Lingcod (*Ophidodon elongatus*) Egg Mass and Reef Fish Density SCUBA Survey in the Strait of Georgia, February 15-25, 2010 and 2011

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LINGCOD (*Ophidodon elongatus*) EGG MASS AND REEF FISH DENSITY SCUBA SURVEY IN THE STRAIT OF GEORGIA, FEBRUARY 15-25, 2010 AND 2011

by

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Dives were conducted in the Strait of Georgia at Snake Island Reef and Entrance Island between February 15th and February 25th, 2010 and at Snake Island Reef and Law Point between February 15th and February 25th, 2011 in order to provide updated lingcod (*Ophidodon elongatus*) egg mass density estimates and to examine egg mass and guarding male characteristics relative to data collected in previous years. Reef fish (>20cm) density estimates and habitat characteristics were also determined and compared among years with available information. In total, twenty-five survey dives were conducted in 2010 over six dive days (Snake Island reef n = 24; Entrance Island reef n = 1) and thirty survey dives were conducted in 2011 over five dive days (Snake Island reef n = 24; Law Point n = 6). On Snake Island reef in 2010 within a total surveyed area of 7539.823 m^2, a total of 19 lingcod egg masses were located. No lingcod egg masses were observed during the one dive carried out at Entrance Island. In 2011, a total of 28 lingcod egg masses were located on Snake Island reef (total surveyed area of 7539.823 m^2); and a total of three lingcod egg masses were located at Law Point (total surveyed area of 1884.9558 m^2). Overall, lingcod egg mass and guarding male characteristics appear to be relatively stable at Snake Island reef, with no significant differences found between: 1) egg mass densities; 2) egg mass volumes; 3) guarding male length; or 4) lingcod density in 2010 and 2011. Although data from 2008 and 2009 are lacking, multiple comparisons with previous years' data (2001 onwards) suggest that no dramatic or sustained change in lingcod or lingcod egg mass characteristics have occurred over the last twenty-one years (1990-2011).

RESUME

McPhie, R.P., and King, J.R. 2011. Lingcod (*Ophidodon elongatus*) egg mass and reef fish density SCUBA survey in the Strait of Georgia, February 15-25, 2010 and 2011. Can. Tech. Rep. Fish. Aquat. Sci. 2932: x + 33p.

Des plongées ont été effectuées dans le détroit de Georgia, aux récifs de l'île Snake et de l'île Entrance, du 15 au 25 février 2010, ainsi qu'à ce même récif de l'île Snake et à la pointe Law du 15 au 25 février 2011. Ces plongées visaient à obtenir des estimations à jour de la densité des masses d'œufs de morue-lingue (*Ophidodon elongatus*) et à examiner les caractéristiques de ces masses et des mâles qui les protègent en vue de les comparer aux données recueillies les années précédentes. Les estimations de la densité des poissons de récifs (> 20 cm) et les caractéristiques de l'habitat ont également été déterminées et comparées avec les données disponibles pour d'autres années. Au total, 25 plongées ont été menées sur six jours en 2010 (récif de l'île Snake : n = 24; récif de l'île Entrance : n = 1), et 20 plongées sur cinq jours, en 2011 (récif de l'île Snake : n = 24; pointe Law : n = 6). En 2010, au récif de l'île Snake, un total de 19 masses d'œufs de morue-lingue ont été localisées au sein de la zone de relevé d'une superficie totale de 7 539,823 m^2. Aucune masse d'œufs de morue-lingue n'a été observée au cours de l'unique plongée effectuée à l'île Entrance. En 2011, un total de 28 masses d'œufs de morue-lingue ont été localisées au récif de l'île Snake (zone de relevé totale de 7 539,823 m^2), tandis qu'un total de trois masses d'œufs de morue-lingue ont été localisées à la pointe Law (zone de relevée totale de 1 884,9558 m^2). Dans l'ensemble, les caractéristiques des masses d'œufs et des mâles qui les gardent semblent relativement stables au récif de l'île Snake. En effet, aucune différence significative n'a été constatée entre les données de 2010 et de 2011 en ce qui concerne : 1) la densité des masses d'œufs; 2) le volume des masses d'œufs; 3) la longueur des mâles protecteurs; 4) la densité des morues-lingues. Bien que les données de 2008 et de 2009 soient manquantes, de multiples comparaisons avec les données des années précédentes (de 2001 à ce jour) donnent à penser que les caractéristiques des morues-lingues et des masses d'œufs de morue-lingue n'ont subi aucun changement dramatique ou soutenu au cours de 21 dernières années (1990-2011).

INTRODUCTION

Lingcod (*Ophidodon elongatus*) is a large demersal marine fish species that inhabits nearshore rocky reefs predominantly at depths from 10 to 100m. Spawning occurs in the winter between January through March, with males arriving and establishing spawning territories as early as November. Egg masses containing as many as 500 000 eggs are deposited by females in rocky crevices or under rocks within male territory, after which individual males actively guard one or more egg masses (to an observed maximum of three) against predation for six weeks until hatching in the early spring (Cass et al. 1990, King and Withler 2005). Spawning locations are returned to year after year by the same males (Withler et al. 2004, King and Withler 2005), who show extremely high levels of nest site fidelity (King and Withler 2005). Unguarded egg masses usually succumb to predation (Low and Beamish 1978).

Lingcod in the Strait of Georgia, British Columbia have traditionally been a very important species in both commercial and recreational fisheries. However, populations have been severely depressed for several decades, with early 1990s estimates of spawning biomass at only 5% of observed historic levels (Martell and Wallace 1998). Recovery is occurring slowly following the closure of the commercial fishery for lingcod in the Strait of Georgia in 1990, and of the recreational fisheries from 2002-2005 (Richards and Hand 1989, King 2001, Logan et al. 2005) with the last stock assessment estimating the biomass to only be at 15% of historic biomass levels (Logan et al. 2005). In order to monitor and assess the population, egg mass density SCUBA surveys - which first started in 1978 (Low and Beamish 1978) – were re-established but were carried out intermittently through the 1990s (Yamanaka and Richards 1995), and then annually from 2001-2007 (King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty et al. 2005, Haggarty and King 2007, Surry and King 2007). This survey was undertaken to add to the existing time series from Snake Island Reef, one of the primary index sites, and to provide an ongoing source of biological and relative abundance information for Strait of Georgia lingcod, as recommended in the 2003 stock assessment framework (King et al. 2003).

In 2001 a stock assessment document outlined conservation concerns regarding inshore rockfish (*Sebastes spp*.) in the Strait of Georgia and the need for non-intrusive methods of assessing abundance (Yamanaka and Lacko 2001). Rockfish density estimates obtained using visual counts can provide auxiliary information to fishery and research surveys for inshore rockfish. From 2004-2007, visual counts of large, commonly encountered reef fishes – including rockfish *spp.* - have been undertaken during annual lingcod egg mass density surveys at Snake Island and Entrance Island reefs (King and Haggarty 2004, Haggarty et al. 2005, Haggarty and King 2007).

In previous years, egg mass density surveys in Statistical Area 17 of the Strait of Georgia have occurred mainly at Snake Island Reef, and Entrance Island near Nanaimo (Low and Beamish 1978, 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 2010 and 2011 egg mass density surveys were largely undertaken at Snake Island Reef, with one dive at Entrance Island Reef in 2010 and six dives at Law Point in 2011. Egg mass density estimates now exist for Snake Island Reef for 1990, 1991, 1994, 2001-2007, and 2010-2011. For Entrance Island, egg mass density estimates exist for 2004-2006, and for 2010. The dive survey at Law Point is the first available survey.

METHODS

Snake Island reef is a small reef approximately 10 by 20m with an average depth of 10m, located near Nanaimo, British Columbia (**Figure 1** and **Figure 2**). It is predominantly flat and open without large flora such as Agarum *spp*., but containing several large rocks and boulders providing suitable lingcod nesting sites.

Entrance Island is a small rock island situated one mile off the northeast end of Gabriola Island (**Figure 3**). The south and west sides of the island drop off relatively steeply, with the reef extending more gradually off the north and west sides of the island. Reef complexity, relief, and substrate type vary widely with dive location. Some sites are characterized by relatively high complexity, high relief, rocky substrate, and high flora coverage, whereas others are simple, flat and dominated by finer substrate (i.e. sand and gravel)

Law Point is located at the northeast end of Gabriola Island, slightly northwest of Vance Island (**Figure 4**). Between Vance Island and Law Point, the bottom is quite shallow (< 10 m), while at Law Point and to the west of Law Point, the bottom drops off relatively steeply at around the 10 m depth contour. Large boulders and caves are present, the relief is steep in places, and much of the substrate is covered in large flora (predominantly Agarum *spp*.).

In 2010, survey dives were carried out on Snake Island reef between February 15th – 19th and on February 22nd, 2010 by Department of Fisheries and Oceans staff. One dive was carried out at Entrance Island reef on February 25th, 2010, with weather limiting further dive opportunities within the allotted time frame for the survey. In 2011, survey dives were carried out at Snake Island reef on February 15th, 17th, 21st and 23rd, 2011. A high abundance of sea lions (approx. 30 – 50) at Entrance Island prevented diving at this site. Six dives were carried out at Law Point on February 25th, 2011. As a dive platform, an aluminum tender vessel (6.7m) equipped with twin 115-hp engines, a depth sounder, GPS, and notebook computer with Nobeltec Visual Navigation Suite v.4.0 was used.

In all previous surveys, Snake Island reef was divided into 8 sections (section 1 to the north and section 8 to the south (**Figure 5**). Dive locations were chosen in sequence by randomly selecting sections and then deploying an anchor buoy within the selected sections, using the depth sounder to target appropriate substrate and depth (bottom with some relief and with a maximum diveable depth of 20m or 60 ft) (outlined in King and Beaith 2001). To ensure even coverage within a short time period, for the 2010 and 2011

surveys, approximate dive locations (GPS points) at Snake Island reef were selected prior to the survey based on dive locations from the 2001 survey (for the 2010 survey) and from 2001 and 2002 surveys (for the 2011 survey). Specifically, for the 2010 survey the first three dive locations in each section from the 2001 survey (for a total of 24 dive locations) were chosen. For the 2011 survey, any subsequent, remaining dive locations in each section from the 2001 survey were chosen, followed by sequential dive locations in each section from the 2002 survey. Error in GPS location, slight movement of the boat off the pre-chosen GPS location, and the imprecise nature of the anchor buoy deployment mean actual dive quadrats are randomly selected near target areas. . For the 2010 Entrance Island Dive locations, the first four dive locations were taken from the 2005 survey (Haggarty et al. 2005), for a total of four planned dives. For the 2011 Law Point locations, the anchor buoy was deployed randomly along the 10 m depth contour line. To provide maximum possible coverage of suitable habitat for all sites, dive positions were distributed over the reefs and care was taken to avoid overlap of surveyed areas.

QUADRAT DIVES

For each quadrat dive, after locating the approximate planned GPS location, an anchor buoy was deployed from the vessel and the exact position and depth recorded using Nobeltech. Divers were equipped with a dive light, a 1m fabric measuring tape, a 10m line on a spool. Two divers descended the line together to the anchor weight, with the second diver attaching the 10m line to the anchor line close to the weight while the first diver recorded buoy depth. The primary diver then systematically searched for, measured and recorded lingcod egg masses within the circular quadrat formed by the secondary diver swimming slowly and sweeping the 10m line around the weight. The primary diver used a dive light when necessary to search under rocks, within crevices, or beneath large flora.

