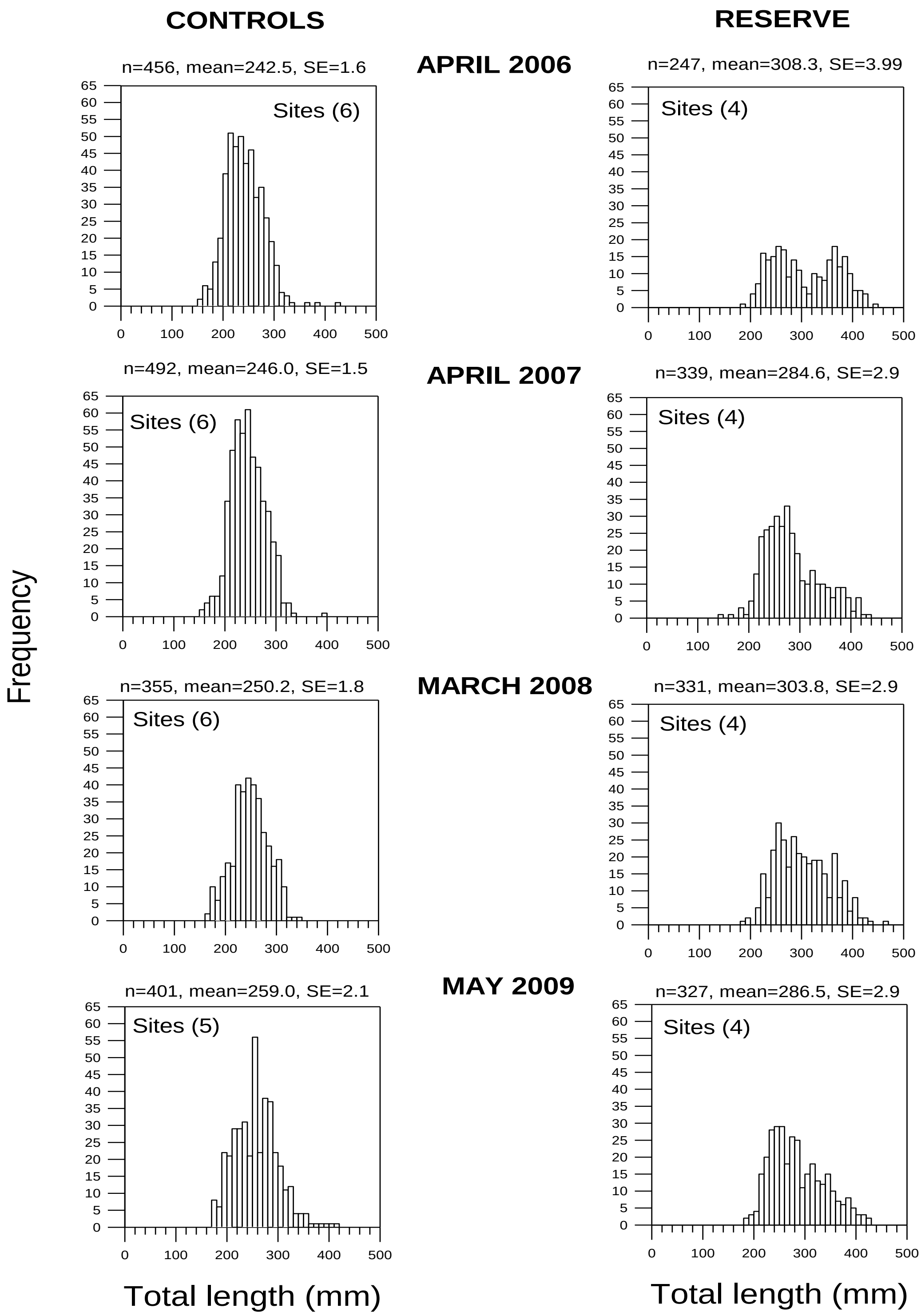


Figure 16. Length-frequency of blue cod from pooled Long Island-Kokomohua Marine Reserve and control sites from April 2006 to May 2009.

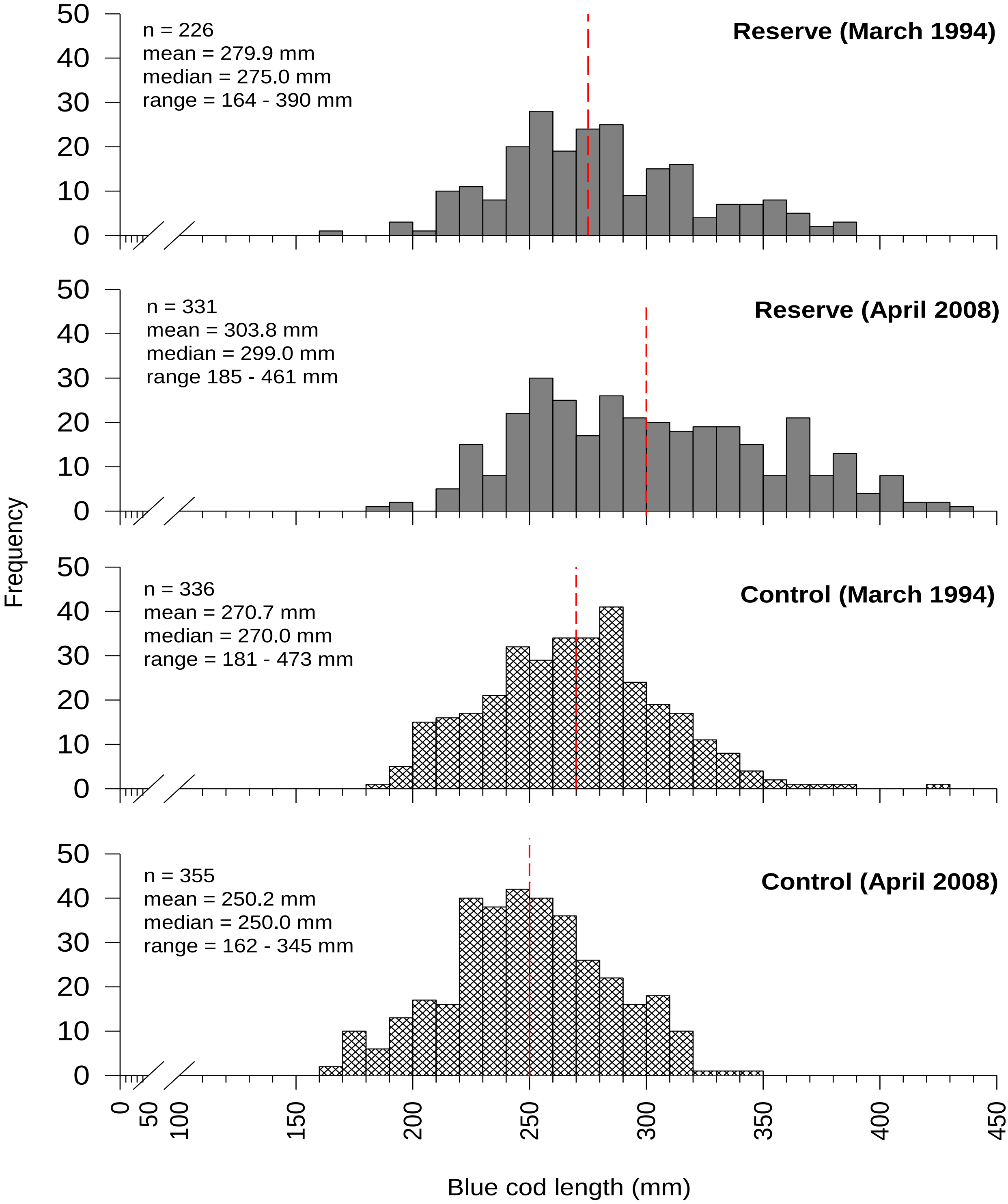


Figure 17. Size-frequencies of blue cod from pooled reserve (shaded bars) and control (hatched bars) catch, measure and release sampled for 1994 and 2008. Vertical line represents the median

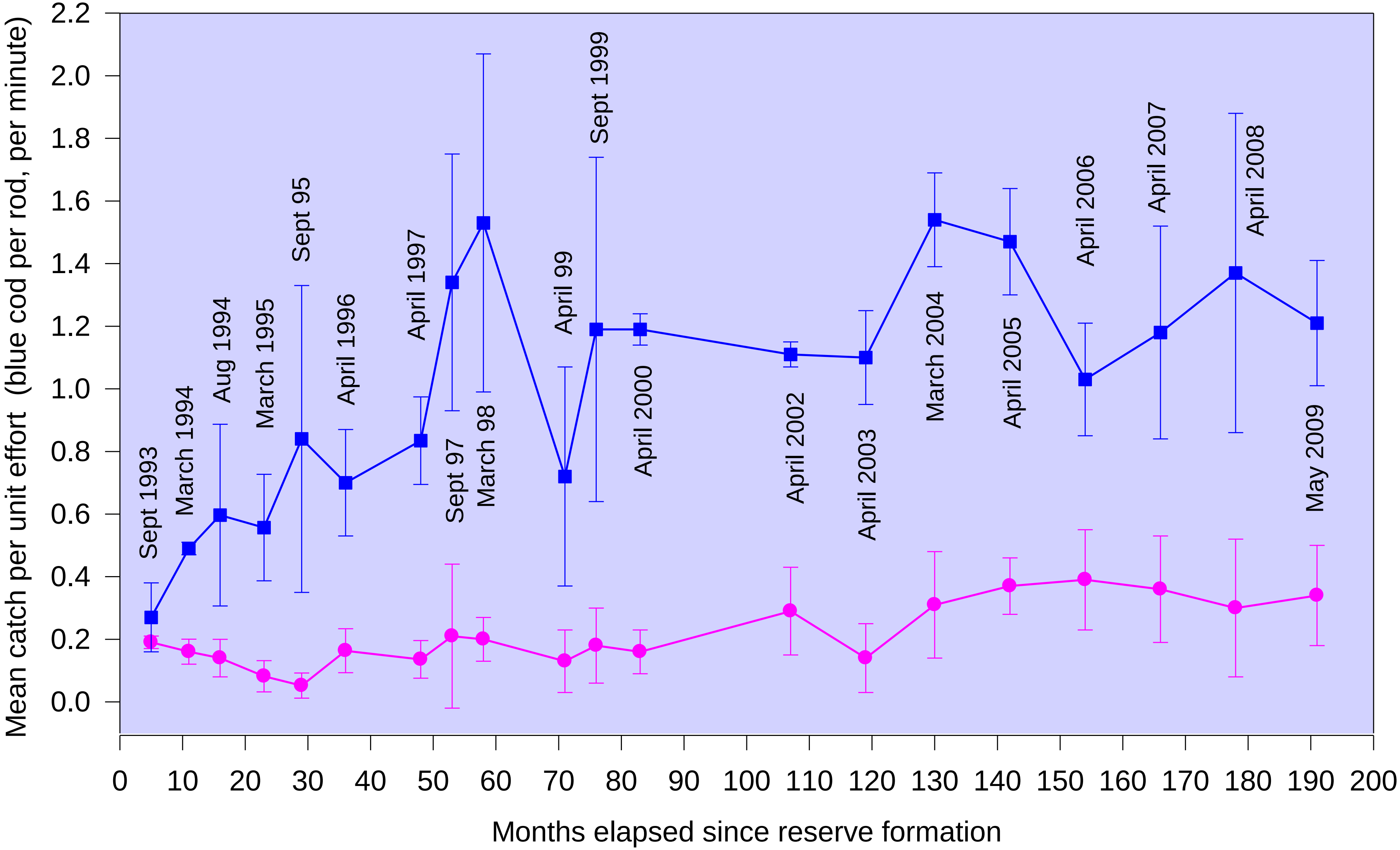


Figure 18. Mean catch per unit effort (CPUE) for blue cod pooled from reserve and control sites, September 1993 to May 2009. Error bars are 95% confidence intervals.

5.2 Underwater visual surveys

Divers observed a total of 13 species of reef fish over rubble habitat at reserve and control sites over the duration of the study (Table 11). Blue cod and spotty were recorded from all rubble sites on all occasions. Leatherjacket (*Parika scaber*) was recorded sporadically as individual adults. Kingfish (*Seriola grandis*) were occasionally observed, always in small groups. All other species were rarely observed from rubble-dominated habitat inside and outside the reserve.

Table 11. Relative abundance of fish species (excluding triplefins) assessed by divers during underwater counts over the duration of the study (1992-2009) from rubble and macroalgae reserve and control sites.

