Lingcod (*Ophiodon elongatus*) Egg Mass and Reef Fish Density SCUBA Survey in the Strait of Georgia, February 15-22, 2012

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LINGCOD (*Ophiodon elongatus*) EGG MASS AND REEF FISH DENSITY SCUBA SURVEY IN THE STRAIT OF GEORGIA, FEBRUARY 15-22, 2012

by

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ABSTRACT

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Dives were conducted in the Strait of Georgia at Snake Island reef between February 15th and February 22nd, 2012 in order to provide updated lingcod (*Ophiodon elongatus*) egg mass density estimates. Previous lingcod egg mass SCUBA surveys involving egg mass counts were conducted at this index site in 1990, 1991, 1994, 2001, 2002, 2004, 2005, 2007, 2010, and 2011. As with prior surveys, the 2012 survey also included measurements of egg mass volume and guardian male length, and counts of predominant reef fish (>20 cm), namely copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*), and kelp greenling (*Hexagrammos decagrammus*). Habitat characteristics such as complexity, relief, substrate type, and percent algae cover were also recorded. In total, twenty-five dives were conducted, covering a surveyed area of 7853.983 m^2. Thirty-two lingcod egg masses were located within the circular quadrats, with a mean egg mass density of 0.004074 egg masses/ m^2 and a median egg mass density of 0.003183 egg masses/ m^2. Twenty-two guardian males were successfully measured, with a mean length of 65.16 cm. Including non-guardian male lingcod, the mean density of lingcod observed was 0.009040 fish/ m^2, and the median was 0.009549 fish/ m^2. The predominant reef fish observed were copper rockfish and kelp greenling. Overall, lingcod and guarding male characteristics, as well as reef fish densities, appear to be relatively stable at Snake Island reef, with no significant differences observed between the 2012 data and data from recent years.

RESUME

McPhie, R.P., and King, J.R. 2012. Lingcod (*Ophiodon elongatus*) egg mass and reef fish density SCUBA survey in the Strait of Georgia, February 15-22, 2012. Can. Tech. Rep. Fish. Aquat. Sci.2987: viii + 22 p.

Nous avons réalisé entre le 15 et le 22 février 2012 des relevés en plongée autonome au récif de l'île Snake, dans le détroit de Georgie, en vue de mettre à jour l'estimation de la densité des masses d'œufs de morue-lingue (*Ophiodon elongatus*). Les relevés en plongée autonome des masses d'œufs de morue-lingue précédents comprenant les dénombrements des masses d'œufs ont été réalisés dans ce site témoin au cours des années 1990, 1991, 1994, 2001, 2002, 2004, 2005, 2007, 2010 et 2011. Comme pour les relevés antérieurs, le relevé de 2012 comprenait des mesures du volume de masses d'œufs et de la longueur du gardien mâle ainsi que des décomptes des espèces de poissons de récifs prédominantes (>20 cm), à savoir le sébaste cuivré (*Sebastes caurinus*), le sébaste à dos épineux (*S. maliger*) et le sourcil de varech (*Hexagrammos decagrammus*). Des caractéristiques des habitats telles que la complexité, le relief, le type de substrat et le pourcentage d'algues ont également été recensées. Au total, vingt-cinq relevés ont été réalisés sur une superficie de 7853,983 m^2. Trente-deux masses d'œufs de morue-lingue ont été repérées à l'intérieur des quadrats circulaires, pour une densité moyenne de 0,004074 masse d'œufs/m^2 et une densité médiane de 0,003183 masse d'œufs/m^2. On a réussi à mesurer vingt-deux mâles gardiens, pour une longueur moyenne de 65,16 cm. En incluant la morue-lingue mâle non gardienne, la densité moyenne observée était de 0,009040 poissons/m^2, et la médiane, de 0,009549 poissons/m^2. Les espèces de poissons de récifs dominantes observées étaient le sébaste cuivré et le sourcil de varech. Dans l'ensemble, les caractéristiques des morues lingues et des mâles gardiens de même que les densités de poissons de récifs semblent relativement stables au récif de l'île Snake. Il n'y a pas de grandes différences observées entre les données de 2012 et celles des dernières années.

INTRODUCTION

The 2012 lingcod (*Ophiodon elongatus*) egg mass and reef fish density SCUBA survey was carried out to: 1) provide an ongoing source of biological and relative abundance data for Strait of Georgia lingcod, as recommended in the 2003 stock assessment framework for this species (King et al. 2003); and 2) add to the existing time series of non-intrusive, visual counts of commonly encountered reef fishes from Snake Island reef. Lingcod egg mass and guarding male density estimates now exist for Snake Island reef for 1990, 1991, 1994, 2001-2007, and 2010-2012. Visual estimates of rockfish (*Sebastes spp.*) and other reef fish species' densities now exist for Snake Island reef for 2004-2007, and 2010-2012. This fishery-independent data can be used to address future management and conservation concerns for lingcod and inshore rockfish in the Strait of Georgia.

METHODS

Snake Island reef – a small reef averaging 10m depth and located near Nanaimo, British Columbia - has been the index site for lingcod egg mass surveys since 1990 (**Figure 1**). It is characterized by flat and largely barren bedrock, interspersed with large rocks and boulders and occasional patches of large flora such as *Agarum spp*. Suitable lingcod nesting sites can be found under boulders, or in horizontal or vertical crevices.

Survey dives were carried out on Snake Island reef between February 15th – 22nd 2012 by Department of Fisheries and Oceans staff. As a dive platform, an aluminum tender vessel (6.7 m) equipped with twin 115-hp engines, a depth sounder, GPS, and notebook computer with Nobeltec Visual Navigation Suite v.4.0 was used. Similar to in 2010 and 2011, dive quadrats were chosen prior to the survey. To ensure even coverage of all previously-defined 8 sections of Snake Island reef (King and Beaith 2001), approximate locations (GPS points) at Snake Island reef were selected from 2001, 2002, and 2004 survey points, respectively. Any sequential dive locations from each section (1 through 8) from 2001 and 2002 that had not been surveyed in 2010 or 2011 were chosen, after which sequential dive locations were chosen from the 2004 survey, for a total of 24 dive locations (3 from each section) and eight back-up dive locations (1 from each section). Slight movement of the boat off the pre-chosen GPS location, and the imprecise nature of the anchor buoy deployment meant that actual dive quadrats were randomly selected near target areas. The on-water recorded GPS locations of each dive quadrat are listed in **Table 1**.

QUADRAT DIVES

Prior to each dive, a surface deployed anchor buoy was released. Exact position and depth were recorded using Nobeltec. Two divers descended from the maker buoy to the anchor. Once at the reef, the secondary diver attached a 10 m line to the fixed marker buoy line while the primary diver (the recorder) noted quadrat depth. The secondary diver then swam slowly, sweeping the 10 m line around the weighted marker line, while

the primary diver systematically searched within the circular quadrat for lingcod egg masses and guarding male lingcod. The primary diver used a dive light when necessary to search under rocks, within crevices, or beneath large flora; and the secondary diver assisted with spotting and measuring male lingcod.

