Davidson Environmental Limited

Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound: update of biological monitoring, 1992 – 2014

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Blue cod release after CMR session

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SUMMARY

1. This report presents data collected from Long Island-Kokomohua Marine Reserve and adjacent control sites over a period of 22 years (1992 to 2014).
2. Data updated since the previous report includes: (i) reef fish size and density; (ii) lobster size sex and density; (iii) black foot paua size and density; (iv) kina size and density; and (v) cats-eye density.
3. In 2014, legal sized blue cod were 3 times more abundant in the reserve than at control sites. Unexpectedly, the mean size of blue cod within the reserve had decreased since the previous survey. The reason was primarily due to an increase in the number of small blue cod in the catch. At control sites, the mean size of blue cod changed over the duration of the study and was often linked to changes in fisheries legislation. The drop in the bag limit for cod appears to have had a positive impact on the mean size of blue cod at control sites.
4. For other edible reef fish species, an increase in the size of blue moki was the only documented change attributable to reservation.
5. The density of lobsters inside the reserve increased dramatically from 1.39 individuals per 100 m^2 in 1992 to 13.5 individuals per 100 m^2 in 2014. In 2014, lobsters were 11.5 times more abundant in the reserve than at control sites. Large reproductive males and females dominated the reserve lobster population. This suggests that relative to a similar area of unprotected coastline, where large males and females were relatively uncommon, egg production within the reserve will be significantly greater.
6. Black foot paua were larger and more abundant in the reserve compared to control sites. Paua mean size did however, decline over the study. This combined with observations of paua scars on rocks suggests that some poaching occurs.
7. The abundance of small kina <45 mm diameter has decreased within the reserve since 1992. This may be related to predation by large blue cod or snapper. This may represent the first indirect change related to reservation recorded for this marine reserve.

1.0 INTRODUCTION

This report presents data collected during a monitoring programme based at Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound, Marlborough Sounds. The marine reserve was formally established on 30 April 1993. To date, data has been collected over a period of 22 years from the reserve and adjacent control sites (Davidson 1995, 1997, 2004; Davidson *et al.* 2009; present study).

Since 1992, a variety of biological data has been collected. Data collected since the last report (Davidson *et al*., 2009) has been highlighted in the following list.

- Shore profiles.
- Reef fish densities and edible species size.
- Blue cod catch, measure and release.
- Rock lobster density, size and sex.
- Black foot paua size and density.
- Black foot paua density and size.
- Kina density and size.
- Cats-eye density.
- Baited underwater video.

The sample frequency for each aspect of the study has been variable. Reef fish, blue cod catch, measure and release and lobster data for example, have been collected more regularly than other data (Table 1).

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

Sample	03 92	03 93	09 93	03 94	08 94	03 95	09 95	04 96	04 97	09 97	03 98	04 99	09 99	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Catch, measure & release			■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	
Underwater visual (rubble)	■	■		■		■		■	■		■	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■
Underwater visual (algae)	■	■		■		■		■	■		■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Reef fish sizes																■	■	■	■	■	■	■	■	■	■	■	■	■
Baited underwater video (BUV)																		■										
Lobster density	■					■			■			■			■	■	■	■	■	■	■	■	■	■	■	■	■	■
Lobster size and sex	■					■			■			■			■	■	■	■	■	■	■	■	■	■	■	■	■	■
Paua density	■											■									■		■	■		■	■	
Paua size	■											■						■			■		■	■		■	■	
Kina density	■											■										■		■				■
Kina size	■											■										■		■				■
Cats eye density	■											■										■		■				■
Cats eye size	■																											
Shore profiles & video	■																											
Report produced						■			■									■					■					■

2.0 STUDY AREA

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.

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.

Study sites were often selected on the basis of habitat. 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 depth. *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.

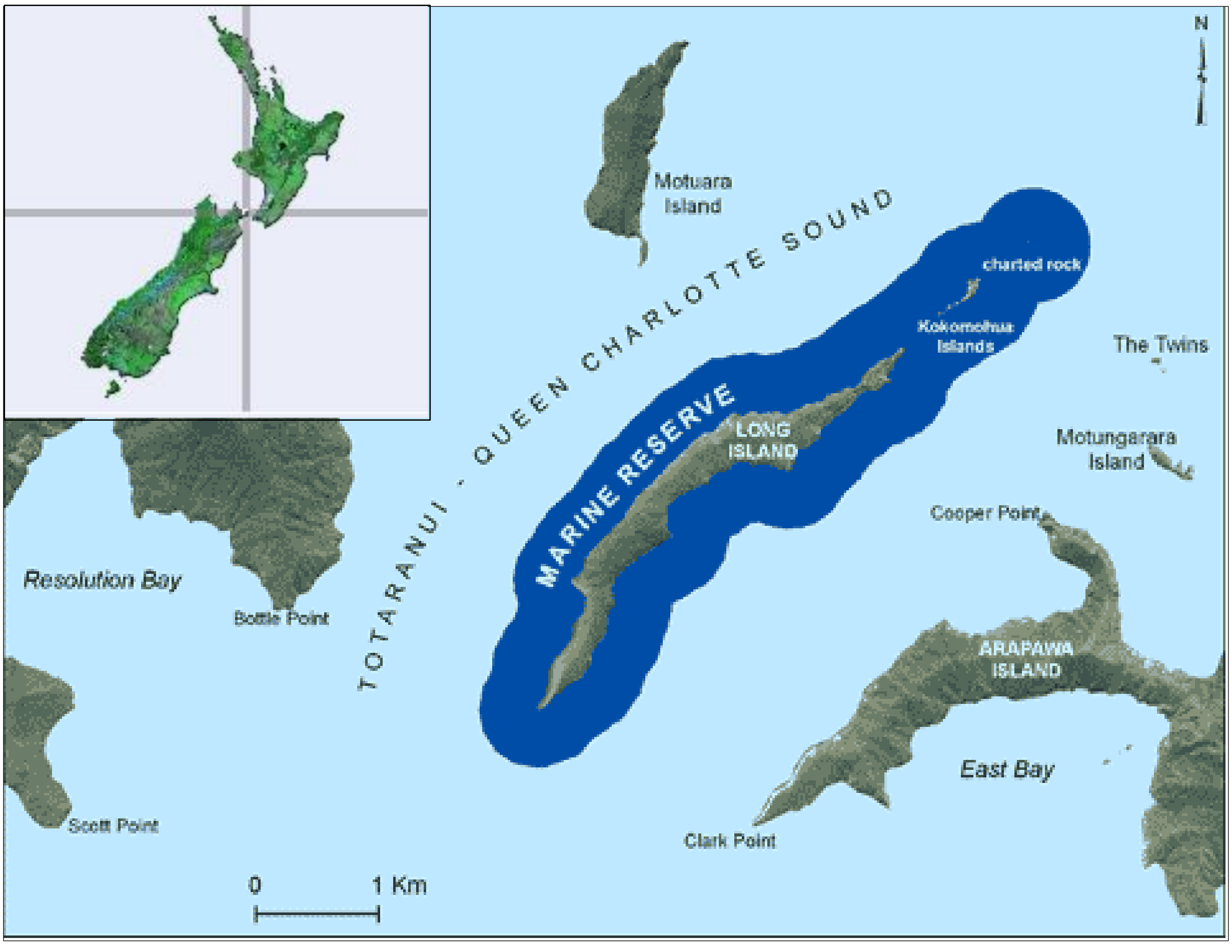

Figure 1. Location of Long Island-Kokomohua Marine Reserve in outer Queen Charlotte Sound.

3.0 SAMPLING SUMMARY SINCE 2009 REPORT

Data collected in relation to the Long Island-Kokomohua Marine Reserve have previously been presented in four monitoring reports (Davidson 1995, 1997, 2004; Davidson *et al.* 2009). The current report, which incorporates data collected since Davidson *et al*. (2009) (Table 1), compares changes in the density, size and/or sex of monitored species between marine reserve sites and adjacent control sites over the entire sampling period from 1992 to 2014 (Figures 2 to 7, Tables 2 to 7).

Table 2. Blue cod catch, measure and release sites sampled since 2004. Note: site R4 was not sampled prior to 2004.

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

Table 3. Underwater visual fish sites sampled from rubble substrata since 1992.

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

Table 4. Underwater visual fish sites sampled from algae habitat since 2002. Note: only site C3 was sampled prior to 2002.

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
C 2	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

Table 5. Spiny lobster sites sampled since 2001. Note: sites sampled prior to 2001 have been detailed in Davidson (2004).

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

Table 6. Black-foot paua sites sampled since 1999. Note: sites sampled prior to 1999 have been detailed in Davidson (2004).

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

Table 7. Kina and cats-eye sites sampled since 1999. Note: sites sampled prior to 1999 have been detailed in Davidson (2004).

Site no.	Area	Sample site	Habitat	Depth (m)	Coordinates
R1	Reserve	Long Is (SE)	Cobble	3-8 m	41 07.298, 174 16.589
R2	Reserve	Eduardo Rock	Cobble	3-8 m	41 06.783, 174 17.586
R3	Reserve	Kokomohua Is.	Cobble	3-8 m	41 06.220, 174 18.382
R4	Reserve	Charted Rock	Rock	3-8 m	41 05.896, 174 18.809
R5	Reserve	Long Is. (west)	Cobble-bedrock	3-4 m	41 07.160, 174 16.379
R6	Reserve	Long Is. (south Spit)	Cobble	3-8 m	41 07.567, 174 16.212
C1	Control	Bottle Rock	Cobble	3-8 m	41 07.491, 174 14.609
C2	Control	Motuara Is. (south)	Cobble	3-8 m	41 05.888, 174 16.275
C3	Control	Motuara Is. (west)	Cobble	3-8 m	41 05.539, 174 16.296
C4	Control	Kotukutuku	Cobble-bedrock	3-8 m	41 08.221, 174 17.469
C5	Control	Clark Point	Cobble	3-8 m	41 07.492, 174 18.299

Figure 2. Location of fish catch, measure and release sites (CMR) sampled since 2004. ***Note: the location of sites prior to 2004 can be found in Davidson (2004).***

Figure 3. Location of underwater rubble sites (UVC) used for visual estimates of fish density and size sampled since 1992.

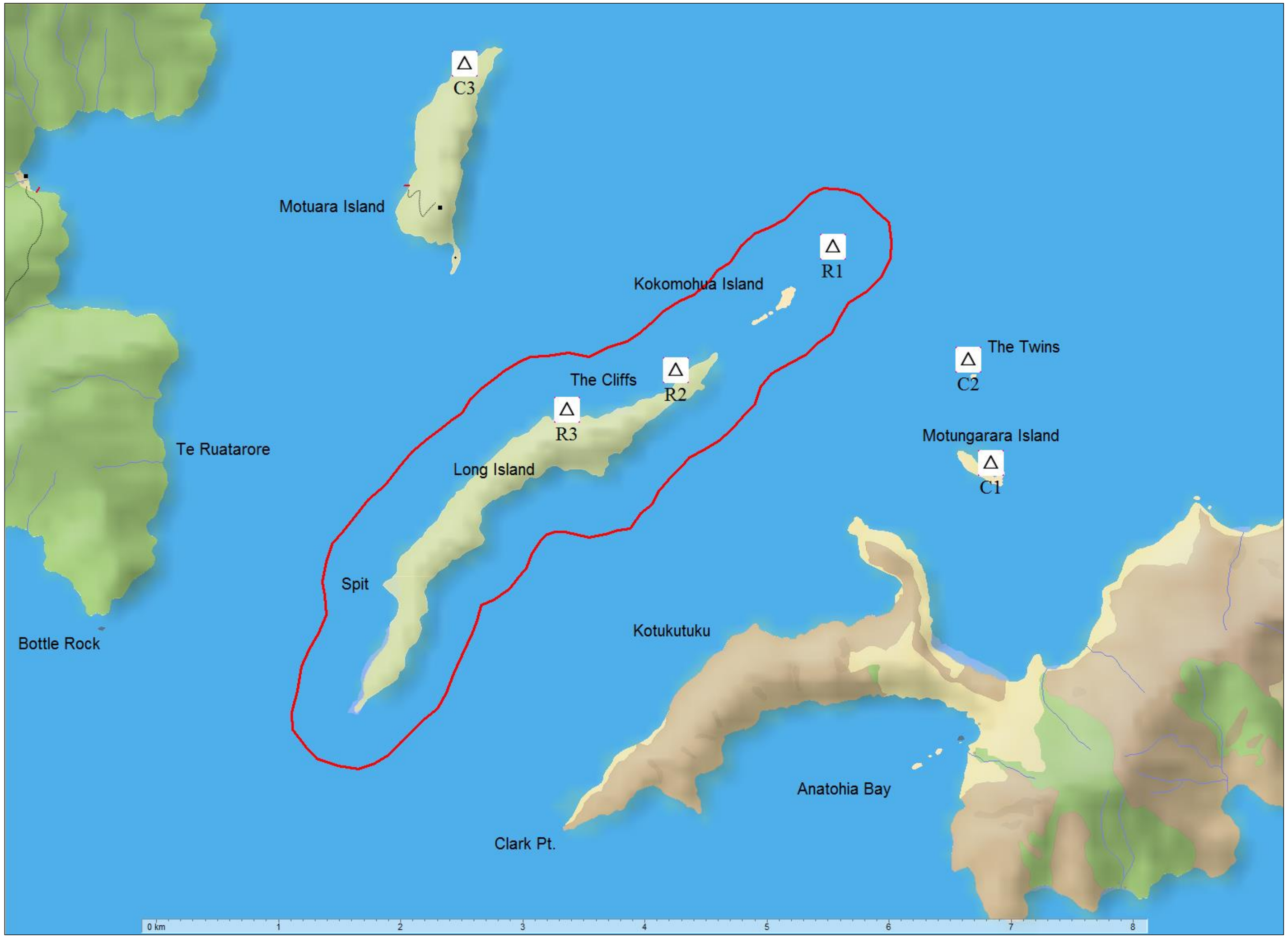

Figure 4. Location of algal habitat sites used for visual estimates of fish density and size (UVC) sampled since 2002. ***Note: the location of sites prior to 2004 can be found in Davidson (2004)*.**

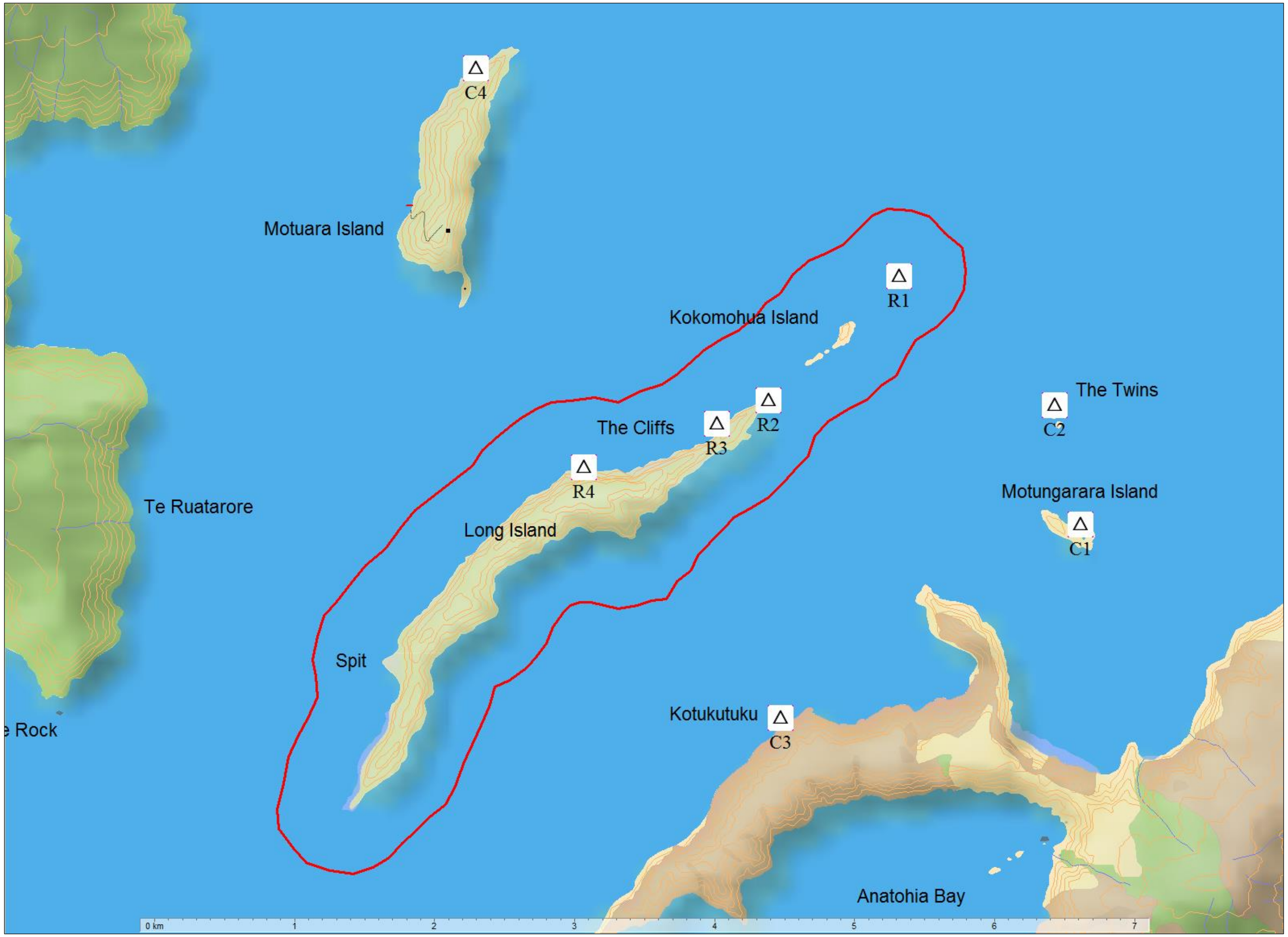

Figure 5. Location of spiny lobster sites sampled since 2001. ***Note: the location of sites prior to 2004 can be found in Davidson (2004).***

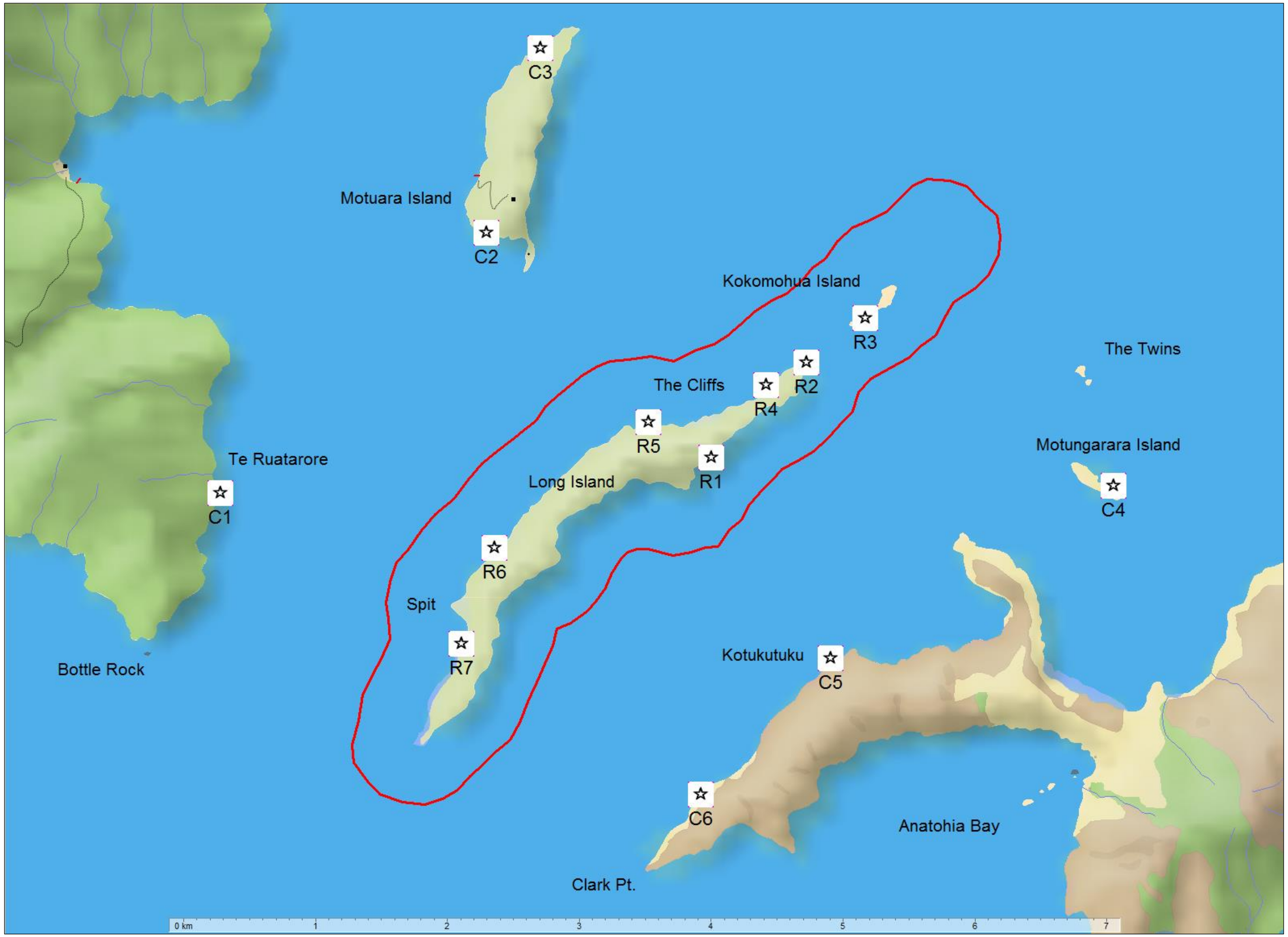

Figure 6. Location of black-foot paua sites sampled since 1999. ***Note: the location of sites prior to 2004 can be found in Davidson (2004).***