Species name	Common name	Rubble	Macroalgae
Caesioperca lepidoptera	Butterfly perch	1	2
Upeneichthys lineatus	Goatfish	1	1
Scorpis lineolatus	Sweep	1	2
Aplodactylus arctidens	Marblefish	1	2
Nemadactylus macropterus	Tarakihi	1	2
Cheilodactylus spectabilis	Red moki	1	2
Cheilodactylus nigripes	Magpie moki		1
Latridopsis ciliaris	Blue moki	2	2
Latridopsis aerosa	Copper moki		1
Notolabrus celidotus	Spotty	3	3
Notolabrus fucicola	Banded wrasse	2	2
Pseudolabrus miles	Scarlet wrasse	2	2
Pseudolabrus cinctus	Girdled wrasse		1
Parapercis colias	Blue cod	3	2
Parika scaber	Leatherjacket	1	2
Odax pullus	Butterfish		2
Latris lineata	Trumpeter		1
Scorpis violaceus	Blue maomao		1
Seriola lalandi	Kingfish	2	2
Hippocampus abdominalis	Seahorse		1
Total number of species		**13**	**20**

Note: Relative abundance score: blank = absent; 1 = rare (1-2 individuals seen per dive), 2 = occasional (3-10 individuals seen per dive), 3 = common (11+ individuals seen per dive or present in schools).

Twenty species of reef fish were recorded from the macroalgae habitat at reserve and control sites over the duration of the study (Table 11). Spotty was the most abundant species followed by banded and scarlet wrasse. Blue cod were relatively uncommon from this habitat. Of interest was the occasional observation at the Charted Rock of a northern species of fish, blue maomao (*Scorpis violaceus*) and a southern species, girdled wrasse (*Pseudolabrus cinctus*).

After five years of sampling, the density of blue cod pooled from all rubble reserve sites reached significantly higher levels compared to the control treatment (Table 12, Figure 19). The density of blue cod at the control sites remained low over the duration of the study, reaching an all time low in March 1998. This difference between the reserve and control treatments was most pronounced for the large size class (≥ 300 mm TL). The density of this large size class remained relatively low at the control treatment compared to the reserve treatment where large blue cod gradually increased in density over the duration of the study (Figure 19). For small blue cod (TL < 300 mm), densities for both reserve and control treatments remained relatively stable (Figure 19), but their density was consistently higher from the reserve treatment compared to the controls (this difference was significantly different in all years from April 2000; $P < 0.002$).

Table 12. T-test of all blue cod density data collected from underwater visual counts from rubble bottom sites compared between pooled reserve and pooled control sites from 1992 to 2009.

Year	df	T	P	Significance
Mar-92	40	0.686	0.4962	Not Significant
Mar-93	88	-0.214	0.2177	Not Significant
Mar-94	91	1.484	0.1412	Not Significant
Mar-95	97	-2.331	0.0218	Not Significant
Apr-96	78	2.065	0.0422	Not Significant
Apr-97	111	-3.151	<0.0021	Significant
Mar-98	106	5.082	<0.00001	Significant
Apr-99	106	-3.832	<0.0002	Significant
Apr-00	106	5.404	<0.00001	Significant
Apr-01	94	-4.21	<0.00001	Significant
Apr-02	118	4.939	<0.0001	Significant
Apr-03	106	-6.265	<0.00001	Significant
Mar-04	106	-4.778	<0.00001	Significant
Mar-05	106	6.385	<0.00001	Significant
Apr-06	106	-3.944	<0.0001	Significant
Apr-07	106	3.812	<0.0002	Significant
Mar-08	106	-5.44	<0.00001	Significant
Mar-09	106	3.84	<0.0002	Significant

Spotty were recorded from all rubble sites in variable densities (Figure 20). Their density from both treatments showed similar trends, consisting of highs every second or third year. Apart from March 1993, spotty were more abundant from the control treatment on all occasions. Banded wrasse (*Notolabrus fucicola*) was generally more abundant from control sites compared to reserve sites (Figure 20). Tarakihi (*Nemadactylus macropterus*) were relatively uncommon from rubble habitats both inside and outside the reserve (Figure 20). In March 1994, a large school of tarakihi was recorded at one reserve site; however, only occasional tarakihi individuals were observed in most years. Other reef fishes occasionally recorded from rubble banks were leatherjacket (*P. scaber*), blue moki (*Latridopsis ciliaris*), butterfly perch (*Caesioperca lepidoptera*), and scarlet wrasse (*Pseudolabrus miles*) (Table 11).

The density of most reef fish in macroalgae area differed little between reserve and control sites (Figure 21). In many years, blue cod, blue moki, tarakihi and butterfish were more abundant in the reserve compared to the control treatment, but only occasionally were these differences statistically significant. For both reserve and control treatments, blue cod densities recorded from macroalgae habitat were lower than densities recorded from rubble habitat. In contrast, blue moki and tarakihi were more abundant from the macroalgae habitat compared to rubble areas (Figures 20 and 21).

The mean size of tarakihi estimated by divers from April 2002 to May 2009 at macroalgae sites revealed considerable variability between years at reserve and control treatments (Figure 22). This was influenced by the larger numbers of juvenile fish in particular years and the absence of particular size classes of tarakihi from some sites in certain years. The mean size of blue moki from the reserve and control treatments was similar from 2002-2004, but from April 2005 onwards, moki were larger within the reserve (Figure 22). Apart from April 2006 ($T = -1.86$, $P = 0.06$), this difference between treatments was significantly different.

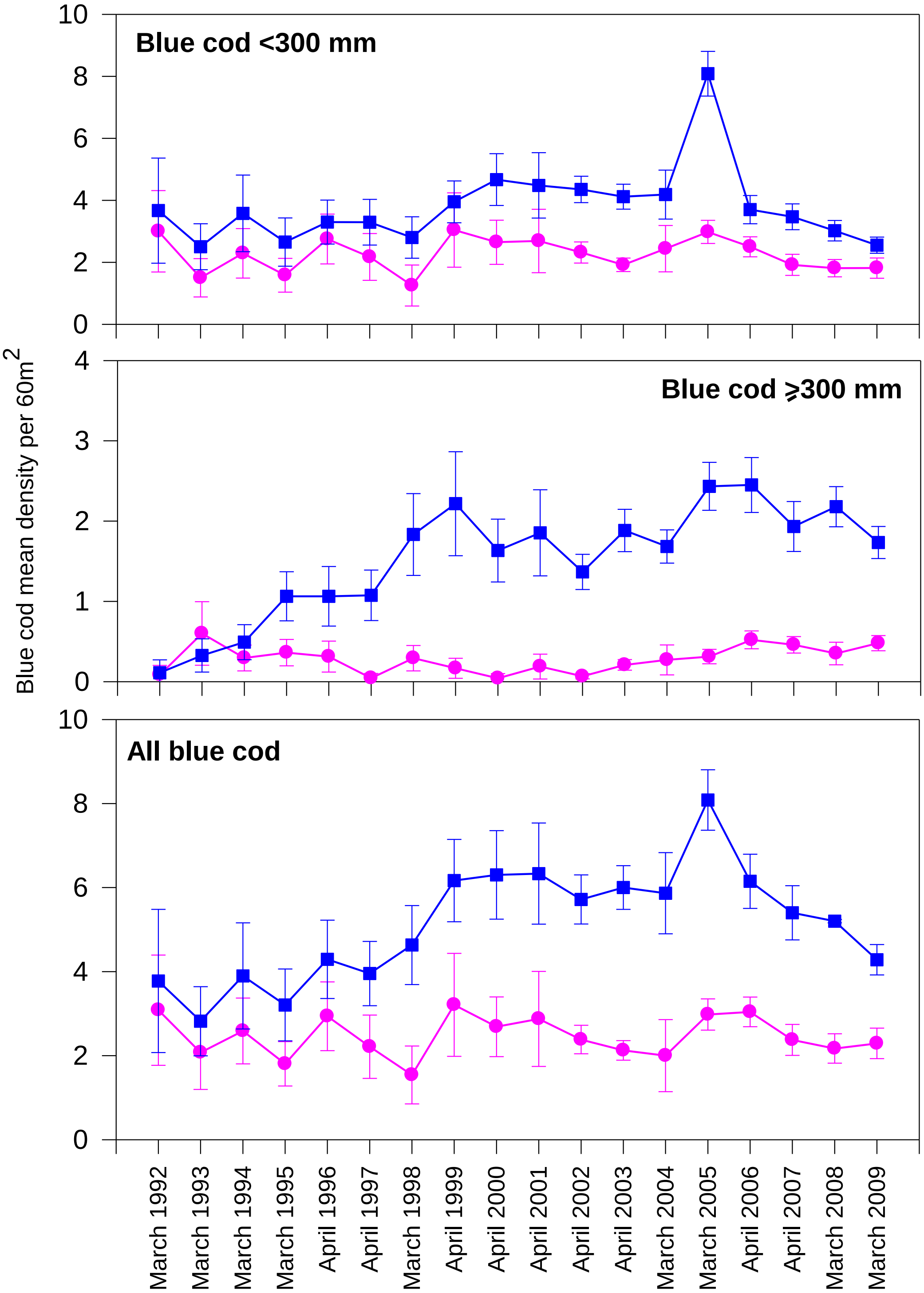


Figure 19. Mean density of blue cod from underwater visual diver counts pooled from rubble sites in the reserve (n = 5; blue squares) and control sites (n = 4; pink circles). Error bars = +/- 1 s.e. Note: Y axis scales differ between each size class graph.

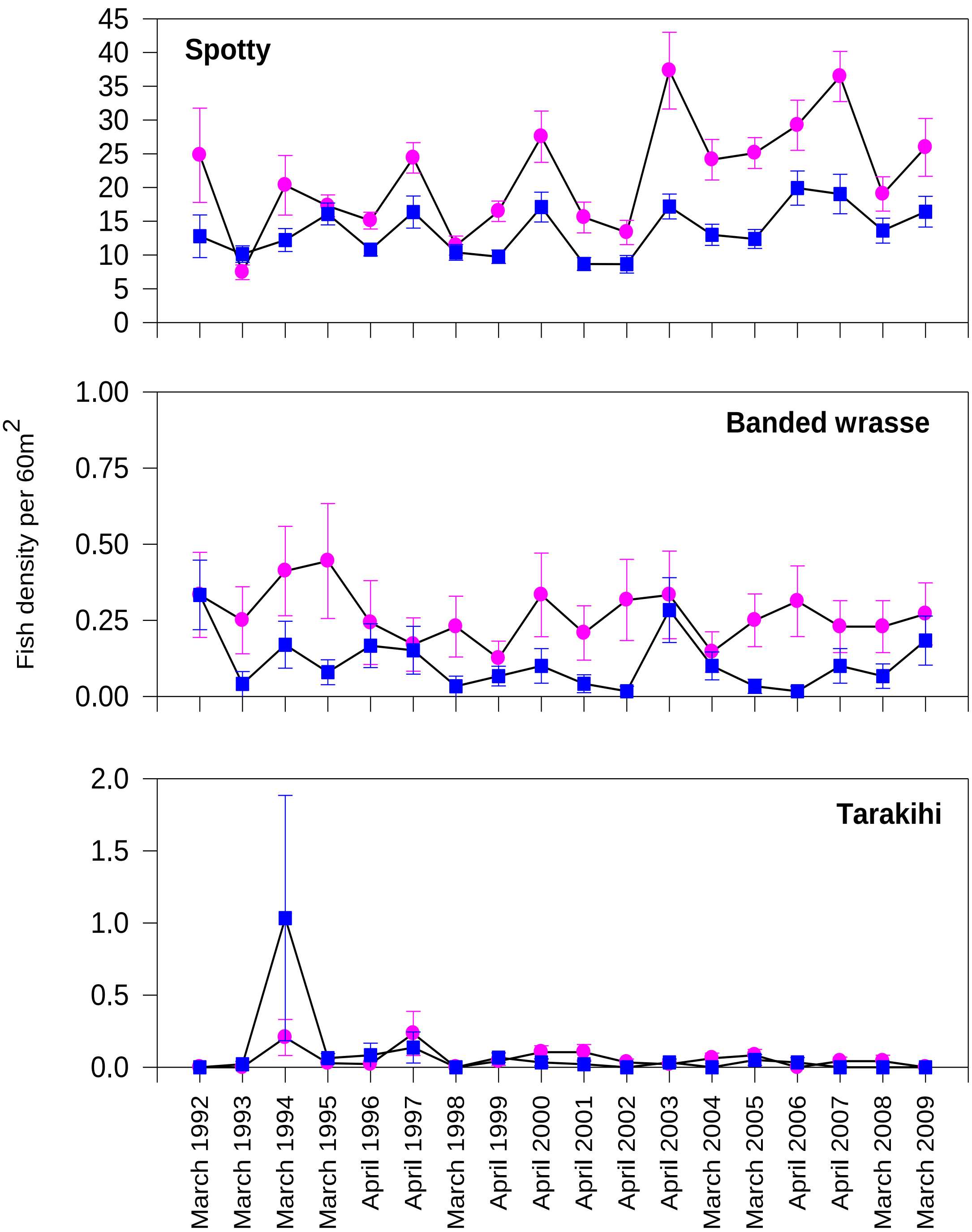


Figure 20. Mean density of selected fish species from underwater visual diver counts pooled from rubble sites in the reserve (n = 5; blue squares) and control sites (n = 4; pink circles). Error bars = +/- 1 s.e.