Upon discovery of an egg mass, the depth, position, appearance, dimensions and presence or absence of a guarding male was recorded. The position of the egg mass was recorded as either (0) out in the open; (1) under a rock; (2) in a horizontal crevice; (3) in a vertical crevice. Egg development stages were (0) pink-white = freshly laid; (1) creamy white = new; (2) white = intermediate; (3) grey-white = old; (4) eyed eggs = almost hatched; (5) hatched. If the eggs within an egg mass were at different stages of development, the combinations were recorded. Length, width and height of each egg mass were measured to the nearest centimetre to estimate egg mass volume (cm^3). The total length for any guardian male (i.e. observed within 1-2 m of the egg mass and exhibiting protective behaviour) was estimated by using measuring tape pulled alongside the resting male, or between two points on the seafloor representing the length of the fish (as observed and marked by the primary or secondary diver). In those quadrats containing *Agarum spp*., a conscious effort was made to lift large fronds in search of hidden egg masses.

Divers also counted non-guarding male lingcod (and took measurements when possible), copper rockfish (*Sebastes caurinus*) and quillback rockfish (*S. maliger*) adults and juveniles, kelp greenling (*Hexagrammos decagrammus*) males and females, and any other large (>20 cm) reef fishes encountered within each quadrat.

Habitat was quantified by approximating percentage within each quadrat (by visual estimate) corresponding to four levels of complexity; four types of relief (slope); and three types of substrate. In addition, coverage of large flora was visually estimated as a percentage of the quadrat area (**Table 1**).

ANALYSIS

Egg mass density (number of egg masses/ m^2) for each quadrat was calculated by dividing the number of egg masses by the area of the circular quadrat. The density of lingcod (guarding and non-guarding males combined) and other reef fishes was calculated in the same manner.

Egg mass density, egg mass volume, lingcod density, other reef fish densities, and length of guarding male lingcod were compared among years with available data using the Kruskal-Wallis nonparametric analysis of variance (Zar 1999). Multiple comparisons were then performed on the rank data to determine if significant differences existed between 2012 data and those from previous years in the time series. STATISTICA 7 was used to perform all statistical tests.

For egg mass density, data was available for all years (1990, 1991, 1994, 2001-2007 and 2010-2012). Egg mass volume was estimated in 1990 and 2001 and measured quantitatively in 2002-2007; only the quantitative measurements from 2002-2007 were

considered in this report. Length of guarding males – in addition to being measured in recent years (2001-2012) – was also measured in 1990, whereas no measurements were taken in 1991 and 1994. Lingcod density (and other reef fish densities) were only determined from 2001 onwards for lingcod, and from 2004 onwards for the other dominant reef fish (**Appendix Table 1**).

RESULTS

In 2012, a total of twenty-five quadrat dives were carried out on Snake Island reef between February 15th and February 22nd (**Table 1**). Dive quadrats were distributed over the reef at depths ranging from 5.7 m (18.7 ft) to 14.9 m (48.9 ft) (**Table 1**). Quadrats generally covered areas of the reef that were flat or gradually sloping with open, barren areas mixed with rocks, boulders, and crevices) (**Table 2**).

EGG MASS DENSITY

Seventeen out of twenty-five quadrats (i.e. 68%) at Snake Island Reef contained lingcod egg masses. A total of 32 egg masses were observed in the 25 sampled quadrats within a total surveyed area of 7853.983 m^2 (**Tables 1** and **3**). Egg mass density over the twenty-five quadrats ranged from 0 to 0.015915493 egg masses/ m^2, with a median of 0.003183 egg masses/ m^2 and a mean of 0.004074 egg masses/ m^2 (**Table 1** and **Appendix Table 1**).

When egg mass density was compared among year there was a significant difference in density across years (Kruskal Wallis $\chi^2 = 47.02625$, df = 12, p = 0.000; **Figure 2A**). Multiple comparisons on the ranked data showed significant differences between density in 1994 and densities in 2012 (p = 0.019966), 2011 (p = 0.024700), 2010 (p = 0.000126), 2007 (p = 0.000432), 2005 (p = 0.001994), and 1991 (p = 0.013713). Density in 1994 was significantly higher than in all other years where significant differences were detected (**Figure 2A**).

EGG MASS AND GUARDING MALE OBSERVATIONS

Egg Mass Location and Appearance

Egg mass locations were largely under rocks or boulders (Table 3). Out of the 32 egg masses observed during quadrat dives, two were located out in the open, twenty were observed under a rock or boulder, eight were observed in a horizontal crevice, one was observed in a vertical crevice, and one was observed partially under a rock and partially in a horizontal crevice (**Table 3**).

Egg mass appearance ranged from stage 2 (white = intermediate) to stage 4 (eyed = almost hatched). A large proportion of egg masses (11 out of 32; 34%) contained some eggs of one stage of development and the remaining eggs of another stage of development, with the predominant combination being eggs of stage 2 with eggs of stage

3. The principal stage was stage 2 (white) (n = 16), followed by a combination of stage 2 (white) with stage 3 (grey) (n = 9), and then by stage 3 (n = 5), and lastly by a combination of stage 3 with stage 4 (eyed) (n = 2) (**Table 3**).

Egg Mass Volume

Egg mass volume ranged from 1260 – 12500 cm^3 with a median of 4600.00 cm^3 and a mean of 5189.87 cm^3 (**Table 3** and **Appendix Table 1**). In three instances (9%), the primary diver was unable to obtain egg mass measurements due to the location of the egg mass deep under a rock or boulder, or within a crevice.

When egg mass volume was compared among years (2002-2007, and 2010-2012), an overall significant difference in volume was found (Kruskal Wallis χ^2 = 31.34728, df = 8, p = 0.0001; **Figure 2B**). Multiple comparisons on the ranked data showed a significant difference in volume between 2012 and 2004 (p = 0.034004), with a box plot indicating that egg mass volume was significantly higher in 2012 than in 2004 (**Figure 2B**). Egg mass volume was also significantly higher in 2011 than in 2004 (p = 0.003359), 2005 (p = 0.029796), and 2007 (p = 0.014550) (**Figure 2B**).

Guarding Males

Twenty-nine out of the thirty-two egg masses observed (i.e. 91%) were guarded, with four males guarding two egg masses each (**Table 3**). No apparent predation was observed on the three unguarded egg masses observed in 2012.

Measurements of guarding male length were obtained in all but three cases where guarding males were observed, for a total of twenty-two measurements of male length. Total lengths ranged from 53 – 83 cm total length (TL), with a mean length of 65.2 cm (**Table 3**).

When compared across years, no significant difference in guarding male length was found (Kruskal Wallis χ^2 = 13.51136, df = 10, p = 0.1965; **Figure 3**). Similarly, when multiple comparisons were performed on the ranked data, no significant differences were found between guarding male length in 2012 and all other years' data (**Figure 3**). The only significant difference found was between guarding male length in 2011 and that in 2003, with guarding male length being significantly lower in 2011 (p = 0.014643) (**Figure 3**).

REEF FISH DENSITY

Lingcod

In addition to the twenty-five guarding male lingcod observed in the quadrats, fourty-six non-guarding lingcod were observed within the dive quadrats (**Tables 3** and **4**). This count was much higher than in 2010 or in 2011, where 14 and 22 non-guarding males were observed, respectively (McPhie and King 2011). In 2012, lingcod were observed in

every dive quadrat. Total lingcod density per quadrat ranged from 0.003183 – 0.019099 lingcod/ m^2 with a median of 0.009549 lingcod/ m^2 and a mean of 0.009040 lingcod/ m^2 (**Table 4** and **Appendix Table 1**).