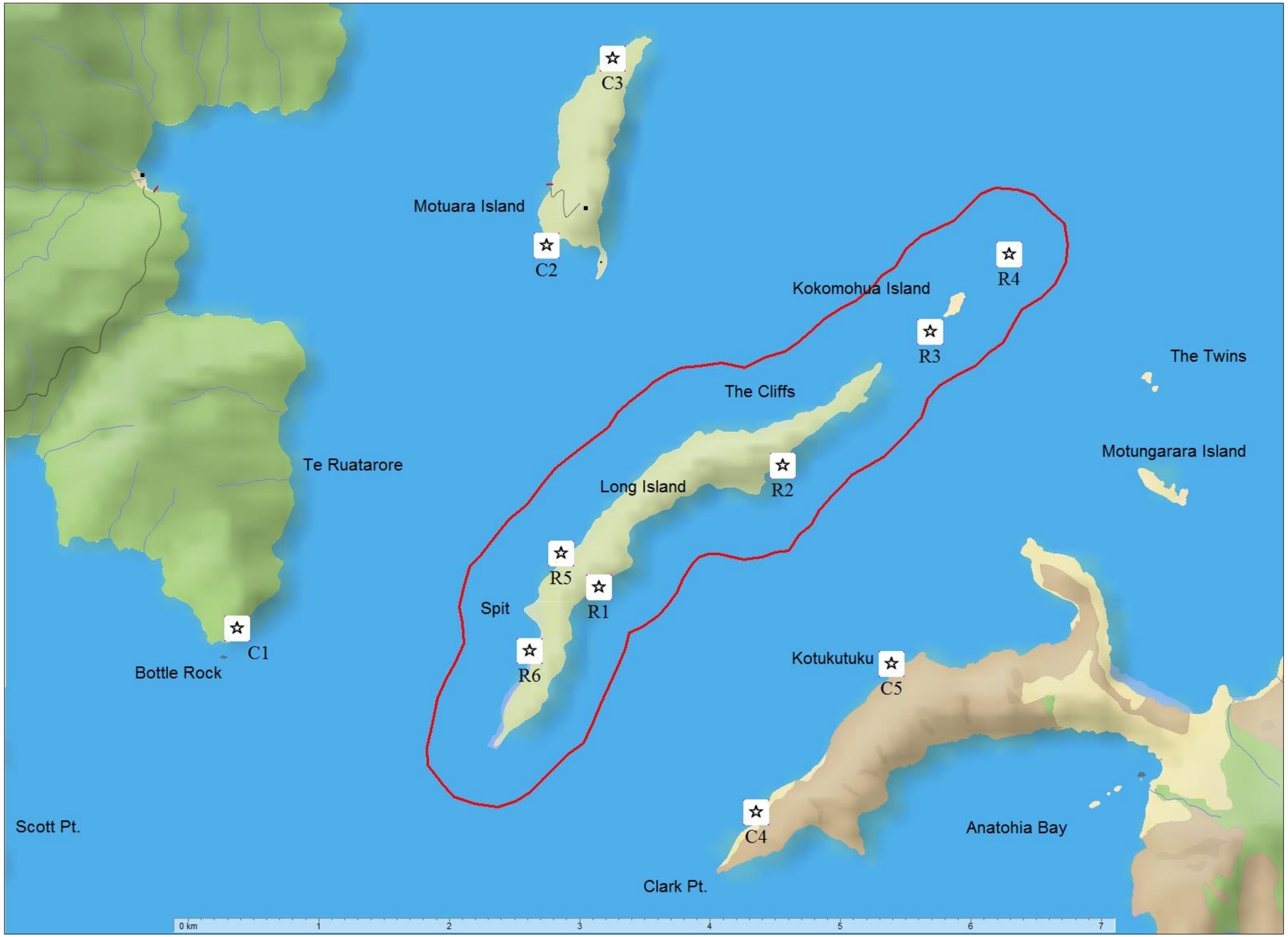

Figure 7. Location of kina and cats-eye sites sampled since 1999. ***Note: the location of sites prior to 2004 can be found in Davidson (2004).***

4.0 METHODS

4.1 Catch, measure and release (CMR)

The size and catch rates of fish, predominantly blue cod (*Parapercis colias*), were investigated at six control and three (1993-2003) or four (2004-2014) reserve sites (Figure 2, Table 2). Between 1992 and 2006, a maximum of 60 blue cod were sampled annually from each site, but this was increased to a maximum of 80 individuals from 2007 onwards. From 1992 to 1999, sampling was conducted on an annual or biannual basis. From 2000 onwards, sampling was carried out annually each autumn.

Control sites were established in areas subject to a range of recreational fishing pressures. Two sites regarded as 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. On each sampling day, one reserve and one control sites were sampled apart from one day each year when two control sites were sampled. Site selection each day was random and usually based on logistical constraints such as weather. By randomising sites any effects from environmental variables such as of time of day or tide were minimised.

All fishing surveys were located over rubble habitat (i.e. cobbles and small boulder substrata), close to 12 m depth. At each site, the survey vessel was positioned perpendicular to the shore using bow and stern anchors, thereby ensuring minimal boat movement. A supermarket 3 kg bag of ground-bait (berley) was secured inside a weighted plastic mesh container and lowered to the sea floor below the boat. Fishers used 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 the largest size range 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 sinker (i.e. tight lines) to minimize swallowing of hooks.

At each site catch per unit effort data were recorded (CPUE = catch/effort (total number of minutes fished by all fishers). CPUE was calculated for total catch and also blue cod. 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 to the boat and supplied with fresh circulating seawater. All fish were handled using clean cotton gloves to minimise damage and risk of infection. 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*).

Due to low catch rates at some sites, a maximum fishing period was set at two hours. Fishing ceased at two hours or when the target number of blue cod individuals were captured (i.e. up to 60 blue cod 1992-2006 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 (UVC)

In all years since 2009, the density of blue cod (*Parapercis colias*) and other reef fish was monitored 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; Davidson 2001; Davidson and Richards 2013; Davidson *et al*. 2013).

Fish data were collected from (1) rubble (cobble and boulder substrata) with no macroalgae (Table 3, Figure 3), and (2) bedrock, rubble substrata with a high percentage cover of macroalgae dominated by *Carpophyllum* spp., *Ecklonia radiata, Macrocystis* *pyrifera* and a variety of other brown, red and green algae (Table 4, Figure 4). For the rubble habitat, four reserve and four control sites were sampled annually from 1992 to 2014 in most years (Table 1). For macroalgae, three control and three reserve sites were sampled annually from 2002 to 2014 (Table 3). Prior to April 2002, algae habitats were sampled from three reserve and one control site (C3) annually (table 1); however, this data has not been presented in the present report due to the low number of sites.

All transects were established parallel to shore in boulder and reef habitat at depths from 3 - 15 m (Table 3 and 4, Figures 3 and 4). Since 2000, the size of blue cod, blue moki (*Latridopsis ciliaris*), red moki (*Cheilodactylus spectabilis*), tarakihi (*Nemadactylus macropterus*), butterfish (*Odax pullus*) and snapper (*Pagrus auratus*) were visually estimated by trained and ground-truthed divers to the nearest centimeter of fish body length. Snapper were rarely observed by divers primarily due to their diver negative behaviour, meaning their real abundance is likely underestimated. Divers ignored triplefins (Tripterygiidae) and cave- and crevice-dwelling species. For most of the study, the same three divers have collected reserve and control fish data.

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 (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". Transects were swum at a constant slow speed, but fast enough to ensure that swimming fish did not overtake the divers. Twelve replicate transects were sampled at each site. Underwater visibility was at least 4.5 m horizontal distance for the collections of fish transect data.

4.3 Spiny lobster density, sex and size

Spiny lobster density and sex was sampled in March 1992, March 1995, April 1997 and April 1999. Since 2001, annual samples were collected from four reserve and four control sites (Tables 1 and 5, Figure 5).

Prior to April 2001, three to eight 60 m^2 quadrats were sampled per site. From April 2001 onwards, a total of six 100 m^2 quadrats (25 m long x 5 m wide) were sampled. Lobster quadrats were haphazardly placed and oriented within depth stratum that corresponded to the presence of lobster habitat at each site. Two divers independently searched all crevices, caves and cracks within each quadrat using an LED dive torch. The size and sex of lobsters encountered was recorded. For most of the study, the same two divers collected lobster data.

The methodology for estimating lobster size also changed during the monitoring programme. Prior to 1999, total body length was visually estimated and individuals were grouped into four size classes: juvenile (< 150 mm), small (150 – 250 mm), medium (250 – 350 mm), and large (> 350 mm). From 1999 onwards, carapace length (CL) was estimated to the nearest 5 mm. Lobsters were separated into four groups based on carapace length and/or sex: (i) reproductive male (≥140 mm CL (ii) non-reproductive male (85-139 mm), (iii) mature female (≥85 CL), (iv) juvenile ≤ 80 mm CL. A ruler attached to an extendable lanyard was used to measure lobsters.

Occasionally, the size and sex of some lobsters could not be measured because they were deeply concealed beneath boulders or within caves. As a result, the number of lobsters presented in density and size data does not correspond.

4.4 Black-foot paua density and size

The density and size (maximum length) of black foot paua (*Haiotis iris*) was sampled at eight reserve and three control sites in 1992 (0-2 m depth below mean low water). Since 1992, the number of sites was altered to seven reserve and six control sites (Figure 6, Table 6). Paua were sampled in 1992, 1999, 2004, 2007, 2009, 2010, 2012, and 2013, however, only paua size was sampled in 2004 and 2012. In 2012, one control site was sampled (Site 5), while five of the seven reserve sites (sites 2, 3, 7, 8, and 9) were sampled.

Paua sites were located in areas supporting either "mixed algae" habitat or a macroalgal (*C. maschalocarpum*) sublittoral strip growing on bedrock located from 0 to 2 m depth. Divers methodically searched each site in an attempt to find and measure a minimum of 50 paua. This was not always possible as paua were uncommon in some years and at some sites.

Numbers therefore ranged from 15 to 115 paua. Paua were measured with callipers to the nearest millimetre *in situ.*

At each site, paua density was sampled from between 30 and 60 (1 m^2) haphazardly placed quadrats deployed 0-2 m below low tide (Table 6). Quadrats were haphazardly placed on bedrock and boulder substrata and all visible black-foot paua were counted. No paua were counted from under rolled boulders.

4.5 Kina density and size

Kina / sea urchin (*E. chloroticus*) density and size data were collected in 1992, 1999, 2008, 2010 and 2014 (Table 1). 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 (Table 7, Figure 7). Analysis of sizes excluded data collected form additional sites in 1992. At each site, numbers of kina were counted from 34 to 66 1 m^2 quadrats haphazardly placed within a predetermined depth range (generally 3-8 m) from rock or rubble substrata not covered by foliose macroalgae (Table 7). The test diameters of all surface-dwelling kina within quadrats were measured *in situ* to the nearest 1 mm using callipers. When insufficient kina were measured from quadrats, additional kina were measured from adjacent areas within the predetermined depth range by thoroughly and methodically searching substrata.

4.6 Cats eye density

Cats eye snail (*T. smaragdus*) density was sampled from 5-6 reserve and five control sites in 1992, 1999, 2008, 2010 and 2014 (Table 7, Figure 7). The number of sites sampled was reduced after 1992. Cats eyes were counted in 21 to 60 1 m^2 quadrats haphazardly placed with a predetermined depth range (generally 3-8 m) on rock or rubble habitat free of foliose macroalgae (Table 7).

4.7 Statistical analysis

All size and density raw data were entered into a Mircrosoft Excel 2010 spreadsheet. Mean, standard deviation, standard error and sample sizes were calculated using inbuilt function commands. On occasion raw data from individual sites were pooled into reserve and control groups where means, standard deviation and standard errors were calculated in Excel 2010. Statistical analyses of raw data were conducted using Sigmaplot 12.5 unpaired t-Test where data were first tested using the Shapiro-Wilk Normality Test. An equal variance test was also conducted on raw data to check variability about the means. The P value determining the probability of being incorrect in concluding that the data is not normally distributed was set at 0.05. All raw data in the present study failed this test and a Mann-Whitney Rank Sum Test was then applied. The Mann-Whitney Rank Sum Test tests for a difference between two groups that is greater than what can be attributed to random sampling variation. The null hypothesis was that the two samples were not drawn from populations with different medians. The Rank Sum Test is a nonparametric procedure, which does not require assuming normality or equal variance. It ranks all the observations from smallest to largest without regard to which group each observation comes from. The ranks for each group are summed and the rank sums compared. If there is no difference between the two groups, the mean ranks should be approximately the same. If they differ by a large amount, we assumed that the low ranks tend to be in one group and the high ranks are in the other, and conclude that the samples were drawn from different populations (for example, that there is a statistically significant difference).

In all significance tests Alpha was set at 0.05 where α is the acceptable probability of incorrectly concluding that there is a difference.

5.0 RESULTS

This report updates monitoring data collected from Long Island-Kokomohua Marine Reserve and nearby control sites from 2010 to 2014.

5.1 Fish catch, measure and release (CMR)

Since 2009, blue cod dominated the catch at both reserve (98.3%) and control (83.5%) sites followed by spotty (*Notolabrus celidotus*), kahawhai (*Arripis trutta*), carpet shark (*Cephaloscyllium isabellum*), tarakihi (*Nemadactylus macropterus*) and barracouta (*Thrysites atun)* (Tables 8 and 9)

Table 8. Fish recorded from pooled reserve sites sampled since 2009 (CMR).

Species name	Common name	2010	2011	2012	2013	2014	Total
Parapercis colias	Blue cod	328	326	324	333	381	1692
Nemadactylus macropterus	Tarakihi		9			1	10
Notolabrus celidotus	Spotty	1	5	5	1	5	17
Thyrsites atun	Barracouta						0
Cephaloscyllium isabellum	Carpet shark		1				1
Parika scaber	Leatherjacket						0
Arripis trutta	Kahawhai						0
Helicolenus papillosus	Sea perch				1		1
Pseudolabrus miles	Scarlet wrasse						0
Notolabrus fucicola	Banded wrasse						0
Squalus acanthias	Spiky dogfish						0
Total catch (n)		329	341	329	335	387	1721
Total no. species		2	4	2	3	3	5

Table 9. Fish recorded from pooled control sites sampled since 2009 (CMR).

Species name	Common name	2010	2011	2012	2013	2014	Total
Parapercis colias	Blue cod	486	438	423	412	393	2152
Nemadactylus macropterus	Tarakihi	7	1	7	11	13	39
Notolabrus celidotus	Spotty	78	19	62	59	50	268
Thyrsites atun	Barracouta			3			3
Cephaloscyllium isabellum	Carpet shark	3		3	23	9	38
Parika scaber	Leatherjacket	4	2	7	6		19
Arripis trutta	Kahawhai	17	1	8	14	2	42
Helicolenus papillosus	Sea perch					1	1
Pseudolabrus miles	Scarlet wrasse			1	1		2
Notolabrus fucicola	Banded wrasse			1	1		2
Squalus acanthias	Spiky dogfish	2		2	6	2	12
Total catch (n)		597	461	517	533	470	2578
Total no. species		7	5	10	9	7	11

A variety of other species were occasionally captured (e.g. leatherjacket (*Parika scaber*), banded wrasse (*Notolabrus fucicola*), scarlet wrasse (*Pseudolabrus miles*)). A total of five species of fish were captured between 2010 and 2014 at reserve sites compared to 11 species from control sites (Tables 8 and 9).

5.1.1 Size structure of blue cod (CMR)

Total length (TL) of blue cod varied between reserve and control treatments throughout the study (Figure 8). Apart from 2012, the median blue cod length at reserve sites always exceeded control values, however in some years the differences were small (1994, 2010, 2014).

Mean TL for blue cod in the reserve always remained above means recorded at controls, however, in August 1994, April 2012 and May 2014 the difference was small and not significantly different (Figure 9, Table 10).

Soon after the reserve was established, reserve blue cod length increased, peaking in September 1999 (mean = 318.5 mm) (Figure 9). From 2000 onwards, mean blue cod length typically fluctuated between 284 mm and 308 mm (Figure 9), although in 2014 it dramatically declined to 270.6 mm. The previous low was recorded in September 1995 (mean = 276 mm) (Figure 9).

Mean TL for blue cod at pooled control sites was more variable than in pooled reserve sites (Figure 9). In control sites, it initially increased from September 1993 to August 1994, but declined dramatically by September 1995. Mean TL of blue cod at control sites gradually increased in the following four sample events to March 1998, but again declined to a low of 223.3 mm 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. From March 2004, mean blue cod TL at control sites consistently increased for 8 years consecutive years, peaking in April 2012 at 280.9 mm TL (Figure 9). This event was one of the three occasions the difference between reserve and control means (7.3 mm) was not significantly different (Table 10). Since 2012, control means declined by 18.8 mm to 262.0 mm length.

Table 10. Mann-Whitney U test statistics comparing pooled blue cod length between reserve and control sites for each CMR sampling year. ***Note: for the magnitude of statistical differences see Fig.9.***

Date	U value	P value	N (small, large)	Sig.
Sep-93	11827	<0.001	131-305	Yes
Mar-94	33525	0.019	226-336	Yes
Aug-94	33407	0.176	193-372	No
Mar-95	25547	<0.001	185-372	Yes
Sep-95	6134	<0.001	131-181	Yes
Apr-96	13308	<0.001	181-289	Yes
Apr-97	14593	<0.001	186-302	Yes
Sep-97	20613	<0.001	250-281	Yes
Mar-98	9315	<0.001	200-205	Yes
Apr-99	8247	<0.001	177-132	Yes
Sep-99	5738	<0.001	183-275	Yes
Apr-00	6953	<0.001	179-268	Yes
Apr-02	15761	<0.001	187-313	Yes
Apr-03	13832	<0.001	185-227	Yes
Mar-04	13318	<0.001	251-367	Yes
Apr-05	32960	<0.001	320-451	Yes
Apr-06	22904	<0.001	247-456	Yes
Apr-07	47855	<0.001	339-492	Yes
Apr-08	24417	<0.001	331-355	Yes
May-09	47086	<0.001	327-401	Yes
Apr-10	66317	<0.001	328-486	Yes
Apr-11	52275	<0.001	326-438	Yes
Apr-12	67750	0.749	324-423	No
Apr-13	45631	<0.001	333-412	Yes
May-14	64132	0.195	381-393	No

5.1.2 Blue cod size composition (CMR)

Large differences in the proportion of fish in each size existed between reserve and control sites (Figure 10). The size class structure of blue cod at both reserve and control sites were usually dominated by small blue cod < 280 mm length (reserve = 23 to 65%, control = 44 to 93 %). The proportion of these small cod was usually higher at controls (Figure 10). In contrast, the largest size class at reserve sites occasionally exceeded the proportion of the smallest class. At controls, the largest size class (330 – 650 mm TL) usually represented a small part of the population, however in August 1994, April 2011 and April 2012 peaks were recorded (Table 11, Figure 10). These peaks were below reserve values; however, they were well above background control levels for this size class. Between May 2009 and

May 2014 (i.e. fishery closure and subsequent slot rule), the percentage of large >330 mm blue cod from control sites remained relatively high compared to previous years. The proportion of the two medium size classes were comparable between reserve and control sites, however, they did fluctuate between years.

Table 11. Proportion of blue cod in three size classes from pooled reserve and control sites (CMR).

Date	<280 mm		280-299 mm		300-329 mm		>330 mm	
	Control	Reserve	Control	Reserve	Control	Reserve	Control	Reserve
Sep-93	72.5	43.9	17.6	21.6	8.5	15.1	1.5	19.3
Mar-94	56.9	54	20.5	15.9	14.8	15.9	7.9	14.2
Aug-94	54.8	51.2	18	16	16.4	16	10.8	16.6
Mar-95	62.5	45.4	18.3	17.3	12.9	15.7	6.2	21.6
Sep-95	86.3	51.9	8.4	20.4	5.3	14.4	0	13.3
Apr-96	81.7	45	9.3	7.8	4.8	17.2	4.2	30
Apr-97	77.7	44	12.3	15.1	8.3	9.1	2	31.7
Sep-97	76.2	45.6	13.9	12.4	6.4	12.8	3.6	29.2
Mar-98	59.5	26	24.4	16.5	12.2	22.5	3.9	35
Apr-99	84.3	41.8	7.4	12.4	5.2	19.2	3	26.6
Sep-99	84.4	23	8.7	13.7	4	24.6	3	38.8
Apr-00	92.9	36.9	3	11.7	3.4	16.2	0.7	35.2
Apr-02	82.4	50.3	11.2	12.3	4.2	16.6	2.2	20.9
Apr-03	78.4	52.4	11	8.6	6.2	7.6	4.4	31.4
Mar-04	84.7	35.9	8.7	10.4	4.9	17.5	1.6	36.3
Apr-05	82.5	45.3	12.2	14.4	4.9	13.1	0.44	27.2
Apr-06	84.4	40.9	10.1	9.3	4.6	7.7	0.9	42.1
Apr-07	82.5	55.2	11.4	13.6	5.7	10.3	0.4	20.9
Apr-08	78	36.9	11.8	13.3	9.3	18.1	0.9	31.7
May-09	67.6	51.7	15.5	9.8	11.2	15.3	5.7	23.2
Apr-10	61.52	53.7	18.1	13.1	12.96	11.28	7.41	21.95
Apr-11	60.5	43.25	14.4	14.1	13.5	14.1	11.6	28.5
Apr-12	44.6	51.5	24.5	12	19.6	10.2	11.3	26.2
Apr-13	57	37.8	19.9	16.3	14.2	17.8	9	28.1
May-14	65.3	65.9	15.4	9.2	11.3	8	8	16.9

5.2.3 Blue cod size-frequency (CMR)

Blue cod size-frequency distributions differed between pooled reserve (4 sites) and pooled control sites (6 sites) (Figures 11-17), and individual sites (Figures 18 and 19). In most years the control population was characterised by most individuals below the legal size, with a considerably smaller number of individuals greater than the minimum legal size. Blue cod within the reserve were generally dominated by sub-legal fish, although relative to the control sites, greater numbers of legal blue cod occurred within the reserve.