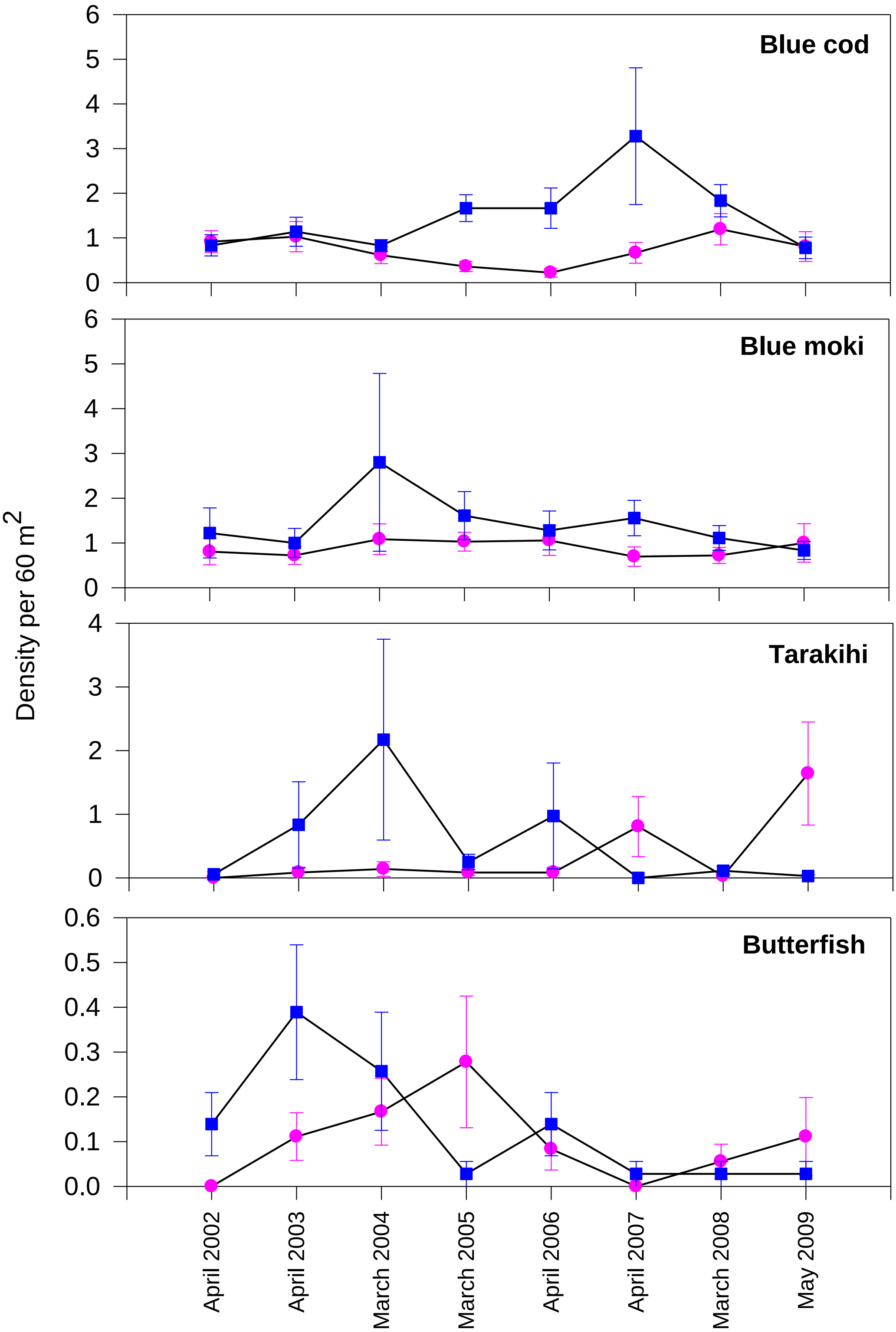


Figure 21. Mean density of selected fish species from diver counts pooled from macroalgae-dominated sites in the reserve (n = 3; blue squares) and control sites (n = 3; pink circles). Error bars = +/- 1 s.e.

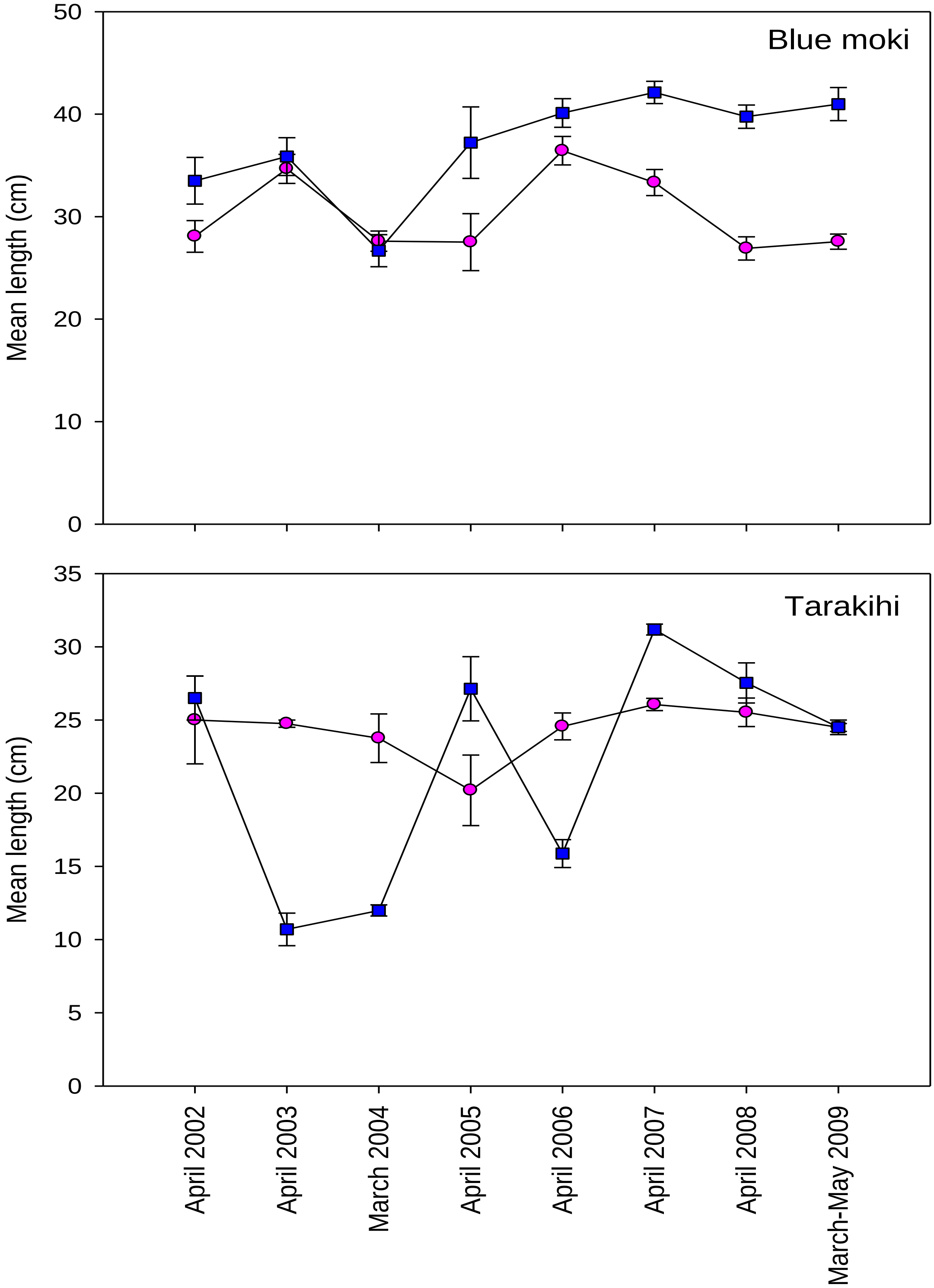


Figure 22. Mean length (cm) of blue moki and tarakihi estimated by divers from all macroalgae and rubble reserve (blue squares) and control sites (pink circles) from 2002 to 2009. Error bars = +/- 1 s.e.

5.3 Spiny lobster density, sex, and size

Reserve spiny lobster density remained at relatively low levels for the first nine years after the reserve was established. Density then increased from April 2002 onwards (Figure 23). Lobster density also remained at low or very levels for the first 10 years at control sites, but increased from April 2003 to April 2006 (Figure 23). Lobster density at the control treatment fell back to lower levels between April 2007 and March 2009 (Figure 23, Table 13). Since April 2002, the mean density of reserve lobsters has been higher than the peak control density recorded in April 2006. Comparison of the means for all years between the two treatments showed a significantly higher average density for the reserve group compared to the control group ($T = 3.42$, $P = 0.0024$). In March 2009, the mean density of lobsters in the reserve was 3.3 times higher than the mean control density (Table 13).

Table 13. Mean density of spiny lobster (per 100m^2) from pooled reserve and control sites. Note: not all sites were sampled each year; additional control sites were sampled from 2002 onwards.

Year	Reserve (mean and 1SE)	Control (mean and 1SE)
March 1992	1.90 (0.94)	2.50 (0.63)
March 1995	3.89 (1.60)	4.63 (1.98)
April 1999	3.67 (1.45)	0.56 (0.28)
April 2001	2.78 (0.66)	0.54 (0.22)
April 2002	10.17 (2.38)	0.72 (0.42)
April 2003	7.50 (2.15)	2.03 (0.60)
March 2004	10.50 (2.04)	2.67 (0.88)
April 2005	12.13 (2.12)	5.75 (2.01)
April 2006	14.29 (2.22)	6.71 (1.79)
April 2007	13.00 (2.38)	2.29 (0.73)
March 2008	13.63 (1.51)	2.17 (0.50)
March 2009	10.75 (1.24)	3.25 (0.65)

The mean size of lobsters from the pooled reserve treatment was higher than the control treatment from 1999 to 2008 (Figures 24 - 27). In 2009, the reserve mean lobster carapace length (CL) was 115.5 mm compared to 97.9 mm from the pooled control treatment, showing a significant difference ($T = 5.17$, $P< 0.00001$). The range of lobster sizes recorded between 2004 and 2009 was also very different between reserve and control treatments. For example, in 2009, the reserve lobster size range was 60 mm to 185 mm CL compared to 70 mm to 150 mm CL for the controls. Relatively few large individuals over 115 mm CL were recorded from the control treatment (18%) compared to the reserve (45%).

Male spiny lobsters dominated the reserve sites in 1995 and 1997; however, this may be an artefact of the relatively small samples sizes in those years (Table 14, Figure 28). Since April 1999, the percentage of reserve males and females has been comparable, ranging from 29 to 53.8% for males and 33.1 to 53.1% for females. In contrast, the proportion of males relative to females has varied at control sites with females representing a smaller part of the population from 2006-2009 (Figure 28). In most years, the percentage of females in the control treatment was < 40%; the exceptions being 1995, 2001 and 2003. The lowest proportion of females at controls was 18.8% in 2002 and 17.8% in 2008. At no time did the proportion of females drop below 33% for the reserve treatment and for many years it was > 40% (Figure 28, Table 14).

Table 14. Sex composition of spiny lobsters sampled in Long Island-Kokomohua Marine Reserve and control sites (1992 to 2009). Note: numbers and percentages include lobsters measured outside density quadrats.