Lingcod egg masses

When an egg mass was encountered, the depth, position, appearance, dimensions and presence or absence of a guarding male was recorded. Depth was measured in feet using the primary diver's depth gauge and later converted to meters. The position of the egg mass was 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).

Guarding males

When an egg mass was located, the presence or absence of a guarding male was noted, as well as how many other nests each male was guarding. Guarding males were attributed to an egg mass if they were within 1-2m of the egg mass and exhibited protective or territorial behaviour when the egg mass was approached. If a male was guarding a nest

outside the quadrat area, the outside nest was considered in the classification of the male (i.e. M2 = male guarding two egg masses) but was not included in the nest count. If possible, the length of each guarding male was measured in centimetres by pulling a measuring tape alongside the fish as it rested on the bottom.

Reef Fishes

In addition to recording guarding males, divers also counted and recorded non-guarding male lingcod, copper rockfish (*Sebastes caurinus*) and quillback rockfish (*S. maliger*) adults and juveniles, kelp greenling (*Hexagrammos decagrammus*) males and females, and any surfperches (*Rhacochilus spp.*) or other large (>20cm) reef fishes encountered within each quadrat. Small abundant fishes such as Puget Sound rockfish (*Sebastes emphaeus*), sculpins, and gobies were not counted.

Habitat and Structure Characteristics

On each dive, the habitat within each quadrat was quantified by recording the percentage within the quadrat area (by visual estimate) that corresponded to each of four levels of complexity: simple = smooth, no crevices; low complexity = less than 25% covered by crevices; medium complexity = 25-50% covered by crevices; and high complexity = more than 50% covered by crevices. Relief (slope) was also quantified by recording the percentage of the quadrat area (by visual estimate) that corresponded to each of four levels of 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 less than 45 degree slope); wall (greater than 45 degree slope). Lastly, the substrate within each quadrat was quantified by recording the percentage of the quadrat area (by visual estimate) that corresponded to each of three types of substrate: rock (hardpan, bedrock, or boulders); coarse (cobble, gravel, shell); and fine (sand or mud). Coverage of large flora was visually estimated as a percentage of the quadrat area.

ANALYSIS

Egg mass density (number of egg masses/m^2) for each quadrat was calculated by dividing the number of egg masses encountered by the area of the circular 10m radius quadrat. The density of lingcod and other reef fishes was calculated in the same manner.

Egg mass density, egg mass volume, reef fish densities, and length of guarding lingcod were compared among years with available data using the Kruskal-Wallace nonparametric analysis of variance (Zar 1999). Multiple comparisons were then performed on the ranked data to determine if significant difference existed between 2010 and 2011 data and those from previous years in the time series. The software package STATISTICA 7 was used to perform all statistical tests.

Pie charts were created to categorically represent the dominant habitat characteristics of quadrats where lingcod egg masses were found at Snake Island reef in 2010 and 2011.

Dominant complexity, relief and substrate type respectively were chosen based on highest percentage observed within each quadrat.

RESULTS

In 2010, a total of twenty-four quadrat dives were carried out on Snake Island reef between February 15th and February 24th (**Table 1**). Due to weather and time constraints, only one dive was carried out at Entrance Island reef, on February 25th, 2010 (**Table 1**). Out of a total of ten working days allotted to the survey (February 15th - February 19th and February 22nd - February 26th), weather conditions permitted diving to occur on five days.

In 2011, a total of twenty-four quadrat dives were carried out on Snake Island reef between February 15th and February 23rd (**Table 2**). No dives were carried out at Entrance Island because of a high abundance of sea lions at the site. Six dives were carried out at Law Point on February 25th, 2011 (**Table 2).** Out of a total of nine working days allotted to the survey (February 15th – February 18th and February 21st – February 25th), weather conditions permitted diving to occur on five days.

At Snake Island reef, quadrats were distributed over the reef at depths ranging from 6.1 m (20 ft) to 18.3 m (60 ft) in 2010, and from 6.3 m (21 ft) to 15.5 m (51 ft) in 2011 (**Table 1** and **Table 2**). Quadrats generally covered areas of the reef that have been identified as containing suitable nesting habitat (i.e. flat or gradual slope with open, barren areas mixed with rocks, boulders, and crevices, and lacking large concentrations of the brown algae Agarum *spp.*) (King and Beaith 2001). The dive carried out at Entrance Island reef in 2010 was to a depth of 12.8 m (42 ft) (**Table 1**). Law Point quadrats were deployed along the 10 m depth contour, and ranged from maximum depths of 9.1 m (30 ft) to 13.6 m (45 ft) (**Table 2**).

For both surveys and at all sites, suitable weather conditions for entering and exiting the water for diving were generally winds of less than 17 knots, with swells less than 1.0 m and no whitecaps.

EGG MASS DENSITY

Snake Island

In 2010, fourteen quadrats at Snake Island Reef contained lingcod egg masses (**Tables 1, 3** and **5**). A total of 19 egg masses were observed in 24 quadrats within a total surveyed area of 7539.823 m^2. Egg mass density over the twenty four quadrats ranged from 0 to 0.009549 egg masses/ m^2, with a median of 0.003183 egg masses/ m^2 and a mean of 0.002520 egg masses/ m^2.

In 2011, nineteen quadrats at Snake Island Reef contained lingcod egg masses (**Tables 2, 4** and **6**). A total of 29 egg masses were observed in 24 quadrats within a total surveyed

area of 7539.823 m^2. Egg mass density over the twenty four quadrats ranged from 0 to 0.012732 egg masses/ m^2, with a median of 0.003183 egg masses/ m^2 and a mean of 0.003846 egg masses/ m^2.

When egg mass density was compared among years (2001-2007 and 2010-2011), there was a significant difference in density across years (Kruskal Wallace $\chi 2 = 17.38281$, df = 8, p = 0.0264; **Figure 6A**). Multiple comparisons on the ranked data between 2010, 2011 and all other years, respectively, showed significant differences between 2010 and both 2001 and 2003 densities, but no significant differences between 2011 and all other years' densities. Box plots (**Figure 6A**) indicated that egg mass density was significantly lower in 2010 than in 2001 and 2003.

Entrance Island

No egg masses were observed during the single dive at Entrance Island in 2010.

Law Point

Two quadrats at Law Point contained lingcod egg masses (**Tables 2**, **4** and **6**). A total of three egg masses were observed in six quadrats within a total surveyed area of 1884.9558 m^2. Egg mass density over the six quadrats ranged from 0 to 0.006366 egg masses/ m^2, with a median of 0 egg masses/ m^2 and a mean of 0.001592 egg masses/ m^2.

EGG MASS AND GUARDING MALE OBSERVATIONS

Snake Island

Egg Mass Location and Appearance

In 2010, out of the nineteen egg masses observed during quadrat dives, none were located out in the open or in a vertical crevice, fifteen were located under a rock, and four were observed in a horizontal crevice (**Table 5**). In 2011, results were more variable, with one egg mass was located out in the open, one egg mass located half out in the open and half under a rock, eighteen located entirely under a rock, seven observed in a horizontal crevice and two observed in a vertical crevice (**Table 6**). These results are consistent with egg mass locations in previous surveys, where the largest proportion of egg masses were observed 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, JRK: Unpublished Data).

In 2010, egg mass appearance ranged from stage 2 (white) to stage 4 (eyed). Unlike in previous years, egg masses in 2010 appeared uniform with no combinations of stages observed. The predominant stage was stage 2 (white) with ten egg masses, followed by stage 3 (grey) with seven egg masses, and lastly by stage 4 (eyed) with two egg masses (**Table 5**). In 2011, egg masses were largely stage 2 (white) (n = 15). Three egg masses

were stage 1 (creamy), ten egg masses were a combination of stage 1 (creamy) and stage 2 (white), and one egg mass was a combination of stage 2 (creamy) and stage 3 (grey-white) (**Table 6**). These results are inconsistent with egg mass development in previous surveys at Snake Island, where all stages of development (from 1 to 5) were present, 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; JRK: Unpublished Data).

Egg Mass Volume

Egg mass volume in the 2010 quadrats ranged from 1000 – 6720 cm^3 with a median of 2944 cm^3 and a mean of 3280.59 cm^3 (**Table 5**). In 2011, egg mass volume ranged from 1440 – 10692 cm^3 with a median of 5661.00 cm^3 and a mean of 5852.25 cm^3 (**Table 6**). When quantitative measurements of egg mass volume were compared across years (2002-2007, and 2010-2011), a significant difference in volumes was found (Kruskal Wallace $\chi 2 = 24.88893$, df = 7, p = 0.0008; **Figure 6B**). Multiple comparisons on the ranked data indicated no significant differences between 2010 and all other years' volumes, while significant differences in volume were found between 2011 and 2004, 2005 and 2007 respectively. Box plots (**Figure 6B**) suggested that egg mass volume was significantly higher in 2011 than in 2004, 2005 and 2007.

Guarding Males

In 2010, seventeen of the nineteen observed egg masses were guarded, with two males guarding two nests each (**Tables 1** and **5**). In the first instance, the second egg mass guarded by the observed male was outside of the quadrat area (quadrat 6), whereas in the second case, the second egg mass guarded by the observed male was within the quadrat area (quadrat 14). In 2011, twenty-five of the twenty-eight observed egg masses were guarded, with one male guarding two nests (**Tables 2** and **6**). These results are consistent with previous surveys, where typically over 70% of the observed nests were guarded, and over 60% of the guarding males were guarding only one nest (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; JRK: Unpublished Data). No apparent predation was observed on the two unguarded nests observed in 2010, or on the three unguarded nests observed in 2011.

In 2010, measurements of guarding male length were obtained in all but three cases where guarding males were observed, for a total of thirteen measurements of male length (**Table 5**). 2010 lengths ranged from 52 – 84 cm total length (TL), with a mean length of 62.38 cm. Similarly, in 2011 measurements of guarding male length were obtained in all but three cases where guarding males were observed. In total twenty-two measurements of male length were obtained, ranging from 50 – 82.5 cm total length (TL) with a mean length of 60.11 cm (**Table 6**).

When guarding male lengths were compared across years, no significant difference in lengths was found (Kruskal Wallis $\chi 2 = 13.37613$, df = 8, p = 0.0996; **Figure 7**). Multiple comparisons, however, indicated a significant difference between guarding male length in 2011 and 2003. Box plots (**Figure 7**) suggested a significantly lower guarding male length in 2011 than in 2003.

Entrance Island

No egg masses were observed during the single dive carried out at Entrance Island in 2010.

Law Point

Egg Mass Location and Appearance

Out of the three egg masses observed at Law Point, one was out in the open and two were found under rocks. All egg masses were stage 2 (white) (**Table 6**).

Egg Mass Volume

Egg mass volume ranged from 5200 – 16380 cm^3 with a median of 12672 cm^3 and a mean of 11424 cm^3 (**Table 6**).

Guarding Males

Two of the three egg masses observed at Law Point were guarded. Both observed egg nests were guarded by a single lingcod (TL = 50 cm) (**Table 2** and **6**). No apparent predation was observed on the one unguarded nest.

