Lingcod Egg Mass Density Survey in the Strait of Georgia, February – March , 2006

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ABSTRACT

Haggarty, D.R., and King, J.R. 20076. Lingcod egg mass density survey in the Strait of Georgia, February – March, 2006. Can. Tech. Rep. Fish. Aquat. Sci. 2691: iv + 28 p.

Lingcod spawn by laying eggs in crevices on rocky reefs which are then aggressively guarded by male lingcod until the larvae hatch in early spring. Scientists at Fisheries & Oceans Canada (DFO) have been conducting lingcod egg mass density surveys over the years as one estimate of relative abundance of lingcod. This year DFO involved the recreational SCUBA diving community in the lingcod egg mass density survey. Groups from around the Strait of Georgia, the north end of Vancouver Island and Barkley Sound were recruited to dive. Overall, 127 dives were completed by 80 volunteers at 27 sites. Nest density was higher in Statistical Area (SA) 23 (Barkley Sound) than it was in Statistical Area 15, 16 or 17. Lingcod density was significantly higher in SA 23 than it was in SA 15-19, but not different from SA 14. Statistical Areas 12, 13, 28 and 29 had too few samples to test. The overall mean density of egg masses and lingcod in the Strait of Georgia is 0.2 nest/m^2 and 0.3 lingcod/m^2; however, high variability exists for both density estimates. Data collected from 2001-2006 by Fisheries & Oceans Canada staff from Snake Island (SA 17), were compared and egg mass density did not vary significantly between years; however, lingcod density did vary. Lingcod densities observed in 2001 were greater than in 2005. Lingcod density in 2006 was lower than it was in all other years.

RÉSUMÉ

Haggarty, D.R. et King, J.R. 2006. Lingcod egg mass density survey in the Strait of Georgia, February – March, 2006. Can. Tech. Rep. Fish. Aquat. Sci. 2691: iv + 28 p.

La morue-lingue dépose ses œufs dans les crevasses de récifs rocheux. Par la suite, les mâles défendent agressivement les œufs jusqu'à leur éclosion au début du printemps. Des scientifiques de Pêches et Océans Canada (MPO) ont effectué des relevés en vue d'estimer la densité des masses d'œufs de morue-lingue au fil des ans et, de là, l'abondance relative de l'espèce. Cette année, le MPO a offert à des amateurs de plongée autonome la possibilité de participer à ces relevés. Des groupes de plongeurs provenant de divers endroits du détroit de Georgie, de l'extrémité nord de l'île de Vancouver et du bassin de Barkley ont pris part aux relevés. Au total, 127 plongées ont été effectuées par 80 bénévoles à 27 endroits différents. La densité des nids était plus élevée dans le secteur statistique (SS) 23 (bassin de Barkley) que dans les SS 15, 16 ou 17. La densité de morues-lingues était significativement plus élevée dans le SS 23 que dans les SS 15 à 19, mais comparable à celle observée dans le SS 14. Le nombre d'échantillons était trop faible dans les secteurs statistiques 12, 13, 28 et 29 pour permettre la tenue de comparaisons. Les valeurs de densité moyenne globale de masses d'œufs et de morues-lingues dans le détroit de Georgie s'élevaient à respectivement 0,2 nids/m^2 et 0,3 morues-lingues/m^2; toutefois, ces deux estimations de densité étaient caractérisées par une forte variabilité. Une comparaison des données recueillies à l'île Snake (SS 17) par le personnel de Pêches et Océans Canada durant la période 2001-2006 a révélé que la densité des masses d'œufs n'a pas fluctué de façon significative d'une année à l'autre; en revanche, la densité des morues-lingues a varié durant cette même période. Ainsi, la densité de morues-lingues était plus élevée en 2001 qu'en 2005, et la densité de morues-lingues était plus faible en 2006 qu'au cours de toutes les années précédentes.

Introduction

Lingcod inhabit rocky reefs and spawn in the winter. The eggs are laid in crevices on rocky reefs and are aggressively guarded by male lingcod until the larvae hatch in early spring (Cass *et al.* 1990). Studies have shown that a single female lays each egg mass and that spawning locations are returned to year after year by the same males (Withler *et al.* 2004; King and Withler 2005). A male lingcod can guard more than one egg mass and unguarded eggs usually succumb to predation (Low and Beamish 1978).

The lingcod population in the Strait of Georgia has been severely depressed for numerous years, but is starting to recover (King 2001; Logan *et al.* 2005). Scientists at Fisheries & Oceans Canada have been conducting lingcod egg mass density surveys over the years as one estimate of relative abundance of lingcod. In 2005, we conducted a pilot project with a small group of recreational divers in order to expand the number of sites surveyed (Haggarty *et al.* 2005).

Based on success of the 2005 pilot project, in 2006 we involved a broader range of the recreational SCUBA diving community in the lingcod egg mass density survey. Groups from around the Strait of Georgia, the north end of Vancouver Island and Barkley Sound completed dives. Data collected were used to calculate an egg mass density at each site surveyed. Egg mass and lingcod densities at different sites and in different regions of the Strait of Georgia are compared to each other and to sites outside of the Strait.