Year	Reserve sites				Control sites			
	Male		Female		Male		Female	
	N	% of total	N	% of total	N	% of total	N	% of total
1995	23	82	0	0	10	40	13	52
1997	7	100	0	0	1	100	0	0
1999	13	40.6	17	53.1	0	0	1	33.3
2001	43	48	38	42.7	4	30.8	6	46.2
2002	57	36.3	58	36.9	30	62.5	9	18.8
2003	69	40.8	69	40.8	24	34.3	30	42.9
2004	67	29.1	66	28.7	32	28.3	43	38.1
2005	98	34	133	46.2	60	42.6	42	29.8
2006	166	48.7	113	33.1	74	47.7	34	21.7
2007	98	34	133	46.2	60	42.6	42	29.8
2008	146	44.5	142	43.3	54	60	16	17.8
2009	136	53.8	107	42.3	54	57.1	31	36.9

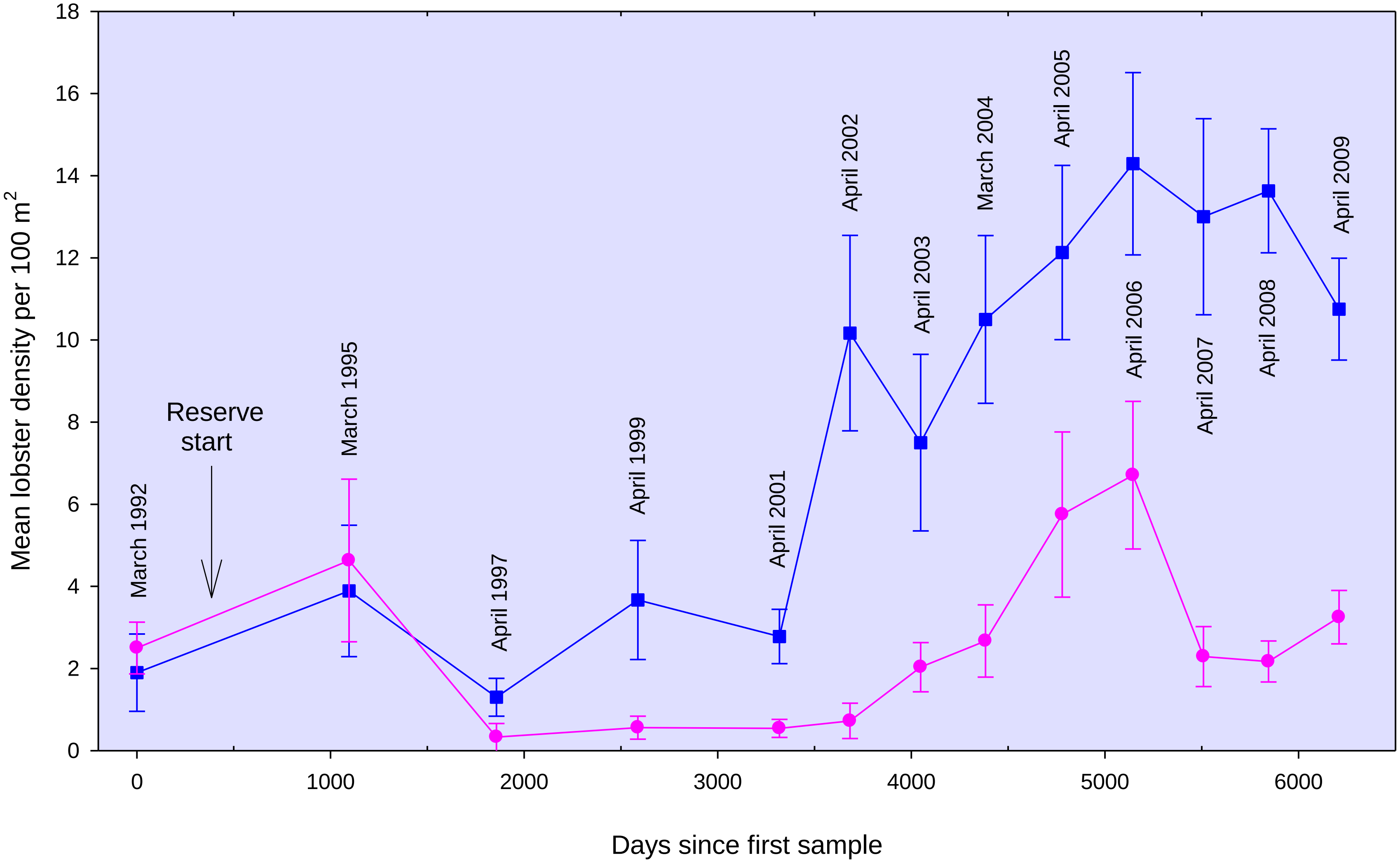


Figure 23. Mean density of spiny lobster from reserve sites (R1 – R4, blue squares) and control sites (C1 – C4, pink circles). Error bars = +/- 1 s.e. Note: prior to 2003, some sites were not sampled in each year.

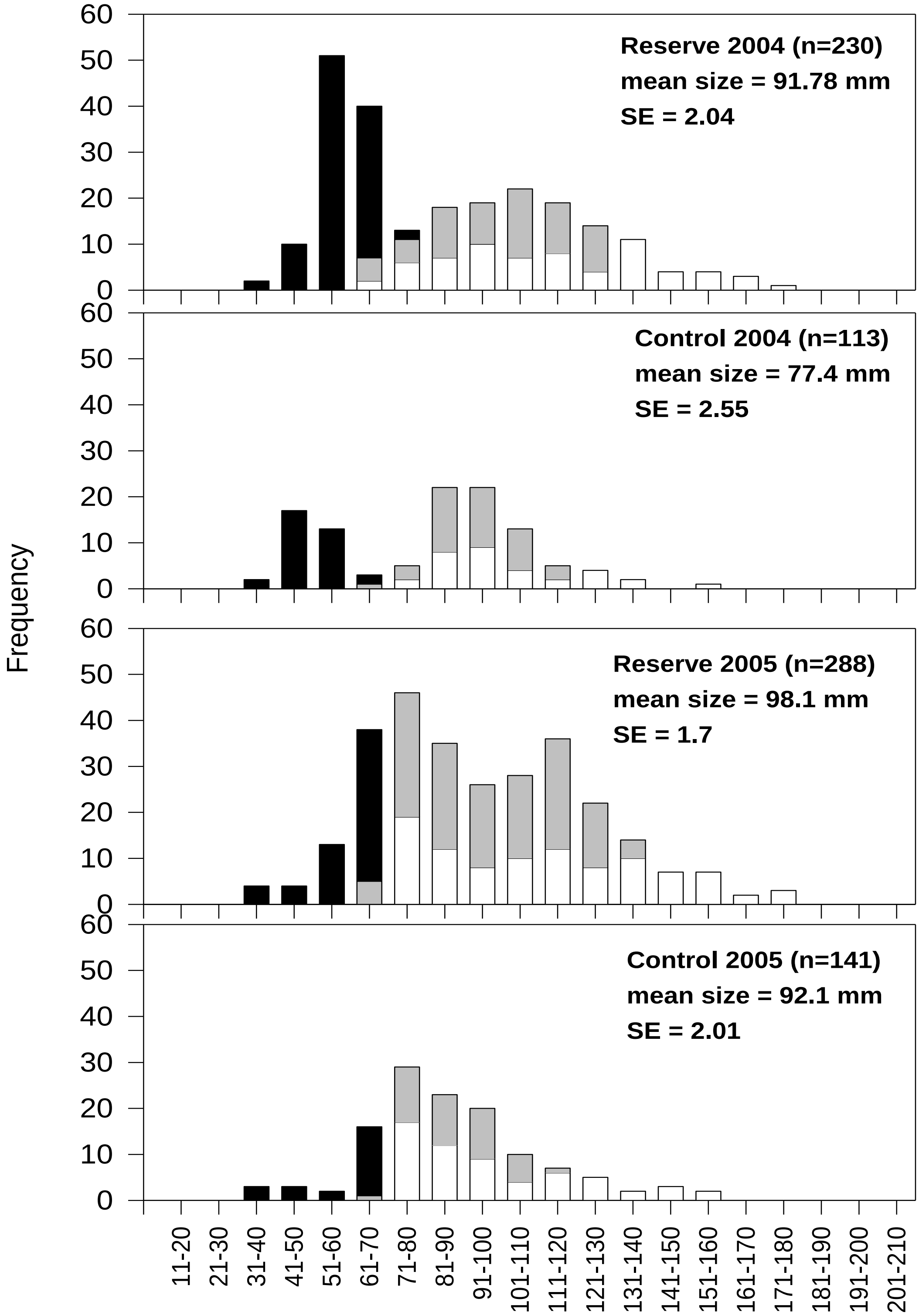


Figure 24. Size frequency of all lobsters sampled from pooled reserve and control sites in March 2004 and April 2005. Open = male, grey = female, black = juvenile.

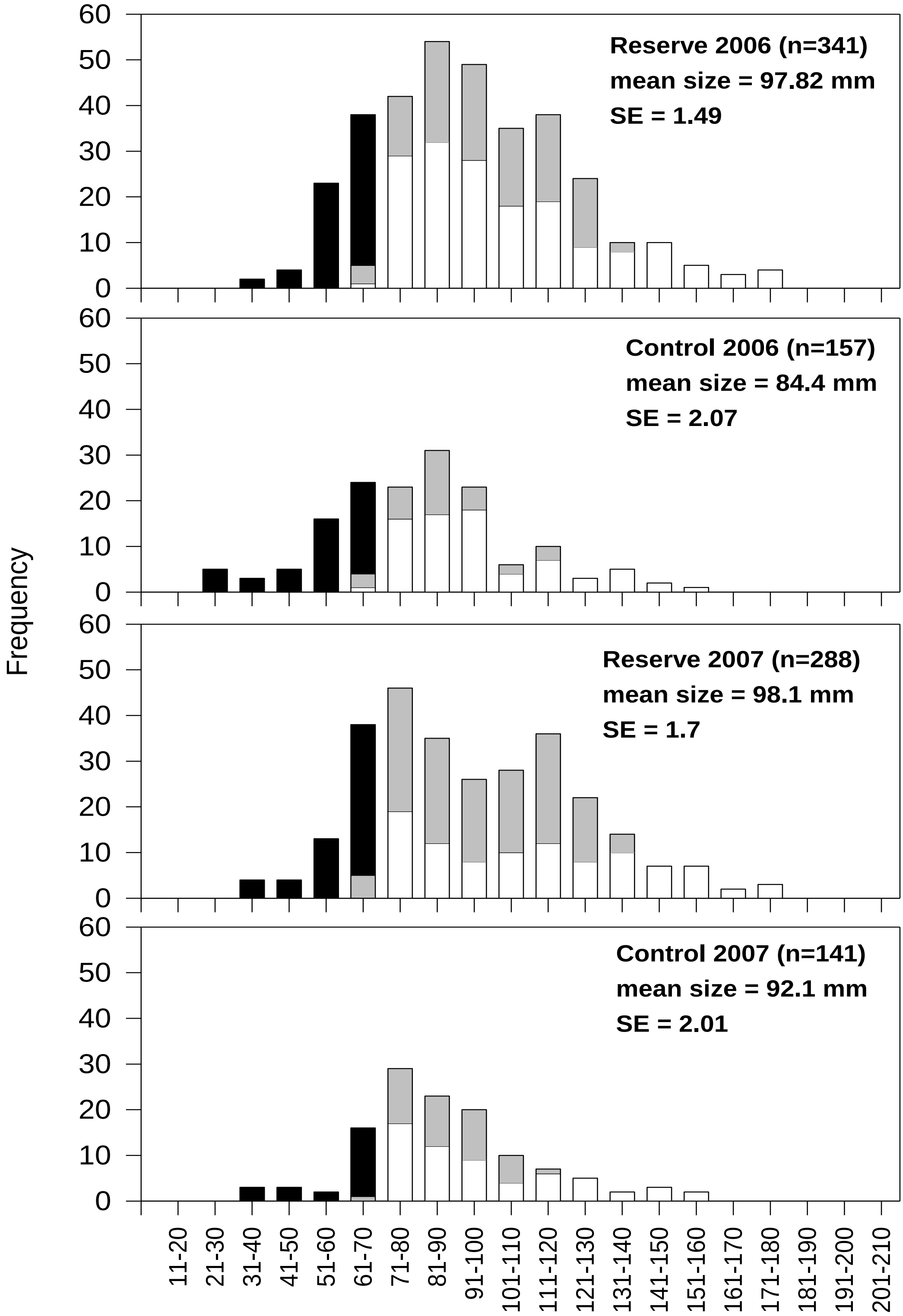


Figure 25. Size frequency of all lobsters sampled from pooled reserve and control sites in April 2006 and April 2007. Open = male, grey = female, black = juvenile.