The size structure of control blue cod at individual control sites in 2004 was comprised primarily of sub-legal sized individuals (< 300 mm TL), with no individuals over 380 mm TL being recorded (Figure 18). This contrasts with reserve sites where much of the population was over the minimum legal size limit and many individuals were > 380 mm TL. In 2004, sites in each treatment (i.e. reserve, control) showed comparable size-frequency distributions. In 2014, control sites exhibited variable population structures (Figure 19). Sites 1 (Bottle Rock), 2 (Blumine north) and 3 (Clark Point) had few individuals over the legal size limit (>300 TL). At Bottle Rock, only three blue cod greater than 300 mm TL were recorded. In contrast, Sites 4 (Anatohia), 5 (Scott Point) and 6 (Blumine south) supported a greater numbers of large cod > 300 TL. Conversely, in 2014 the size frequency distributions of blue cod within the reserve were consistent across sites.

In 2014, the numbers of legal cod (>300 TL) were lower than most previous years at three of the four sites (Figure 19).

5.1.3 Blue cod catch per unit effort (CMR)

Pooled catch per unit effort (CPUE) values were significantly higher in the reserve compared to the control sites ($T = -10.02$, $P<0.001$, $df = 36$). For most of the study, pooled control CPUE values remained low relative to the reserve (Figure 20). From 2004 onwards, CPUE at controls gradually increased, peaking in April 2013, followed by a small drop in 2014.

CPUE in the reserve initially increased rapidly peaking in March 1998. Since 1998 CPUE fluctuated, but remained between 0.72 and 1.54 blue cod per minute.

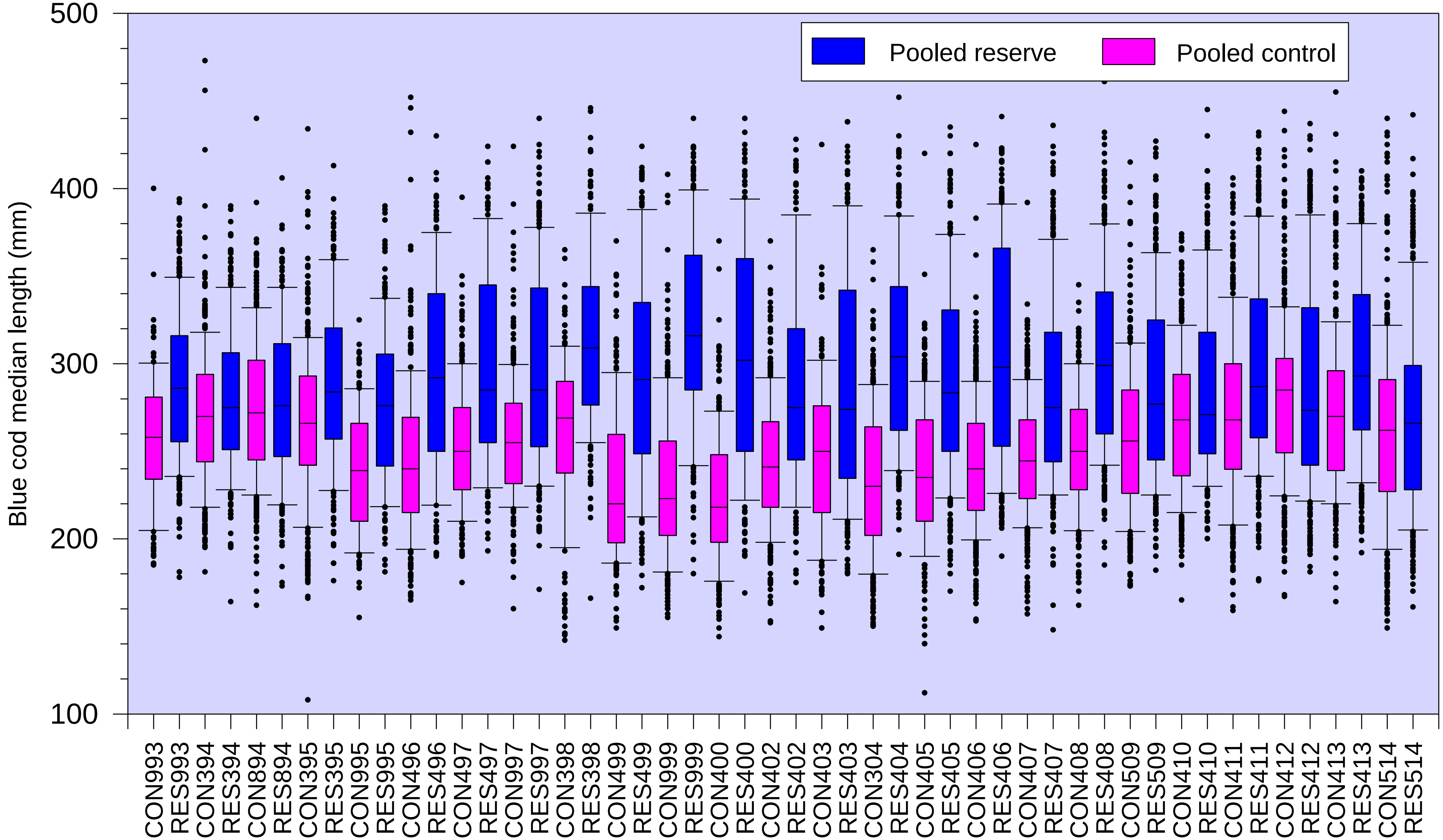

Figure 8. Box plot of CMR blue cod length from pooled reserve (blue) and control sites (pink). Enclosed boxes represent 25th and 75th percentiles and the horizontal line the median. Error bars are 10th and 90th percentiles..

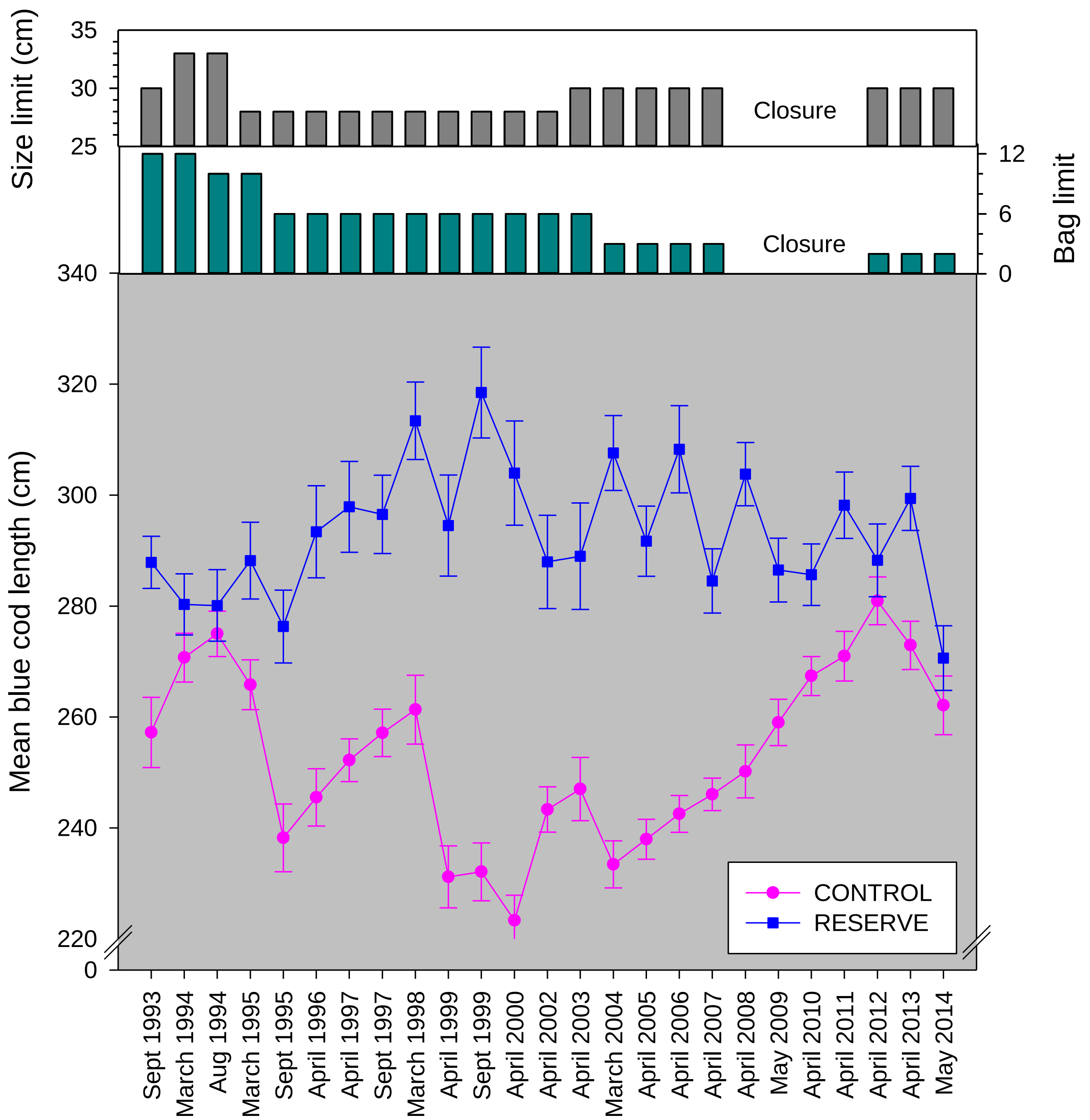

Figure 9. Mean blue cod length from CMR pooled reserve (blue squares) and control sites (pink circles). Error bars represent 95% confidence intervals. Changes to blue cod bag limits and minimum sizes are indicated for the Marlborough Sounds.

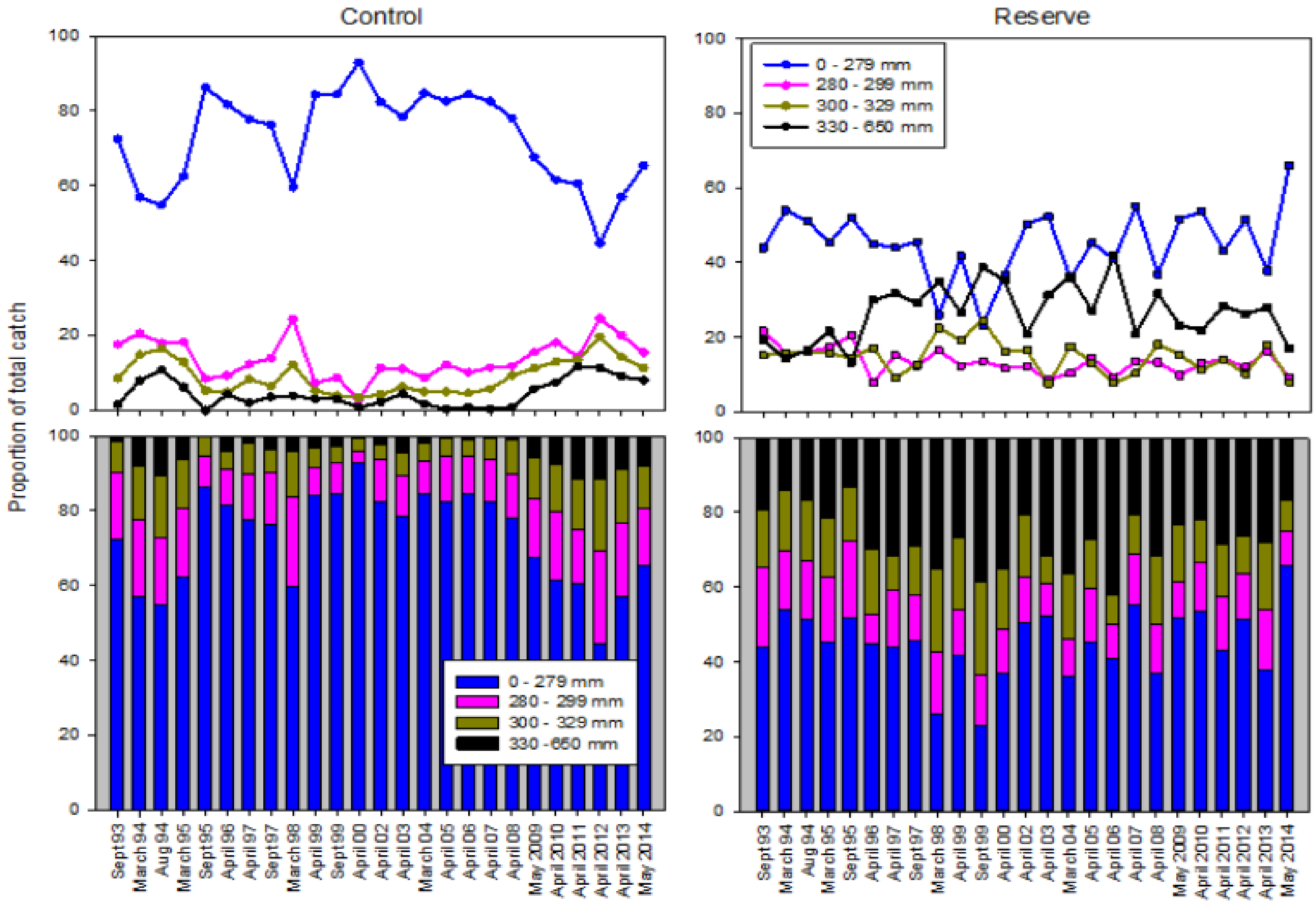

Figure 10. Proportion of blue cod (CMR) from pooled reserve and control site separated into four size categories. Line (top) and bar (bottom) graphs display the same pooled data for control (left) and reserve (right) samples.

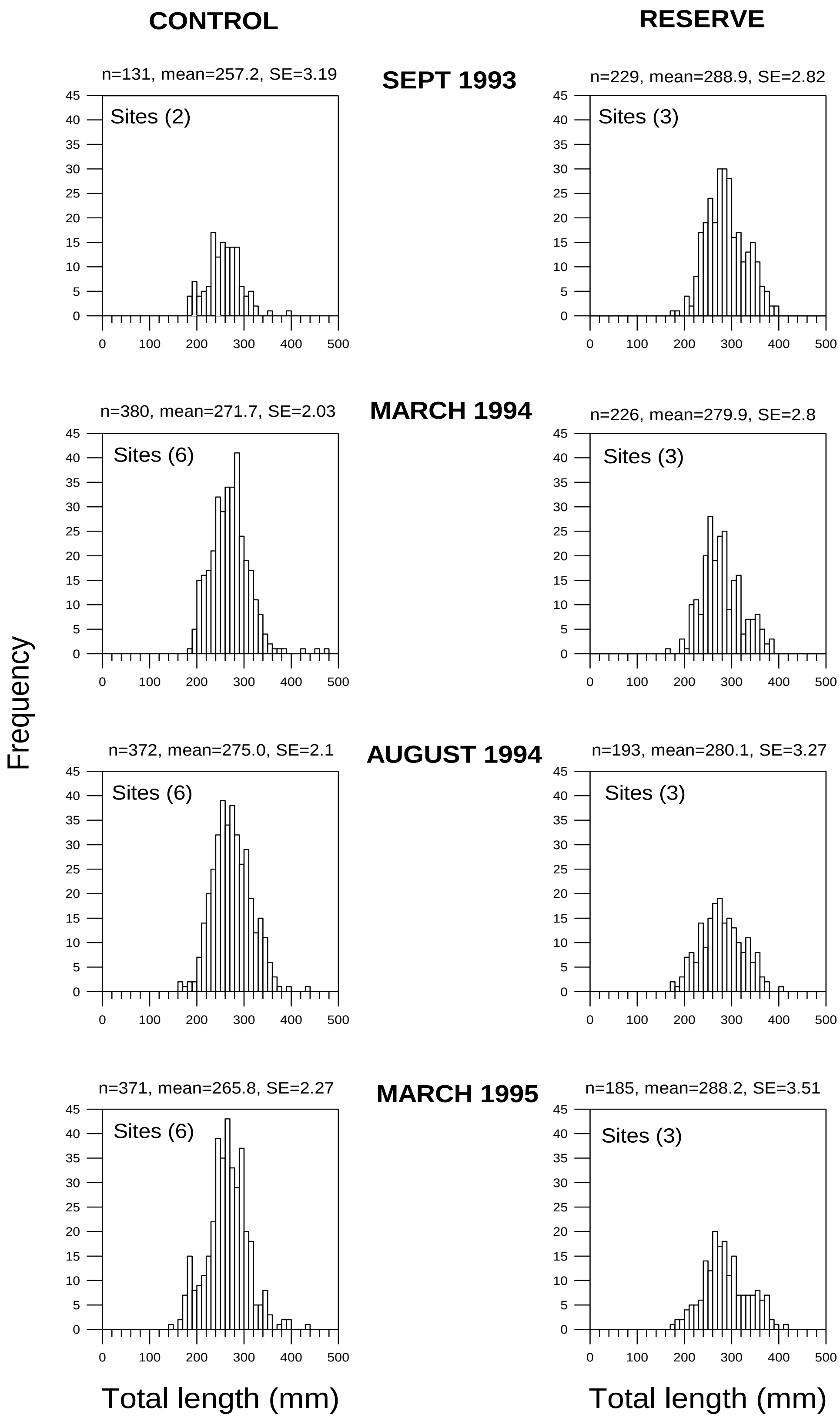

Figure 11. Length-frequency distributions of blue cod from CMR pooled reserve and control sites from September 1993 to March 1995.

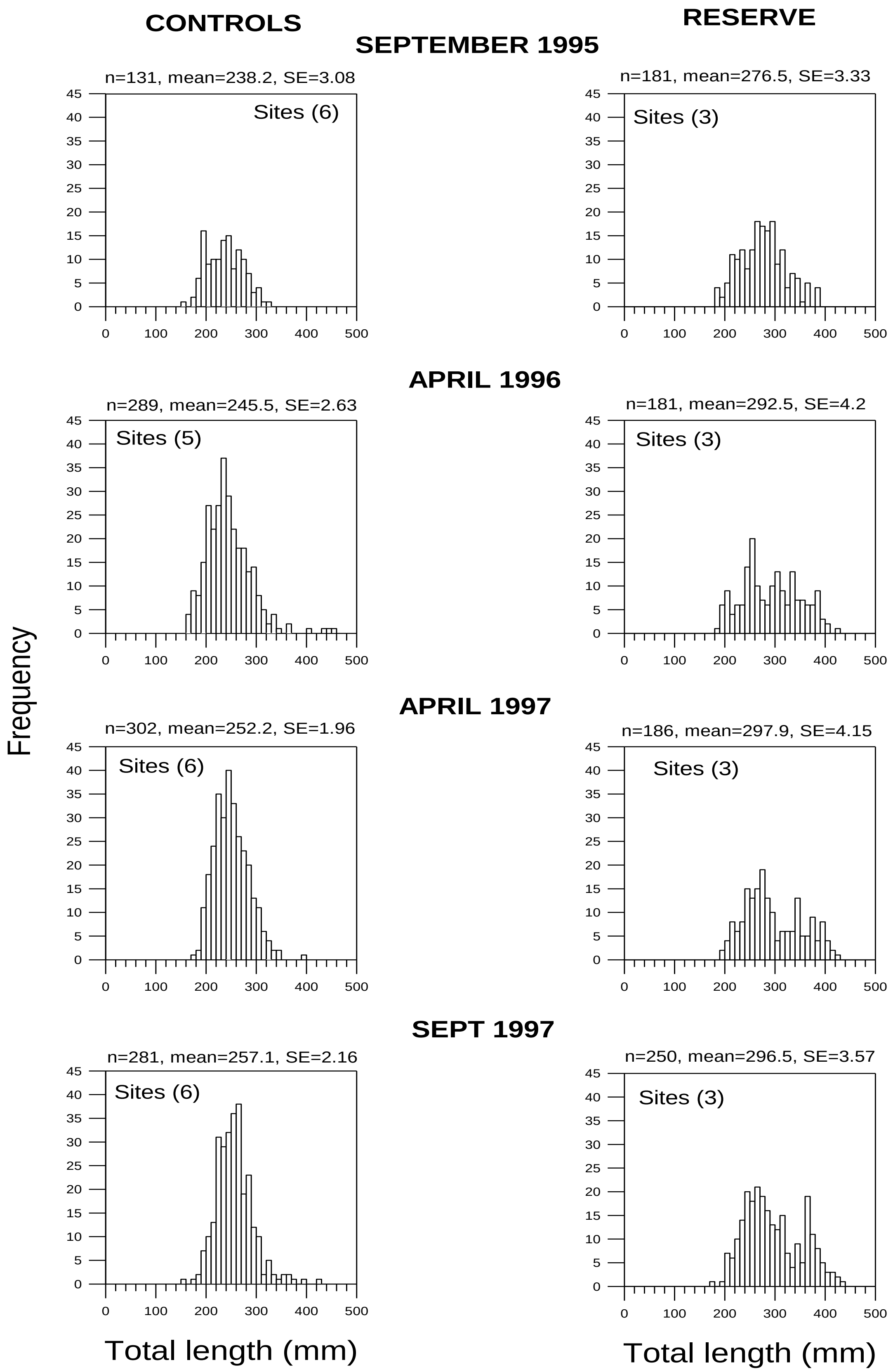

Figure 12. Length-frequency distributions of CMR blue cod from pooled reserve and control sites from September 1995 to September 1997.