Non-guardian male lengths were measured in sixteen (of the forty-six) cases (i.e. 35%), with a mean total length (TL) of 59.3 cm (**Table 5**). Guarding and non-guarding lingcod were also counted in 2001-2011 (McPhie and King 2011; **Appendix Table 1**).

An overall significant difference in lingcod density was found among years (2001-2007 and 2010-2012) (Kruskal Wallis $\chi^2 = 40.17184$, df = 9, p = 0.000; **Figure 4**). However, multiple comparisons on the ranked data revealed no significant differences between lingcod density in 2012 and all other years (**Figure 4**). Significant differences in lingcod density were found between the following years: 2011 and 2001 (p = 0.012487); 2010 and 2001 (p = 0.000525); 2010 and 2002 (p = 0.015024); 2010 and 2003 (p = 0.016616); 2010 and 2004 (p = 0.009858); 2007 and 2001 (p = 0.000261); 2007 and 2002 (p = 0.004543); 2007 and 2003 (p = 0.004812); 2007 and 2004 (p = 0.002922); 2006 and 2001 (p = 0.044424); 2005 and 2001 (p = 0.004416); 2005 and 2002 (p = 0.048783); 2005 and 2003 (p = 0.039147); and 2005 and 2004 (p = 0.029010). In all cases, lingcod density was significantly lower in the more recent survey year (**Figure 4**).

Other Reef Fishes

Copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and kelp greenling (*Hexagrammos decagrammus*) were the most consistently encountered large (>20cm) reef fishes at Snake Island Reef other than lingcod (**Table 4** and **Appendix Table 1**). Of particular note, a wolf-eel (*Anarrhichthys ocellatus*), a painted greenling (*Oxylebius pictus*) and a Pacific cod (*Gadus macrocephalus*) were encountered during dives (**Table 4**).

Reef fish (not including lingcod) were observed in all quadrats, with the maximum number observed in quadrat 15 ($n = 18$) and the minimum number observed in quadrats 9 and 21 ($n = 2$, respectively) (**Table 4**). Copper rockfish density ranged from 0 – 0.031831 fish/ m^2 with a median of 0.000000 fish/ m^2 and a mean of 0.007257 fish/ m^2. Quillback rockfish density ranged from 0 – 0.015915 fish/ m^2 with a median of 0.003183 fish/m^2 and a mean of 0.004329 fish/ m^2. Kelp greenling had densities per quadrat ranging from 0 - 0.0159155 fish/ m^2. The median and mean densities for kelp greenling were 0.006366 fish/ m^2 and 0.006875 fish/ m^2 respectively (**Table 4** and **Appendix Table 1**).

When reef fish densities (kelp greenling, copper rockfish, and quillback rockfish, respectively) were compared among years, both kelp greenling and copper rockfish showed significant differences among years (kelp greenling: Kruskal Wallis $\chi2 = 22.31954$, df = 6, p = 0.0011; copper rockfish: Kruskal Wallis $\chi2 = 38.73665$, df = 6, p = 0.0000). Quillback rockfish showed no significant differences among years (Kruskal Wallis $\chi2 = 10.12836$, df = 6, p = 0.1194). Multiple comparisons revealed no significant difference between kelp greenling density in 2012 and all other years. A significant

difference was detected between the 2011 kelp greenling density and that observed in 2010, with the 2010 density being significantly higher ($p = 0.049667$) (**Figure 5**). A significant difference was detected between copper rockfish density in 2012 and 2005, with the 2012 density being significantly lower (**Figure 5**). The 2011 copper rockfish density was significantly lower than densities recorded in 2004 ($p = 0.000192$), 2005 ($p = 0.000000$), 2006 ($p = 0.001279$), and 2007 ($p = 0.003051$) respectively. Also, the density of copper rockfish in 2010 was significantly lower than that in 2005. No significant differences were observed between quillback rockfish density in 2012 and all other years (**Figure 5**).

HABITAT CHARACTERISTICS

The dominant habitat characteristics of quadrats where lingcod egg masses were found were simple, flat, rocky areas with no (or very little) algae cover (**Table 2**). In most instances, large areas of the quadrats where lingcod egg masses were found during this survey were simple (i.e. smooth, no crevices) hardpan or bedrock, but with large boulders under which lingcod could lay their eggs.

DISCUSSION

The 2012 lingcod egg mass and reef fish density SCUBA survey at Snake Island Reef continues the time series for this index site, and provides data consecutive with the 2010 and 2011 survey data. Mean lingcod egg mass density was slightly higher than in recent years (2006, 2007, 2010 and 2011). However, no significant differences were observed between the 2012 density and densities in recent years. The only significant difference detected when the 2012 egg mass density was compared with all other years' densities was that between 2012 and 1994, with the 1994 density being significantly higher. Overall, lingcod densities (guarding and non-guarding males) appeared to be lower in recent years (2011, 2010, 2007, 2006, and 2005) than in earlier years (2001-2004), with numerous significant differences between years. However, mean lingcod density was slightly higher in 2012 (compared to 2005-2007, and 2010-2011), but not significantly. There were no significant differences detected between the 2012 lingcod density and all other years' densities, including earlier 2001-2004 densities. Similar to previous surveys, egg mass locations were largely under rocks or boulders (Yamanaka and Richards 1995; King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty et al. 2005, Haggarty and King 2007, Surry and King 2007, McPhie and King 2011). Quadrats with medium to high complexity, with high relief, and dominated by coarse, fine substrate and with heavy *Agarum spp.* coverage appeared to be less favourable for nest placement than simpler, flatter sites. These habitats were identified by King and Beaith (2001) as suitable nesting habitat. Egg mass developments observed in 2012 were mainly early stages, while previous surveys at Snake Island observed all stages of development (from 1 to 5), and the highest proportion were in the later stages of development (Yamanaka and Richards 1995; King and Beaith 2001; King and Winchell 2002; King and Haggarty 2004; Haggarty et al. 2005; Haggarty and King 2007; Surry and King 2007). Previous surveys were generally carried out slightly later in the season, with

many dives occurring in March, which could account for these differences. The stages observed in 2012 were consistent with those seen in 2010 and 2011 (surveys also carried out from mid-February until the end of February), where the majority of egg masses observed were in early stages of development, albeit exhibiting more uniform development with fewer combinations than in 2012 (McPhie and King 2011). In 2012, a high proportion (91%) of the observed egg masses were guarded by a lingcod. Eighty-four percent of the guarding males were guarding only one nest (versus two). In previous surveys, typically over 70% of the observed egg masses were guarded, and over 60% of the guarding males were guarding only one egg mass (Yamanaka and Richards 1995, King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty et al. 2005, Haggarty and King 2007, Surry and King 2007). The predominant reef fish observed were copper rockfish and kelp greenling, with no significant trends observed over time for either species.

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Table 1. Position and depth of anchor buoy, visibility, number of guarded and unguarded lingcod egg masses, and egg mass density (egg masses/ m^2), for quadrat dives at Snake Island Reef, Feb 15 - 22, 2012.