REEF FISH DENSITY

Snake Island

Lingcod

In 2010, in addition to the sixteen guarding male lingcod observed in the quadrats, fourteen non-guarding lingcod were observed within the dive quadrats (**Table 7**). Total lingcod density in each quadrat ranged from 0 – 0.009549 lingcod/m^2 with a median of 0.004775 lingcod/m^2 and a mean of 0.006063 lingcod/m^2. In 2011, in addition to the twenty-five guarding male lingcod observed in the quadrats, twenty-two non-guarding male lingcod were observed within the dive quadrats (**Table 8**). Total lingcod density in each quadrat ranged from 0 – 0.015915 lingcod/ m^2 with a median of 0.006366 lingcod/ m^2 and a mean of 0.006234 lingcod/ m^2. Non-guardian male lengths were measured in fourteen (of the twenty-two) cases, with a mean total length (TL) of 55 cm (**Table 9**).

Guarding and non-guarding lingcod were also counted in 2001-2007 (**Appendix Table 1**).

Previous reports comparing lingcod densities among years found significant differences (Haggarty and King 2007, Surry and King 2007), with the mean density in 2007 being the lowest on record (0.002984 fish/ m^2). With the addition of 2010 and 2011 data, significant differences were also found among years (Kruskal Wallis $\chi 2 = 38.16213$, df = 8, $p < 0.05$; **Figure 8**). Multiple comparisons revealed significant differences in density between 2010 and 2001, 2002, 2003 and 2004 (respectively) (with 2010 density being significantly lower; **Figure 8**). However, density in 2011 was higher than that observed in 2010, and was only significantly lower than that observed in 2001.

Other Reef Fishes

As in previous years, 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 in both 2010 and 2011 (**Tables 7** and **8**). In previous years (for example, in 2007), small numbers of tiger rockfish (*S. nigrocinctus*), striped surfperch (*Embiotoca lateralis*), and wolf-eel (*Anarrhichthys ocellatus*) were encountered, whereas no individuals of these species were observed during this survey. In both 2010 and 2011, reef fish (not including lingcod) were observed in all but one quadrat, with the maximum number observed in quadrat 7 ($n = 18$) in 2010 (**Table 7**) and in quadrat 3 ($n = 21$) in 2011 (**Table 8**). The minimum number of reef fish observed in 2010 was in quadrat 20 ($n = 0$) (**Table 7**), and in 2011 was in quadrat 16 ($n = 0$) (**Table 8**).

In 2010, copper rockfish density ranged from 0 – 0.019099 fish/m^2 with a median of 0.007958 fish/m^2 and a mean of 0.010052 fish/m^2. In 2011, copper rockfish density ranged from 0 – 0.003183 fish/m^2 with a median of 0.00000 fish/m^2 and a mean of 0.001194 fish/m^2. Quillback rockfish density in 2010 ranged from 0 – 0.012732 fish/m^2 with a median of 0.006366 fish/m^2 and a mean of 0.006897 fish/m^2. In 2011, quillback rockfish density ranged from 0 – 0.057296 fish/m^2 with a median of 0.003183 fish/m^2 and a mean of 0.006499 fish/m^2. Kelp greenling were the most abundant reef fish in both 2010 and 2011, with densities ranging from 0 - 0.022282 fish/m^2 (in 2010) and from 0 – 0.019099 fish/m^2 (in 2011). Medians were 0.009549 fish/m^2 (in 2010) and 0.001592 fish/ m^2 (in 2011), and means were 0.008719 fish/m^2 (in 2010) and 0.003979 fish/m^2 (in 2011) (**Tables 7** and **8**).

Quadrat counts of reef fishes other than lingcod have been completed at Snake Island Reef each year from 2004-2007 (**Figure 8**). When densities were compared among years for copper rockfish, quillback rockfish and kelp greenling, both kelp greenling and copper rockfish showed significant differences among years (kelp greenling: Kruskal Wallis $\chi^2 = 15.82454$, df = 5, $p = 0.0074$; copper rockfish: Kruskal Wallis $\chi^2 = 34.94843$, df = 5, $p = 0.0000$). Quillback rockfish showed no significant differences among years (Kruskal Wallis $\chi^2 = 8.300880$, df = 5, $p = 0.1404$). Multiple comparisons revealed significant differences between 2010 and 2011 kelp greenling densities; 2010 and 2005

copper rockfish densities; and 2011 and 2004, 2005, 2006, and 2007 copper rockfish densities, respectively. Box plots (**Figure 8**) suggested kelp greenling densities were significantly higher in 2010 than in 2011, and that copper rockfish density was significantly lower in 2010 than in 2005, and in 2011 when compared to all other years except 2010.

Entrance Island

Lingcod

No lingcod were observed during the single dive at Entrance Island.

Other Reef Fishes

The most abundant reef fish observed during the single dive on Entrance Island reef was kelp greenling, with a density of 0.124141 fish/m^2. No copper rockfish were observed; 1 juvenile quillback rockfish and 1 juvenile china rockfish (*Sebastes nebulosus*) were observed respectively; and 3 pile surfperch (*Rhacochuilus vacca*) were observed, for a total of 44 reef fishes other than lingcod.

Law Point

Lingcod

A total of nine lingcod were observed at Law Point, of which only one was a guarding male. Lingcod were observed in every dive quadrat, with total lingcod density ranging from 0.003183 – 0.009549 lingcod/m^2 with a median of 0.003183 lingcod/m^2 and a mean of 0.004775 lingcod/m^2 (**Table 8**). Non-guardian male lengths were measured in three cases with a mean total length (TL) of 70.3 cm (**Table 9**).

Other Reef Fishes

Large reef fishes were observed in all dive quadrats at Law Point, with kelp greenling being the most abundant (**Table 8**). Densities ranged from 0.009549 – 0.035014 fish/ m^2 with a median of 0.020690 fish/ m^2 and a mean of 0.021221 fish/ m^2. Copper rockfish, quillback rockfish, pile surfperch (*Rhacochilus vacca*) and one black rockfish (*Sebastes melanops*) were also observed. Copper rockfish density ranged from 0 – 0.006366 fish/m^2 with a median of 0.003183 fish/m^2 and a mean of 0.003979 fish/m^2. Quillback rockfish density ranged from 0 – 0.009549 fish/m^2 with a median of 0.006366 fish/m^2 and a mean of 0.006366 fish/m^2. The maximum number of pile surfperch observed in one quadrat was 10, while the minimum was 0. The one black rockfish was observed in quadrat LP4 at a depth of approximately 10.7 m (35 ft).

HABITAT CHARACTERISTICS

The dominant habitat characteristics of quadrats where lingcod egg masses were found (in both 2010 and 2011) were simple, flat, rocky areas (**Table 3** and **Table 4, Figure 9**). 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. Quadrats dominated by coarse, fine substrate and with heavy Agarum *spp.* coverage appeared to be less favourable.

At Law Point, both quadrats where lingcod were observed had high complexity (i.e. more than 50% of each quadrat was covered by crevices), low relief (i.e. 2-7 ft. difference in depth), and were dominated by either rock (hardpan, bedrock and/or boulders) or coarse substrate (cobble, gravel and/or shell). Agarum *spp.* covered from 40-65 % of each quadrat where lingcod were observed (**Table 4**).

DISCUSSION

2010 and 2011 are the eleventh and twelfth years, respectively, that lingcod egg mass density has been estimated at the Snake Island Reef index site. Although 2010 and 2011 data are not consecutive with previous years' data (i.e. lacking survey data for 2008 and 2009), it appears that no dramatic change in egg mass density, egg mass volume, guarding male length, or lingcod density has occurred over the last two years since the 2007 survey. Similarly, no longer-term, sustained change in any of the observed lingcod variables is apparent based on the data from 2001-2007 and 2010-2011, and based on previous studies that considered data from the 1990s. Surry and King (2007) found that egg mass density, egg mass volume, and total lingcod density for 2007 were among the lowest of the time series; however, differences between 2007 and other years' data were for the most part not statistically significant. When 2010-2011 data were compared to 2007 data, slightly higher values were apparent for egg mass density, egg mass volume, and guarding male length in recent years, but the only statistical difference was found between egg mass volume (with that observed in 2011 being higher than that observed in 2007). Although no lingcod were observed during the single dive carried out at Entrance Island, future surveys should still include this site, as it had the highest lingcod egg mass density out of all sites surveyed in 2005 (6 sites total) (Haggarty et al. 2005). Habitat characteristics at Law Point were markedly different from those at Snake Island, with a high percent cover of Agarum *spp.* for all dive quadrats. Nevertheless, one guarding male, eight non-guarding males and three lingcod egg masses were observed, suggesting some variability in habitat and nest site characteristics for this 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 and Entrance Island Reef, Feb 15 - 25, 2010.

Quadrat	Date	Latitude	Longitude	Depth (m)	Visibility (m)	No. Egg Masses		
						Guarded	Not Guarded	Density
1	15/02/2010	49° 12' 45.18"	123° 53' 01.86"	13.4	11	0	0	0
2	15/02/2010	49° 12' 47.10"	123° 53' 03.06"	13.7	11	1	0	0.003183
3	15/02/2010	49° 12' 39.42"	123° 53' 04.68"	6.4	11	1	0	0.003183
4	15/02/2010	49° 12' 41.88"	123° 53' 04.74"	7.6	11	0	0	0
5	16/02/2010	49° 12' 37.50"	123° 53' 07.98"	10.7	12	1	0	0.003183
6	16/02/2010	49° 12' 36.42"	123° 53' 07.08"	12.2	10	1	1	0.006366
7	16/02/2010	49° 12' 38.64"	123° 53' 07.38"	9.1	10	0	0	0
8	16/02/2010	49° 12' 37.62"	123° 53' 02.46"	18.3	10	0	0	0
9	18/02/2010	49° 12' 41.88"	123° 53' 07.56"	11.9	9	1	0	0.003183
10	18/02/2010	49° 12' 44.64"	123° 53' 05.64"	10.7	9	0	0	0
11	18/02/2010	49° 12' 43.20"	123° 53' 03.06"	9.1	9	0	0	0
12	18/02/2010	49° 12' 55.98"	123° 53' 03.24"	12.8	9	0	1	0.003183
13	18/02/2010	49° 12' 45.60"	123° 53' 04.86"	6.1	9	1	0	0.003183
14	18/02/2010	49° 12' 46.92"	123° 53' 05.16"	12.2	8	3	0	0.009549
15	19/02/2010	49° 12' 44.46"	123° 53' 02.04"	14.3	9	0	0	0
16	19/02/2010	49° 12' 46.38"	123° 53' 02.82"	12.2	9	1	0	0.003183
17	19/02/2010	49° 12' 43.08"	123° 53' 06.00"	9.1	9	1	0	0.003183
18	19/02/2010	49° 12' 39.30"	123° 53' 07.80"	8.5	10	0	0	0
19	19/02/2010	49° 12' 37.44"	123° 53' 06.00"	6.7	10	0	0	0
20	22/02/2010	49° 12' 36.42"	123° 53' 05.52"	9.8	7	0	0	0
21	22/02/2010	49° 12' 39.00"	123° 53' 04.98"	7.6	7	2	0	0.006366
22	22/02/2010	49° 12' 40.50"	123° 53' 08.40"	9.4	7	1	0	0.003183
23	22/02/2010	49° 12' 43.80"	123° 53' 06.78"	11.9	7	2	0	0.006366
24	22/02/2010	49° 12' 44.16"	123° 53' 03.90"	8.8	7	1	0	0.003183
E1	25/02/2010	49° 12' 32.52"	123° 48' 24.72"	12.8	11	0	0	0

Table 2. 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 and Law Point, Feb 15 - 25, 2011.