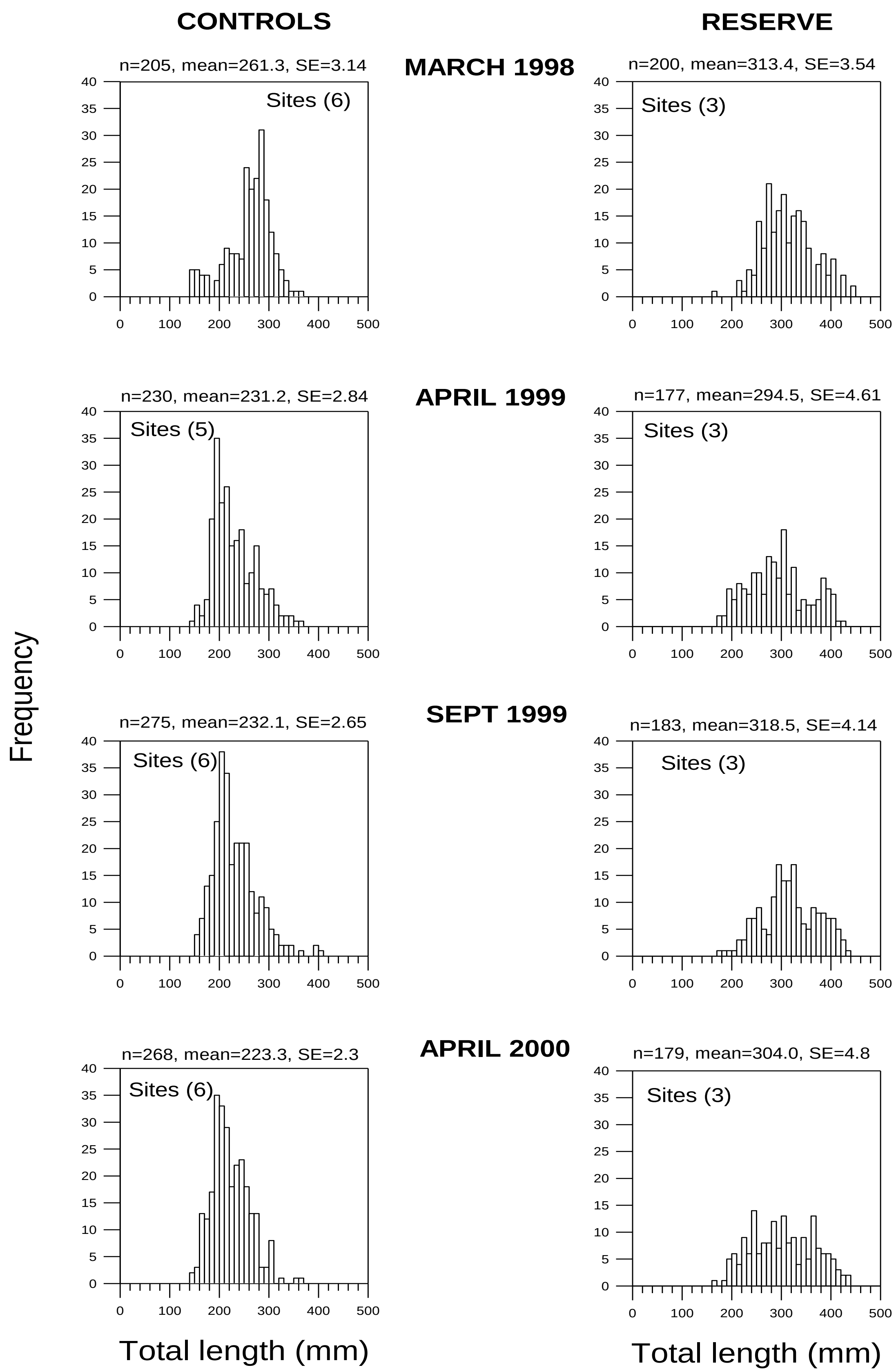

Figure 13. Length-frequency distributions of CMR blue cod from pooled reserve and control sites from March 1998 to April 2000.

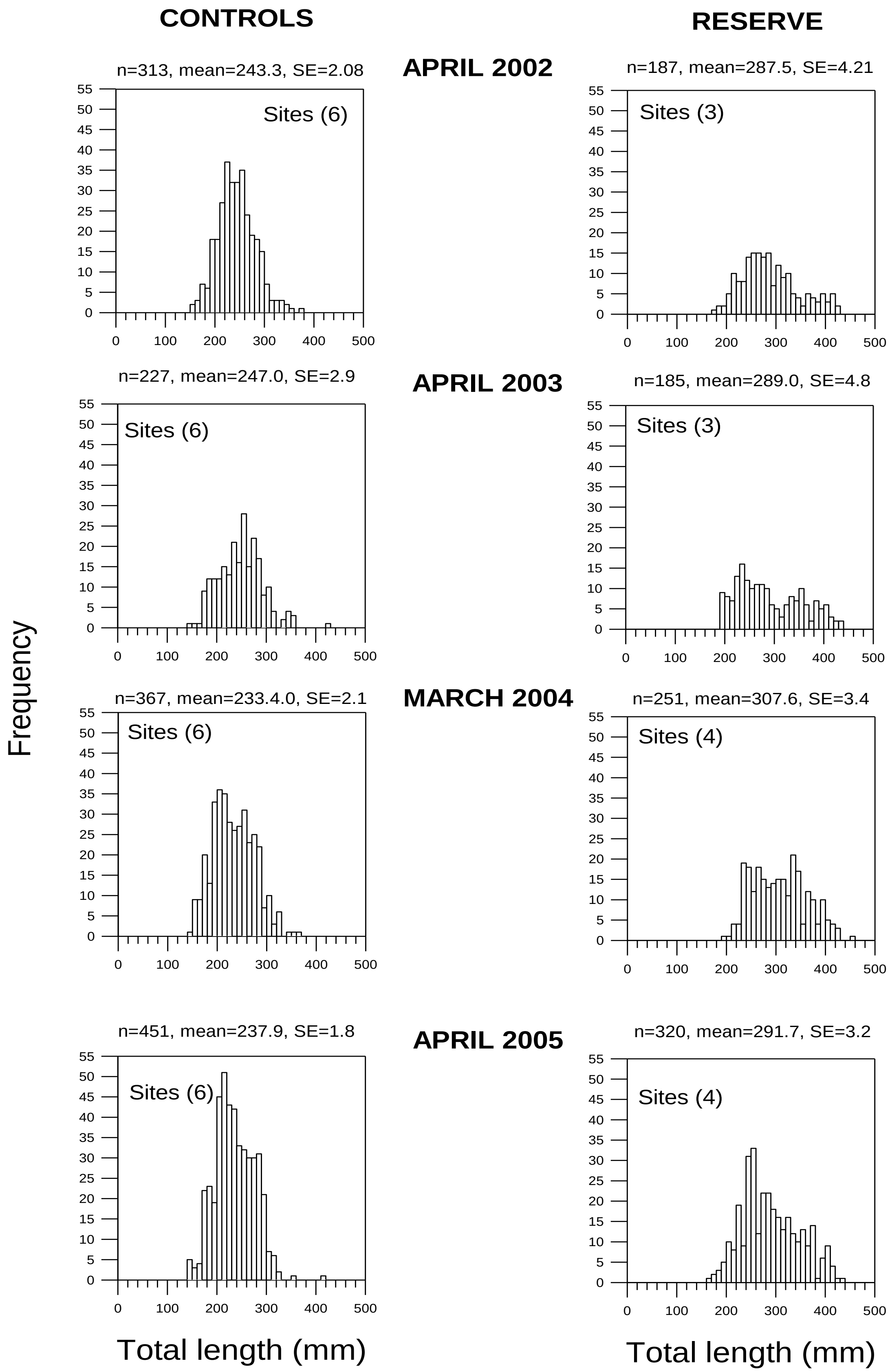

Figure 14. Length-frequency distributions of CMR blue cod from pooled reserve and control sites from April 2002 to April 2005.

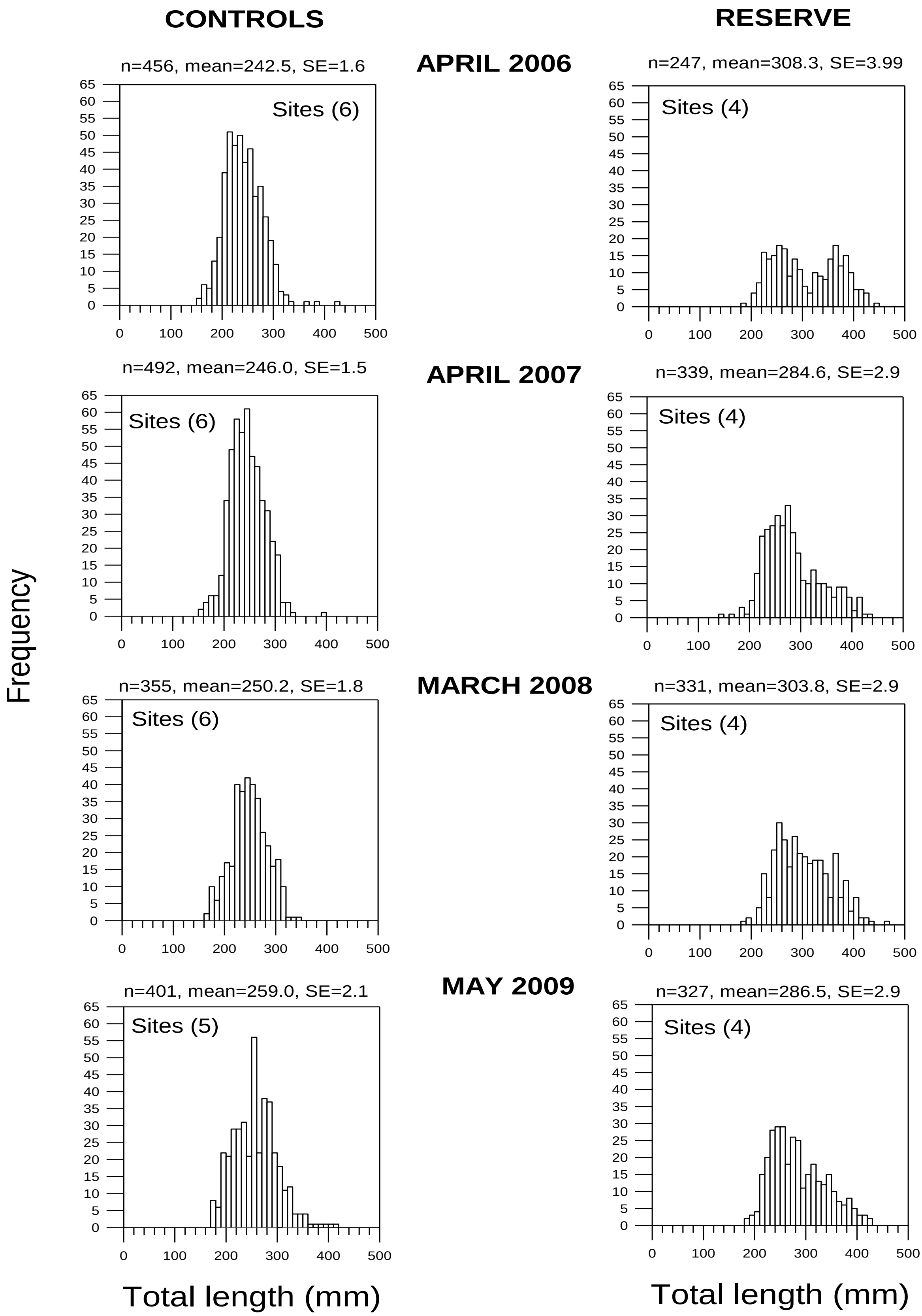

Figure 15. Length-frequency distributions of CMR blue cod from pooled reserve and control sites from April 2006 to May 2009.

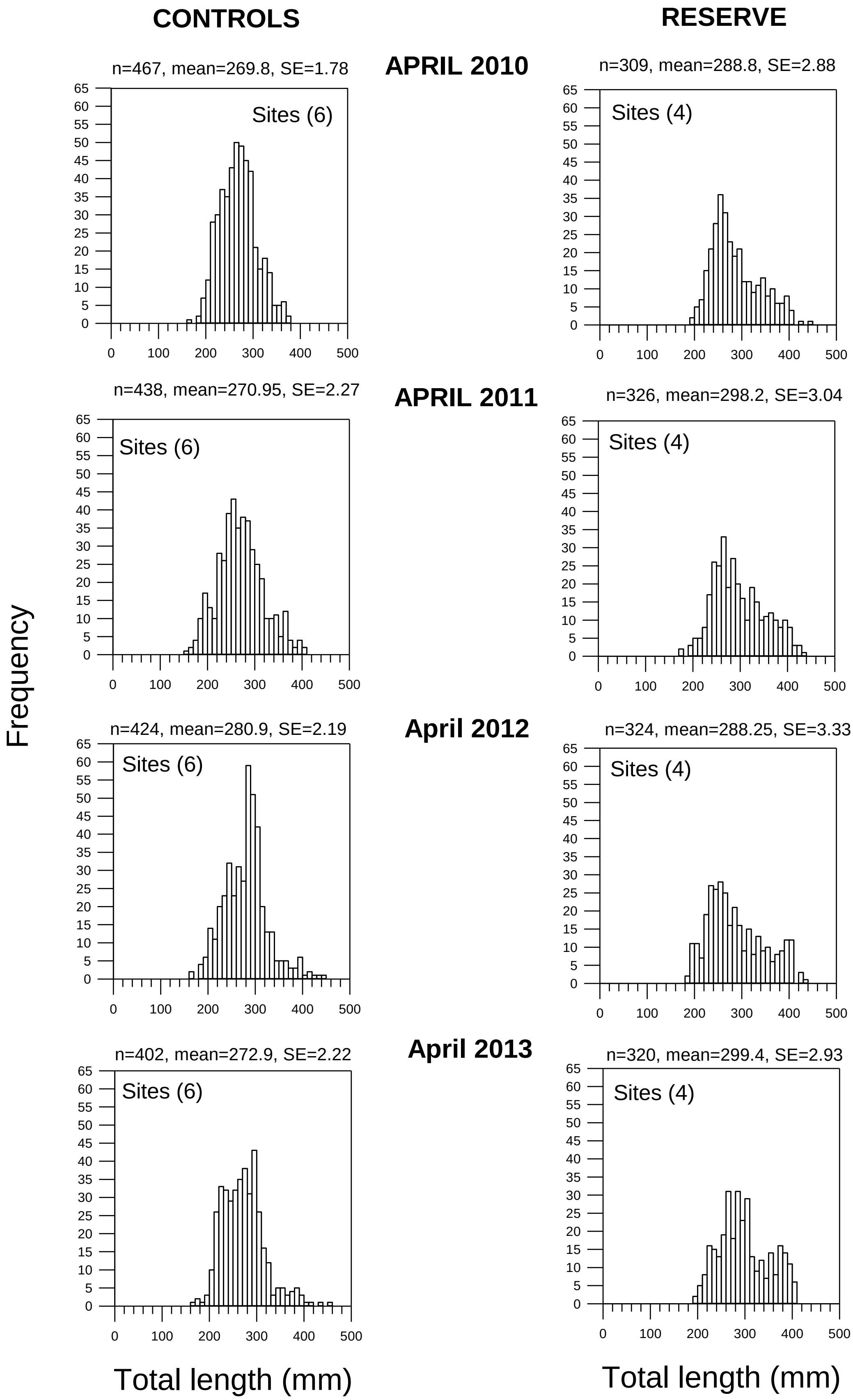

Figure 16. Length-frequency distributions of CMR blue cod from pooled reserve and control sites from April 2010 to April 2013.

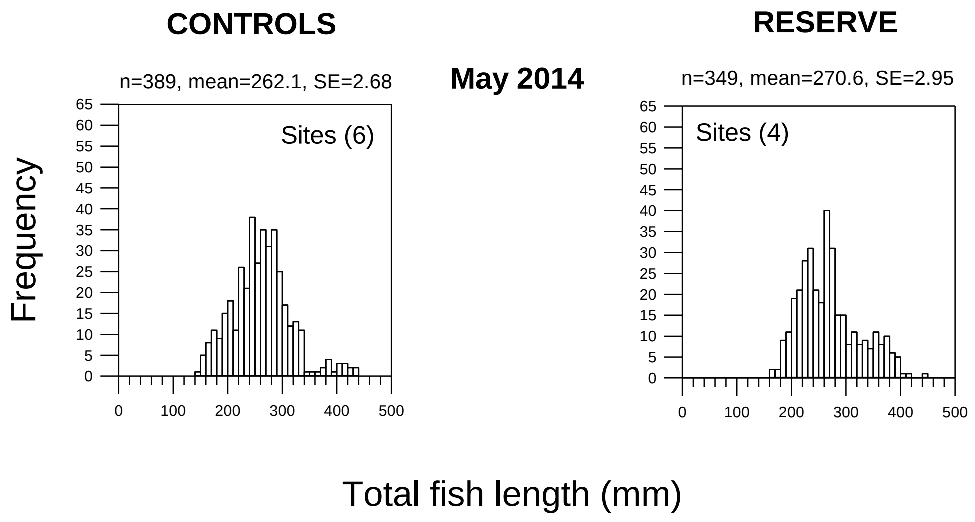

Figure 17. Length-frequency distributions of CMR blue cod from pooled reserve and control sites in May 2014.

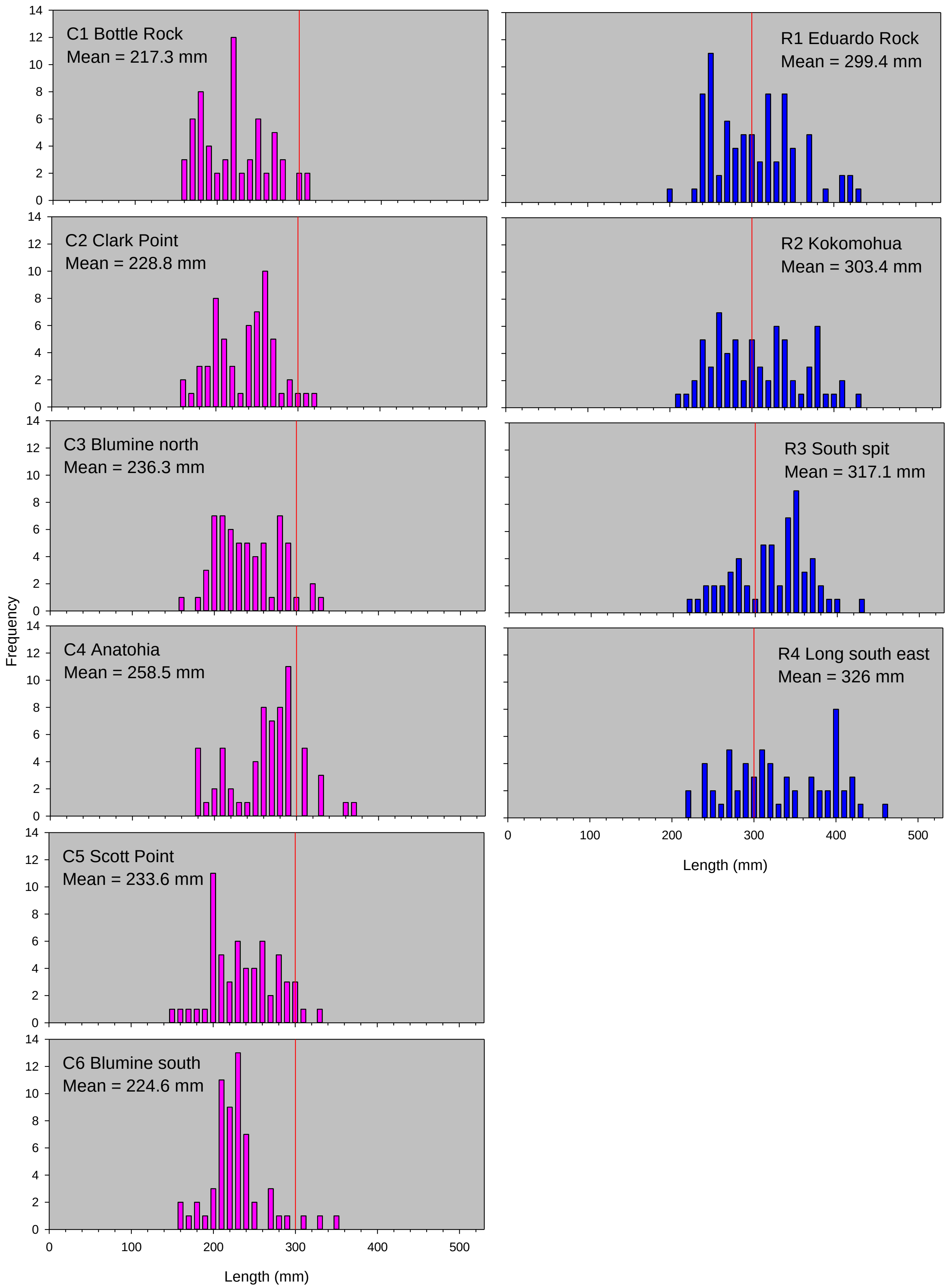

Figure 18. Length-frequency distributions of CMR blue cod from individual reserve and control sites in April 2004.