Quadrat	Date	Latitude	Longitude	Depth (m)	Visibility (m)	No. Egg Masses		
						Guarded	Not Guarded	Density
1	15/02/2012	49° 12' 47.4"	123° 53' 04.32"	14.9	12	2	0	0.006366197
2	15/02/2012	49° 12' 46.38"	123° 53' 04.80"	11.9	12	2	0	0.006366197
3	15/02/2012	49° 12' 46.68"	123° 53' 02.46"	13.1	12	0	0	0
4	15/02/2012	49° 12' 41.88"	123° 53' 03.00"	12.4	10	0	0	0
5	15/02/2012	49° 12' 42.6"	123° 53' 07.32"	11.0	12	1	0	0.003183099
6	15/02/2012	49° 12' 44.28"	123° 53' 04.92"	7.2	12	0	0	0
7	17/02/2012	49° 12' 42.60"	123° 53' 04.50"	7.6	9	2	0	0.006366197
8	17/02/2012	49° 12' 43.56"	123° 53' 04.38"	7.6	10	3	1	0.012732394
9	17/02/2012	49° 12' 45.24"	123° 53' 02.70"	10.7	9	0	0	0
10	17/02/2012	49° 12' 38.94"	123° 53' 05.58"	5.7	8	0	1	0.003183099
11	20/02/2012	49° 12' 41.76"	123° 53' 05.10"	7.6	12	1	0	0.003183099
12	20/02/2012	49° 12' 40.08"	123° 53' 04.62"	6.7	12	5	0	0.015915493
13	20/02/2012	49° 12' 40.68"	123° 53' 06.48"	8.5	12	3	0	0.009549296
14	21/02/2012	49° 12' 40.62"	123° 53' 07.80"	8.4	6	0	1	0.003183099
15	21/02/2012	49° 12' 37.56"	123° 53' 05.64"	12.1	7	0	0	0
16	21/02/2012	49° 12' 39.84"	123° 53' 03.36"	6.3	6	1	0	0.003183099
17	21/02/2012	49° 12' 36.24"	123° 53' 05.76"	7.3	7	1	0	0.003183099
18	21/02/2012	49° 12' 37.50"	123° 53' 04.08"	12.5	5	0	0	0
19	21/02/2012	49° 12' 37.74"	123° 53' 08.40"	12.0	8	1	0	0.003183099
20	22/02/2012	49° 12' 37.38"	123° 53' 07.26"	11.6	12	3	0	0.009549296
21	22/02/2012	49° 12' 36.12"	123° 53' 08.10"	10.2	12	1	0	0.003183099
22	22/02/2012	49° 12' 33.12"	123° 53' 06.90"	8.6	6	0	0	0
23	22/02/2012	49° 12' 34.74"	123° 53' 07.08"	11.3	12	1	0	0.003183099
24	22/02/2012	49° 12' 32.34"	123° 53' 05.28"	13.7	12	0	0	0
25	22/02/2012	49° 12' 44.40"	123° 53' 06.30"	9.1	5	2	0	0.006366197
			Average	9.9	9.6	1.16	0.12	0.004074366

Table 2. Complexity of habitat, relief (slope), substrate type, and coverage by Agarum *sp.* for lingcod egg mass quadrat dives at Snake Island Reef, Feb 15-22, 2012. Quadrats indicated with bold type contained egg masses.

Quadrat	Date	Complexity[a] (% of quadrat)				Relief[b] (% of quadrat)				Substrate[c] (% of quadrat)			Agarum	Other algae *sp.*
		Simple	Low	Medium	High	Flat	Low	High	Wall	Rock	Coarse	Fine	(% of quadrat)	(% of quadrat)
1	**15/02/2012**	**25**	**25**	**50**	**0**	**25**	**50**	**25**	**0**	**90**	**10**	**0**	**0**	**0**
2	**15/02/2012**	**50**	**0**	**50**	**0**	**50**	**50**	**0**	**0**	**80**	**20**	**0**	**0**	**0**
3	15/02/2012	30	10	40	10	20	80	0	0	80	20	0	0	0
4	15/02/2012	50	20	30	0	60	40	0	0	50	30	20	50	5
5	**15/02/2012**	**0**	**50**	**50**	**0**	**80**	**20**	**0**	**0**	**20**	**80**	**0**	**0**	**0**
6	15/02/2012	70	30	0	0	75	25	0	0	93	3	2	0	**0**
7	**17/02/2012**	**95**	**5**	**0**	**0**	**100**	**0**	**0**	**0**	**100**	**0**	**0**	**0**	**0**
8	**17/02/2012**	**20**	**30**	**40**	**10**	**10**	**90**	**0**	**0**	**30**	**50**	**20**	**10**	**0**
9	17/02/2012	95	5	0	0	75	25	0	0	100	0	0	0	**0**
10	**17/02/2012**	**50**	**25**	**25**	**0**	**90**	**10**	**0**	**0**	**80**	**20**	**0**	**5**	**0**
11	**20/02/2012**	**80**	**10**	**10**	**0**	**50**	**50**	**0**	**0**	**95**	**5**	**0**	**2**	**0**
12	**20/02/2012**	**15**	**80**	**5**	**0**	**20**	**75**	**5**	**0**	**90**	**8**	**2**	**0**	**0**
13	**20/02/2012**	**90**	**0**	**10**	**0**	**100**	**0**	**0**	**0**	**90**	**10**	**0**	**0**	**0**
14	**21/02/2012**	**98**	**2**	**0**	**0**	**30**	**18**	**50**	**2**	**98**	**2**	**0**	**0**	**0**
15	21/02/2012	20	30	40	10	20	60	20	0	30	40	30	50	**0**
16	**21/02/2012**	**95**	**5**	**0**	**0**	**90**	**10**	**0**	**0**	**98**	**2**	**0**	**0**	**0**
17	**21/02/2012**	**95**	**5**	**0**	**0**	**90**	**10**	**0**	**0**	**97**	**3**	**0**	**1**	1
18	21/02/2012	5	5	70	20	10	90	0	0	5	75	20	40	2
19	**21/02/2012**	**85**	**10**	**5**	**0**	**10**	**40**	**25**	**25**	**90**	**5**	**5**	**0**	**0**
20	**22/02/2012**	**20**	**30**	**30**	**0**	**40**	**20**	**20**	**0**	**60**	**40**	**0**	**0**	**0**
21	**22/02/2012**	**25**	**25**	**50**	**0**	**18**	**80**	**5**	**0**	**50**	**45**	**5**	**5**	2
22	22/02/2012	80	20	0	0	85	10	5	0	80	15	5	3	1
23	**22/02/2012**	**80**	**0**	**10**	**10**	**90**	**10**	**0**	**0**	**100**	**0**	**0**	**0**	0
24	22/02/2012	10	20	20	50	100	0	0	0	90	8	2	80	0
25	**22/02/2012**	**10**	**40**	**50**	**0**	**5**	**90**	**5**	**0**	**40**	**50**	**10**	**0**	0

[a] Complexity: Simple = smooth, no crevices; Low = less than 25% covered by crevices; Medium = 25-50% covered by crevices; High = more than 50% covered by crevices.

[b] Relief: Flat = less than a 2 ft difference in depth; Low = 2 to 7 ft. difference in depth; High = over 7 ft. difference in depth and/or <45° slope; Wall = >45° slope.

[c] Substrate: Rock = hardpan, bedrock or boulders; Coarse = cobble, gravel, shell; Fine = sand or mud.