Quadrat	Date	Latitude	Longitude	Depth (m)	Visibility (m)	No. Egg Masses		
						Guarded	Not Guarded	Density
1	15/02/2011	49° 12' 45.60"	123° 53' 03.30"	12.2	10	1	0	0.003183099
2	15/02/2011	49° 12' 46.00"	123° 53' 04.80"	14.0	10	0	1	0.003183099
3	15/02/2011	49° 12' 45.40"	123° 53' 07.00"	15.5	10	4	0	0.012732394
4	17/02/2011	49° 12' 43.74"	123° 53' 03.96"	8.8	11	0	0	0
5	17/02/2011	49° 12' 44.40"	123° 53' 03.18"	8.2	11	1	0	0.003183099
6	17/02/2011	49° 12' 44.52"	123° 53' 02.58"	10.2	10	0	0	0
7	17/02/2011	49° 12' 44.40"	123° 53' 05.28"	7.7	15	1	0	0.003183099
8	17/02/2011	49° 12' 42.84"	123° 53' 06.18"	7.6	10	1	0	0.003183099
9	17/02/2011	49° 12' 43.98"	123° 53' 05.46"	8.8	10	1	0	0.003183099
10	21/02/2011	49° 12' 36.96"	123° 53' 04.68"	7.4	5	1	1	0.006366197
11	21/02/2011	49° 12' 39.36"	123° 53' 05.70"	8.1	5	0	0	0
12	21/02/2011	49° 12' 40.86"	123° 53' 05.70"	6.5	6	0	0	0
13	21/02/2011	49° 12' 41.58"	123° 53' 06.48"	7.6	6	2	0	0.006366197
14	21/02/2011	49° 12' 44.40"	123° 53' 04.92"	6.3	5	1	1	0.006366197
15	21/02/2011	49° 12' 40.74"	123° 53' 08.46"	8.2	6	1	0	0.003183099
16	21/02/2011	49° 12' 38.22"	123° 53' 04.86"	7.2	5	0	0	0
17	21/02/2011	49° 12' 36.90"	123° 53' 04.92"	6.9	5	1	0	0.003183099
18	21/02/2011	49° 12' 37.56"	123° 53' 04.98"	5.7	6	1	0	0.003183099
19	23/02/2011	49° 12' 38.28"	123° 53' 07.38"	9.5	6	1	0	0.003183099
20	23/02/2011	49° 12' 37.20"	123° 53' 06.42"	8.1	7	3	0	0.009549296
21	23/02/2011	49° 12' 36.60"	123° 53' 07.08"	8.8	6	2	0	0.006366197
22	23/02/2011	49° 12' 34.98"	123° 53' 07.56"	9.1	7	1	0	0.003183099
23	23/02/2011	49° 12' 35.40"	123° 53' 06.18"	7.8	7	1	0	0.003183099
24	23/02/2011	49° 12' 31.86"	123° 53' 07.32"	8.6	8	2	0	0.006366197
LP1	25/02/2011	49° 12' 34.14"	123° 42' 03.84"	9.1	5	0	1	0.003183099
LP2	25/02/2011	49° 09' 34.92"	123° 42' 08.88"	13.2	5	0	0	0
LP3	25/02/2011	49° 09' 34.92"	123° 42' 13.26"	13.3	5	0	0	0
LP4	25/02/2011	49° 09' 35.28"	123° 42' 17.10"	13.6	5	2	0	0.006366197
LP5	25/02/2011	49° 09' 35.52"	123° 42' 26.40"	12.1	5	0	0	0
LP6	25/02/2011	49° 09' 35.94"	123° 42' 31.26"	11.2	6	0	0	0

Table 3. Complexity of habitat, relief (slope), substrate type, and coverage by Agarum *spp.* for lingcod egg mass quadrat dives at Snake Island Reef and Entrance Island Reef, Feb 15-25, 2010. Quadrats indicated with bold type contained egg masses.

Quadrat	Date	Complexity[a] (% of quadrat)				Relief[b] (% of quadrat)				Substrate[c] (% of quadrat)			Agarum (% of quadrat)
		Simple	Low	Medium	High	Flat	Low	High	Wall	Rock	Coarse	Fine	
1	15/02/2010	25	25	50	0	50	0	50	0	95	5	0	10
2	**15/02/2010**	**60**	**40**	**0**	**0**	**75**	**25**	**0**	**0**	**90**	**10**	**0**	**0**
3	**15/02/2010**	**40**	**60**	**0**	**0**	**100**	**0**	**0**	**0**	**90**	**10**	**0**	**0**
4	15/02/2010	80	20	0	0	100	0	0	0	100	0	0	0
5	**16/02/2010**	**70**	**20**	**10**	**0**	**100**	**0**	**0**	**0**	**90**	**10**	**0**	**0**
6	**16/02/2010**	**0**	**20**	**80**	**0**	**95**	**5**	**0**	**0**	**0**	**0**	**0**	**0**
7	16/02/2010	20	30	50	0	10	90	0	0	15	50	35	0
8	16/02/2010	50	0	0	50	95	5	0	0	0	85	15	80
9	**18/02/2010**	**0**	**5**	**0**	**95**	**5**	**95**	**0**	**0**	**100**	**0**	**0**	**0**
10	18/02/2010	50	0	50	0	50	50	0	0	95	0	5	0
11	18/02/2010	95	5	0	0	100	0	0	0	95	5	0	0
12	**18/02/2010**	**10**	**40**	**0**	**50**	**50**	**50**	**0**	**0**	**90**	**10**	**0**	**40**
13	**18/02/2010**	**70**	**10**	**20**	**0**	**80**	**0**	**20**	**0**	**100**	**0**	**0**	**0**
14	**18/02/2010**	**20**	**10**	**10**	**60**	**50**	**50**	**0**	**0**	**90**	**10**	**0**	**0**
15	19/02/2010	80	0	20	0	10	85	5	0	95	5	0	15
16	19/02/2010	**90**	**0**	**5**	**5**	**0**	**98**	**2**	**0**	**98**	**2**	**0**	**0**
17	19/02/2010	**85**	**0**	**5**	**10**	**95**	**5**	**0**	**0**	**95**	**5**	**0**	**0**
18	19/02/2010	90	5	5	0	20	75	5	0	98	2	0	0
19	19/02/2010	98	2	0	0	95	5	0	0	98	2	0	0
20	22/02/2010	85	15	0	0	100	0	0	0	100	0	0	0
21	**22/02/2010**	**85**	**5**	**10**	**0**	**100**	**0**	**0**	**0**	**100**	**0**	**0**	**0**
22	**22/02/2010**	**80**	**10**	**10**	**0**	**80**	**20**	**0**	**0**	**95**	**5**	**0**	**0**
23	**22/02/2010**	**20**	**30**	**50**	**0**	**60**	**10**	**30**	**0**	**95**	**5**	**0**	**0**
24	**22/02/2010**	**80**	**10**	**10**	**0**	**100**	**0**	**0**	**0**	**95**	**5**	**0**	**5**
E1	25/02/2010	0	0	15	85	0	10	90	0	65	25	10	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 4. Complexity of habitat, relief (slope), substrate type, and coverage by Agarum *spp.* for lingcod egg mass quadrat dives at Snake Island Reef and Law Point, Feb 15-25, 2011. Quadrats indicated with bold type contained egg masses.

Quadrat	Date	Complexity[a] (% of quadrat)				Relief[b] (% of quadrat)				Substrate[c] (% of quadrat)			Agarum (% of quadrat)
		Simple	Low	Medium	High	Flat	Low	High	Wall	Rock	Coarse	Fine	
1	**15/02/2011**	**20**	**60**	**20**	**0**	**50**	**25**	**25**	**0**	**60**	**30**	**10**	**0**
2	**15/02/2011**	**90**	**10**	**0**	**0**	**100**	**0**	**0**	**0**	**85**	**15**	**0**	**1**
3	**15/02/2011**	**10**	**10**	**40**	**40**	**0**	**50**	**20**	**30**	**85**	**10**	**5**	**0**
4	17/02/2011	75	25	0	0	0	100	0	0	100	0	0	0
5	**17/02/2011**	**75**	**25**	**0**	**0**	**0**	**100**	**0**	**0**	**95**	**5**	**0**	**0**
6	17/02/2011	90	10	0	0	90	10	0	0	95	5	0	0
7	**17/02/2011**	**65**	**35**	**0**	**0**	**90**	**10**	**0**	**0**	**85**	**10**	**5**	**0**
8	**17/02/2011**	**75**	**10**	**15**	**0**	**0**	**100**	**0**	**0**	**95**	**5**	**5**	**5**
9	**17/02/2011**	**80**	**10**	**10**	**0**	**90**	**10**	**0**	**0**	**85**	**15**	**0**	**0**
10	**21/02/2011**	**10**	**80**	**10**	**0**	**10**	**90**	**0**	**0**	**25**	**70**	**5**	**10**
11	21/02/2011	10	80	10	0	98	2	0	0	80	15	5	0
12	21/02/2011	60	20	20	0	98	2	0	0	90	7	3	0
13	**21/02/2011**	**60**	**20**	**20**	**0**	**85**	**15**	**0**	**0**	**25**	**75**	**5**	**0**
14	**21/02/2011**	**25**	**60**	**15**	**0**	**80**	**20**	**0**	**0**	**60**	**40**	**0**	**0**
15	**21/02/2011**	**60**	**20**	**20**	**0**	**5**	**15**	**80**	**5**	**95**	**5**	**0**	**0**
16	21/02/2011	80	20	0	0	90	10	0	0	85	15	0	0
17	**21/02/2011**	**90**	**10**	**0**	**0**	**95**	**5**	**0**	**0**	**95**	**5**	**0**	**0**
18	**21/02/2011**	**80**	**20**	**0**	**0**	**100**	**0**	**0**	**0**	**98**	**2**	**0**	**0**
19	**23/02/2011**	**50**	**25**	**25**	**0**	**90**	**10**	**0**	**0**	**50**	**40**	**10**	**0**
20	**23/02/2011**	**60**	**15**	**25**	**0**	**90**	**10**	**0**	**0**	**75**	**25**	**0**	**0**
21	**23/02/2011**	**10**	**20**	**30**	**40**	**10**	**90**	**0**	**0**	**20**	**75**	**5**	**0**
22	**23/02/2011**	**25**	**25**	**50**	**0**	**50**	**40**	**10**	**0**	**60**	**40**	**0**	**0**
23	**23/02/2011**	**98**	**2**	**0**	**0**	**100**	**0**	**0**	**0**	**98**	**2**	**0**	**2**
24	**23/02/2011**	**20**	**40**	**20**	**20**	**98**	**2**	**0**	**0**	**25**	**65**	**10**	**10**
LP1	**25/02/2011**	**0**	**0**	**10**	**90**	**20**	**80**	**0**	**0**	**10**	**70**	**20**	**40**
LP2	25/02/2011	0	10	10	80	10	60	20	10	50	30	20	70
LP3	25/02/2011	10	20	20	50	65	15	5	15	2	70	28	70
LP4	**25/02/2011**	**0**	**0**	**20**	**80**	**0**	**40**	**30**	**30**	**60**	**20**	**20**	**65**
LP5	25/02/2011	0	0	0	100	0	0	45	55	60	40	0	80
LP6	25/02/2011	0	0	10	90	0	0	2	98	78	20	2	75