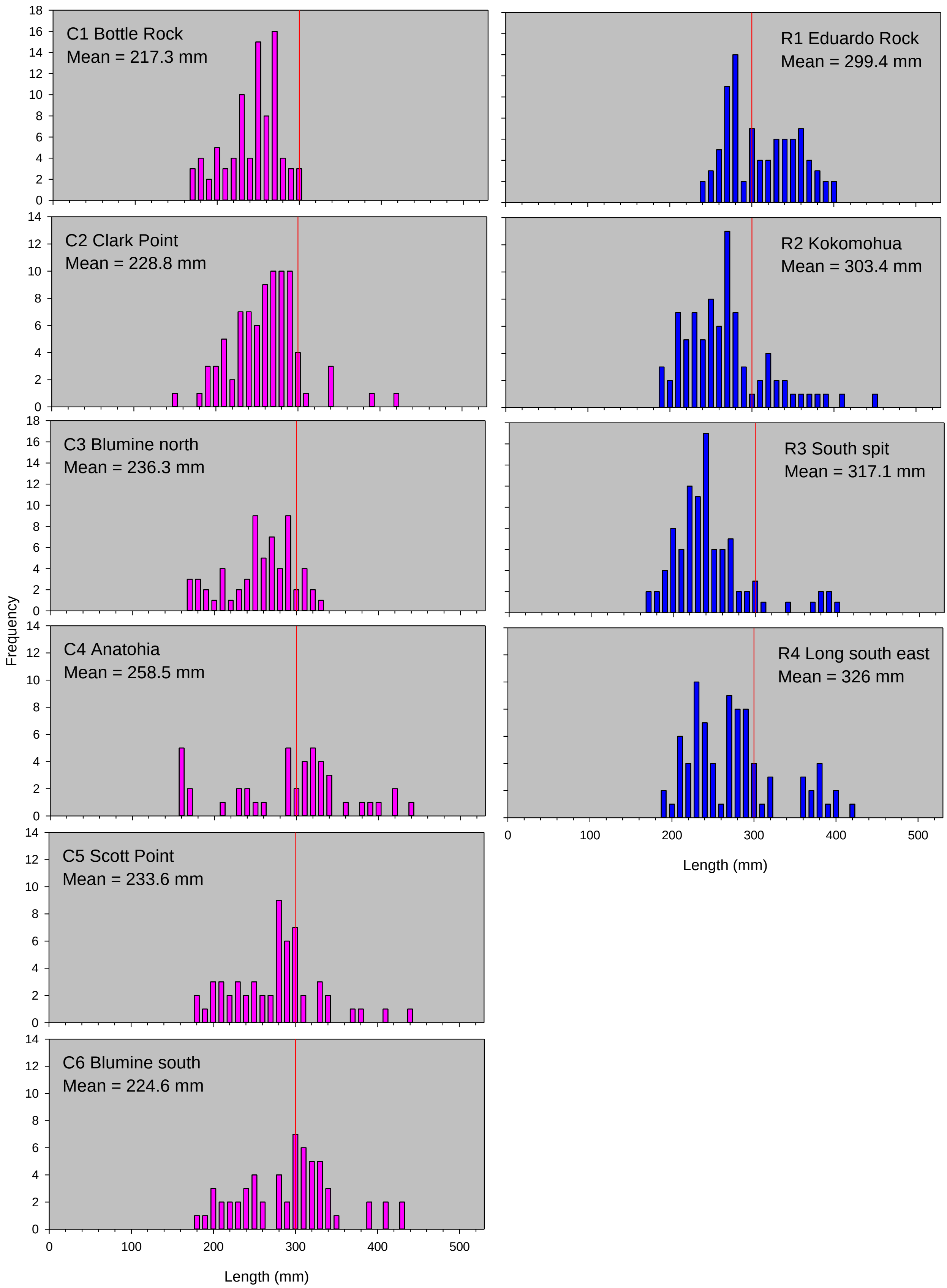

Figure 19. Length-frequency distributions of CMR blue cod from individual reserve and control sites in April 2014.

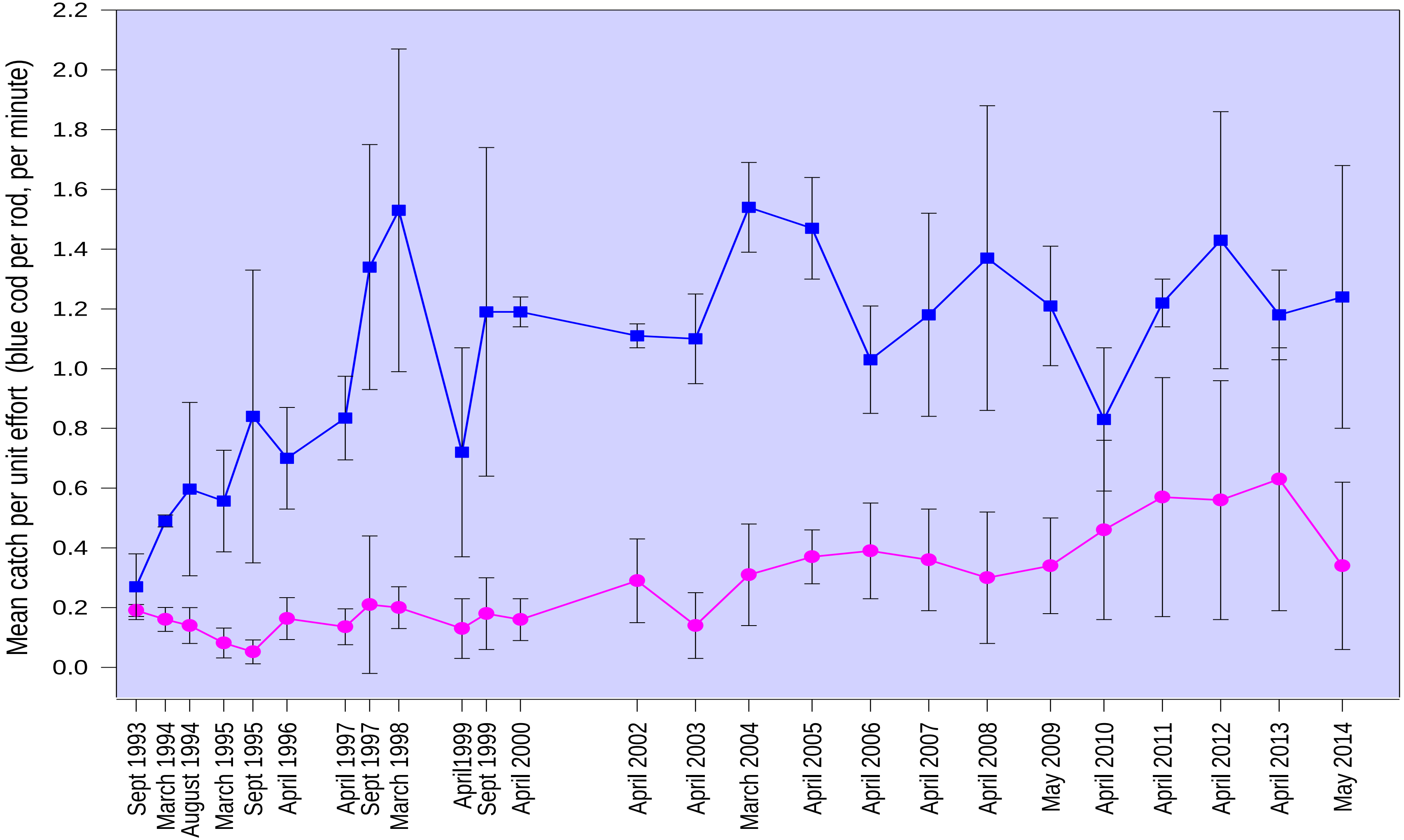

Figure 20. Mean catch per unit effort (CPUE) for blue cod pooled from reserve and control sites (CMR). Error bars are 95% confidence intervals.

5.2 Underwater visual counts (UVC)

Divers counted reef fish annually from rubble habitat in control and reserve sites from 1992 to 2014, and in macroalgae habitat from 2002 to 2014.

5.2.1 Presence-absence and relative abundance (UVC)

Divers observed 15 species of reef fish from rubble substrata at reserve and control sites during the study (Table 12). Blue cod and spotty were recorded from all rubble sites on all occasions and were usually observed in high numbers relative to other species. The presence of tarakihi varied between years, but when present, they were frequently observed, usually in small groups or as large schools. Other species like leatherjacket (*Parika scaber*) were recorded regularly, although in relatively low numbers; however, small groups of juveniles associated with occasional macroalgae plants or were sometimes seen on rubble by divers. Kingfish (*Seriola grandis*) were rarely observed, and when they were, it was as individuals or small groups (<6 indiviuals). All other species were rarely observed from rubble-dominated habitat inside and outside the reserve.

Twenty species of reef fish were recorded from macroalgae (Table 12). Spotty were the most frequently seen and abundant species, followed by tarakihi, leatherjacket, blue moki, butterfly perch, sweep and butterfish. Blue cod were relatively uncommon from this habitat, or when they were seen, were usually located around its seaward edges. Of interest was the occasional observation of a northern species, blue maomao (*Scorpis violaceus*) and a southern species, girdled wrasse (*Pseudolabrus cinctus*) at Charted Rock.

5.2.2 Fish density from rubble substrata (UVC)

Three years after the monitoring began, and two years after reservation, the density of blue cod at rubble sites within the reserve was significantly higher than at control sites (Table 13, Figure 21). This difference was primarily due to an increase in abundance of large cod (>300 cm TL). Small blue cod were almost always more abundant in the reserve, but this difference was not significant until April 2000 onwards (excluding March 2011). From 1995 onwards, significantly more large blue cod were recorded from reserve sites compared to control sites.

The density of large blue cod at the control sites remained relatively low over the duration of the study, with small increases in March 1993, and the last six years of the study (Figure 21). Small blue cod at control sites ranged from 1-3 individuals per 60 m^2 compared to 1.8-8 individuals per 60 m^2 at reserve sites.

Table 12. Relative abundance of fish (excluding triplefins) assessed by divers during underwater counts (1992-2014) from rubble and macroalgae reserve and control sites.

Species name	Common name	Rubble	Macroalgae
Caesioperca lepidoptera	Butterfly perch	1A	2C
Upeneichthys lineatus	Goatfish	1A	1A
Scorpis lineolatus	Sweep	1A	1B
Aplodactylus arctidens	Marblefish	2A	2B
Nemadactylus macropterus	Tarakihi	2C	3C
Cheilodactylus spectabilis	Red moki	1A	3A
Cheilodactylus nigripes	Magpie moki		1A
Latridopsis ciliaris	Blue moki	1A	3B
Latridopsis aerosa	Copper moki		1A
Notolabrus celidotus	Spotty	3C	3C
Notolabrus fucicola	Banded wrasse	1A	2A
Pseudolabrus miles	Scarlet wrasse	3A	2A
Pseudolabrus cinctus	Girdled wrasse		1A
Parapercis colias	Blue cod	3C	3C
Parika scaber	Leatherjacket	2A	3B
Odax pullus	Butterfish		2A
Latris lineata	Trumpeter	1A	1A
Scorpis violaceus	Blue maomao		1A
Seriola lalandi	Kingfish	1B	1B
Hippocampus abdominalis	Seahorse	1A	1A
Total number of species		**15**	**20**

Note: Relative abundance score: blank = absent; 1 = rare (seen every 10+ dives), 2 = occasional (seen every 3-4 dives), 3 = common (seen most dives).

When observed usually seen as: A = 1-2 individuals, B = 3-10 individuals, C = 11+ individuals or as a school).

Table 13. Mann-Whitney U statistic test for all blue cod density data collected from rubble sites compared between pooled reserve and pooled controls (UVC). ***Note: for the magnitude of statistical differences see Figure 21.***

Year	df	T	P	Significance
Mar-92	18,24	408	0.589	Not Significant
Mar-93	40, 50	1614	0.09	Not Significant
Mar-94	34, 59	1394	0.1	Not Significant
Mar-95	36, 63	1459	0.012	Significant
Apr-96	32, 48	1093	0.044	Significant
Apr-97	47, 66	2086	<0.001	Significant
Mar-98	48, 60	1767	<0.001	Significant
Apr-99	48, 60	1862	<0.001	Significant
Apr-00	48, 60	1778	<0.001	Significant
Apr-01	48, 60	2953	<0.001	Significant
Apr-02	48, 60	2692	<0.001	Significant
Apr-03	48, 60	1687	<0.001	Significant
Mar-04	48, 60	1825	<0.001	Significant
Mar-05	48, 60	1624	<0.001	Significant
Apr-06	48, 60	1942	<0.001	Significant
Apr-07	48, 60	2022	<0.001	Significant
Mar-08	48, 60	1765	<0.001	Significant
Mar-09	48, 60	1962	<0.001	Significant
Mar-10	48, 60	1546	<0.001	Significant
Mar-11	48, 60	2556	0.712	Not Significant
Feb-12	48, 60	2104	0.001	Significant
Mar-13	48, 60	1720	<0.001	Significant
Mar-14	48, 60	2110	0.002	Significant

Spotty were recorded from all rubble sites in variable densities (Figure 22). Their densities at control and reserve sites showed similar trends; however, the scales of change were different between reserve and controls. Apart from March 1993 and March 2013, spotty were more abundant from the control treatment. At both reserve and control sites, spotty densities ranged from 7 to 36 individuals per 60 m^2.

Banded wrasse (*Notolabrus fucicola*) were usually more abundant in rubble at control sites than reserve sites (Figure 22), although relative to other species, they were uncommon. Overall, banded wrasse at reserve and control sites did not exhibit any consistent abundance trends that could be correlated to fishing regulations or reservation. The density of banded wrasse at reserve and control sites ranged from 0.02 to 0.44 individuals per 60 m^2.

Tarakihi (*Nemadactylus macropterus*) were relatively uncommon from rubble habitats both inside and outside the reserve (Figure 22). In March 1994, a large school of tarakihi was recorded at one reserve site; however, only occasional tarakihi individuals were observed in most years. A small reserve increase was also recorded in March 2013. This small increase was due to two small groups of tarakihi (4-6 individuals) recorded at one reserve site. 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 12).

5.2.3 Fish density from macroalgae (UVC)

Apart from blue cod, the density of most reef fish from macroalgae habitats differed little between reserve and control sites (Figure 23). In most years, blue cod were more abundant at the reserve sites compared to control sites ($P < 0.001$). Peak densities at reserve sites occurred in April 2007 and March 2014 (Figure 23). Blue cod at macroalgae control sites remained stable and relatively low from 2002 to 2014 (Figure 23). Blue cod densities in macroalgae habitats at reserve and control sites were less abundant than densities in rubble habitats (Figures 21 and 23). Blue moki and tarakihi were more abundant from the macroalgae habitats compared to rubble habitats (Figures 22 and 23). Butterfish were not recorded from rubble habitats at either reserve or control sites. Blue moki were often more abundant in the reserve compared to controls; however, this difference was seldom significant and no increasing trend over time was recorded for reserve sites. The density of tarakihi and butterfish in control and reserve sites showed no patterns that could be related to reservation.

5.2.4 Fish size from macroalgae (UVC)

The mean length of blue moki in reserve and control sites was initially similar (2002-2004), but increased at reserve sites from April 2005 onwards (Figure 24). With the exception of April 2006 ($T = 9365$, $P = 0.947$), from March 2005 the mean length of moki within the reserve was significantly greater than at control sites.

Mean size of tarakihi was initially variability between years at reserve sites due to low numbers of larger fish in the 20-30 cm size range (Figure 24). Apart form 2003, 2004 and 2006 when larger tarakihi were uncommon at reserve sites, the mean size was usually greater at reserve sites compared to control sites, although this difference was small.

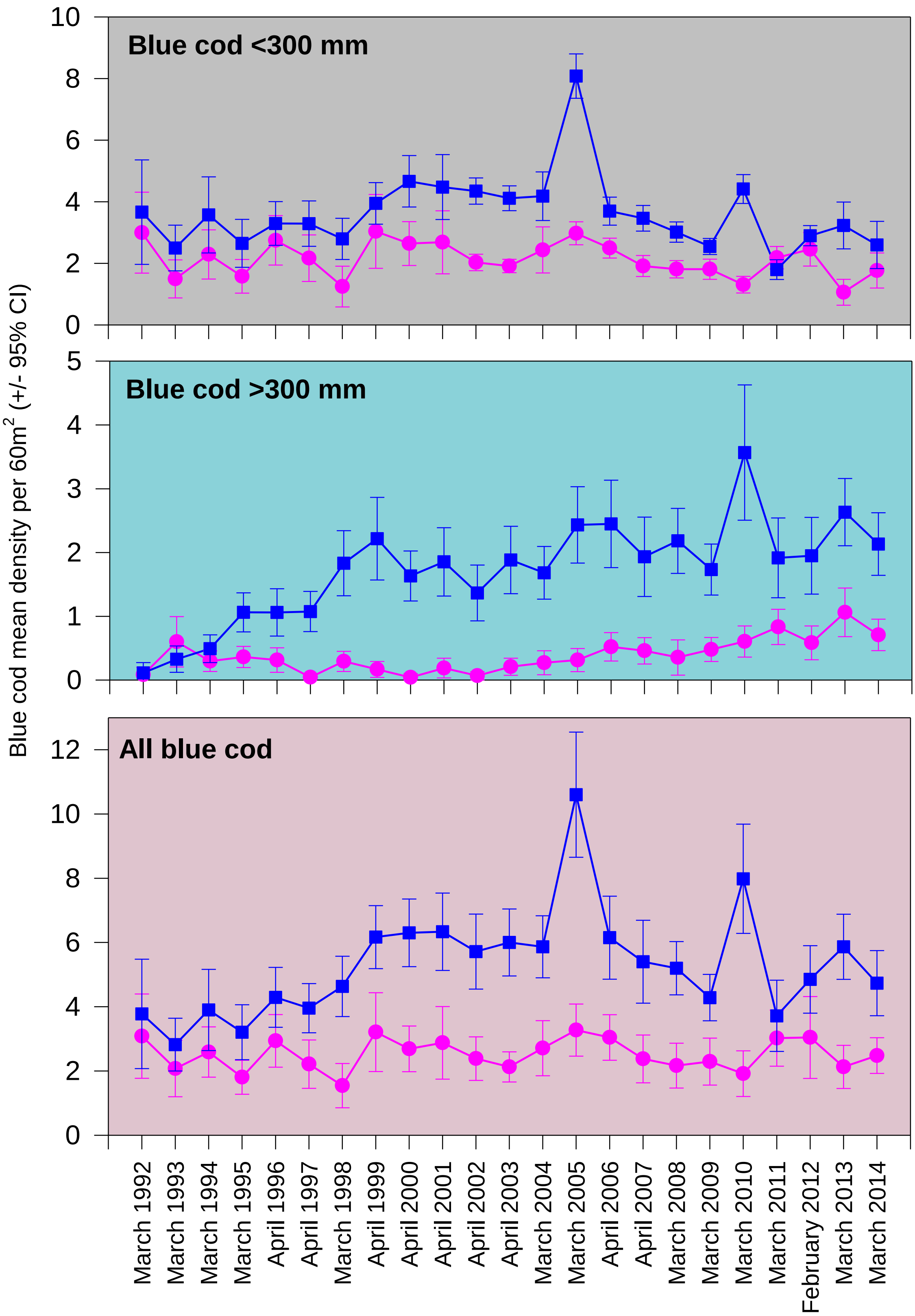

Figure 21. Mean blue cod density from pooled reserve rubble sites (n = 5; blue squares) and control sites (n = 4; pink circles) (UVC). Note: Y-axis scales differ between each size class.

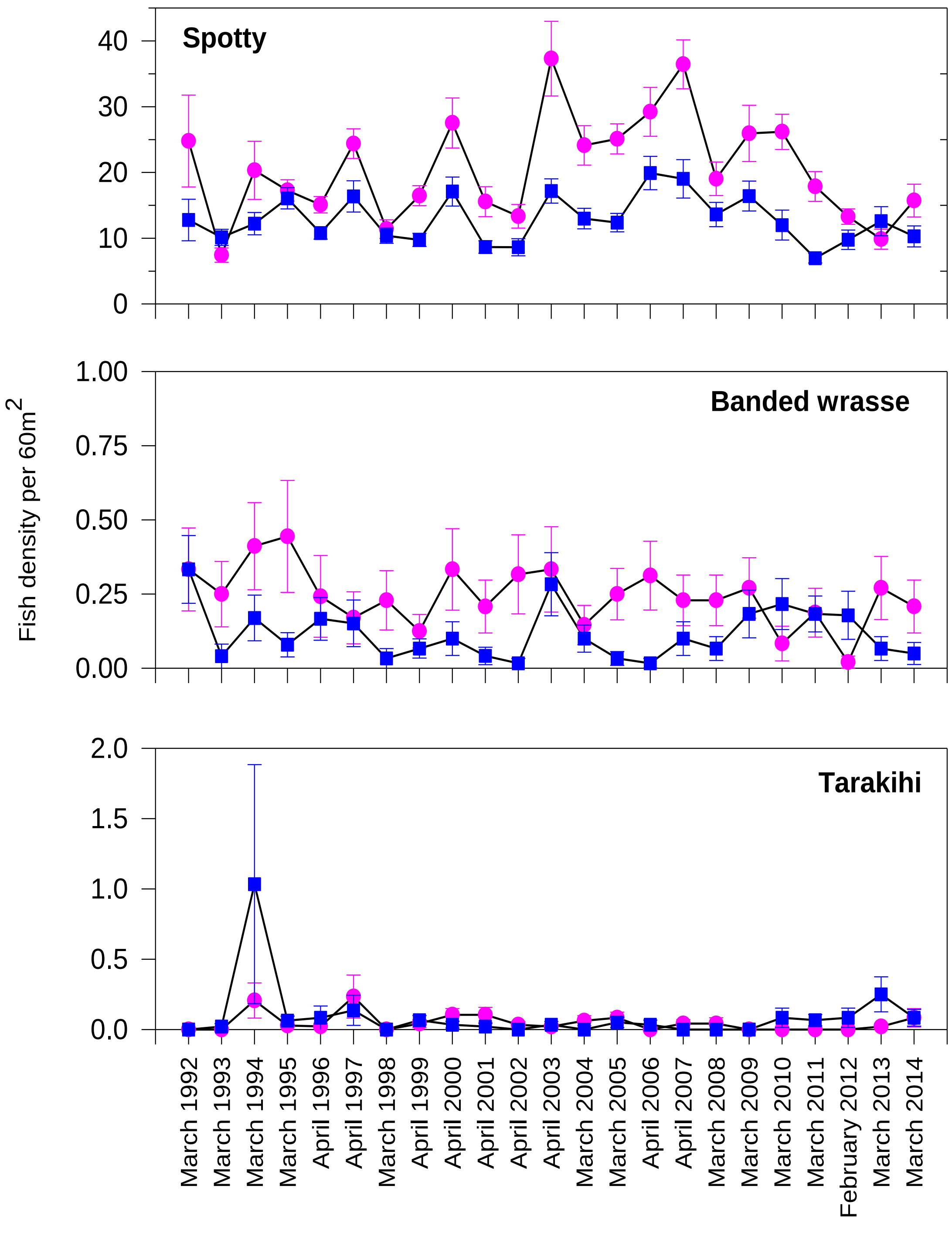

Figure 22. Mean density of selected fish species from underwater visual counts (UVC) pooled from rubble sites in the reserve (n = 5; blue squares) and control sites (n = 4; pink circles). Error bars = +/- 1 s.e. Note: scale of the Y-axis differs between panels.