Table 3. Characteristics of each egg mass and guarding male observed during quadrat dives at Snake Island Reef, February 15-22, 2012. Egg masses are numbered consecutively in the order in which they were discovered. "n/a" indicates "not available" and refers to egg masses that were located too far under a rock to measure or were broken into many pieces, or males that swam away before they could be measured.

Date	Egg Mass	Quadrat	Depth (m)	Egg Mass Location[a]	Appearance[b]	Volume	Volume (cm^3)	Male Present[c]	Male Length (cm)
15/02/2012	1	1	14.3	1	2/3	13x25x20	6500	M1	73.0
15/02/2012	2	1	14.0	1	2	40x14x15	8400	M1	83.0
15/02/2012	3	2	13.4	1	3	25x20x25	12500	M1	80.0
15/02/2012	4	2	13.7	1	2	15x30x20	9000	M1	n/a
15/02/2012	5	5	13.1	1	2	n/a	n/a	M1	65.0
17/02/2012	6	7	7.6	1	2	15x10x10	1500	M2	65.0
17/02/2012	7	7	7.6	0	2/3	25x15x10	3750	same as above	
17/02/2012	8	8	8.4	1	2/3	32x12x16	6144	M1	68.5
17/02/2012	9	8	8.2	1	2	20x12x12	2880	M1	60.0
17/02/2012	10	8	8.1	1	2	27x12x14	4536	M0	n/a
17/02/2012	11	8	8.1	1	2	27x10x16	4320	M1	73.0
20/02/2012	12	10	6.6	1	2	29x11x18	5742	M0	n/a
20/02/2012	13	11	8.2	1	2/3	23x8x15	2760	M1	54.0
20/02/2012	14	12	6.6	1	2/3	n/a	n/a	M2	59.0
20/02/2012	15	12	5.9	0	2/3	15x12x7	1260	same as above	
20/02/2012	16	12	7.6	2	2	28x20x11	6160	M1	n/a
20/02/2012	17	12	6.6	2	2/3	n/a	n/a	M1	62.0
20/02/2012	18	12	6.4	1/2	2	32x15x19	9120	M1	n/a
20/02/2012	19	13	8.5	1	3/4	33x12x10	3960	M2	63.0
20/02/2012	20	13	8.5	2	2	30x13x15	5850	same as above	
20/02/2012	21	13	8.8	1	2	13x19x18	4446	M1	60.0
21/02/2012	22	14	12.7	1	2/3	33x13x16	6864	M0	n/a
21/02/2012	23	16	7.7	1	3	25x10x24	6000	M1	66.0
21/02/2012	24	17	8.2	1	2	31x10x20	6200	M1	58.0
21/02/2012	25	19	13.5	1	3	23x14x17	5474	M1	72.0
22/02/2012	26	20	12.8	2	2	17x11x14	2618	M2	58.0
22/02/2012	27	20	11.6	2	2	20x10x23	4600	same as above	

Table 3 continued

Date	Egg Mass	Quadrat	Depth (m)	Egg Mass Location[a]	Appearance[b]	Volume	Volume (cm^3)	Male Present[c]	Male Length (cm)
22/02/2012	28	20	10.7	2	3	29x10x11	3190	M1	76.0
22/02/2012	29	21	11.1	3	3/4	24x9x16	3456	M1	54.0
22/02/2012	30	23	11.6	1	2/3	26x12x9	2808	M1	70.0
22/02/2012	31	25	7.8	2	3	19x10x23	4370	M1	53.0
22/02/2012	32	25	8.8	2	2	39x12x19	8892	M1	61
		Average	9.6				5190		65.2

[a] Egg Mass Location: (0) out in the open; (1) under a rock; (2) in a horizontal crevice; or (3) in a vertical crevice

[b] Appearance: (1) creamy = new; (2) white = intermediate; (3) grey-white = old; (4) eyed eggs = almost hatched; (5) hatched

[c] Male Present: (M0) = no guarding male present; (M1) = male guarding one egg mass; (M2) = male guarding two egg masses

Table 4. Reef fish observations from quadrat dives at Snake Island Reef, February 15-22, 2012. Total counts and densities (fish/ m^2) in each quadrat are provided for lingcod (*Ophiodon elongatus*), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and kelp greenling (*Hexagrammos decagrammus*). For lingcod, the number of guarding males included in the total is indicated in backets. For copper and quillback rockfish, the number of juveniles included in the total is indicated in brackets. For kelp greenling, the number of females (f) and males (m) included in the total is indicated in brackets. Total counts in each quadrat are provided for other reef fish species encountered.

Quadrat	Lingcod		Copper rockfish		Quillback rockfish		Kelp greenling		Painted greenling	Pacific cod	Wolf eel	Total # fish
	Count	Density	Count	Density	Count	Density	Count	Density				
1	4 (2)	0.012732	2	0.006366	0	0	1 (m)	0.003183	0	0	0	7
2	3 (2)	0.009549	1	0.003183	0	0	0	0	1	1	0	6
3	2 (0)	0.006366	2	0.006366	1	0.003183	1 (m)	0.003183	0	0	0	6
4	2 (0)	0.006366	0	0	4	0.012732	4 (3f, 1m)	0.0127324	0	0	0	10
5	3 (1)	0.009549	2	0.006366	1	0.003183	2 (1f, 1m)	0.0063662	0	0	0	8
6	4 (0)	0.012732	0	0	5	0.015915	1 (m)	0.003183	0	0	0	10
7	2 (1)	0.006366	1	0.003183	1	0.003183	3 (m)	0.009549	0	0	0	7
8	3 (3)	0.009549	3	0.009549	3	0.009549	3 (m)	0.009549	0	0	0	12
9	1 (0)	0.003183	0	0	0	0	2 (1f, 1m)	0.0063662	0	0	0	3
10	3 (1)*	0.009549	0	0	0	0	5 (1f, 4m)	0.0159155	0	0	0	8
11	4 (1)	0.012732	2	0.006366	3	0.009549	2 (1f, 1m)	0.0063662	0	0	0	11
12	6 (4)	0.019099	0	0	0	0	3 (1f, 2m)	0.009549	0	0	0	9
13	3 (2)	0.009549	3	0.009549	0	0	1 (f)	0.003183	0	0	0	7
14	3 (0)	0.009549	0	0	2	0.006366	3 (1f, 2m)	0.0095493	0	0	0	8
15	2 (0)	0.006366	10	0.031831	5	0.015915	3 (1f, 2m)	0.0095493	0	0	0	20
16	5 (1)	0.015915	2	0.006366	3	0.009549	3 (2f, 1m)	0.0095493	0	0	0	13
17	1 (0)	0.003183	0	0	0	0	3 (m)	0.009549	0	0	0	4
18	1 (0)	0.003183	10 (1)	0.031831	2	0.006366	3 (m)	0.0095493	0	0	0	16
19	2 (1)	0.006366	5	0.015915	2	0.006366	0	0	0	0	0	9
20	5 (2)	0.015915	3	0.009549	0	0	3 (2f, 1m)	0.009549	0	0	0	11
21	2 (1)	0.006366	2	0.006366	0	0	0	0	0	0	0	4

Table 4 continued

Quadrat	Lingcod		Copper rockfish		Quillback rockfish		Kelp greenling		Painted greenling	Pacific cod	Wolf eel	Total # fish
	Count	Density	Count	Density	Count	Density	Count	Density				
22	2 (0)	0.006366	0	0	1	0.003183	2 (1f, 1m)	0.006366	0	0	0	5
23	3 (1)	0.009549	2	0.006366	0	0	1 (m)	0.0031831	0	0	0	6
24	2 (0)	0.006366	5	0.015915	0	0	3 (2f, 1m)	0.009549	0	0	1	11
25	3 (2)	0.009549	2	0.006366	1	0.003183	2 (m)	0.006366	0	0	0	8
Average	2.84	0.009040	2.28	0.007257	1.36	0.004329	2.16	0.006875	0.04	0.04	0.04	8.76

*guardian male with nest outside of quadrat area

Table 5. Lengths of non-guardian male lingcod measured during quadrat dives at Snake Island Reef, February 15-22, 2012. For each quadrat, the number of non-guarding males included in the total is indicated in parentheses. "n/a" indicates "not available" and refers to lingcod that were not measured. Average length of those non-guardian males successfully measured is included.