[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 5. Characteristics of each egg mass and guarding male observed during quadrat dives at Snake Island Reef and Entrance Island Reef, February 15-25, 2010. 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 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)
15/02/2010	1	2	14.0	1	2	25x20x10	5000	M1	n/a
15/02/2010	2	3	6.4	1	2	25x25x9	5625	M1	n/a
16/02/2010	3	5	10.7	2	3	28x24x10	6720	M1	65
16/02/2010	4	6	12.2	1	3	23x8x6	1104	M2	52
16/02/2010	5	6	12.2	1	2	28x15x13	5460	M0	n/a
18/02/2010	6	9	11.6	1	2	30x15x6	2700	M1	65
18/02/2010	7	12	11.9	2	3	20x12x9	2160	M0	n/a
18/02/2010	8	13	6.1	1	3	25x11x11	3025	M1	n/a
18/02/2010	9	14	12.8	1	2	25x15x8	3000	M1	63
18/02/2010	10	14	11.6	1	3	n/a	n/a	M2	69
18/02/2010	11	14	11.6	1	2	n/a	n/a	same as above	
19/02/2010	12	16	12.5	1	2	23x11x8	2024	M1	84
19/02/2010	13	17	9.1	1	2	24x12x9	2592	M1	54
22/02/2010	14	21	7.6	1	2	28x11x7	2156	M1	53
22/02/2010	15	21	7.9	1	3	10x10x10	1000	M1	57
22/02/2010	16	22	10.7	1	4	23x16x8	2944	M1	68
22/02/2010	17	23	12.8	2	4	25x23x10	5750	M1	62
22/02/2010	18	23	10.7	1	2	20x9x7	1260	M1	58
22/02/2010	19	24	7.9	2	3	25x13x10	3250	M1	61

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

Table 6. Characteristics of each egg mass and guarding male observed during quadrat dives at Snake Island Reef and Law Point, February 15-25, 2011. 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 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)
15/02/2011	1	1	12.5	2	2	27x22x18	10692	M1	82.5
15/02/2011	2	2	9.0	1	1	33x26x11	9438	M0	n/a
15/02/2011	3	3	13.0	2	1/2	36x24x12	10368	M1	76
15/02/2011	4	3	15.0	3	1	31x15x15	6975	M1	63.5
15/02/2011	5	3	20.0	1	1	31x17x15	7905	M1	51
15/02/2011	6	3	16.0	2	1/2	23x13x12	3588	M1	61
17/02/2011	7	5	31 ft	1	2	22x10x10	2200	M1	n/a
17/02/2011	8	7	8.0	1	2	33x19x12	7524	M1	58
17/02/2011	9	8	26 ft	0	2	25x15x12	4500	M1	53.5
17/02/2011	10	9	8.6	1	2	36x16x15	8640	M1	63
21/02/2011	11	10	8.0	1	2	18x18x12	3888	M0	n/a
21/02/2011	12	10	8.1	1	2	n/a	n/a	M1	n/a
21/02/2011	13	13	8.6	0/1	1/2	26x12x11	3432	M1	50.5
21/02/2011	14	13	8.6	1	1/2	27x11x12	3564	M1	66.5
21/02/2011	15	14	7.5	1	2/3	30x20x14	8400	M1	63.5
21/02/2011	16	14	7.4	1	1/2	33x20x11	7260	M0	n/a
21/02/2011	17	15	9.7	2	2	26x15x12	4680	M1	60.5
21/02/2011	18	17	5.9	1	1/2	45x12x11	5940	M1	57.5
21/02/2011	19	18	6.4	1	2	27x17x11	5049	M1	n/a
23/02/2011	20	19	10.8	1	2	32x18x9	5184	M1	53
23/02/2011	21	20	9.2	1	1/2	31x13x15	6045	M2	56
23/02/2011	22	20	8.1	2	1/2	18x10x8	1440	same as above	
23/02/2011	23	20	8.2	1	1/2	31x20x16	9920	M1	53.5
23/02/2011	24	21	9.2	1	2	23x16x9	3312	M1	71
23/02/2011	25	21	8.3	2	1/2	27x25x9	6075	M1	50
23/02/2011	26	22	10.0	1	2	14x12x9	1512	M1	53
23/02/2011	27	23	8.3	1	2	29x20x12	6960	M1	66
23/02/2011	28	24	10.1	3	2	21x19x10	3990	M1	57
23/02/2011	29	24	9.7	2	2	23x18x13	5382	M1	56
25/02/2011	30	LP1	8.9	0	2	29x18x10	5220	M0	n/a
25/02/2011	31	LP4	10.9	1	2	36x22x16	12672	M2	50
25/02/2011	32	LP4	10.7	1	2	42x26x15	16380	same as above	

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

Table 7. Reef fish observations from quadrat dives at Snake Island Reef and Entrance Island Reef, February 15-25, 2010. Total counts and densities (fish/m^2) in each quadrat are provided for lingcod (*Ophidodon 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 brackets. 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 china rockfish (*Sebastes nebulosus*) and pile surfperch (*Rhacochilus vacca*).

Quadrat	Lingcod		Copper rockfish		Quillback rockfish		Kelp greenling		China rockfish	Pile surfperch	Total # fish
	Count	Density	Count	Density	Count	Density	Count	Density			
1	0	0	1	0.003183	4	0.012732	3 (2f, 1m)	0.009549	0	0	8
2	2 (1)	0.006366	1	0.003183	2	0.006366	2 (m)	0.006366	0	0	7
3	3 (1)	0.009549	3	0.009549	3	0.009549	2 (m)	0.006366	0	0	11
4	0	0	2	0.006366	0	0	1 (m)	0.003183	0	0	3
5	1 (1)	0.003183	1	0.003183	0	0	2 (1f, 1m)	0.006366	0	0	4
6	3 (1)	0.009549	0	0	1 (1)	0.003183	3 (m)	0.009549	0	0	7
7	3	0.009549	11 (2)	0.035014	4	0.012732	3 (f)	0.009549	0	0	21
8	0	0	1	0.003183	3 (1)	0.009549	5 (f)	0.015915	0	0	9
9	2 (1)	0.006366	10	0.031831	0	0	3 (2f, 1m)	0.009549	0	0	15
10	1	0.003183	2	0.006366	1 (1)	0.003183	4 (2f, 2m)	0.012732	0	0	8
11	1	0.003183	0	0	0	0	1 (m)	0.003183	0	0	2
12	1	0.003183	3 (3)	0.009549	0	0	1 (f)	0.003183	0	0	5
13	2 (1)	0.006366	1 (1)	0.003183	1 (1)	0.003183	1 (m)	0.003183	0	0	5
14	2 (2)	0.006366	1 (1)	0.003183	1(1)	0.003183	1 (m)	0.003183	0	0	5
15	1	0.003183	0	0	3 (3)	0.009549	3 (1f, 2m)	0.009549	0	0	7
16	1 (1)	0.003183	0	0	0	0	1 (m)	0.003183	0	0	2
17	2 (1)	0.006366	3	0.009549	2	0.006366	7 (1f, 6m)	0.022282	0	0	14
18	1	0.003183	6	0.019099	0	0	6 (3f, 3m)	0.019099	0	0	13
19	1	0.003183	2	0.006366	0	0	1 (f)	0.003183	0	0	4
20	1	0.003183	0	0	0	0	0	0	0	0	1
21	3 (2)	0.009549	1	0.003183	0	0	2 (m)	0.006366	0	0	6
22	3 (1)	0.009549	1	0.003183	0	0	3 (1f, 2m)	0.009549	0	0	7
23	3 (2)	0.009549	4	0.012732	1	0.003183	5 (m)	0.015915	0	0	13
24	3 (1)	0.009549	6	0.019099	0	0	3 (m)	0.009549	0	0	12
E1	0	0	0	0	1(1)	0.003183	39 (12f, 17m)	0.124141	1(1)	3	44

Table 8. Reef fish observations from quadrat dives at Snake Island Reef and Law Point, February 15-25, 2011. Total counts and densities (fish/m^2) in each quadrat are provided for lingcod (*Ophidodon 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 brackets. 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 china rockfish (*Sebastes nebulosus*), pile surfperch (*Rhacochilus vacca*), and black rockfish (*S. melanops*).

Quadrat	Lingcod		Copper rockfish		Quillback rockfish		Kelp greenling		China rockfish	Pile surfperch	Black rockfish	Total # fish
	Count	Density	Count	Density	Count	Density	Count	Density				
1	3 (1)	0.009549	0	0	3	0.009549	2 (m)	0.006366	0	0	0	8
2	1 (0)	0.003183	0	0	0	0	0	0	0	0	0	1
3	5 (4)	0.015915	0	0	18	0.057296	3 (m)	0.009549	0	0	0	26
4	1 (0)	0.003183	1	0.003183	0	0	0	0	0	0	0	2
5	2 (1)	0.006366	2	0.006366	0	0	0	0	0	0	0	4
6	0	0	0	0	0	0	2 (m)	0.006366	0	0	0	2
7	2 (1)	0.006366	0	0	1	0.003183	2 (m)	0.006366	0	0	0	5
8	3 (1)	0.009549	0	0	0	0	6 (2f, 4m)	0.019099	0	0	0	9
9	3 (1)	0.009549	0	0	2	0.006366	0	0	0	0	0	5
10	1 (1)	0.003183	0	0	1	0.003183	0	0	0	0	0	2
11	1 (0)	0.003183	0	0	1	0.003183	0	0	0	0	0	2
12	1 (0)	0.003183	0	0	1	0.003183	1 (f)	0.003183	0	0	0	3
13	3 (2)	0.009549	0	0	3	0.009549	2 (1f, 1m)	0.006366	0	0	0	8
14	1 (1)	0.003183	0	0	3	0.009549	0	0	0	0	0	4
15	3 (1)	0.009549	0	0	2	0.006366	0	0	0	0	0	5
16	0	0	0	0	0	0	0	0	0	0	0	0
17	1 (1)	0.003183	0	0	0	0	1 (m)	0.003183	0	0	0	2
18	1 (1)	0.003183	0	0	0	0	0	0	0	0	0	1
19	2 (1)	0.006366	0	0	1	0.003183	0	0	0	0	0	3
20	2 (2)	0.006366	1	0.003183	6	0.019099	1 (m)	0.003183	0	0	0	10
21	4 (2)	0.012732	1	0.003183	6	0.019099	2 (m)	0.006366	0	0	0	13
22	4 (1)	0.012732	3	0.009549	1	0.003183	3 (1f, 2m)	0.009549	0	0	0	11
23	1 (1)	0.003183	0	0	0	0	0	0	0	0	0	1
24	2 (2)	0.006366	1 (1)	0.003183	0	0	5 (m)	0.015915	0	0	0	8
LP1	1 (0)	0.003183	1 (1)	0.003183	0	0	5 (3f, 1m)	0.015915	0	0	0	7
LP2	1 (0)	0.003183	0	0	3	0.009549	3 (2f, 1m)	0.009549	0	0	0	7
LP3	1 (0)	0.003183	1 (1)	0.003183	0	0	4 (f)	0.012732	0	0	0	6
LP4	2 (1)	0.006366	1	0.003183	1	0.003183	8 (f)	0.025465	0	9	1	22
LP5	3 (1)	0.009549	0	0	2	0.006366	11 (6f, 5m)	0.035014	0	10	0	26
LP6	1 (0)	0.003183	2	0.006366	0	0	9 (3f, 6m)	0.028648	0	9	0	21

Table 9. Lengths of non-guardian male lingcod observed during quadrat dives at Snake Island Reef and Law Point, February 15-25, 2011. For each quadrat, the number of non-guarding males included in the total is indicated in backets. "n/a" indicates "not available" and refers to lingcod that were not measured.