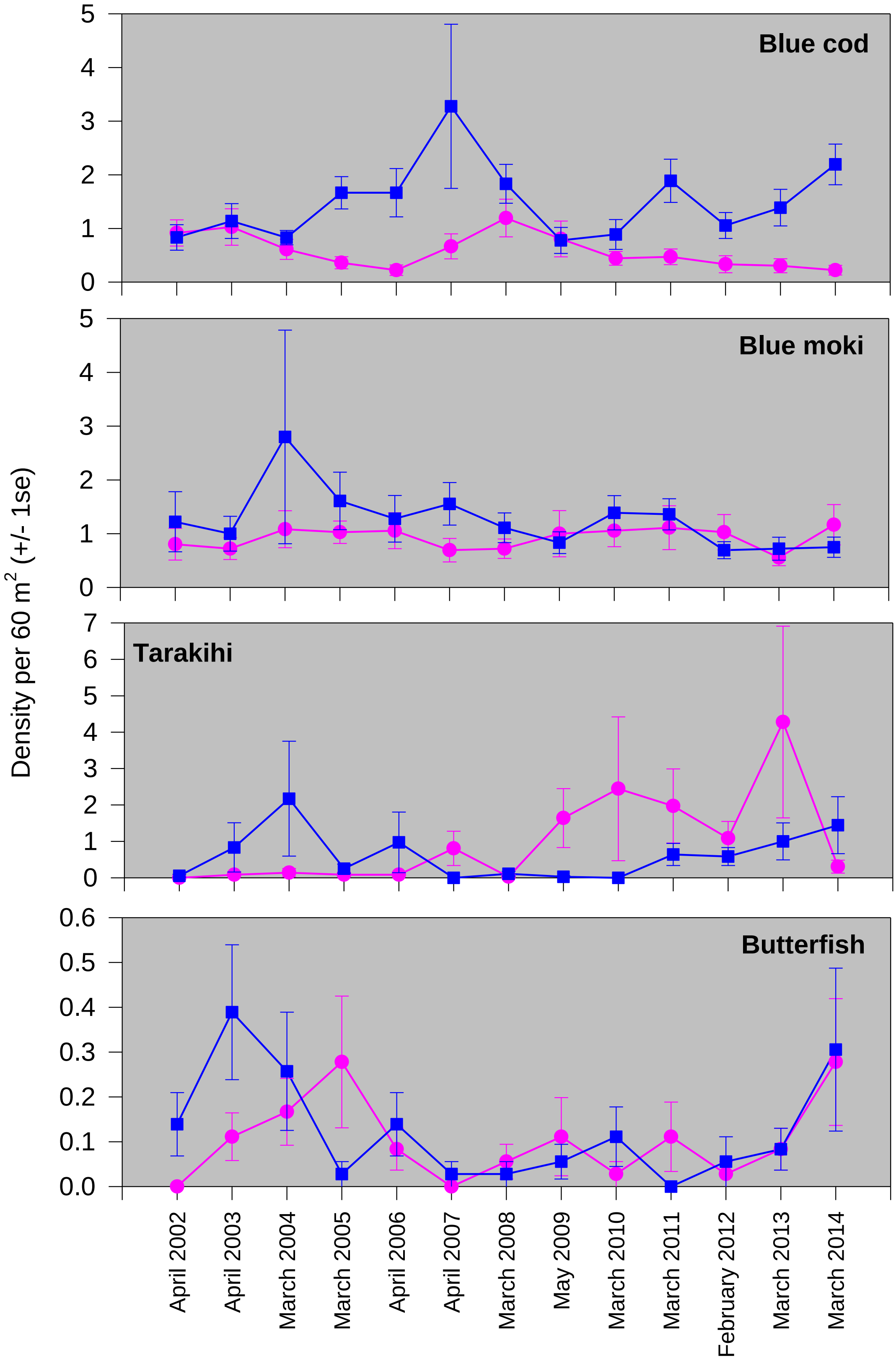

Figure 23. Mean density of selected fish species from macroalgae sites in the reserve (n = 3; blue squares) and at control sites (n = 3; pink circles) (UVC). Error bars = +/- 1 s.e. Note: scale of the Y-axis differs between panels.

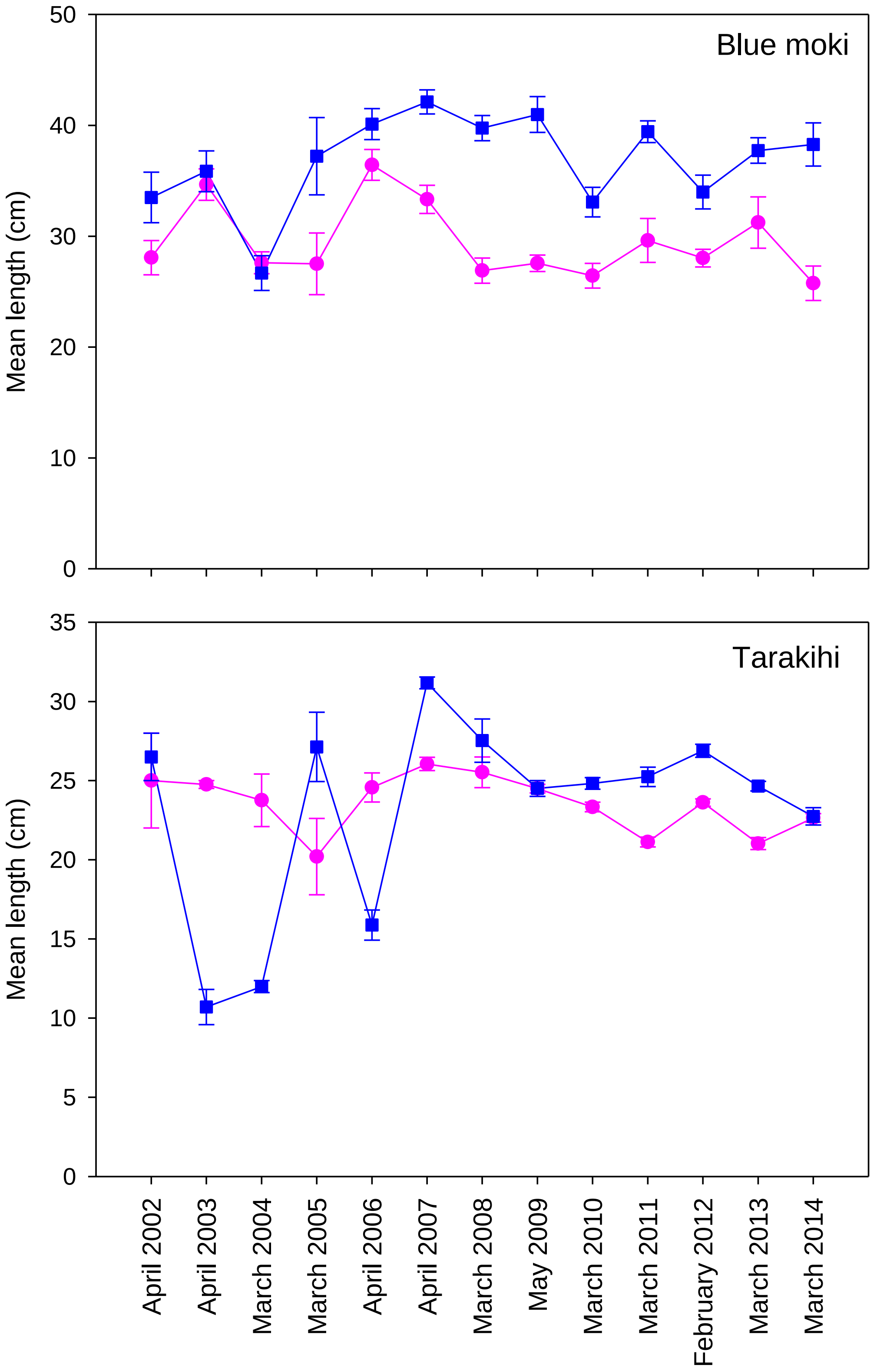

Figure 24. Mean length of blue moki and tarakihi estimated by divers from macroalgae and rubble reserve (blue squares) and control sites (pink circles). Error bars = +/- 1 s.e. Note: scale of the Y-axis differs between panels.

5.3 Lobster density, size, and sex

The density of lobsters within the reserve remained low for the first nine years after reservation (Figure 25, Table 14). From April 2002 onwards, their density dramatically increased within the reserve and remained at high levels for the remainder of the study. At controls, initially low lobster densities increased after 2002, peaking in April 2006 (Figure 25, Table 14). From March 2008 onwards lobster density at controls fell back to lower levels, but remained above levels recorded in the first 10 years of the study. In 2014, mean lobster density in the reserve was 11.5 times higher than at control sites.

Table 14. Mean lobster density (per 100 m^2) from pooled reserve and control sites. Note: not all sites were sampled each year; additional control sites were sampled from 2002 onwards. ***Note: for the magnitude of statistical differences see Figure 25.***

Year	Reserve (mean)	s.e.	Control (mean and 1SE)	s.e.
March 1992	1.39	0.20	0.75	0.12
March 1995	3.11	1.60	1.00	0.26
April 1997	1.00	0.09	0.33	0.07
April 1999	3.67	1.45	0.56	0.33
April 2001	2.78	0.66	0.54	0.22
April 2002	10.17	2.38	0.72	0.43
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	1.80
April 2007	13.00	2.39	2.29	0.73
March 2008	13.63	1.51	2.17	0.50
March 2009	10.75	1.24	3.25	0.65
April 2010	13.46	1.38	1.63	0.37
March 2011	12.00	1.68	1.46	0.33
February 2012	14.08	2.59	3.96	1.08
March 2013	13.17	2.89	1.08	0.39
March 2014	13.50	2.41	1.17	0.52

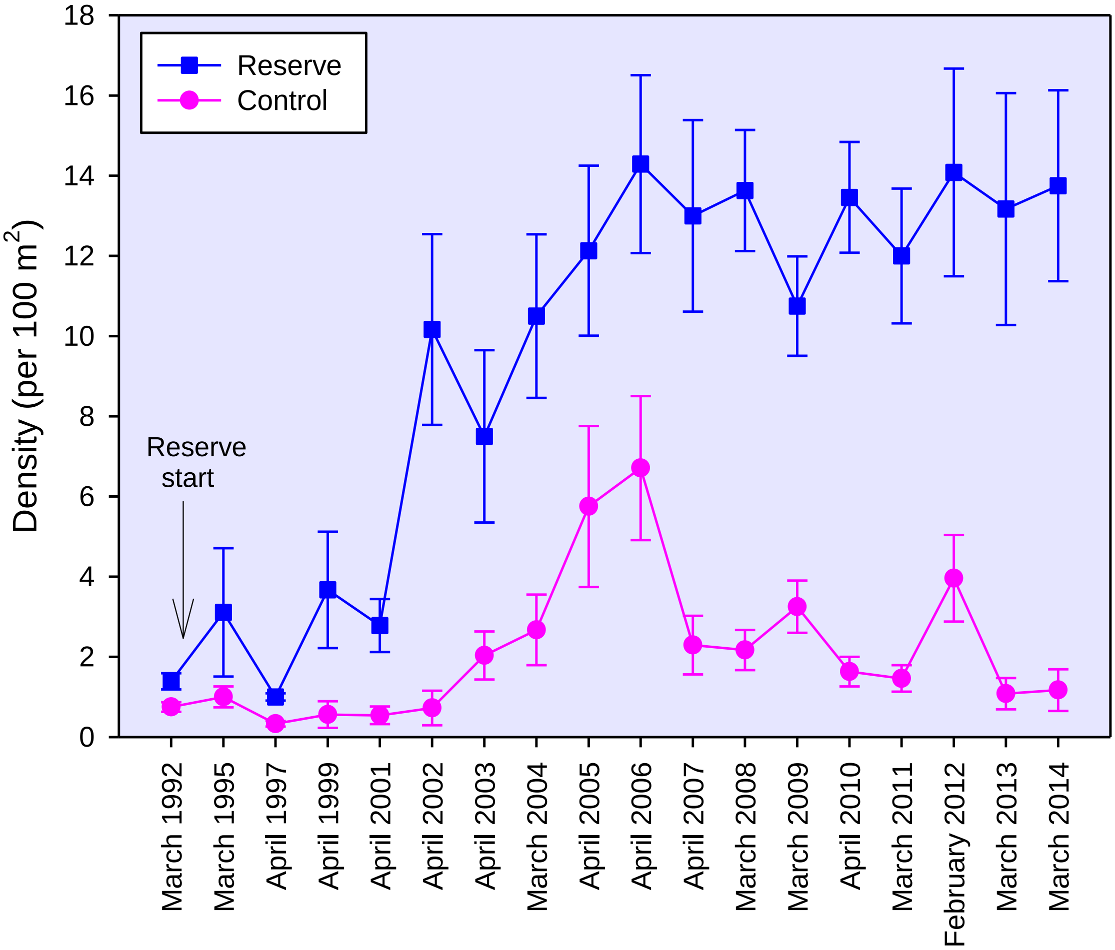

Figure 25. Mean lobster density from reserve (blue squares) and control sites (pink circles). Error bars = +/- 1 s.e. Note: prior to 2003, not all sites were sampled each year.

From 1999 to 2014, the mean carapace length (CL) of lobsters was higher at reserve sites than control sites (Figure 26). In 2014, mean CL at reserve sites was 1.3 times greater at reserve sites than control sites (mean CL at reserve sites = 123.2 mm and control sites 94.5 mm: Figure 26). The reserve lobster population in 2014 was dominated by numerous large males and females, whereas at control sites large individuals were absent (Figure 27). For example, in 2014 the largest male recorded from control sites was 150 mm CL compared to 200 mm CL for reserve sites. Similarly, the largest female at control sites was 125 mm CL compared to 150 mm CL at reserve sites.

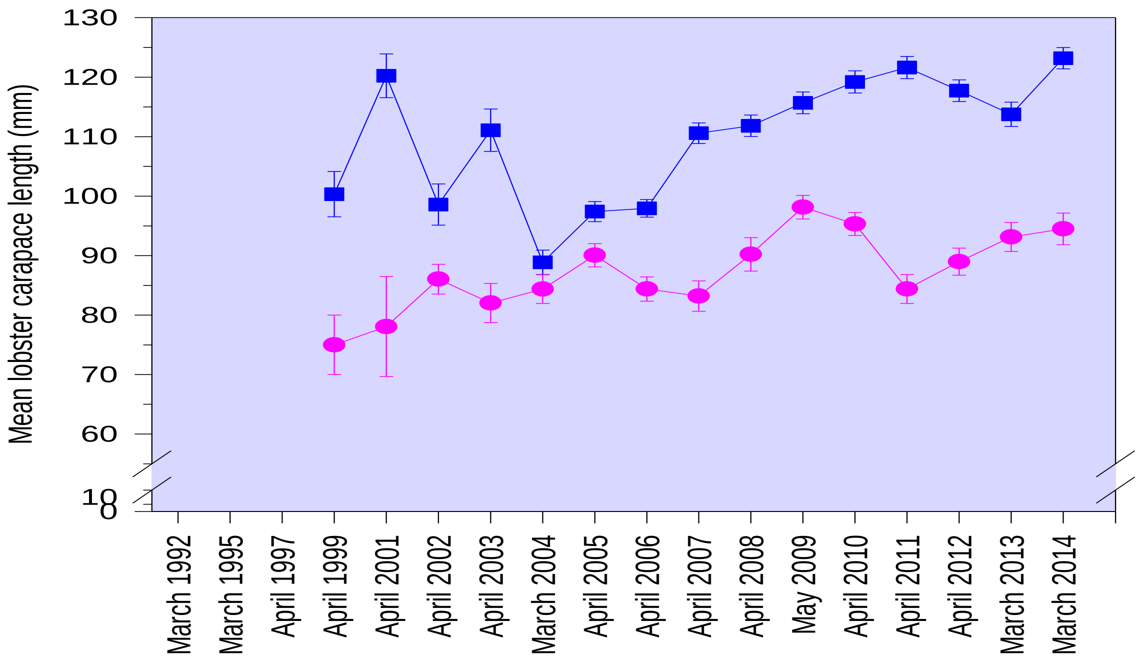

Figure 26. Mean carapace length of lobsters from pooled reserve (blue squares) and control sites (pink circles). Error bars = +/- 1 s.e. Note: no CL measurements were collected 1992-1997.

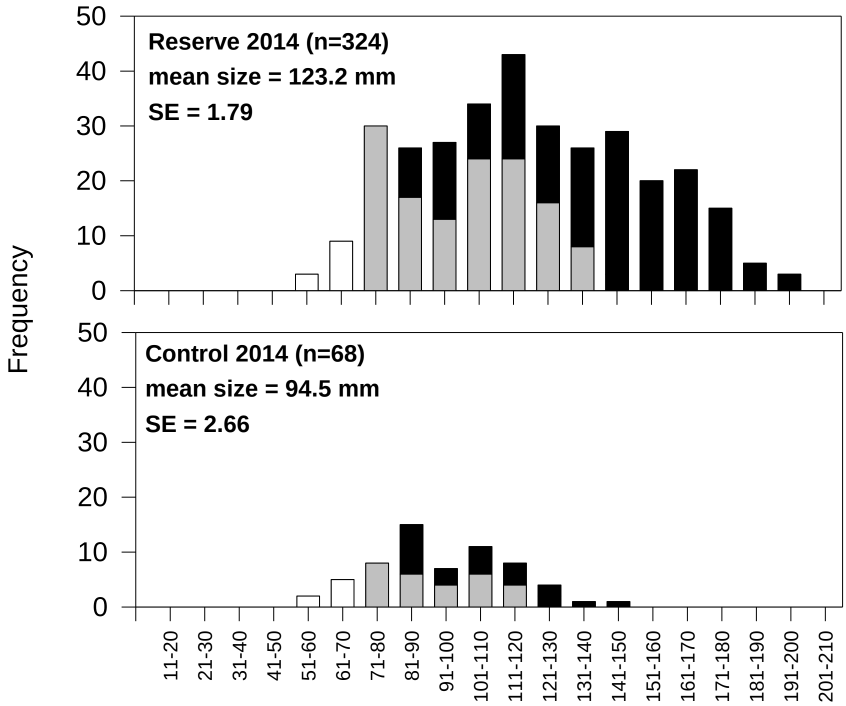

Figure 27. Size frequency of all lobsters sampled from pooled reserve and control sites in March 2014. Black = male, light grey = female, open = juvenile.

From 1995 to 1999, low numbers of lobsters were sampled and the population was often dominated by one demographic group (Table 15, Figure 28). After 2001, the sample size increased and the dominance by one group ceased. Since 2001, the percentage of males and females within the reserve has been comparable, ranging from 29 to 54% for males and 29 to 46% for females. At control sites, the ratio of females to males has typically been more variable (Figure 28). At both control and reserve sites, large males have typically made up the larger proportion of the population (Figure 28). The proportion of juveniles (≤ 80 mm CL) varied between years and between reserve and control sites. The population structure at control sites often consisted of a greater proportion of juveniles than at reserve sites (Figure 28).