Date	Quadrat	Depth (m)	No. Lingcod in Quadrat	Non-Guardian Male Length (cm)
15/02/2012	1	14.9	4 (2)	53
15/02/2012	1	14.9	same as above	63
15/02/2012	2	11.9	3 (1)	n/a
15/02/2012	3	13.1	2 (2)	57.5
15/02/2012	4	12.4	2 (2)	n/a
15/02/2012	5	11.0	3 (2)	n/a
15/02/2012	6	7.2	4 (4)	52.3
17/02/2012	7	7.6	2 (1)	58
17/02/2012	8	7.6	3 (0)	n/a
17/02/2012	9	10.7	1 (1)	n/a
17/02/2012	10	5.7	3 (2)	58
17/02/2012	10	5.7	same as above	61
20/02/2012	11	7.6	4 (3)	51
20/02/2012	12	6.7	6 (2)	72.5
20/02/2012	13	8.5	3 (1)	59
21/02/2012	14	8.4	3 (3)	56
21/02/2012	15	12.1	2 (2)	n/a
21/02/2012	16	6.3	5 (4)	69
21/02/2012	16	6.3	same as above	73
21/02/2012	17	7.3	1 (1)	57
21/02/2012	18	12.5	1 (1)	n/a
21/02/2012	19	12.0	2 (1)	52
22/02/2012	20	11.6	5 (3)	n/a
22/02/2012	21	10.2	2 (1)	n/a
22/02/2012	22	8.6	2 (2)	56
22/02/2012	23	11.3	3 (2)	n/a
22/02/2012	24	13.7	2 (2)	n/a
22/02/2012	25	9.1	3 (1)	n/a
			Average	59.3

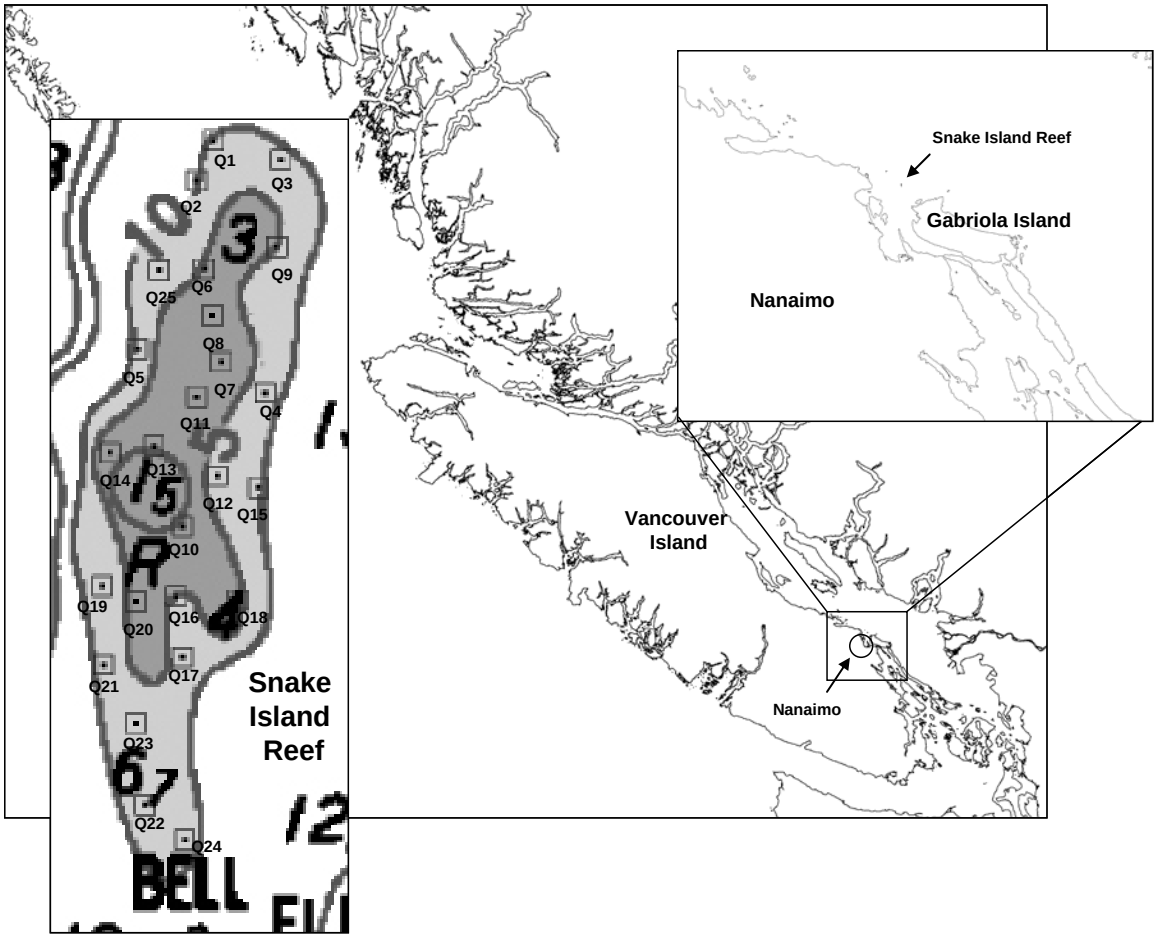

Figure 1. Location and bathymetry of Snake Island reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys. Quadrat points for the 2012 survey (Q1-Q25) are shown.