Date	Quadrat	Depth (m)	No. Lingcod in Quadrat	Non-Guardian Male Length (cm)
15/02/2011	1	12.2	3 (2)	n/a
15/02/2011	2	14.0	1 (1)	n/a
15/02/2011	3	15.5	5 (1)	n/a
17/02/2011	4	15.5	1 (1)	n/a
17/02/2011	5	8.2	2 (1)	n/a
17/02/2011	7	7.7	2 (1)	n/a
17/02/2011	8	7.6	3 (2)	n/a
17/02/2011	8	7.6	same as above	n/a
17/02/2011	9	8.8	3 (2)	45
17/02/2011	9	8.8	same as above	54
21/02/2011	11	8.1	1 (1)	47
21/02/2011	12	6.5	1 (1)	61
21/02/2011	13	7.6	3 (1)	58
21/02/2011	15	8.2	3 (2)	n/a
21/02/2011	15	8.2	same as above	53
23/02/2011	19	9.5	2 (1)	41
23/02/2011	21	8.8	4 (2)	56
23/02/2011	21	8.8	same as above	n/a
23/02/2011	22	9.1	4 (3)	61
23/02/2011	22	9.1	same as above	42
23/02/2011	22	9.1	same as above	42
25/02/2011	LP1	9.1	1 (1)	n/a
25/02/2011	LP2	13.2	1 (1)	n/a
25/02/2011	LP3	13.3	1 (1)	n/a
25/02/2011	LP4	13.6	2 (1)	69
25/02/2011	LP5	12.1	3 (2)	76
25/02/2011	LP5	12.1	same as above	66
25/02/2011	LP6	11.2	1 (1)	n/a

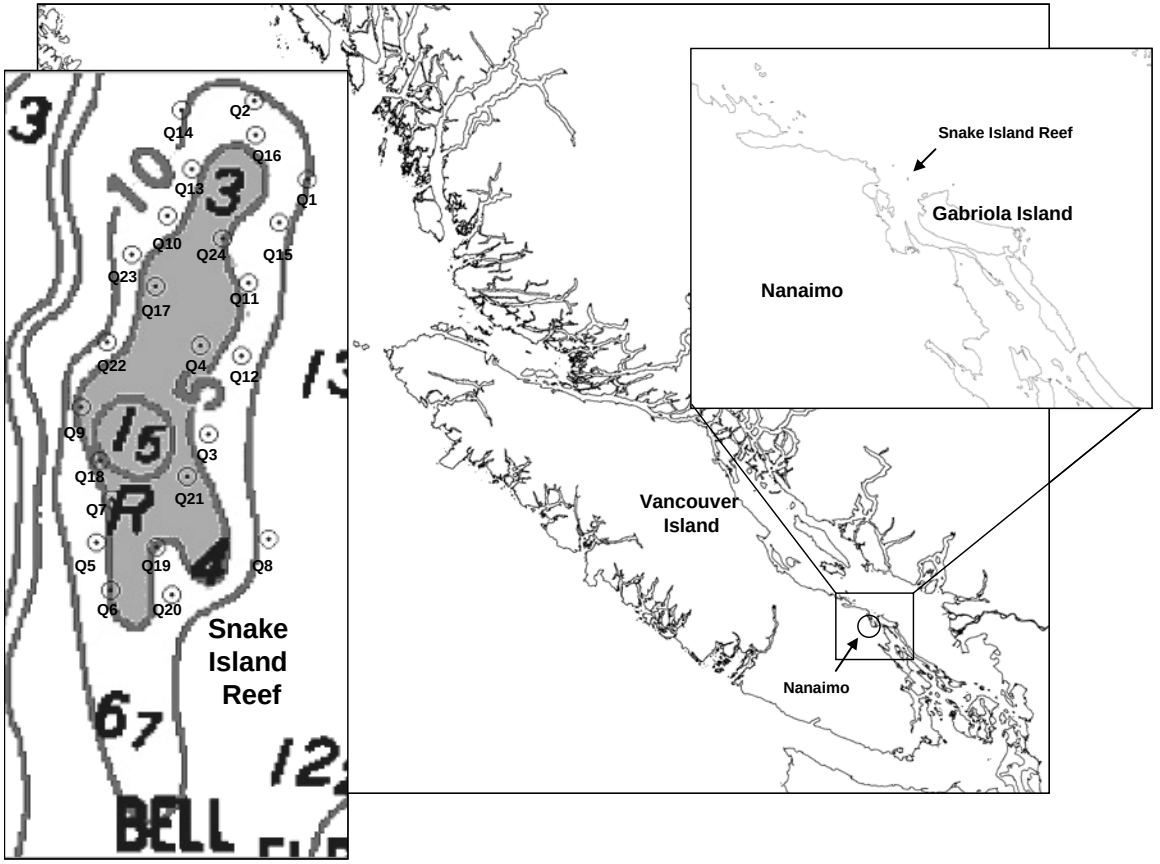

Figure 1. Location and bathymetry of Snake Island Reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys in 1990, 1991, 1994, 2001-2007, and 2010-2011. Quadrat points for the 2010 survey (Q1-Q24) are included.

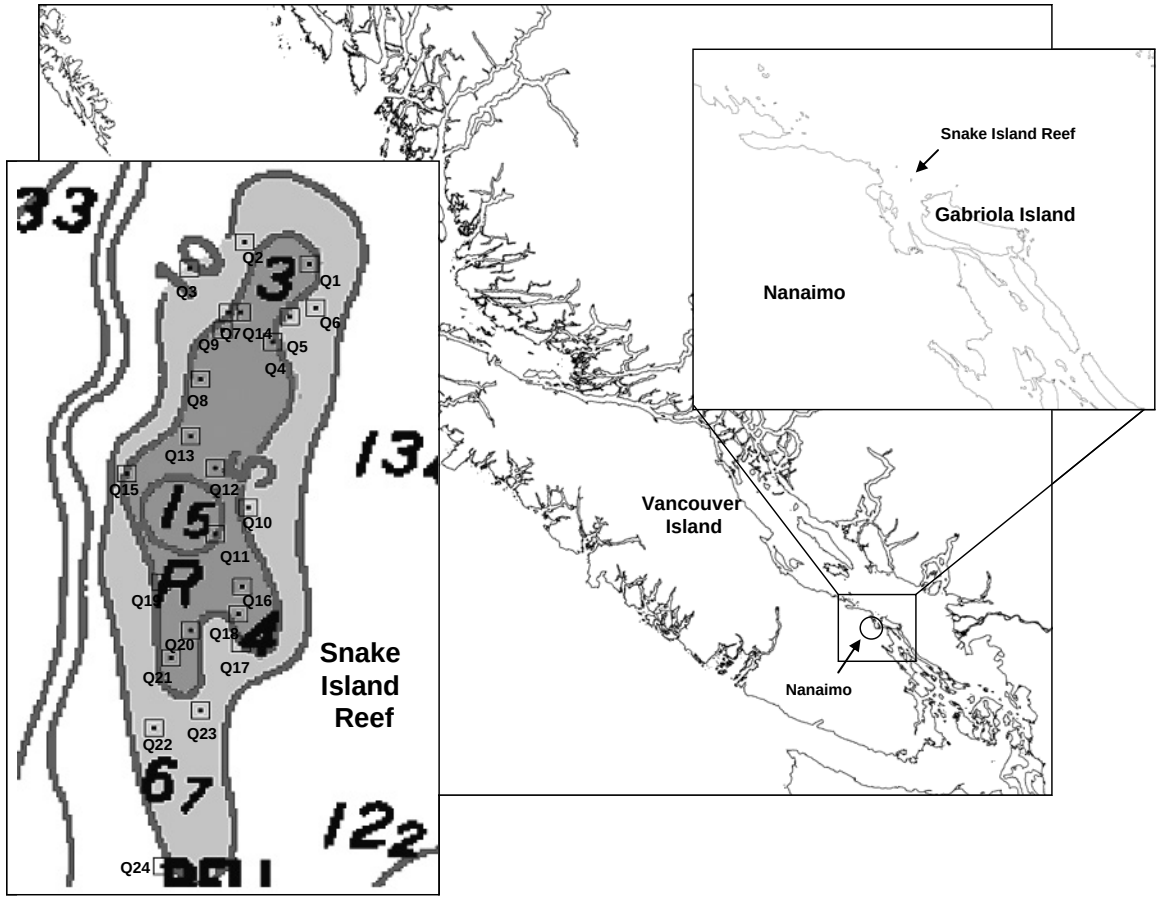

Figure 2. Location and bathymetry of Snake Island Reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys in 1990, 1991, 1994, 2001-2007, and 2010-2011. Quadrat points for the 2011 survey (Q1-Q24) are included.

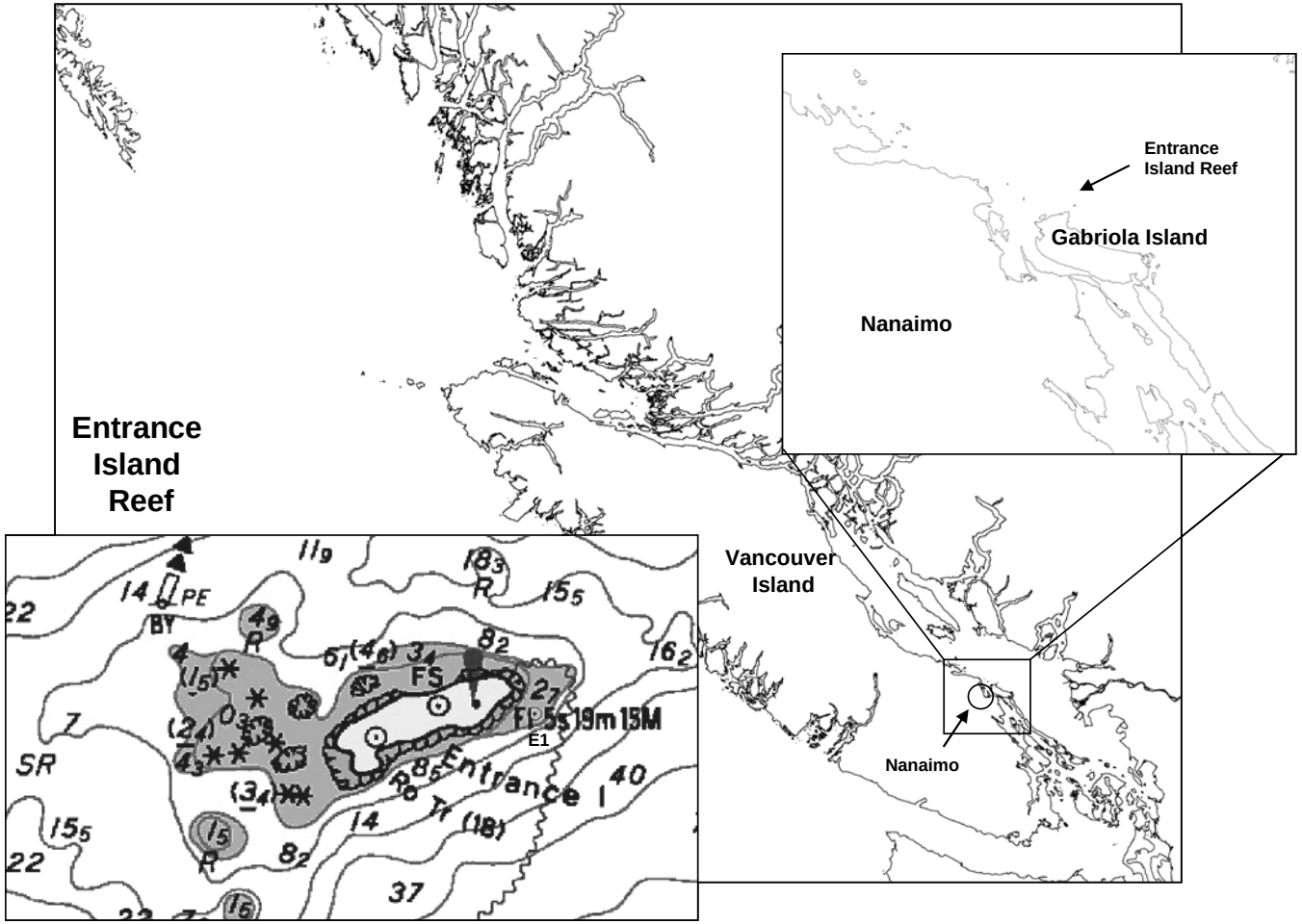

Figure 3. Location and bathymetry of Entrance Island Reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys in 2004-2006, and 2010. The single quadrat point for the 2010 survey (E1) is included.