Table 15. Percentage composition of male and female lobsters sampled from reserve and control sites. Note: values calculated from all lobsters measured inside and outside 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
2010	139	43	133	41.2	51	48.6	38	36.2
2011	143	49.3	120	41.4	28	30.8	30	33
2012	138	40.6	157	46.2	50	38.8	31	24
2013	113	37	100	32.8	15	27.8	20	37
2014	175	54.3	105	32.6	25	36.8	22	32.4

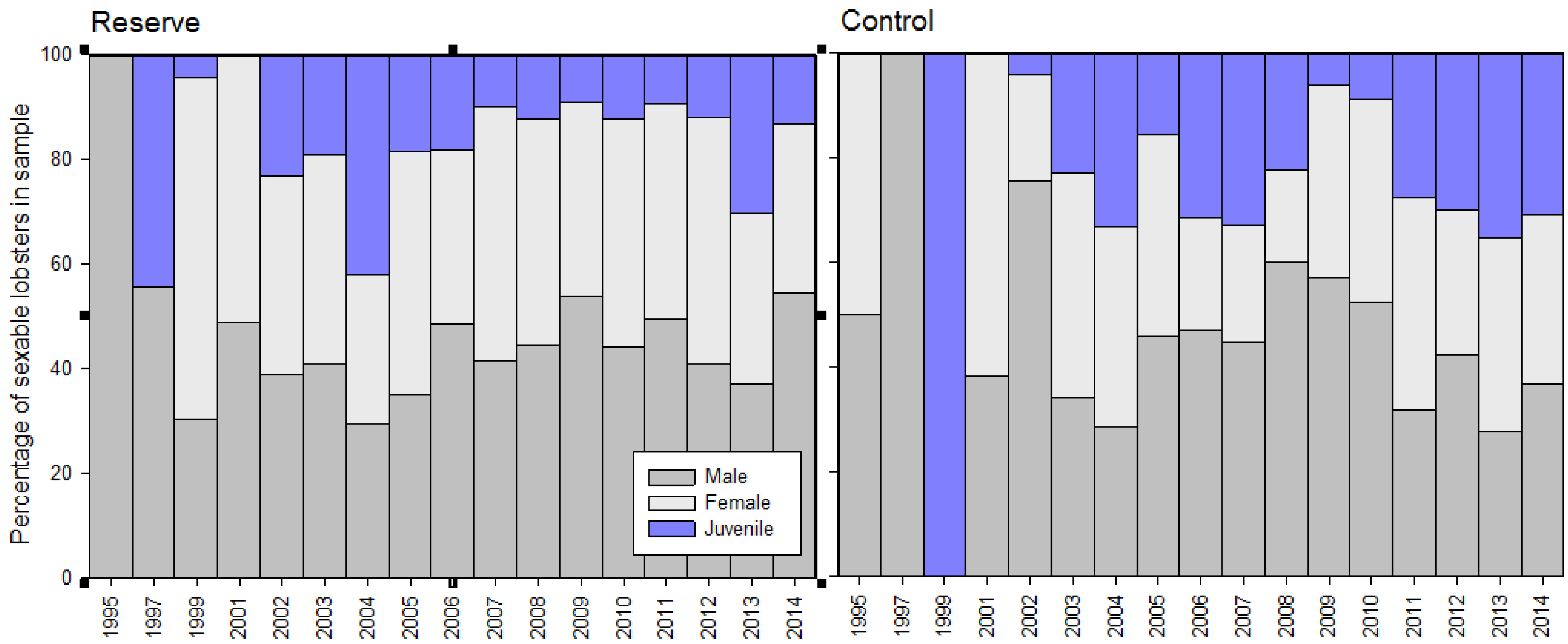

Figure 28. Percentage of the sample represented by male (>80 mm CL), female (>80 mm CL) and juvenile (≤80 mm CL) lobsters from reserve and control sites. Note: values calculated from all lobsters measured inside and outside quadrats.

5.4 Paua density and size

Black-foot paua (*Haliotis iris*) density was measured from a maximum of seven reserve sites and six control sites in 1992, 1999, 2007, 2009, 2010 and 2013; however, not all sites were sampled on each occasion. Mean paua density from the six sample occasions varied between sites, with highest densities occurring within reserve at site 6 (Long Island west) (Figure 29). Highest densities were recorded at reserve and control sites located in areas with a north to north-west aspect, while east or south facing sites supported lowest paua densities (Figure 6).

Mean density of black foot paua pooled for control sites and reserve sites on each sample occasion varied between years (Figure 30). Mean paua density from all reserve sites increased from 0.865 individuals per m^2 in 1992 to 1.58 individuals per m^2 in 2013. In contrast, control densities fluctuated, but ended close to where they started (1.08 individuals per m^2 in 1992 to 1.1 individuals per m^2 in 2013) (Figure 30). Densities of paua at each of the reserve sites increased over the study with the exception of site 6, where numbers dramatically declined in March 2010 (Figure 31). Densities of paua at one control site increased over the duration of the study (C4), however most sites declined or remained relatively stable (Figure 31).

Paua size was sampled on eight occasions (1992, 1999, 2004, 2007, 2009, 2010, 2012, and 2013); however, not all sites were measured in 2004 and 2012. The mean size of reserve paua declined over the duration of the study, from 117.8 mm TL in 1992 to111.7 mm TL in 2013 (Figure 34). The mean size of paua from the control treatment also declined between 1992 and 2013, however mean sizes remained relatively constant from 1999 to 2013 (Figure 34). Mean paua size at control sites was consistently below the reserve mean on all sample occasions ($T = 22435$, $P < 0.001$). In the reserve, a greater size range and a greater number of large individuals occurred compared to control sites (Figures 32 and 33). For example, in 2012 the largest reserve paua was 1.3 times longer than the largest paua from a control site (152 mm TL compared to 118 mm TL). In 2013, less than 1% of paua from control sites were larger than the minimum legal size limit (125 mm TL), compared to 24% at reserve sites.

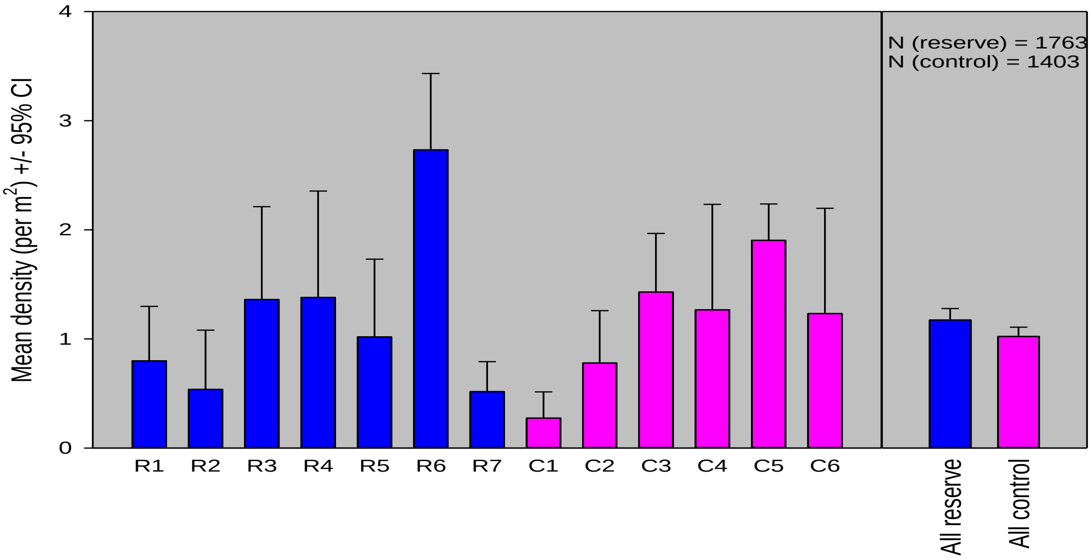

Figure 29. Mean black foot paua density sampled from reserve and control sites pooled from six sample occasions between 1992 and 2014.

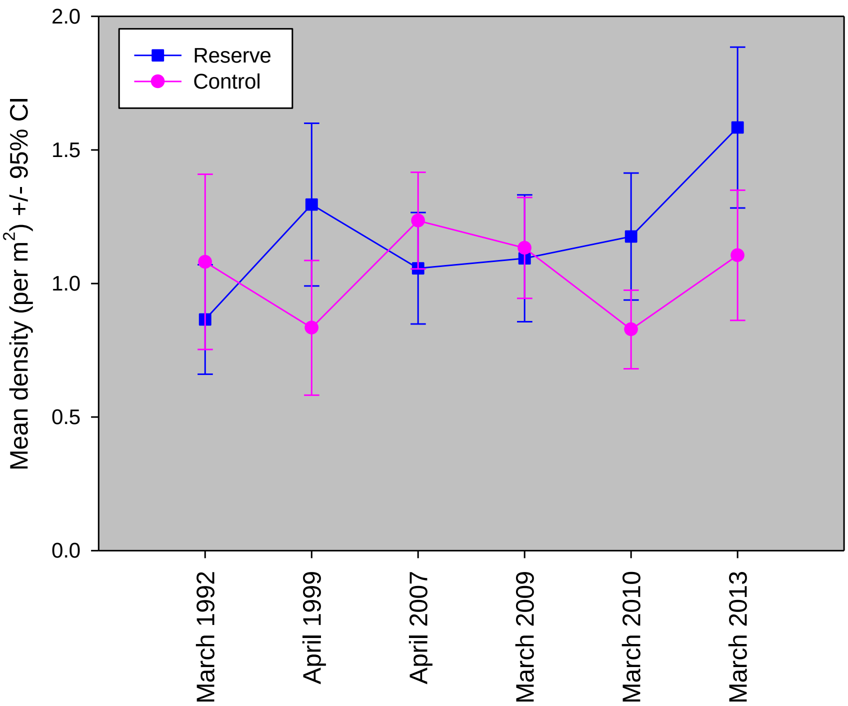

Figure 30. Mean paua density from pooled reserve (blue squares) and controls (pink circles).

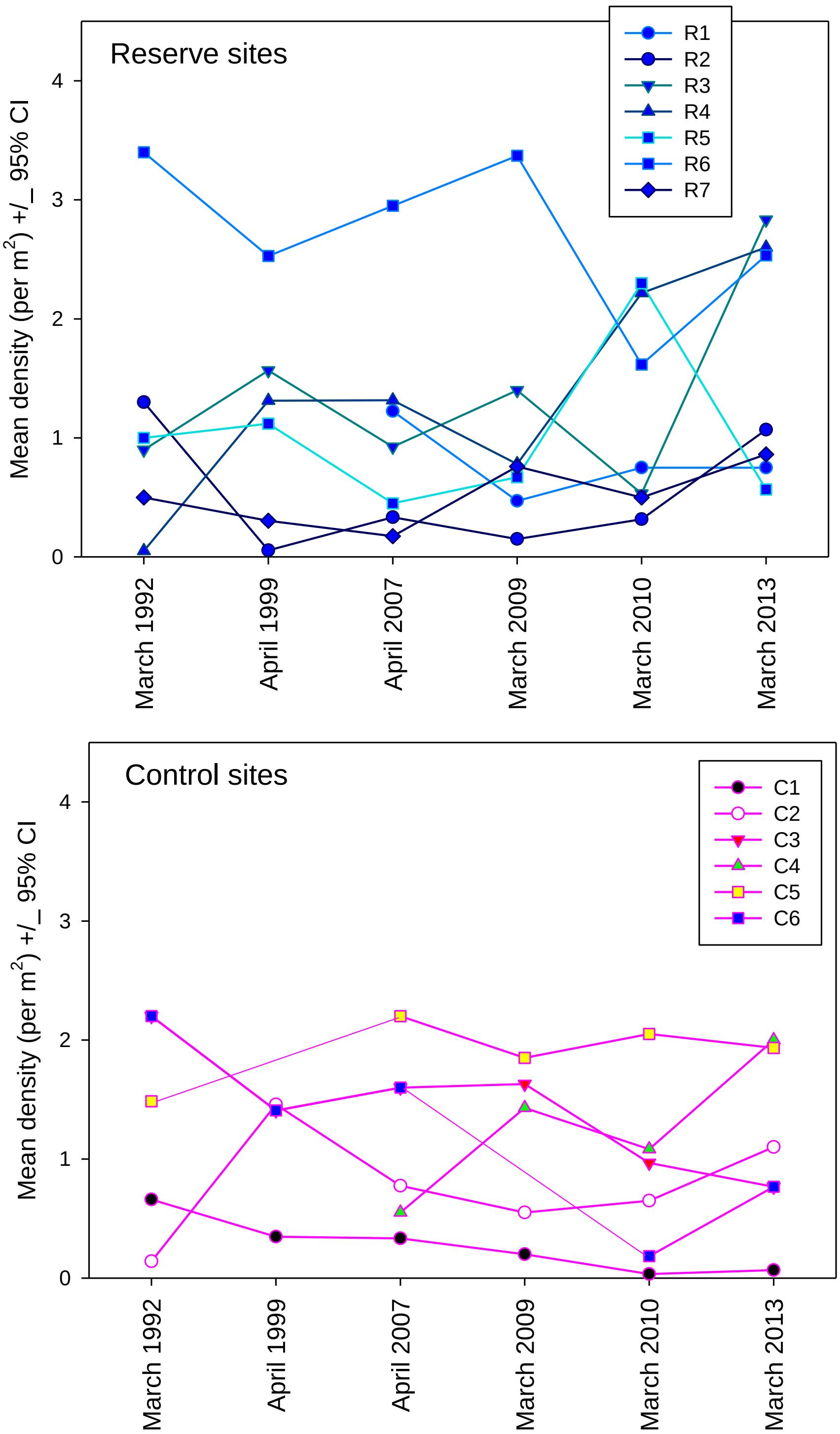

Figure 31. Mean density of black foot paua at individual reserve and control sites. ***Note: Error bars omitted for clarity.***

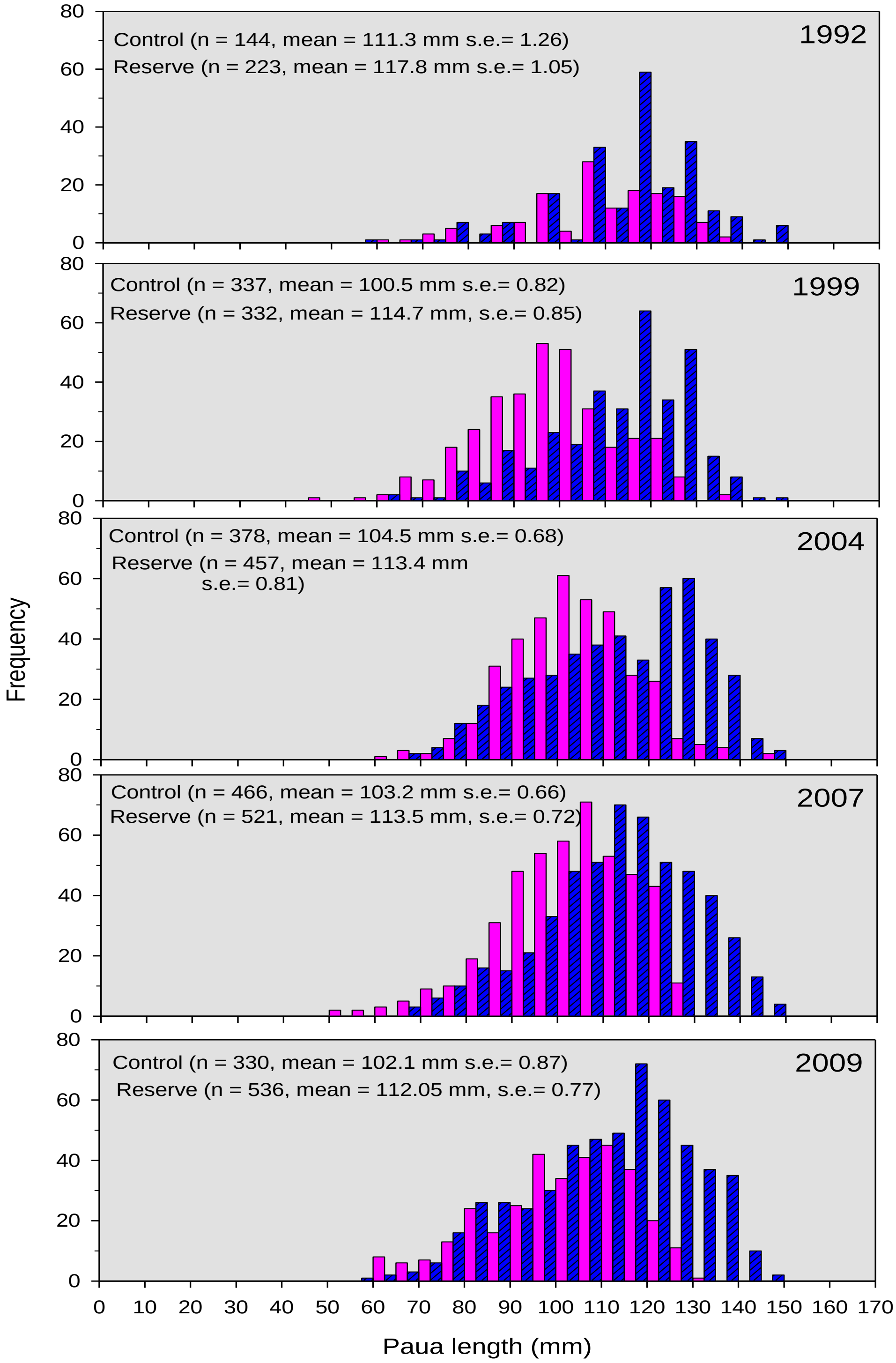

Figure 32. Length frequency for black-foot paua from pooled reserve (blue hatched) and control sites (pink) from 1992 to 2009.

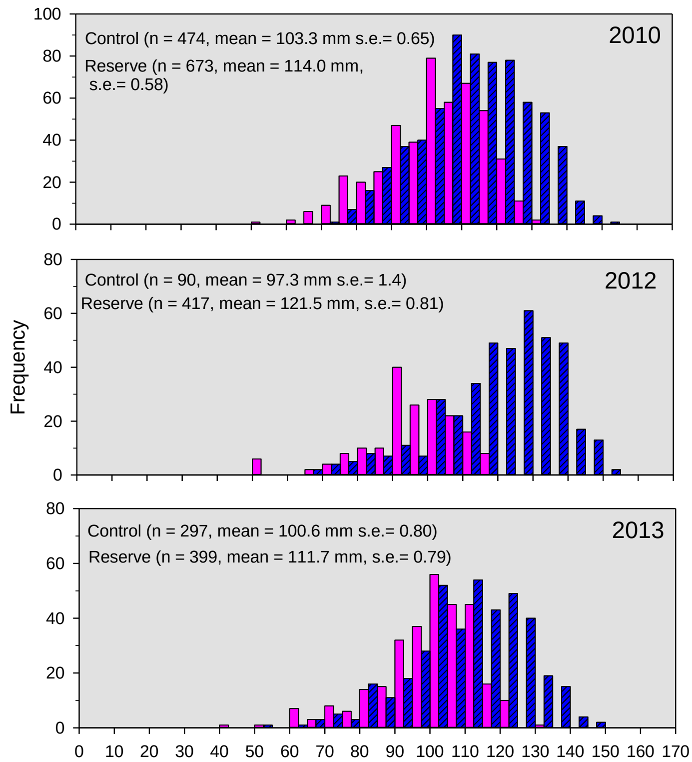

Figure 33. Length frequency for paua from reserve (blue hatched) and controls (pink). *Note: scale of the Y-axis differs between panels.*

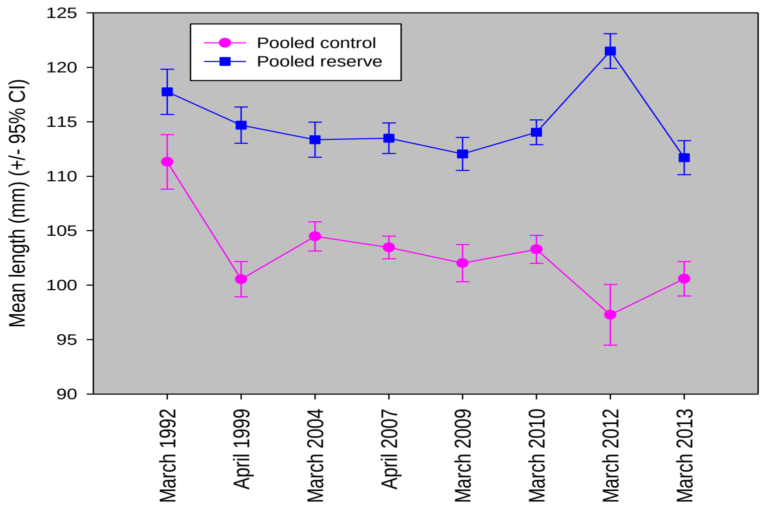

Figure 34. Mean length of paua from pooled reserve (blue squares) and control (pink circles).

5.5 Kina density and size

In most years, the mean density of kina from reserve and control areas was similar (Figure 35). This was despite significant inter-annual fluctuations in kina density (Figure 35). Up until March 2010, the density of kina at both control and reserve sites generally increased; however, in March 2014, the mean density of kina at reserve sites increased (3.67 per m^2), while the control densities decreased (1.47 per m^2).

The size of kina was sampled on five occasions (1992, 1999, 2008, 2010 and 2014). In order to ensure samples were comparable between sites, kina were not sampled from within macroalgae forests; however, macroalgae was located adjacent to one reserve and one control site (C3 Motuara north and R4 Charted Rock). The mean size of kina was always greater within the reserve compared to control sites (Figure 36). In the reserve, the mean size fluctuated between 60.5 mm and 73.4 mm, while at controls it ranged from 57.6 mm to 65.8 mm). From 2008 onwards, kina smaller than ~ 45 mm width were less often encountered within reserve sites compared to control sites. For example, in 2014 13.6% of kina were ≤ 45 mm at control sites, whereas 4.4% were ≤ 45 mm at reserve sites.

5.6 Cats-eye snail density

At individual control and reserve sites, cats-eye snails were either rare/absent or common. For example, in 2014 three reserve sites had no cats-eye snails while the other three sites supported moderate to high densities (1-2.1 individuals per m^2), indicating considerable spatial variability in the distribution of this species. The overall pooled cats-eye densities for reserve and control sites showed little difference and remained relatively low on the five sample occasions (Figure 37).