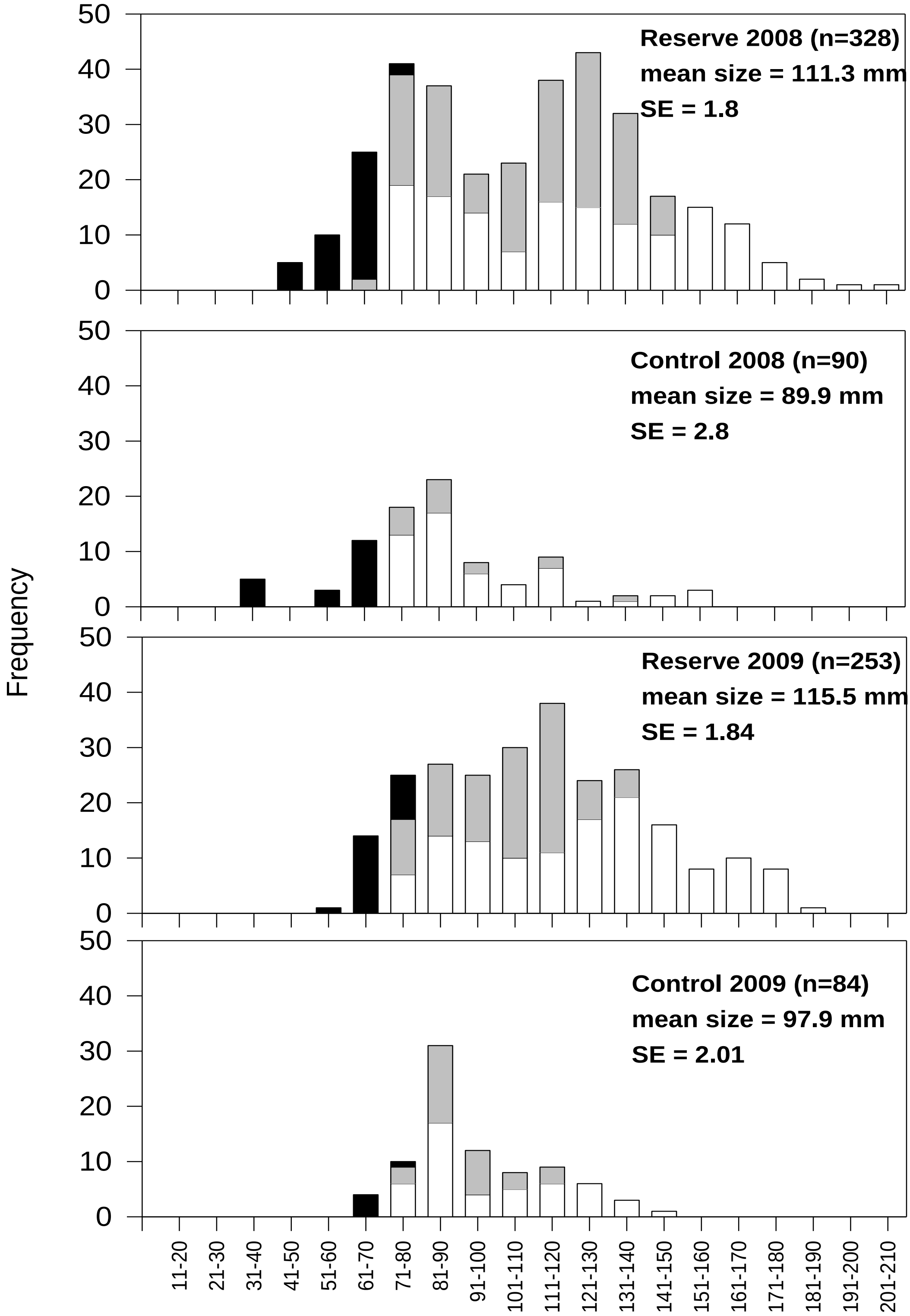


Figure 26. Size frequency of all lobsters sampled from pooled reserve and control sites in March 2008 and 2009. Open = male, grey = female, black = juvenile.

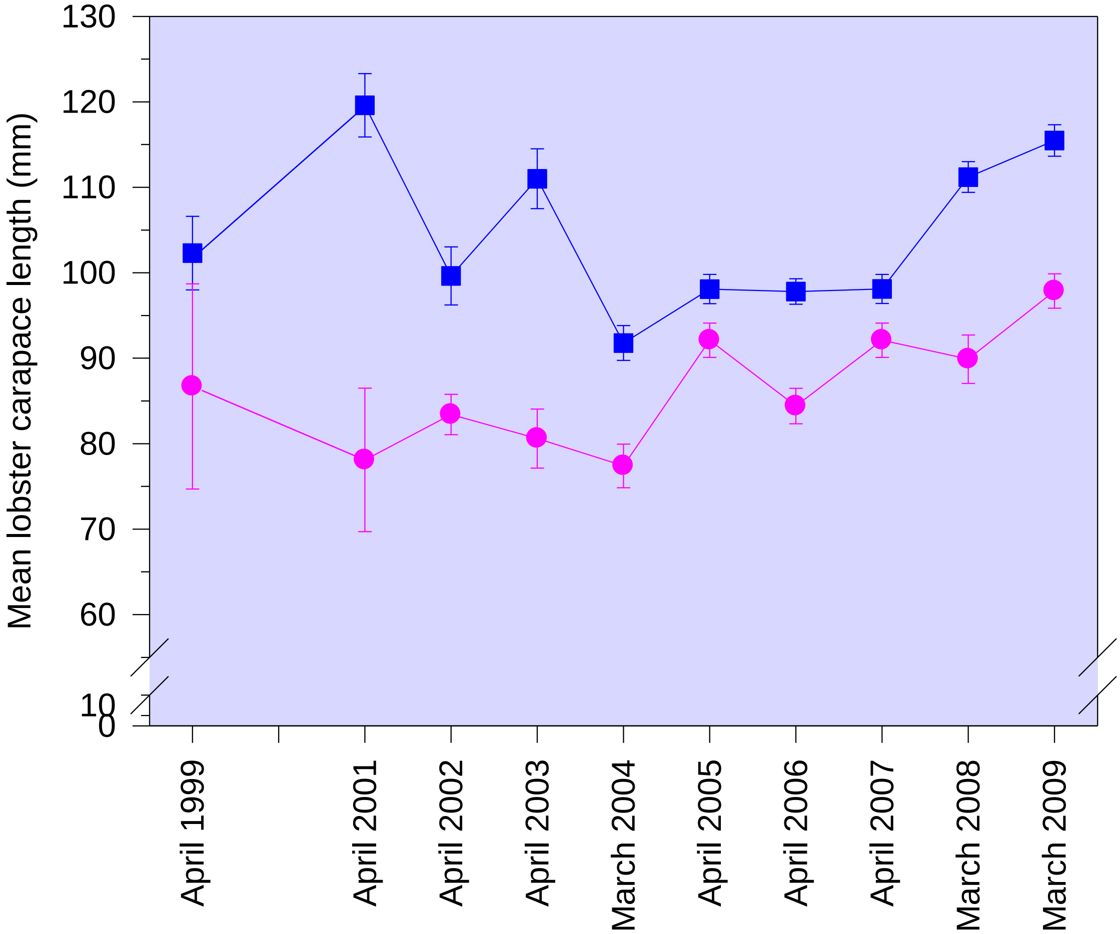


Figure 27. Mean lobster carapace length (mm) sampled from pooled reserve (blue squares) and control (pink circles) treatments. Error bars = +/- 1 s.e. Note: no CL measurements were collected before 1999.

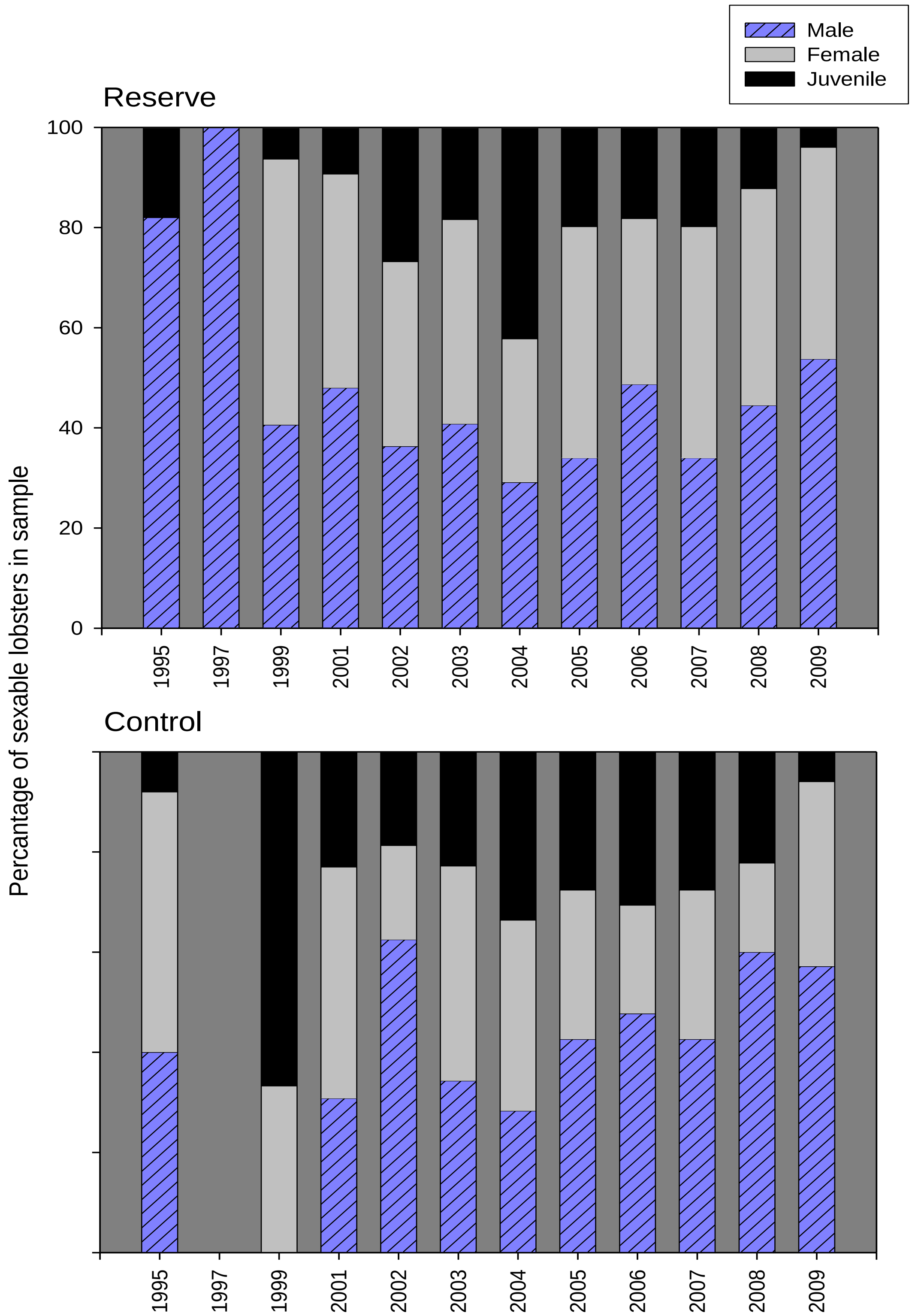


Figure 28. Percentage of the sample represented by male (> 75 mm CL), female (> 75 mm CL) and juvenile (< 75 mm CL) lobsters from reserve and control pooled groups.

5.4 Paua density and size

Black-foot paua density was measured from a maximum of seven reserve sites and five control sites in 1992, 1999, 2007 and 2009; however, not all sites were sampled on each occasion. Paua density at each site often fluctuated between sample occasions with no sites showing consistent upward or downward trends (Figure 29). Mean paua density pooled for all sites on each sample occasion revealed no clear or significant trend over time or between reserve and control treatments ($P > 0.005$, Figure 30).

Black-foot paua size was sampled on five occasions (1992, 1999, 2004, 2007 and 2009). The mean size of reserve paua declined over the duration of the study from a high in 1992 (117.8 mm TL) to a low in 2009 (112 mm TL, Figure 31). The mean size of paua from the control treatment also declined between 1992 and 2009. Mean paua size at control sites was consistently below the reserve mean on all sample occasions. The differences between treatment size means corresponded to differences in size structure, with a greater size range and larger individuals being recorded from reserve sites compared to control sites (Figure 31).

5.5 Kina density and size

At both reserve and control sites, mean kina density declined from 1992 to 1999 and then increased to a maximum in 2008 (Figure 32). Mean kina density at pooled reserve and control sites were not significantly different on any sample occasion ($P > 0.01$).

The size of kina was sampled on three occasions (1992, 1999 and 2008). In order to ensure samples were comparable between sites, kina were not sampled from within macroalgae forests; however, macroalgae was located adjacent or close to one reserve and one control site (C3 and R4). It is probable that the proximity of this rich food source influenced the mean size of kina at these two sites.

Pooled reserve and control size data showed that the mean size of kina was higher from the reserve on all three occasions and the mean size of kina increased over the duration of the study at both treatments (Figure 33). Of particular note was the absence of very small individuals (< 50 mm width) at reserve sites in 2008. Very small kina < 50 mm width were otherwise present in both treatments throughout the study.