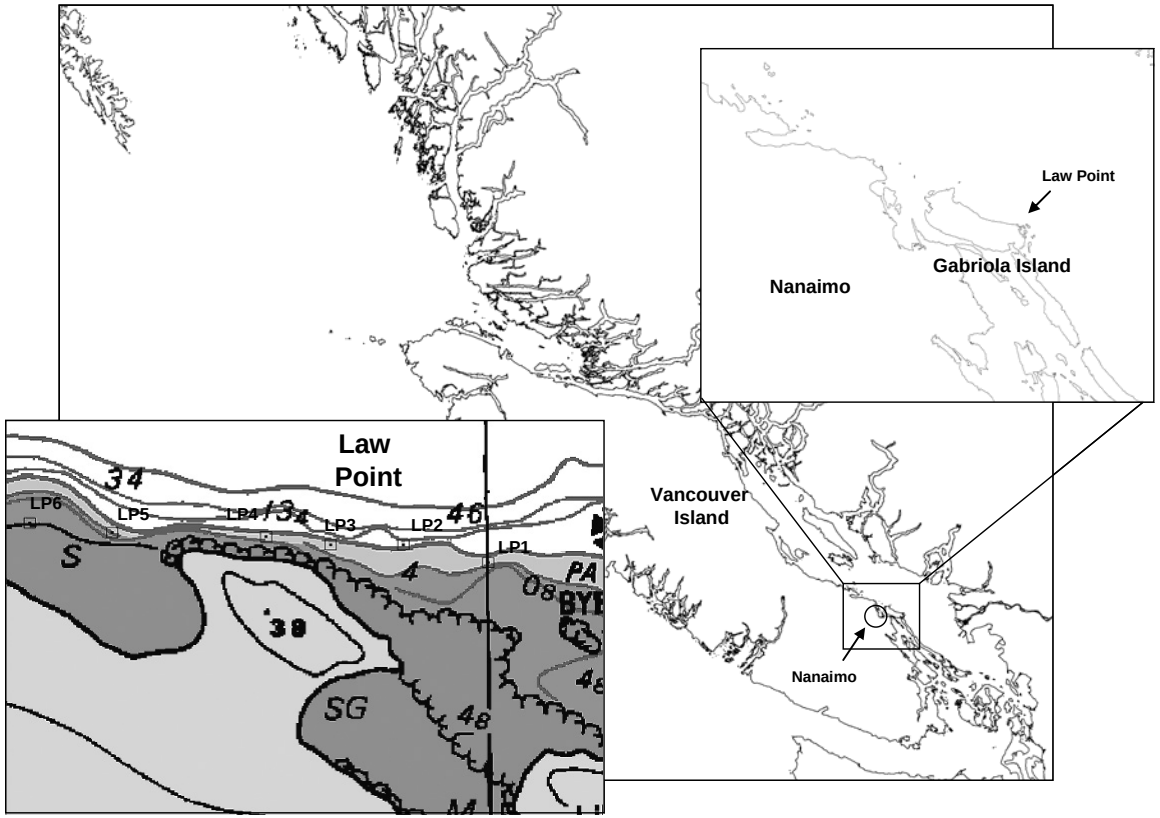

Figure 4. Location and bathymetry of Law Point in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density survey in 2011. Quadrat points for the 2011 survey (LP1-LP6) are included.

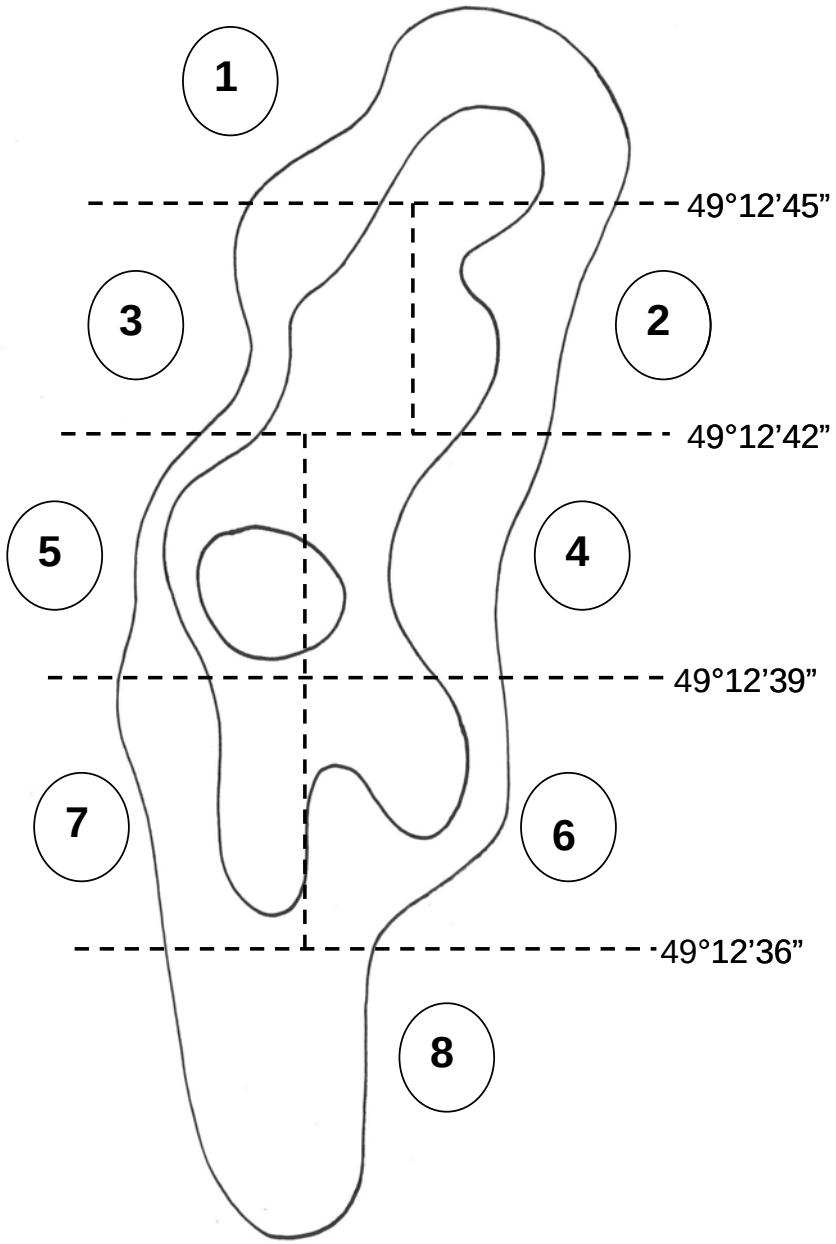

Figure 5. Outline of Snake Island reef, depth contours in 5 m increments. Sections of the reef are numbered in circles, with dotted lines denoting boundaries. The longitude separating section 2 from 3 in 123°53’06.5”.

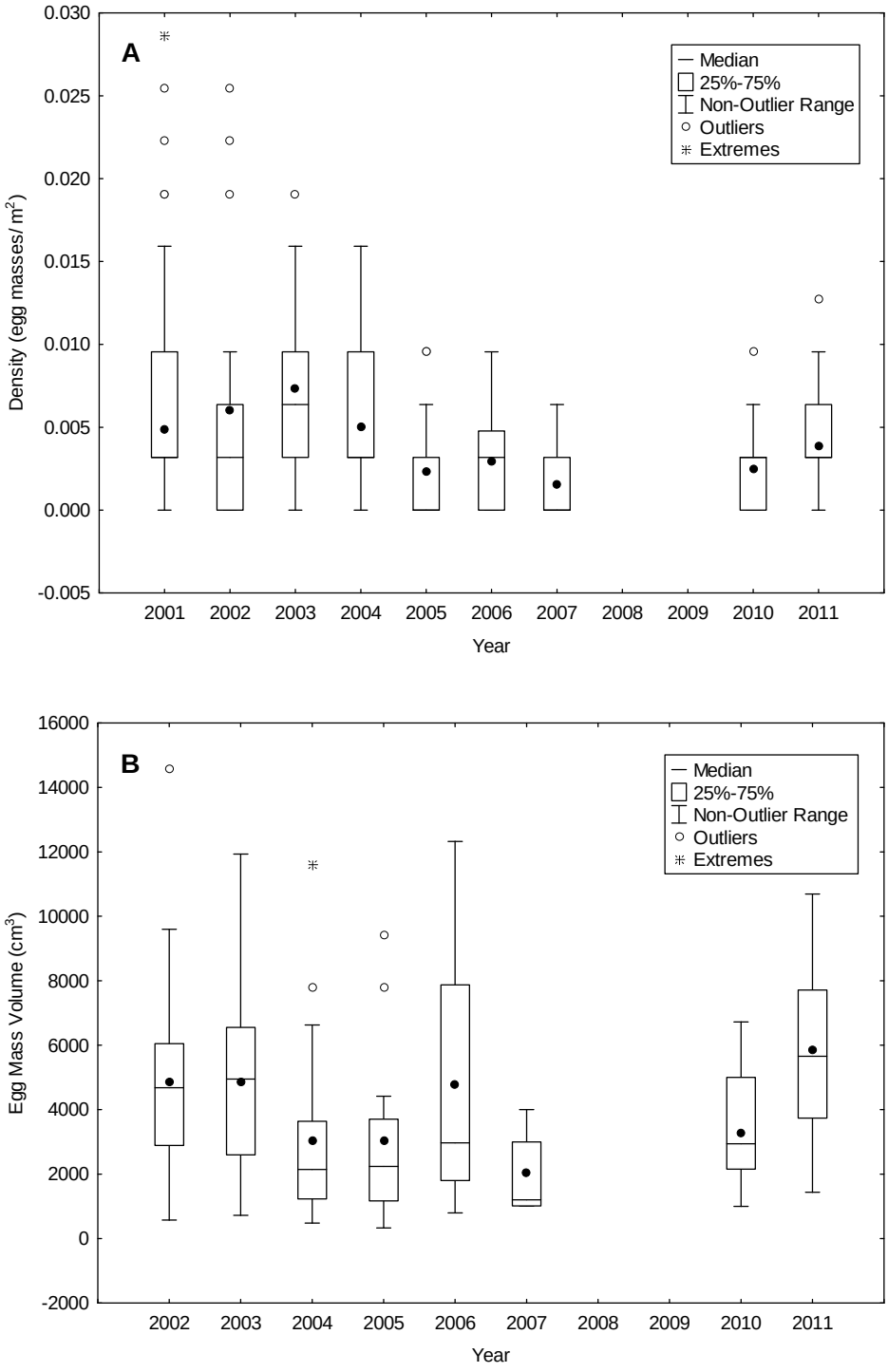

Figure 6. A) Box plots of lingcod egg mass densities at Snake Island Reef from 2001-2007 and 2010-2011; and B) box plots of lingcod egg mass volumes at Snake Island Reef in 2002-2007, and 2010-2011. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