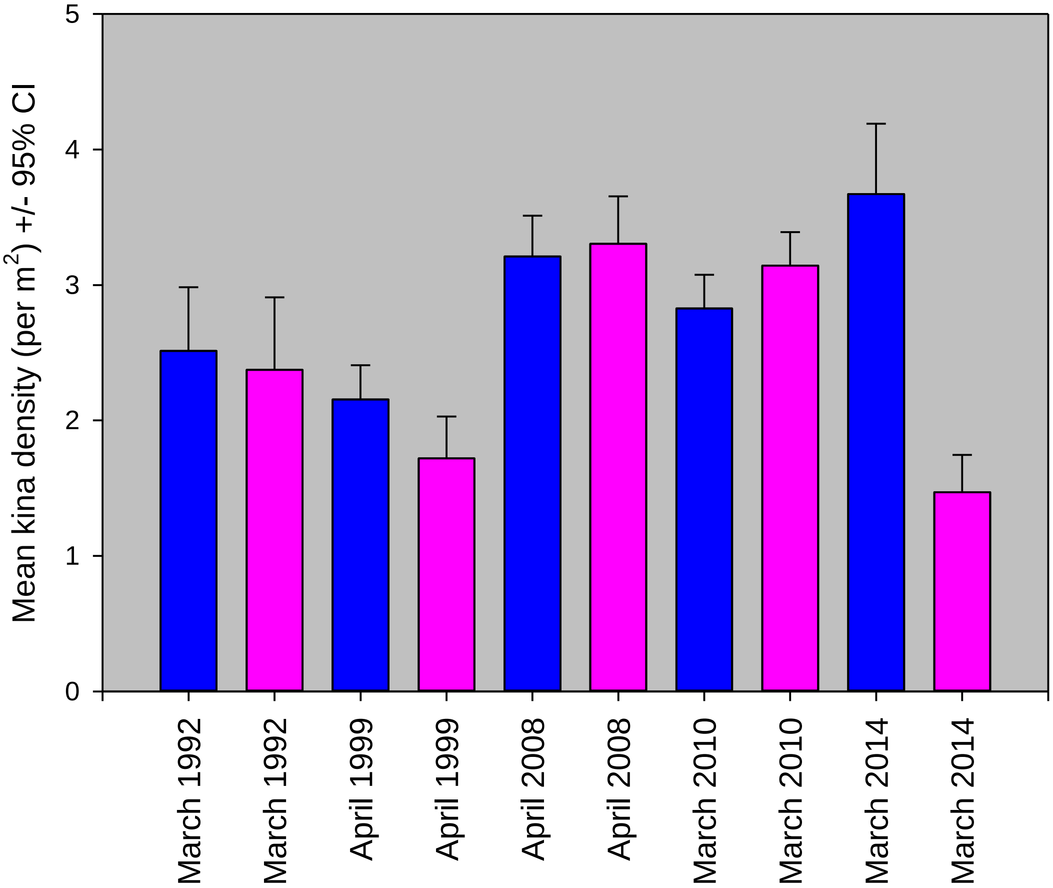

Figure 35. Mean density of kina from reserve (blue squares) and control sites (pink circles). Error bars = 95% confidence intervals.

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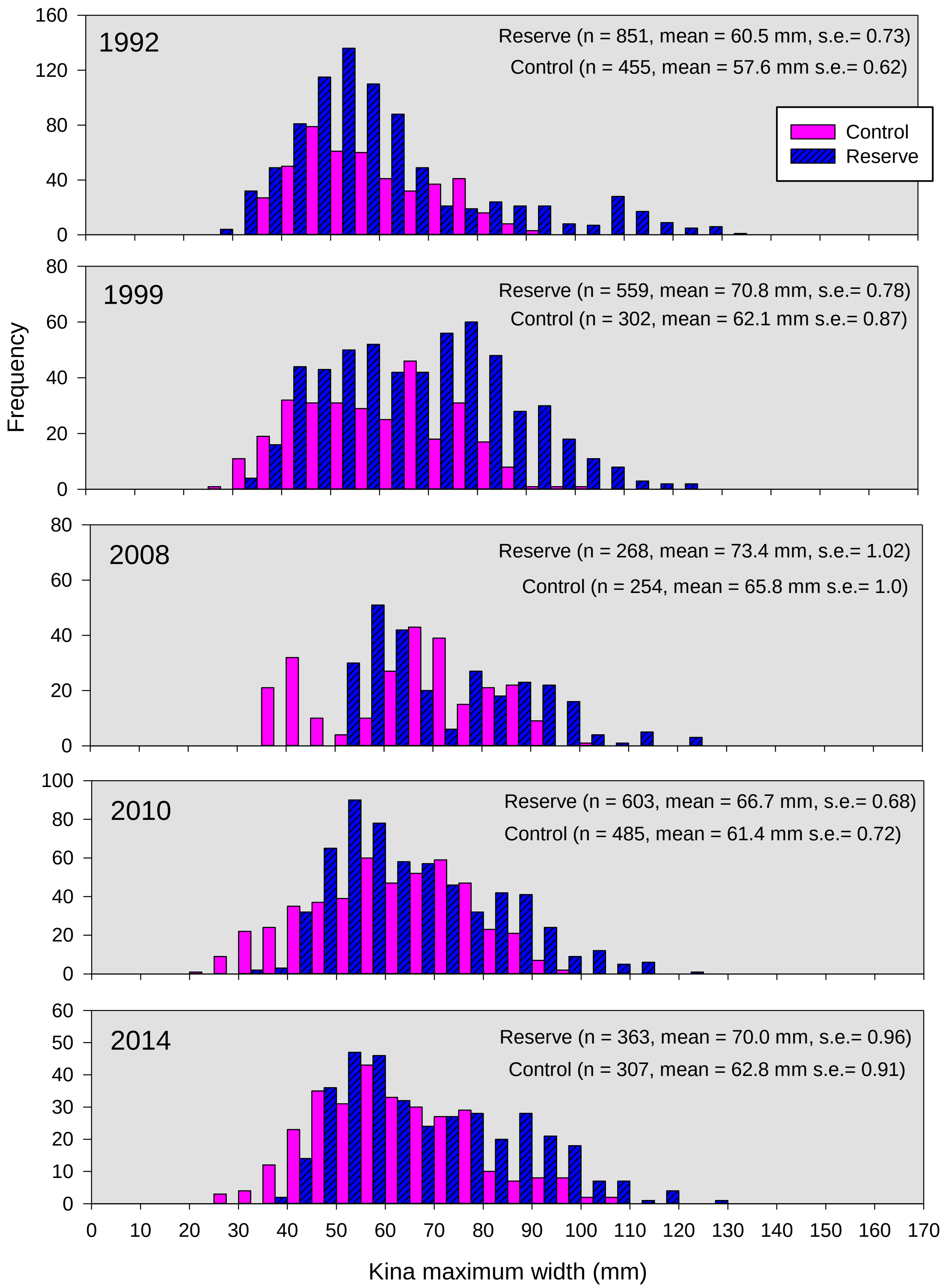

Figure 36. The size frequency of kina at reserve (blue hatched) and control sites (pink).

Note: the scale of the y-axis varies between panels.

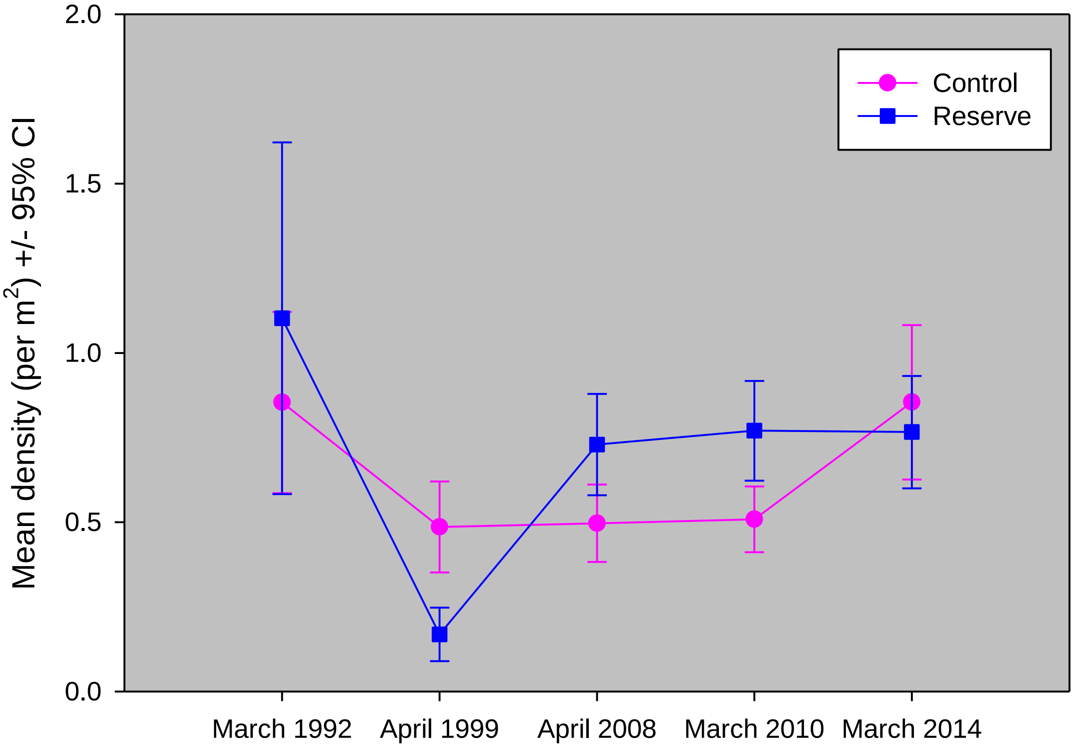

Figure 37. Mean density of cats eye snails from reserve (blue squares) and control sites (pink circles).

Willie Abel measuring paua.

6.0 DISCUSSION

This report presents biological monitoring data from 1992 to 2014 for Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound, Marlborough Sounds. A growing number of New Zealand studies have shown change 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; Freeman 2005; Shears *et al*., 2006; Davidson *et al*., 2007, Pande *et al*., 2008; Freeman and MacDiarmid 2009, Guisado *et al.,* 2012; Freeman *et al*., 2012; Davidson and Richards 2013; Davidson *et al*. 2013). Monitoring in marine reserves has usually focused on recreational or commercially targeted species that respond positively to fishing cessation. Relatively few studies have monitored species seldom targeted by fishers despite the reported large trophic changes that have occurred as a result of over fishing (Cole and Keuskamp, 1998; Tegner and Dayton, 2000; Jackson *et al*., 2001).

The present study has concentrated on species targeted by fishers; however, data was also gathered for non-target species to investigate if the increase in predator abundance and size had any effect on the abundance of their prey.

6.1 Blue cod

Blue cod responded to the cessation of fishing by increasing in size and abundance in the reserve. Since 1995, blue cod were significantly larger and more abundant in the reserve compared to control sites. For example, in 2014 large blue cod recorded by diver counts (> 300 mm length) were 3 times more abundant from reserve rubble habitats compared to controls. In all years blue cod were larger in the reserve compared to controls, however, size at control sizes varied considerably between years. Unexpectedly the mean size of reserve blue cod significantly declined in 2014. The reason was primarily due to an increase in the number of small blue cod in the catch. Small blue cod are often first to attack hooks and when abundant, they may be overrepresented in the catch relative to their abundance, bringing the average size down. Small blue cod < 280 mm TL dominated the catch at both reserve and control sites suggesting good recruitment into both areas. The big difference between the reserve and control sites was the proportion of large individuals (> 330 mm TL). This size class traditionally formed a bigger proportion of the population in the reserve. For example, from 1996 to 2008 large blue cod (> 330 mm TL) comprised <4.4% of individuals at controls compared to >21% in the reserve. It is only with more recent changes to blue cod regulations that the proportion of large blue cod at controls has increased above 4.4%.

In early years of the study (1994-1995 and again from 2009 to 2014) the proportion of large blue cod at control sites increased, probably due to changes in fisheries regulations. Blue cod appear to respond positively to fishing restrictions, increasing in size or abundance (Pande *et al*., 2008). The high abundance and size of blue cod in the reserve has often been accentuated by intermittent and often large declines in the mean cod size at fished sites.

The mean size of blue cod within the reserve initially increased and remained higher than in fished areas. In contrast, the size of blue cod at control sites varied, with periods of gradual and consistent increase interspersed by sharp declines. Most change to the mean size of blue cod at control sites coincided with recreational fishing regulations (Table 16).

A number of major changes to blue cod fishing regulations in Queen Charlotte Sound have been implemented over the duration of the 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, a corresponding increase in the mean size of blue cod occurred at control sites (from 257.2 mm to 270.7 mm). In October 1994, the minimum legal size was reduced to 280 mm from 330 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 control sites declined dramatically (from a mean of 275 mm in August 1994 to 238.2 mm in September 1995). 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 eight consecutive years mean blue cod size from pooled control sites steadily increased from a mean of 233.4 mm in March 2004 to 280.9 mm by April 2012. This increase started from 2004, and was probably accentuated by the closure of the fishery on the 1st of October 2008.

Over the period of the fishery closure, the abundance of large blue cod (>330 mm TL) and their proportional contribution to the population increased. Following the reopening of the fishery in December 2011, the mean length of blue cod continued to increase until April 2012, when it was nearly comparable with the size of blue cod within the reserve. However, following this the mean size of blue cod at control sites once again began to decline, perhaps due to a lag between the reopening of the fishery and observable reductions in the size of blue cod.

The absence of large changes to the density data over this time is likely related to the fact that outside the reserve, large blue cod only make up very small proportion of the population. Removing a small part of the population has relatively little effect on density, but probably has a large effect on reproductive output because large blue cod play a disproportionately larger contribution.

Table 16. 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
20 December 2011	Closure ended, partial season 20 Dec to 31 August. Bag limit 2. Slot fishery introduced (30-35 mm no-take)

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

6.2 Other fish

Apart from blue cod, blue moki was the only other species to respond positively to reservation. Blue moki were significantly larger, but not more abundant at reserve sites compared to control sites. The lack of a reservation effect for other reef fish is probably due the species being:

(a) a non-target recreational fisheries species (e.g. spotty, banded wrasse);

(b) a highly mobile or migratory species (e.g. tarakihi, blue moki); and/or

(c) secretive and is seldom seen by or avoids divers (e.g. butterfish, snapper).

6.3 Spiny lobsters

Increases in both the density and size of lobsters were greater inside the reserve compared to control sites, and happened 7-8 years after reservation. Relative to control sites, lobster density at the end of the study was 11.5 times greater inside the reserve compared to control sites. Haggitt *et al*. (2011) reported that after 18 years of reservation, the density of lobsters in Te Whanganui-a-Hei MR, in northern New Zealand was 9 times higher than controls. An increase in lobster density has also been reported for other northern South Island MR's. Davidson and Richards (2013) reported lobster density at shallow sites inside the Tonga Island marine reserve in 2013 was 8 times greater than at control sites after 20 years of reservation. For the youngest reserve in the northern South Island (Horoirangi MR), lobster density was 3.5 times greater inside than outside the reserve after seven years of reservation, however, a number of reserve sites had changed little (Davidson *et al*., 2013).

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, Davidson 2004, Pande *et al*., 2008; Freeman *et al*., 2012; Guisado *et al*., 2012). These studies suggest that some lobsters remain within un-fished areas, but there is also evidence that migrations may cross reserve borders (e.g. Kelly *et al*., 2000; Kelly, 2001, Freeman *et al*., 2012.). There is also evidence that egg production may be limited in intensively-fished populations due to a lack of large males (MacDiarmid and Butler, 1999). Fishing may also influence the growth and health of lobsters (Freeman *et al*., 2009; Freeman *et al*., 2012a).

During the present study, lobster abundance increased from 1.39 individuals per 100 m^2 in 1992 to 13.5 individuals per 100 m^2 in 2014. This increase in the Long-Island-Kokomohua MR was initially slow (Davidson *et al.,* 2009). From April 2002 onwards, reserve lobster density increased to a high in April 2006 (mean = 14.3 individuals per 100 m^2). 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). Since that peak, lobster numbers at controls have declined, presumably due to fishing and intermittent or lower levels of recruitment. A slow initial response to reservation by lobsters has also been recorded at Tonga Island MR (Davidson and Richards, 2013) and Horoirangi MR (Davidson *et al*., 2013) as well as other reserves in New Zealand (see Freeman *et al*., 2012 for review). Freeman *et al*., (2012) suggested that the rate of lobster recovery and its scale was likely influenced by proximity to juvenile settlement areas. In the present study, a pulse of small non-reproductive lobsters was recorded in 2004 and also 2013. These recruits grew through to the larger reproductive sizes in the reserve, but did not appear at controls, presumably due to fishing extraction.

Females often comprised a larger proportion of the population at reserve sites compared to control sites. In 2008, for example, approximately 43% of the lobster population in the reserve was represented by females compared to only 18% for control sites. The increase in lobster abundance in the reserve combined with the greater proportions of large female and male lobsters theoretically results in greater reproductive output compared to areas outside the reserve. Davidson *et al.* (2002) estimated that approximately nine times as many eggs would be produced from the Tonga Island Marine Reserve compared to an equivalent length of fished coast in Tasman Bay. These calculations were based on mean female lobster size, density, and known egg production. Increased egg production within the reserve relative to the adjacent coast is enhanced by an increase in the number of large reproductive males within the reserve, ensuring a high fertilisation rate compared to control areas where large males are considerably less abundant (MacDiarmid and Butler, 1999).

Tonga Island and Long Island-Kokomohua Marine Reserves were both established in 1993, and supported similar, low densities of rock lobster. Searches at northern Long Island sites prior to reservation revealed few or no lobsters (author pers obs.). 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 MR has been the observed increase in the distribution of lobsters. For example, in 2008 and 2013 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 suggests that lobsters have recently expanded their occupation from prime northern reserve habitats into areas previously unoccupied.

6.4 Black-foot paua

Black-foot paua abundance varied between sites both inside and outside the reserve. Reserve and control sites exposed to northerly weather supported dense beds of macroalgae and supported more paua covering a greater size range. Paua abundance increased slowly in the reserve while remaining relatively stable at control sites. The reason for the slow increase in reserve paua density is difficult to determine, but could be due to:

(a) sampling effects (i.e. paua are patchily distributed resulting in high 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 or low natural recruitment.

It is probable that poaching has accounted for much of this slow response as divers have reported areas in the reserve stripped of paua and the tell-tale marks of paua removal.

On every sample occasion, mean paua size was greater in the reserve with greater numbers of legal-sized individuals (≥ 125 mm length) compared to controls. Despite higher mean sizes in the reserve compared to controls, mean values within the reserve have gradually declined over the duration of the study. This decline occurred at both reserve and 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 mean size.

Histogram data shows no major recruitment events, and even if they had occurred, small paua would have grown through into the larger size classes. It is therefore likely that the recovery of paua size and abundance has been limited due to ongoing poaching.

6.5 Kina

Kina density at both reserve and control sites has remained comparable in most years; however, in 2014 kina abundance in the reserve increased, while their abundance at controls dramatically declined. The reason for their increase in the reserve and decline at controls remains unknown and appears contrary to the concept that more large predators in the reserve act to lower kina numbers through predation. Declines in kina density have been reported at other marine reserves in New Zealand (e.g. Shears and Babcock, 2003). For example, Haggitt *et al*. (2012) reported a decline in the abundance of kina at Te Whanganui-a-Hei MR, which coincided with an increase in the percentage cover of macroalgae. At present, kina abundance from many Long Island-Kokomohua MR sites is well above that for control sites. For example, at the Charted Rock, kina densities were high and most kina were large. This site also supported the highest density of kina (5.9 individuals per m^2).

Kina were 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. In general largest kina at reserve and control sites were recorded 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 where kina appear small and stunted.

At reserve sites from 2008 onwards, small kina < 45 mm diameter became relatively uncommon. This size class was present at reserve sites in 1992 and 1999 and at control sites in all years including 2008, 2010 and 2014. The low abundance of small kina within the reserve may be related to large blue cod eating small kina. This represents the first indirect change related to reservation recorded for this marine reserve. Future monitoring of kina will help better interpret these potential reserve effects.

6.6 Cats-eye snail

Cats-eye abundance remained low at both reserve and control sites, with some sites supporting few or no snails. Overall, mean densities did not differ between reserve and control sites, suggesting reservation has had no impact on their abundance.

6.7 Behavioural changes

Few studies have investigated behavioural change after 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 observed unusual fish behaviour in the reserve, 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 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). Further, lobsters could often be handled with relatively little response within the reserve, an activity not possible at controls 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 also has an observable and relatively quick impact 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 inflate fish counts.

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 1992 to 2014 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:

1. a change to the size structure and abundance of large blue cod;
2. an increase in blue cod catch per unit effort in the reserve;
3. an increase in lobster abundance and size;

4. a wider distribution in the geographical range of lobsters to areas previously not occupied in the reserve;
5. an absence of small kina (< 50 mm diameter) from the reserve, probably due to predation;
6. larger paua in the reserve compared to controls;
7. larger blue moki present within the reserve compared to controls; and
8. behavioural changes for blue cod, lobster and large blue moki in the reserve.

The long term study also provides a powerful temporal data set for not only the reserve but sites outside the reserve. The reserve itself establishes an important set of data little influenced by human induced events outside the reserve. For example, in recent times Long Island-Kokomohua MR has acted as a control site for changes to blue cod fisheries regulations.

Based on data collected over this period the following monitoring is recommended (Table 17).

Fish

Blue cod be captured, measured and released on an annual basis in summer to early autumn (i.e. February to April) at six control sites and four reserve sites. A minimum of 80 cod should be captured and measured, or a maximum of 120 minutes of sampling (i.e. whichever occurs first).

Fish densities using traditional visual underwater count methodology (UVC) be collected annually from rubble sites (5 reserve, 4 control) and macroalgae sites (3 reserve, 3 control).

Spiny lobsters

Lobsters be counted, sexed and sized annually at four reserve and four control sites. Lobster sampling between summer to early autumn (i.e. February 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 40 quadrats be counted and 60 paua measured from each site.

Kina size-frequency data suggests there may be a reserve impact due to increased predation. This preliminary result warrants regular sampling. It is therefore recommended that kina density be sampled every fourth year from six reserve and five control sites. A minimum of 40 quadrats should be counted and 60 kina measured from each site.

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 the same reserve and 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). A sample in 2020 is suggested for this work.

Table 17. Summary of suggested monitoring events from 2015 to 2026.

Sample	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Catch, measure & release												
Underwater visual (rubble)												
Underwater visual (algae)												
Reef fish sizes												
Baited underwater video (BUV)												
Lobster density												
Lobster size and sex												
Paua density												
Paua size												
Kina density												
Kina size												
Cats eye density												
Shore profiles & video												
Report produced												

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