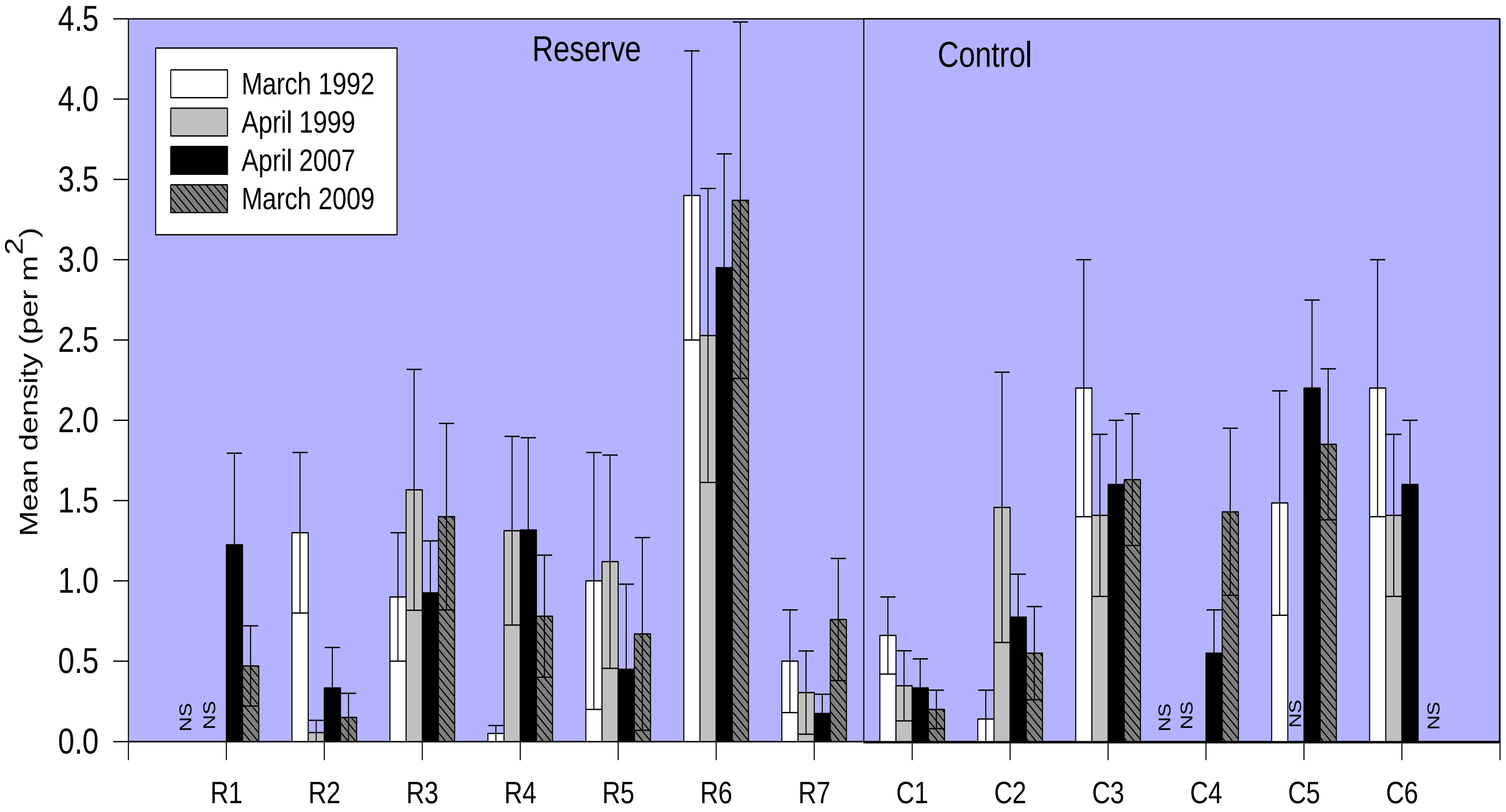


Figure 29. Mean black-foot paua density sampled from reserve (left) and control (right) sites. NS = not sampled.

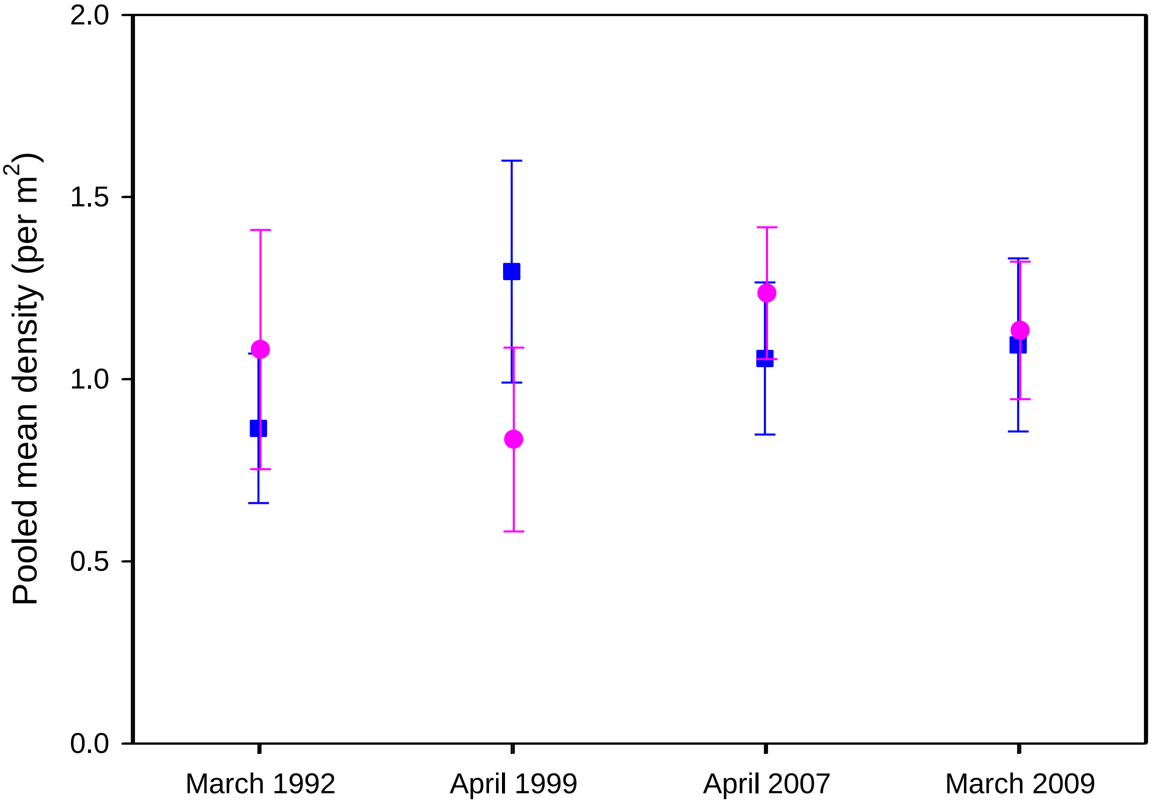


Figure 30. Pooled mean paua density from reserve (blue squares) and control (pink circles) treatments. Note: a new control site (C4) was sampled in 2007 and 2009. Error bars are 95% confidence.

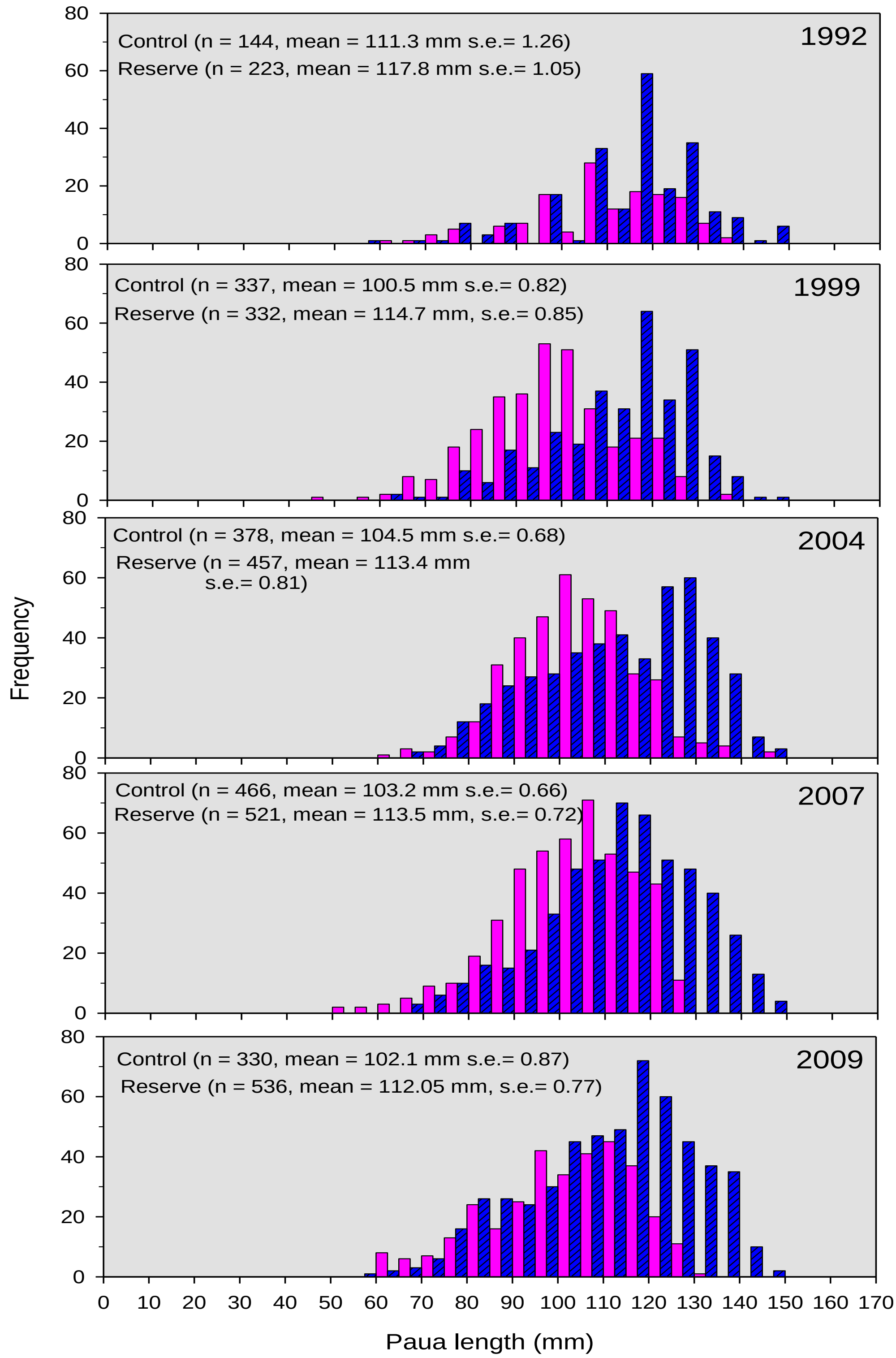


Figure 31. Length frequency for black-foot paua from reserve (blue hatched) and control (pink) pooled groups. Note: new control site (C4) was sampled from 2004 onwards. Note: the Y axis is a difference scale between sample years.

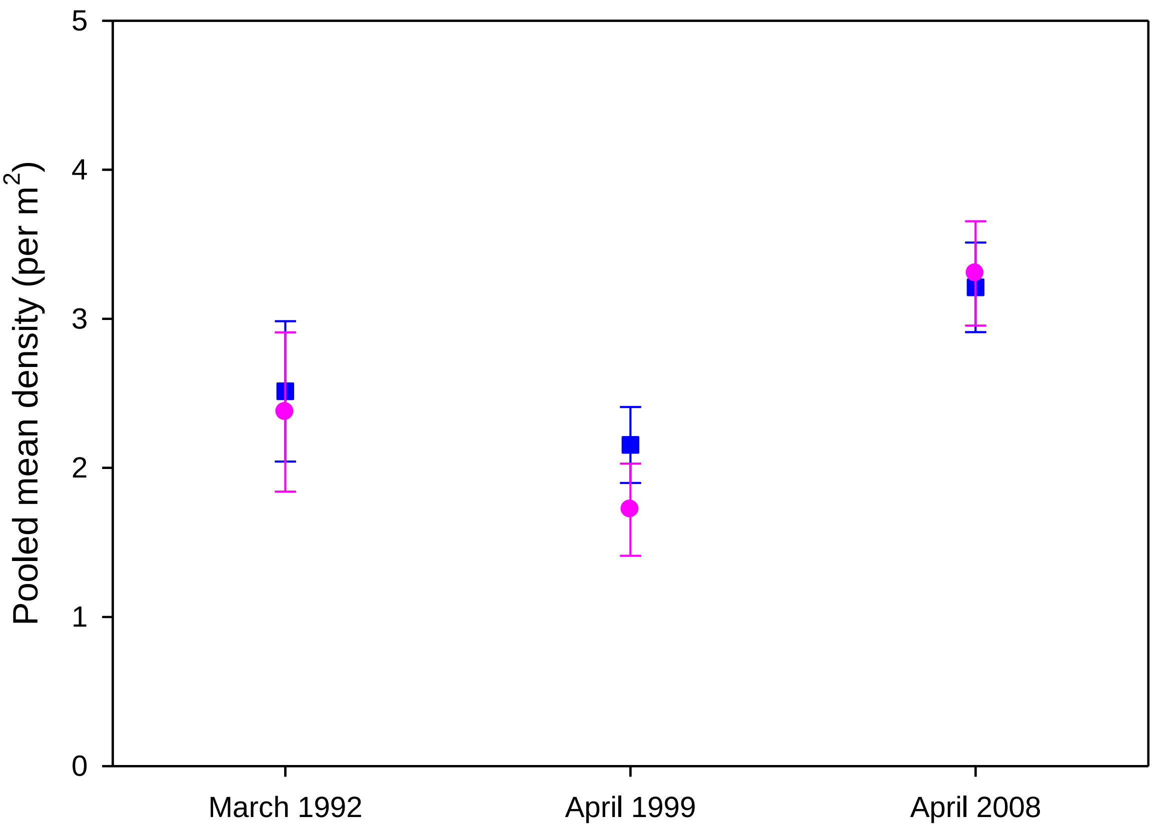


Figure 32. Mean density of pooled kina from reserve (blue squares) and control (pink circles) treatments. Error bars = 95% confidence intervals.