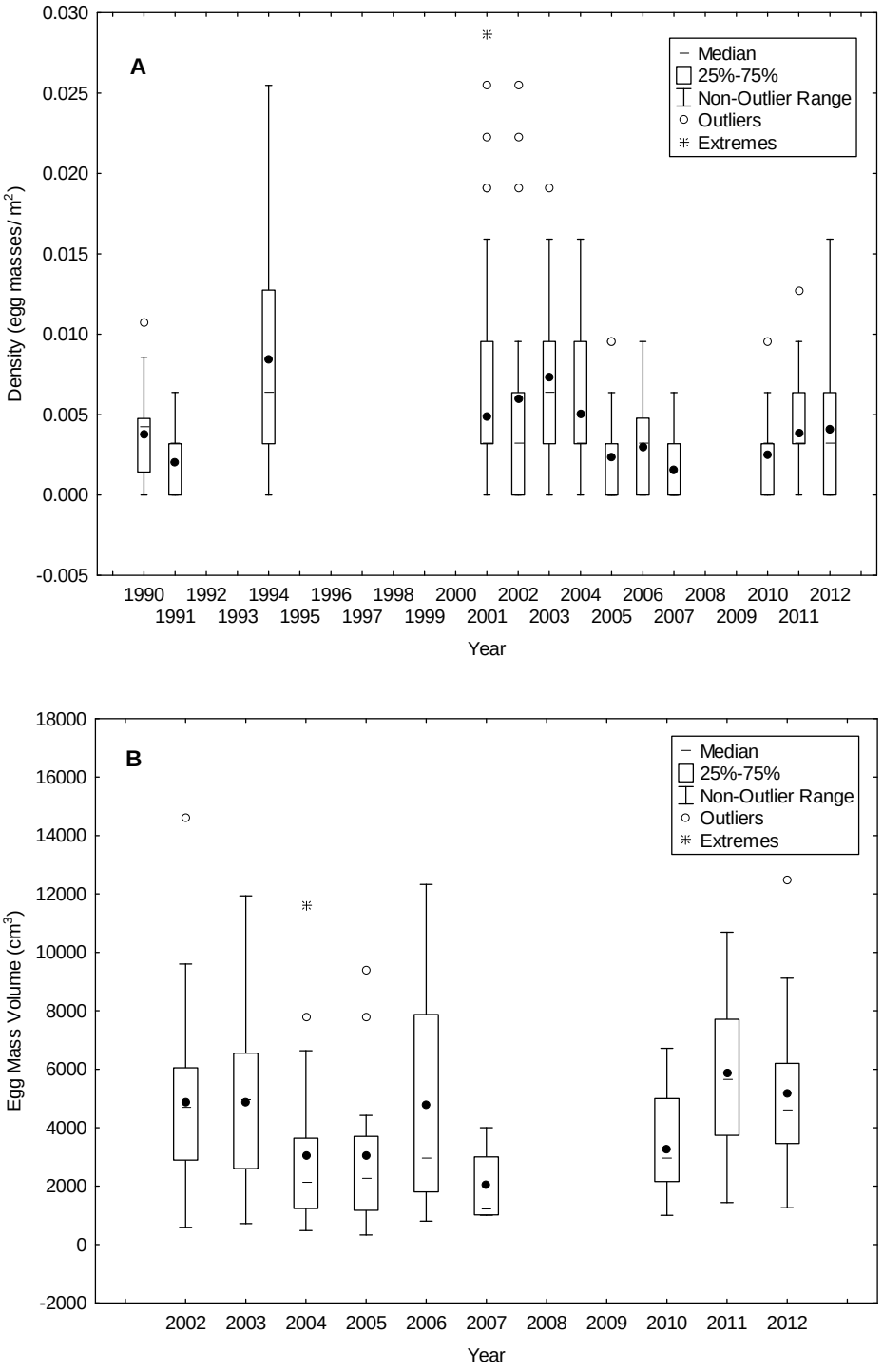

Figure 2. A) Box plots of lingcod egg mass densities at Snake Island Reef from 1990, 1991, 1994, 2001-2007 and 2010-2012; and B) box plots of lingcod egg mass volumes at Snake Island Reef from 2002-2007, and 2010-2011. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

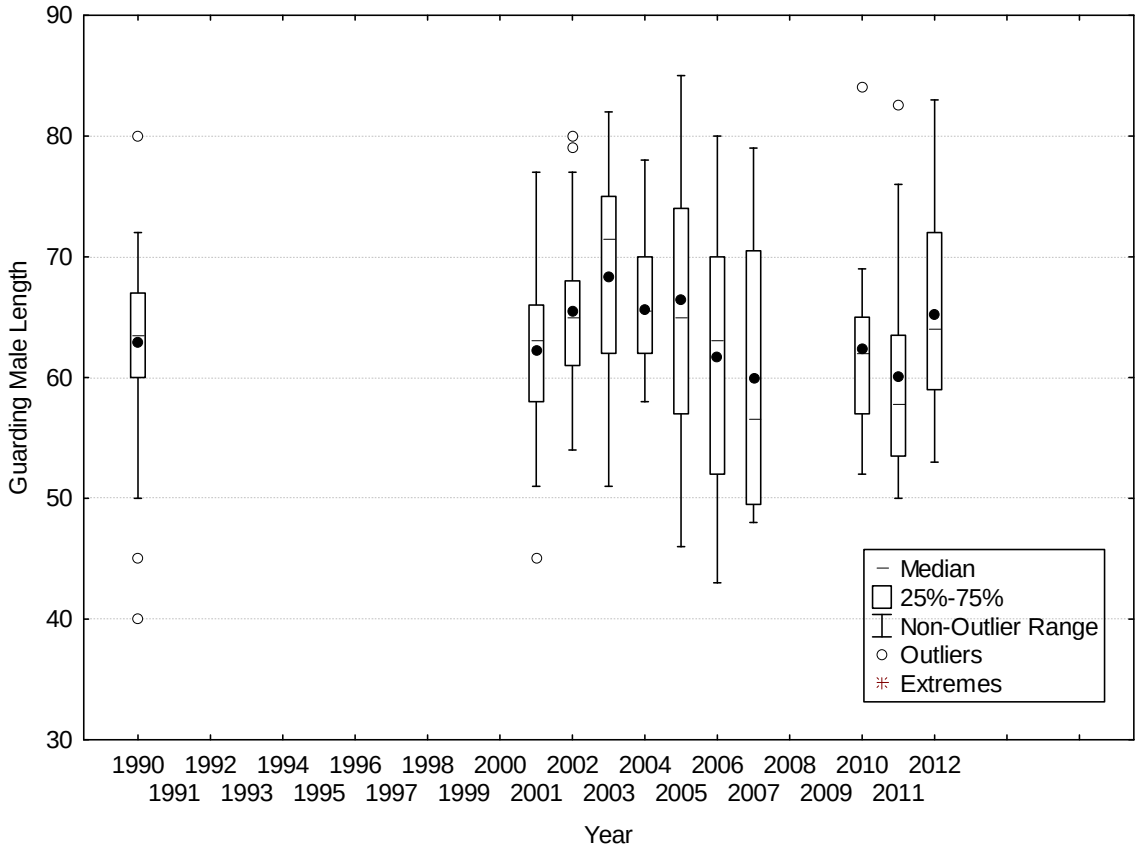

Figure 3. Box plots of guarding male lingcod length (cm) at Snake Island Reef in 1990, 2001-2007 and 2010-2012. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