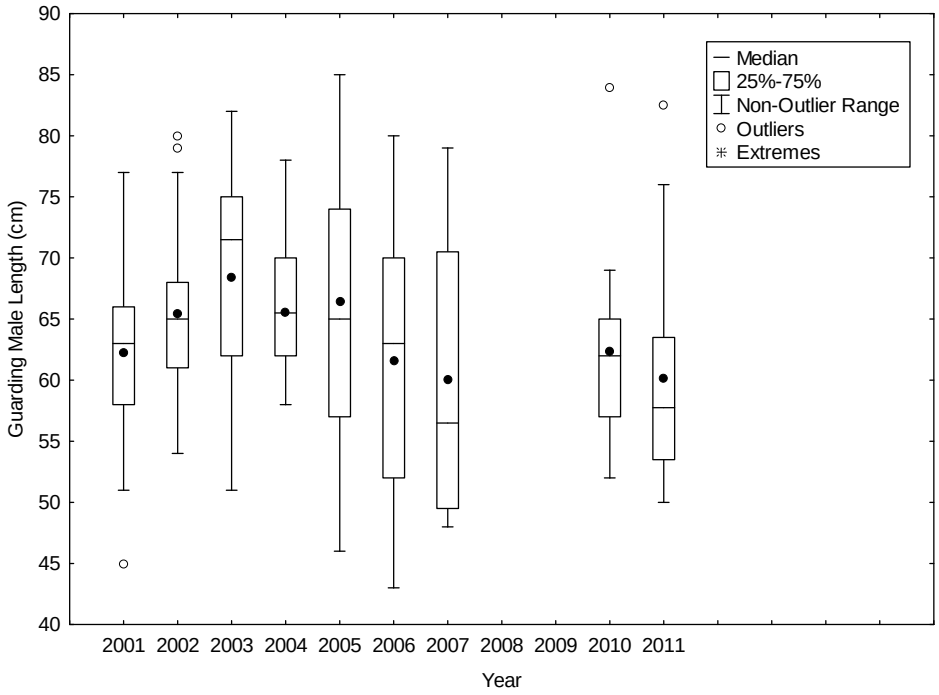

Figure 7. Box plots of guarding lingcod length (cm) at Snake Island Reef in from 2001-2007 and 2010-2011. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

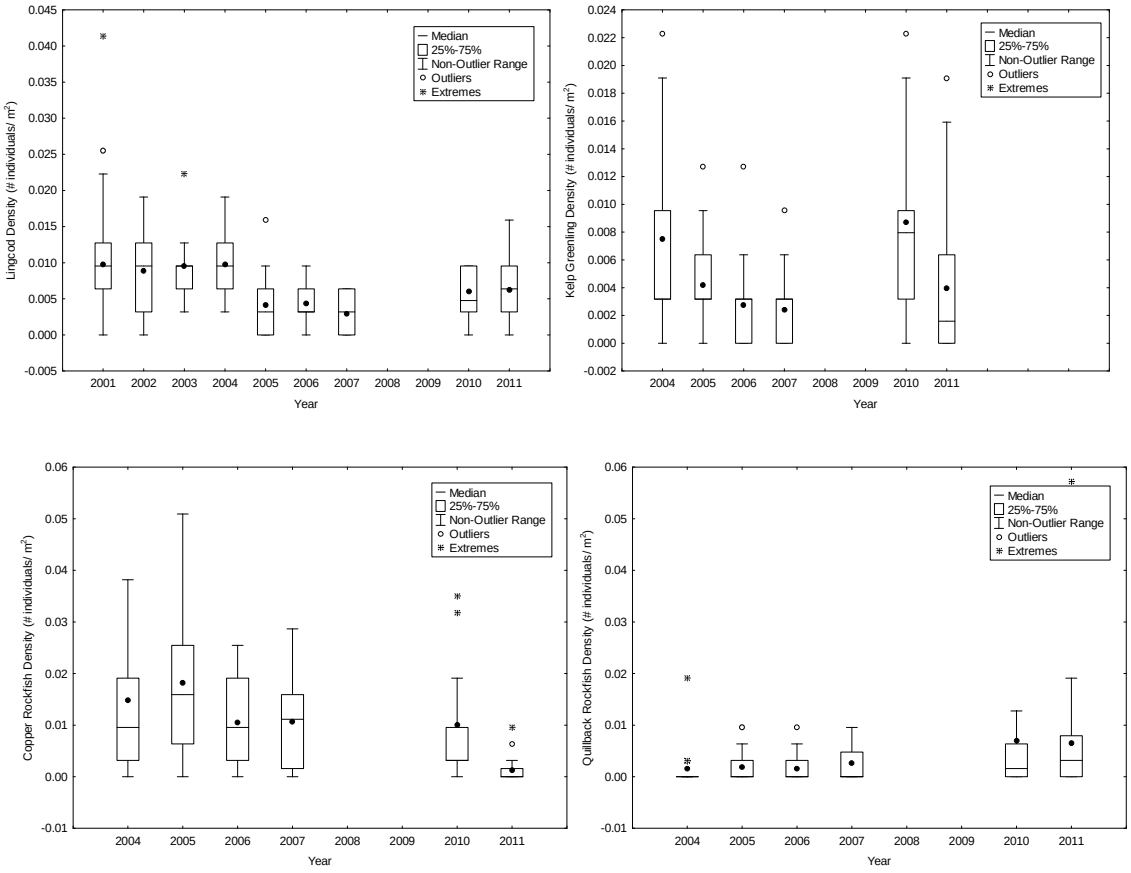

Figure 8. Box plots of reef fish densities at Snake Island Reef for lingcod in 2001-2007 and 2010-2011 and copper rockfish, quillback rockfish, and kelp greenling in 2004-2007 and 2010-2011. The horizontal line inside each box represents the median, while box edges depict the 25th and 75th percentiles. The range of the data is represented by the whiskers. The mean density is represented by ●, while outliers are represented by ○.

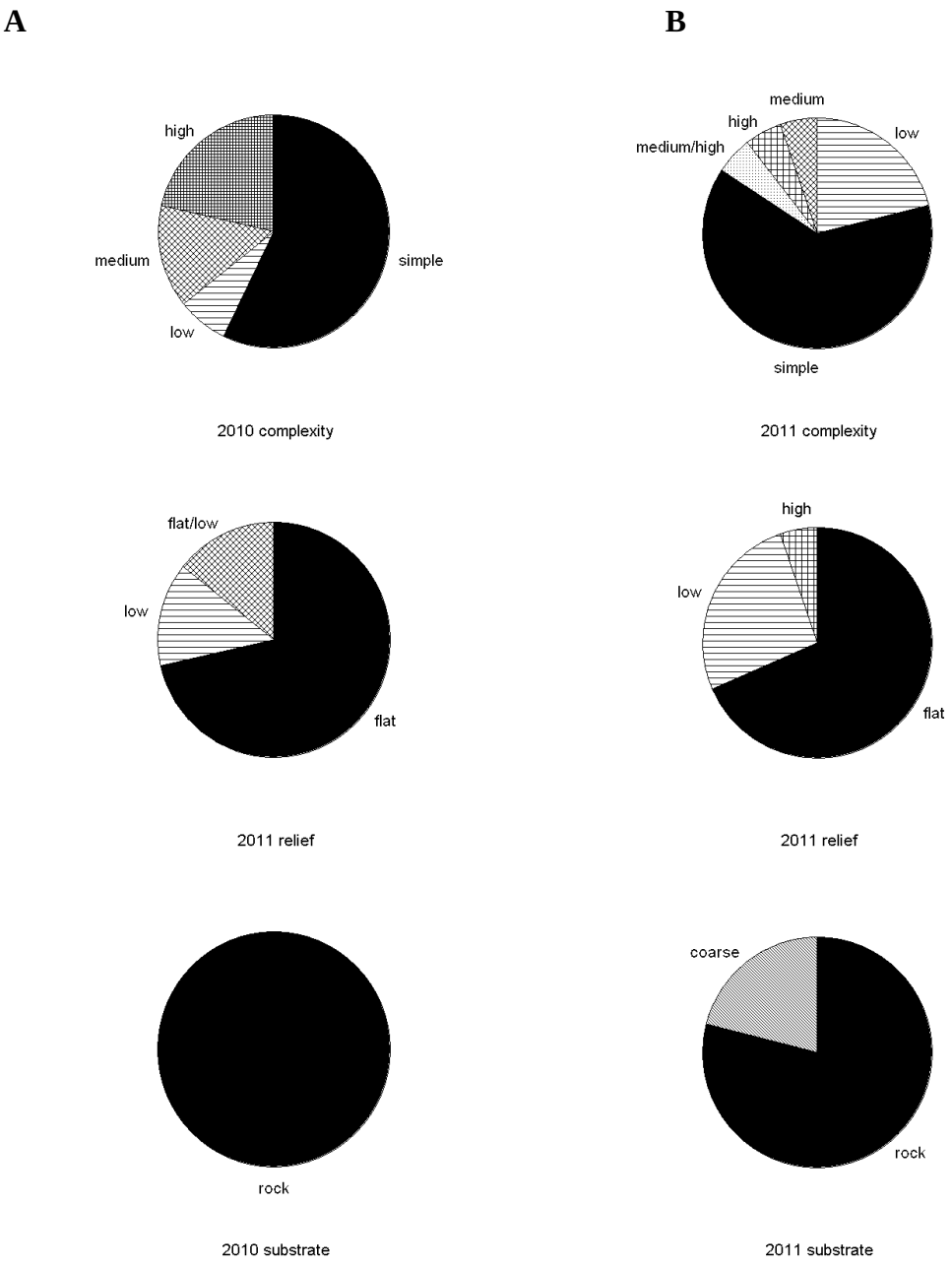

Figure 9: A categorical representation of the dominant habitat characteristics of quadrats where lingcod egg masses were found at Snake Island reef in A) 2010 and B) 2011. Dominant complexity, relief and substrate type respectively were chosen based on highest percentage observed within each quadrat. For descriptions of specific categories within each habitat characteristic, see text.

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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. Yamanaka, Unpublished Data, Pacific Biological Station, Nanaimo, BC, V9K 6N7), 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) and 2010 and 2011.

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**

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
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**

[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