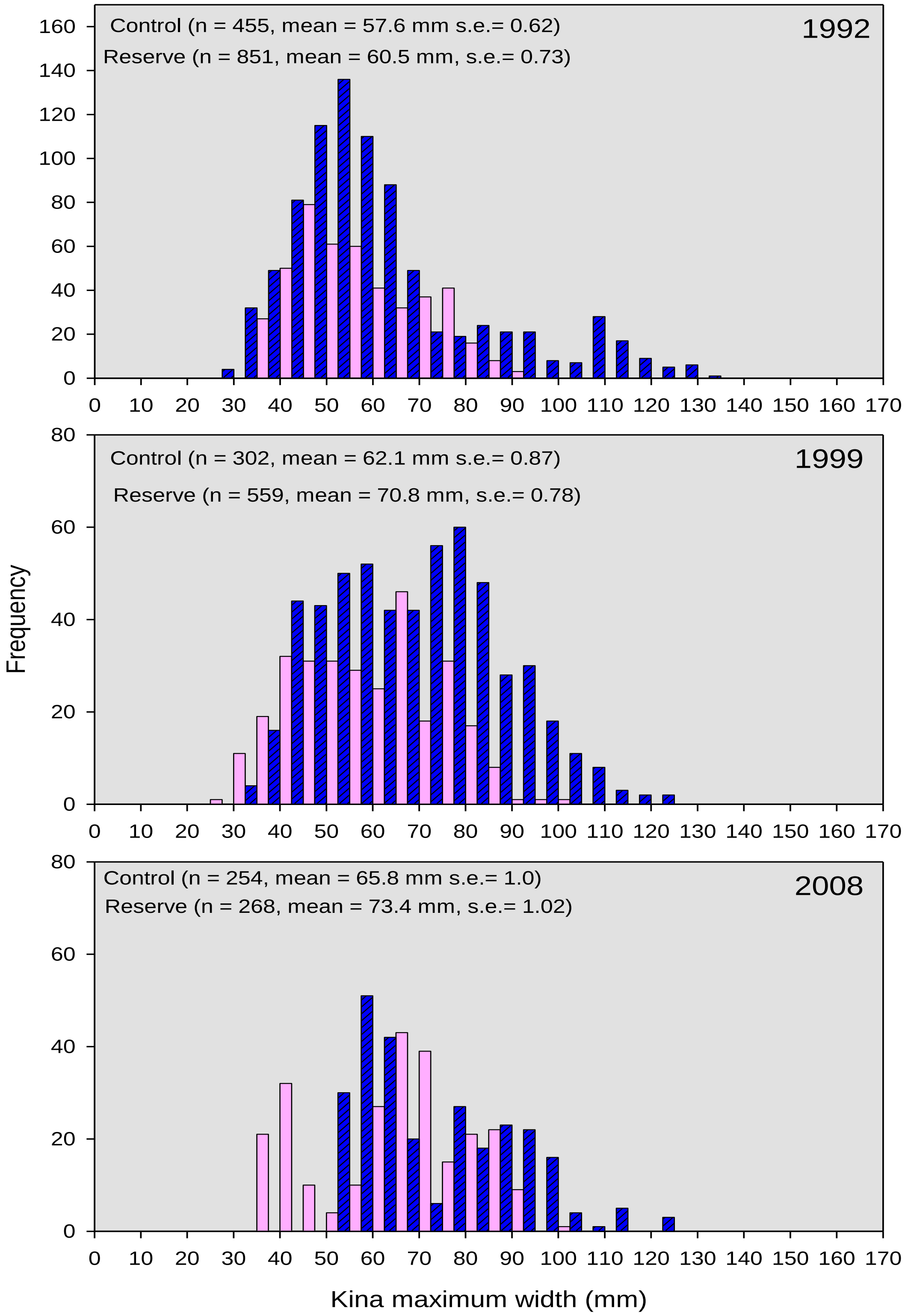


Figure 33. Pooled size frequency for kina at reserve (blue hatched) and control (pink) treatments. Note: the Y axis is a difference scale between sample years.

5.6 Cats eye snail density

The density of cats eye snails declined for the reserve treatment over the three sample occasions (Figure 34). At control sites, their density also declined from 1992 to 1999, but increased between 1999 and 2008. Differences between reserve and control treatments were only significant in 1999 (T = 4.06, P < 0.0001).

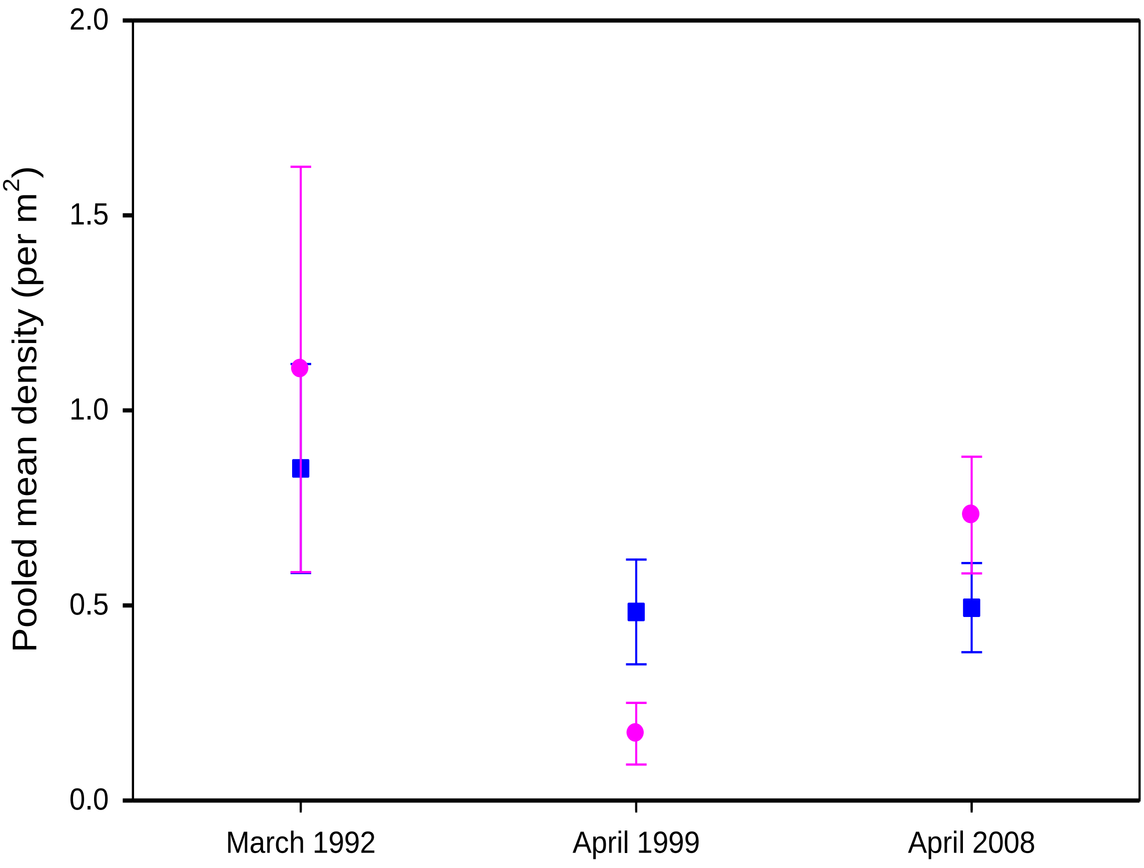


Figure 34. Mean density of pooled cats eye snails from reserve (blue squares) and control (pink circles) treatments. Error bars = 95% confidence.

6.0 DISCUSSION

This report presents biological monitoring data from 1992 to 2009 for Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound, Marlborough Sounds. Spanning 18 years, with some data collected annually, this study compiles one of the most comprehensive data sets for any marine reserve in New Zealand. McCrone (2001) reported that 41 baseline surveys for 25 marine protected areas (including marine reserves) had been established by 2001, yet only nine studies continued beyond June 2000. Despite the lack of long term, repetitive sampling for many marine reserves, a growing number of New Zealand studies have shown changes in marine reserves (McCormick and Choat, 1987; Cole et al., 1990; Creese and Jeffs, 1993; Jones et al., 1993; MacDiarmid and Breen, 1993; Cole, 1994; Cole and Keuskamp, 1998; Kelly, 1999; Kelly et al., 1999; Kelly et al., 2000; Willis et al., 2000; Cole et al., 2000; Davidson, 2001; Davidson et al., 2002; Willis et al., 2003a & 2003b; Denny et al., 2004; Haggitt and Kelly, 2004; Shears et al., 2006; Davidson et al., 2007, Pande et al., 2008). Changes observed in these marine reserves have usually focused on recreational or commercially targeted species that respond to the cessation of fishing. Few studies have monitored species not targeted by fishers. Like most other monitoring, the present study has concentrated on species targeted by fishers, but has also gathered information (less frequently) on non-target species in an effort to determine if reservation indirectly affects these other species.

6.1 Blue cod

Cessation of fishing resulted in direct changes to blue cod size and abundance. Since 1998, blue cod were larger in the reserve and they more abundant compared to control sites. In 2009, large blue cod (> 300 mm length) were 3.6 times more abundant from the rubble habitat in the reserve compared to adjacent control areas. During most of the study, the largest size class of blue cod (330 – 650 mm TL) represented a small part of the population outside the reserve. Since April 2004, a total of 2522 blue cod were sampled at control sites, but only 40 individuals or 1.6% were larger than 330 mm length. In contrast, of the 1815 blue cod measured from the reserve sites over the same period, a total of 534 or 29.4% were in the 330-650 mm size class. Furthermore, blue cod could be captured using traditional fishing techniques 3.6 times quicker in the reserve than at control sites. These results for blue cod are consistent with findings from other marine reserves in New Zealand. In a meta-analysis of various marine reserve studies around New Zealand (including Long Island), Pande et al. (2008) reported blue cod were bigger inside marine reserves than outside in 9 out of 10 studies and more abundant inside reserves in 8 out of 11 studies.

The dramatic change to blue cod populations at Long Island-Kokomohua Marine Reserve is best explained by the exclusion of fishing activities from the reserve. The relative increase in blue cod abundance and size in the reserve has been accentuated by a decline in these same parameters from fished areas outside the reserve.

Reserve blue cod mean size initially increased and has remained high compared to fished areas (controls sites). In contrast, the mean size of blue cod has varied dramatically at control sites, with periods of gradual and consistent increases interspersed by sharp declines. Some changes appear linked to changes in recreational fishing regulations (Table 15).

Table 15. Major blue cod management events including recreational size limit and bags limits for the Marlborough Sounds.

Date	Event
1986	Blue cod introduced into the QMS *[1]
1986	Minimum size limit 30 cm (recreational daily bag limit 12) *[1]
October 1993	Size increased from 30 cm to 33 cm (daily bag limit reduced to 10)
1st October 1994	Size decreased from 33 cm to 28 cm (daily bag limit reduced to 6)
1st October 2003	Size increased from 28 cm to 30 cm (daily bag limit reduced to 3)
1st October 2008	Queen Charlotte and Pelorus Sound blue cod fishing closure

*[1] = events that occurred prior to the present study; QMS = quote management system.

Four major changes to blue cod fishing regulations in Queen Charlotte Sound have been implemented over the duration of the present study. In October 1993, the minimum legal size for blue cod was increased from 300 mm to 330 mm. From September 1993 to August 1994, there was a corresponding increase in the mean size of blue cod at control sites. In October 1994, the minimum legal size was reduced to 280 mm and the bag limit was dropped from ten to six fish per person per day. By September 1995, the mean size of blue cod at the control sites had declined dramatically. For the following eight years the mean size of control blue cod fluctuated. These long term fluctuations do not appear to be related to changes to fisheries rules. In October 2003, the size limit for blue cod was increased from 280 mm to 300 mm and the bag limit further reduced to three cod per person per day. For the following five consecutive years the mean size of blue cod from pooled control sites steadily increased from a mean of 233.4 mm in March 2004 to 259 mm by May 2009. However, mean blue cod size at control areas in 2009 was still well below the August 1994 level (i.e. mean = 275 mm) when the blue cod legal size was 330 mm length.