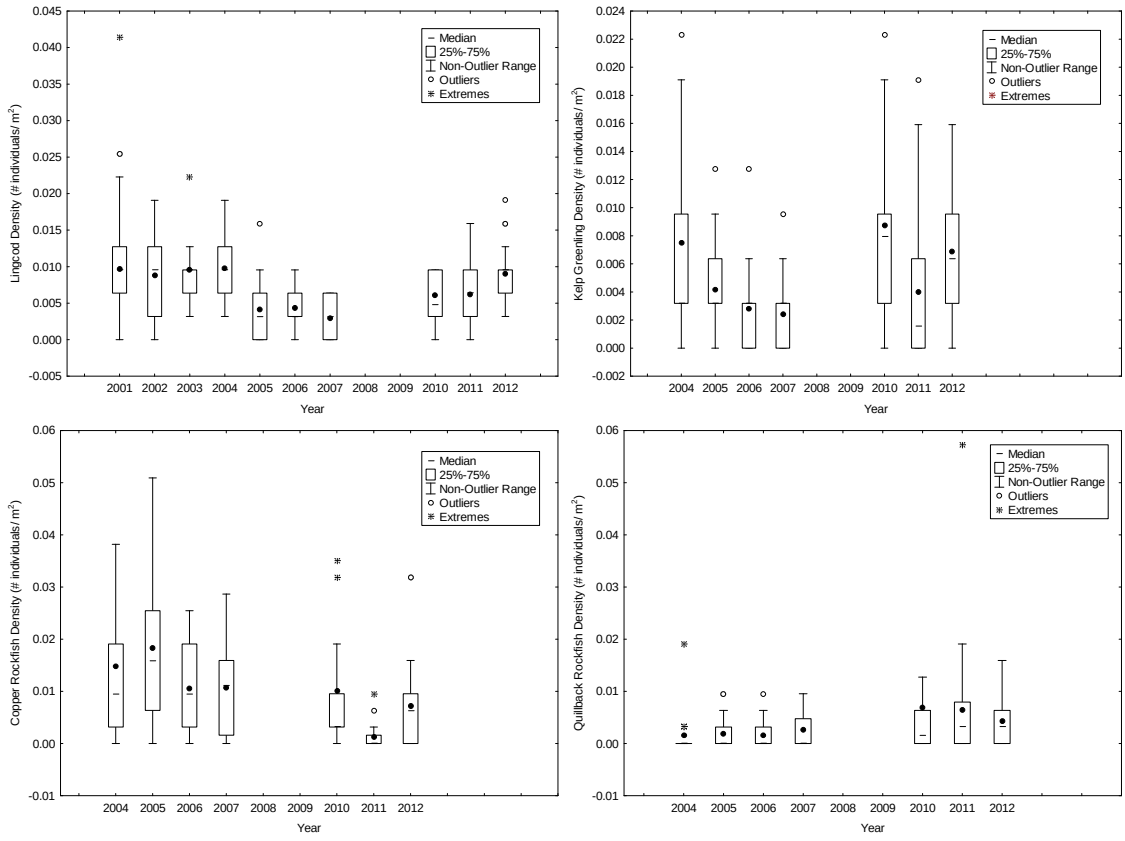

Figure 4. Box plots of reef fish densities at Snake Island Reef for lingcod in 2001-2007 and 2010-2012 and kelp greenling, copper rockfish, and quillback rockfish in 2004-2007, and 2010-2012. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

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Appendix Table 1. Summary of lingcod egg mass density and volume, lengths of guarding males, and density of reef fishes at Snake Island Reef in 1990, 1991 and 1994 (Yamanaka and Richards 1995, K.L), 2001 (King and Beaith 2001), 2002 (King and Winchell 2002), 2003 (JRK: Unpublished Data), 2004 (King and Haggarty 2004), 2005 (Haggarty et al. 2005), 2006 (Haggarty and King 2007), 2007 (Surry and King 2007), 2010 and 2011 (McPhie and King 2011) and 2012.

Year	Time Period	No. of Egg Masses	No. of Quadrats/ Transects	Egg Masses				Guarding Lingcod[b]	
				Density (egg masses/m^2)		Volume (cm^3)[a]		Mean Length (cm)	No. measured
				Median	Mean	Median	Mean		
1990	Feb 16 - Mar 16	104	37	0.004286	0.003745	--	--	62.87	54
1991	Mar 18 - Mar 21	14	22	0.003183	0.002026	--	--	--	0
1994	Feb 10 - Mar 15	78	29	0.006366	0.008452	--	--	--	0
2001	Jan 23 - Ap 6	107	74	0.003183	0.004856	--	--	62.22	73
2002	Feb 1 - Mar 13	51	27	0.006366	0.006013	4680.00	4862.55	65.49	39
2003	Feb 12 - Feb 21	30	13	0.006366	0.007346	4950.00	4852.41	68.40	20
2004	Feb 17 - Mar 3	22	14	0.003183	0.005002	2145.00	3049.67	65.59	17
2005	Mar 3 - Mar 8	14	19	0	0.002345	2241.50	3044.25	66.45	11
2006	Mar 3 - Mar 7	15	16	0.003183	0.002984	2970.00	4796.60	61.63	8
2007	Feb 13 - Feb 27	8	16	0	0.001592	1200.00	2058.86	60.00	4
2010	Feb 15 - Feb 25	19	24	0.003183	0.002520	2944.00	3280.59	62.38	13
2011	Feb 15 - Feb 25	29	24	0.003183	0.003846	5661.00	5852.25	60.11	22
2012	**Feb 15 - Feb 22**	**32**	**25**	**0.003183**	**0.004074**	**4600.00**	**5189.87**	**65.16**	**22**

Year	Time Period	Reef Fish Density (number of fish / m^2)							
		Lingcod[c]		Copper rockfish[d]		Quillback rockfish[d]		Kelp Greenling[d]	
		Median	Mean	Median	Mean	Median	Mean	Median	Mean
1990	Feb 16 - Mar 16	--	--	--	--	--	--	--	--
1991	Mar 18 - Mar 21	--	--	--	--	--	--	--	--
1994	Feb 10 - Mar 15	--	--	--	--	--	--	--	--
2001	Jan 23 - Apr 6	0.009549	0.009721	--	--	--	--	--	--
2002	Feb 1 - Mar 13	0.009549	0.008842	--	--	--	--	--	--
2003	Feb 12 - Feb 21	0.009549	0.009549	--	--	--	--	--	--
2004	Feb 17 - Mar 3	0.009549	0.009777	0.015916	0.014779	0	0.001592	0.006366	0.007503
2005	Mar 3 - Mar 8	0.003183	0.004188	0.015916	0.018261	0	0.001843	0.003183	0.004188

Appendix Table 1 continued

Year	Time Period	Reef Fish Density (number of fish / m^2)							
		Lingcod[c]		Copper rockfish[d]		Quillback rockfish[d]		Kelp Greenling[d]	
		Median	Mean	Median	Mean	Median	Mean	Median	Mean
2006	Mar 3 - Mar 7	0.003183	0.004377	0.009549	0.010544	0	0.001592	0.003183	0.002785
2007	Feb 13 - Feb 27	0.003183	0.002984	0.011141	0.010743	0	0.002586	0.003183	0.002387
2010	Feb 15 - Feb 25	0.004775	0.006063	0.007958	0.010052	0.006366	0.006897	0.009549	0.008719
2011	Feb 15 - Feb 25	0.006366	0.006234	0	0.001194	0.003183	0.006499	0.001592	0.003979
2012	**Feb 15 - Feb 22**	**0.009549**	**0.009040**	**0**	**0.007257**	**0.003183**	**0.004329**	**0.006366**	**0.006875**

[a] egg mass volumes were not measured systematically prior to 2002

[b] guarding males were not measured in 1991 and 1994

[c] lingcod density includes guarding and non-guarding males; non-guarding males were not counted prior to 2001

[d] other reef fishes were not counted prior to 2004