On 1st October 2008, the recreational blue cod fishery in Queen Charlotte and Pelorus Sounds, including all of the control sites, was closed. One blue cod sample event has occurred since this closure (i.e. the 2009 sample). The proportion of large blue cod (330-650 mm) at control sites increased to 5.7% in 2009, a proportion not recorded since 1994 and 1995. To place this result in perspective, in most years since April 2000, the proportion of control blue cod in this size range was < 1%. The mean size of blue cod at control sites in 2009 also increased; however, there was not a corresponding increase in blue cod abundance.

It is unknown how quickly blue cod abundance will change in the recently closed fishing areas outside the reserve, although the rate of blue cod recovery in the reserve following its closure to fishing may provide some insight. Following reservation in 1993, blue cod abundance was relatively slow to change with no statistically significant increase above control densities until April 1997, a period of four years. Large blue cod (> 300 mm length), however, became more abundant in the reserve compared to control sites in a shorter period of only two years after reservation. Because the size scale of the closed areas is dramatically different (i.e. Long Island-Kokomohua Marine Reserve versus Queen Charlotte and Pelorus Sounds) it is impossible to accurately predict how long it will take for blue cod to increase in abundance, however, based on the marine reserve experience, it is probable that such an increase will take a number of years.

6.2 Other fish

Apart from blue cod, blue moki appears to be the only other reef fish that responded positively to reservation over the duration of the study. Blue moki were significantly larger, but not more abundant, from reserve sites compared to control sites. The lack of difference for other fish is probably due to a combination of: (a) the fish not being targeted by fishers outside the reserve (e.g. spotty, banded wrasse); (b) the fish are highly mobile (e.g. tarakihi); (c) the fish are more secretive and seldom recorded during diver counts (e.g. butterfish); and/or (d) wider community level changes are much slower and more difficult to detect.

6.3 Spiny lobsters

Spiny lobsters are intensively fished in many areas of New Zealand (Lipcius and Cobb, 1994). Several studies have shown abundance and size of spiny lobsters to be greater in protected areas than in nearby fished areas (e.g. MacDiarmid and Breen, 1993; Edgar and Barrett, 1999; Kelly et al., 1999, 2000; Davidson et al., 2002; Kelly and MacDiarmid, 2003;

Haggitt and Kelly, 2004). Those findings suggest that some lobsters remain within non-fished areas, but there is also evidence that migrations may cross reserve borders (e.g. Kelly et al., 2000; Kelly, 2001; Kelly and MacDiarmid, 2003). Research also suggests egg production may be limited in intensively fished populations that lack large male lobsters (MacDiarmid and Butler, 1999).

Lobster density at Long Island-Kokomohua Marine Reserve increased from 1.9 individuals per 100 m^2 in 1992 to 10.7 individuals per 100 m^2 in 2009, representing a 5.6 times increase since 1992 (a period of 17 years). Initially lobster abundance in the reserve was slow to change, with no real increase recorded for the first nine years of the present study. From April 2002 onwards, reserve lobster densities within the reserve increased to a high in April 2006 (mean = 14.3 individuals per 100 m^2) and declined slightly from 2007 to 2009. Lobster densities at control sites followed a similar trend to reserve sites, but the peak in April 2006 was lower (mean = 6.7 individuals per 100 m^2) and the decline after this peak was larger than at the reserve.

Both males and females were more abundant in the reserve compared to control sites. In 2008, for example, 6.3 times more males (or 144 versus 23) were counted at the four reserve sites compared to the four control sites. Similarly, 19.8 times more females were recorded from reserve sites compared to control sites for the same year. Also in 2008, approximately 43% of the lobster population in the reserve was represented by females compared to only 18% for control areas. The increase in lobster abundance in the reserve combined with the greater proportions of large female and male lobsters should result in a greater reproductive output compared to areas outside the reserve.

Long Island data compares favourably with findings from other marine reserves and protected areas in New Zealand. Pande et al. (2008) found that rock lobsters were more abundant inside marine reserves in 11 of the 14 of New Zealand studies investigated, with lobsters taking an average of 8.5 years to show a significant increase over control sites. Davidson et al. (2007) reported that lobsters from deep strata (> 7 m depth) at Tonga Island Marine Reserve were 3.4 times more abundant in 2007 compared to 1994, a period of 13 years. Davidson et al. (2007) also reported that 9.2 times more females and 3.8 times more males were present in the Tonga Island Marine Reserve compared to control sites in 2007. Shears et al. (2006) reported a large increase in the abundance of legal-sized lobster during summer-autumn surveys of Tawharanui Marine Park. The authors stated that lobsters were 11 times more abundant and represented 25 times greater biomass following the establishment of the Marine Park in 1983 (a 22 year period).

Tonga Island and Long Island-Kokomohua Marine Reserves were both established in 1993, and at this time supported similar, low densities of rock lobster. Recovery of lobsters has been greater at Long Island compared to Tonga Island Marine Reserve perhaps due to the outer Queen Charlotte Sound being more productive or experiencing higher or more consistent juvenile lobster recruitment.

Changes to methodology (i.e. a change to the sample size, number of replicates, and the addition of new control sites) at Long Island are unlikely to have influenced the observed changes in lobster abundance. Sample size has been standardised to 100 m^2 making it comparable with other marine reserve studies in New Zealand, while the number of replicates has been set at six per site. The two new control sites added in April 2002 were selected from sites that were comparable to reserve sample sites and therefore act to provide a better more reliable comparison between reserve and control treatments. These alterations are unlikely to result in any large change to the pattern of abundance of lobsters from the control treatment.

Of special note at Long Island-Kokomohua Marine Reserve has been the observed increase in distribution of lobsters. In 2008, divers revisited an invertebrate monitoring site located north of the western shingle spit (paua sample site R6). Moderate numbers of lobsters were observed occupying open areas adjacent to bedrock outcrops. No lobsters had ever been observed from this area during previous blue cod counts and invertebrate sampling events (1992, 1999, 2000, 2001, and 2004). This observation suggests that lobsters have expanded from northern reserve habitats into areas previously unoccupied.

6.4 Black-foot paua

The reason for the lack of any increase in reserve paua density is difficult to determine, but it is not due to a lack of suitable substrata or food. Paua density increased at some sites and declined at others in the reserve and this could be due to (a) sampling effects (i.e. paua are patchily distributed resulting in variability), (b) natural mortality, (c) natural predation from the increased number of lobsters in the reserve, (d) poaching by humans, and/or (e) a lack of natural recruitment.

On every sample occasion, mean paua size was greater and there were more legal-sized (≥ 125 mm length) individuals present at reserve sites compared to the control treatment. Despite this result, mean paua size has not increased, but instead has gradually declined over the duration of the study at both reserve or control sites. This may be due to one or more of the factors listed above or may be due to (a) the paua population in the reserve being in a non-harvested, natural equilibrium and/or (b) more juvenile paua being present in the reserve population thereby reducing the population mean size. If the latter is the case, these small paua will grow through into the larger size classes resulting in a future increase to the mean population size.

6.5 Kina

Kina density initially declined and then increased to a high in 2008 at both reserve and control sites, suggesting the influence of natural events rather than any reserve-related effect. Kina were, however, larger at reserve sites compared to control sites, but this size difference existed prior to reservation and is probably due to habitat quality rather than reserve effects. For example, kina grow largest from sites exposed to the north. These exposed sites support extensive beds of macroalgae providing a greater abundance and diversity of food compared to sheltered sites with little or no macroalgae.

The reason for an increase in the mean size of kina at both treatments over the duration of the study is unknown. Within the reserve, this trend will be partially related to the absence of small kina < 50 mm diameter from the reserve in 2008. This size class was present at reserve sites in 1992 and 1999 and at control sites in all years including 2008. The absence of small kina within the reserve may be related to large blue cod and/or lobsters eating small kina. If this is the case, this represents the first structural community change indirectly related to reservation recorded for this marine reserve.

6.6 Cats eye snail

Cats eye snail density declined in the reserve during the three sample events between 1992 and 2008. Cats eye snail density also declined between 1992 and 1999 at control sites, but density increased again by the end of the study. It is too early to determine if the decline in cats eye snails in the reserve is related to increased predation as density differences between the treatments were not significantly different.

6.7 Behavioural changes

Few studies have investigated behavioural changes resulting from the cessation of fishing. Cole (1994) reported that feeding of fish in New Zealand’s longest established marine reserve, Cape Rodney–Okakari Marine Reserve, had altered fish behaviour making fish more diver-positive compared to areas outside the reserve or in areas of the reserve away from the main public beach. Divers undertaking fieldwork over the duration of the present study all observed behavioural changes, particularly for large blue cod. Many blue cod demonstrated a lack of fear, often allowing divers to touch them, while some large blue cod would bite divers’ lips, fingers and equipment.

Divers also reported changes in the behaviour of large blue moki. Large adults of this species often avoid divers and, when seen, are at the edge of the diver's visible range. However, in Long Island-Kokomohua Marine Reserve, these large individuals often ignored divers, even in close proximity.

Spiny lobsters at reserve locations in the present study were often observed at entrances to their holes or out in the open rather than hidden at the back of caves and crevices. Lobsters also occupied locations in the reserve that would traditionally be regarded as poor habitat by fishers and divers (i.e. more open rocky habitat with few deep holes and crevices). Lobsters could also often be handled with relatively little response within the reserve, an activity that was not possible at the control areas or in the reserve during its initial years.

These observations, combined with the dramatic changes observed in blue cod CPUE prior to an increase in blue cod abundance (i.e. due to blue cod becoming naïve to fishing), suggest that marine reserve protection may also have an observable and early effect on animal behaviour. This aspect of marine reserve protection has not been studied in detail in New Zealand and warrants more attention, as it may affect monitoring results and therefore the reliability of particular sampling methods used to study marine reserves. For example, a change from diver-negative behaviour to either diver-neutral or diver-positive behaviour may result in different count results between reserve and control areas when in fact no density difference exists. In the present study, fish counts were always conducted when water visibility was > 4 m horizontal distance in an effort to minimise the impact of behavioural differences between treatments. Clearly, behavioural changes and their impacts on survey methodologies is an important consideration in any study of the recovery of fish stocks due to protection in marine reserves.

7.0 FUTURE BIOLOGICAL MONITORING

The current monitoring programme funded by the Department of Conservation is carried out by Davidson Environmental Ltd. with assistance from Department staff from the Picton Area Office. This study has spanned a period of 16 years and has detected impacts that can be attributed to the establishment of the marine reserve.

Changes detected as part of the present monitoring programme include:

- a change to the size structure of the blue cod population;
- an increase in the catch per unit effort of blue cod in the reserve;
- an increase in lobster abundance and size;
- a wider distribution in the geographical range of lobsters to areas previously not occupied within the reserve;
- an absence of small kina (< 50 mm diameter) from the reserve, possibly due to predation;
- larger size classes of paua in the reserve compared to control sites;
- larger blue moki present within the reserve compared to control sites; and
- changes in behaviour of blue cod, lobster and large blue moki in the reserve (i.e. more approachable and lobsters often observed in the open).

Based on results collected during the present study and suggestions made by Davidson (2004), the following monitoring is recommended over the next three to four years.

Fish

Blue cod should be captured, measured and released on an annual basis in late summer to early autumn (i.e. March to April) at six control sites and four reserve sites. A minimum of 80 should be captured and measured, or a maximum of 120 minutes of sampling be conducted (i.e. whichever occurs first). Fish densities using traditional visual underwater count methodology (UVC) should be collected annually from rubble sites (5 reserve, 4 control) and macroalgae sites (3 reserve, 3 control).

Spiny lobsters

Lobsters should be counted, sexed and sized annually at four reserve and four control sites. Lobster sampling should occur in late summer to early autumn (i.e. March to April).

Macro-invertebrates

It is recommended that black-foot paua size and density be investigated more regularly. It is suggested that paua size and density be sampled every second year from seven reserve and six control sites. A minimum of 400 paua should be measured from each treatment.

Kina size-frequency data suggests there may be a reserve impact due to increased predation. This preliminary result warrants more regular sampling. It is therefore recommended that kina density be sampled every second year from six reserve and five control sites. A minimum of 400 kina should be measured from each treatment.

Cats eye density data can be collected from the kina quadrats, therefore requiring little extra time and effort. It is recommended that cats eye density be sampled from 6 reserve and 5 control sites on the same occasions that kina densities are surveyed.

Shore profiles

Shore profiles should only be re-sampled if divers report obvious community structure changes (e.g. change in location of algal beds).

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