Methods

Volunteer survey:

When possible, volunteers in each study area attended a presentation on Strait of Georgia lingcod survey protocol. Each volunteer was also given a manual detailing the survey methodology, so it was not mandatory for volunteers to attend a talk (Appendix 1). Divers were supplied with data sheets printed on underwater paper, clip boards, pencils, rubber bands, and 10 meter plot lines marked at every meter. Divers needed to supply personal dive gear and a weight (5 to 10 lbs) to attach to the 10 m plot line.

We worked with a dive coordinator for each dive group to choose study sites and to arrange the dates and logistics of each dive. At each dive site, the dive coordinator organized the divers so that dives were spread out over the reef and ensured sampling plots did not overlap. Upon completion of all dives for each site, the dive coordinator mailed us the completed data sheets in postage-paid envelopes.

On the dives, egg masses were counted within circular plots with a radius of 10 meters. Volunteers were asked to complete 5-10 plots per site in order to sample a large enough area of the reef. Dives could be between 5-30 m in depth.

Divers worked in teams of 2 (or 3 in some cases). One diver (Diver A), would descend with the plot line attached to a weight and the other (Diver B) with the clipboard and datasheet. Once the divers adjusted their personal buoyancy, they signalled the start of the dive with the OK sign. The dive team then searched for suitable lingcod spawning habitat (rocky areas with a minimum of sand/mud). Diver A would place the weight in a location where it would not move easily and then swim to the end of the 10 m line. Using the markers on the 10-m plot line, Diver B estimated and recorded the water visibility.

Diver B would then swim down the radius line searching for lingcod and egg masses. When Diver B reached Diver A, Diver A would move the plot line ahead and Diver B would search the next wedge-shaped area of the plot by swimming back up the line to the center of the plot. In addition to controlling the plot line, Diver A helped to search the edge of the plot.

When an egg mass was located, Diver B measured and recorded the depth of water with their depth gauge. The position of the nest was recorded as open; under a rock; in a horizontal crevice; or in a vertical crevice. The colour of the eggs was recorded as cream; white; grey; eyed (black eyes of larvae are visible); or hatched (remainder of gelatinous mass, no larvae). More than one colour could be recorded per egg mass. Egg mass size was estimated by the volunteers as small (approximately the size of a grapefruit); medium (approximately the size of a cantaloupe); large (approximately the size of a watermelon); or very large (much larger than a watermelon). The presence or absence of a male lingcod was also recorded, as well as the number of nests he was guarding. All non-guarding lingcod encountered in the plot were counted.

Habitat information was also recorded for each plot. Depth at the center of the plot and the minimum and maximum depths were recorded in feet and converted to meters. The complexity of the habitat was determined to be one of the following: simple (smooth rock, no crevices); low (less than 25% crevices); medium (25-50% crevices); high (greater than 50% crevices). The relief of the quadrat was recorded as 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). In order to describe the substrate of each plot, the percent cover of rock (hardpan, bedrock or boulders); coarse substrate (cobble, gravel, shell); and fine substrate (sand or mud) was estimated. The percent cover of algae (not identified to species) was also estimated.

If bottom time, air and safe diving limits permitted, the divers could complete a second or third plot during the same dive. However, they were instructed to swim to the edge of the plot and then swim at least another 10 meters away before placing the weight to do another plot.

Fisheries & Oceans Canada Survey:

The methodology used by Fisheries & Oceans Canada staff was as above, with a few modifications. The plot locations were randomly selected, marked with a dive buoy, and mapped on Nobletech© prior to each dive. In addition to recording all of the information listed above in the plots, divers also counted reef fish (Appendix 4), measured the length of guarding lingcod, and measured the volume (length x width x height) of egg masses rather than placing them into size categories. For comparability, the size of each egg mass was also later categorized as small (0.1-2.5 L), medium (2.6-6.0 L) and large (6.1-12.5 L). Fisheries & Oceans Canada staff completed dives at four sites: Snake Island, Entrance Island (SA 17), Maud Island and Discovery Pass (SA 13). The depth range of the DFO dives was 5-20 m.

Analysis

Nest density was calculated for each plot as:

Nest density = (# of egg masses counted / area searched) x 100

and the lingcod density as:

Lingcod density = (guarding lingcod + non-guarding lingcod / area searched) x 100.

The median nest and lingcod density per site and statistical area was tested for significance using the Kruskal-Wallis test and the statistical software Statistix 7.0. Due to an unequal number of plots completed per site, we present the egg mass density and lingcod density among statistical areas rather than among sites. We also omitted sites with three or fewer samples for the density comparisons by statistical area as well as statistical areas with fewer than 4 plots. We also used the Kruskal-Wallis test to look for differences in egg mass and lingcod density at Snake Island among years surveyed.

Results

Eighty volunteers took part in the lingcod egg mass density survey (See Appendix 2 for a list of names and affiliations). 127 plots were completed at 27 sites (Figure 1, Appendix 5) throughout the Strait of Georgia (Statistical Areas 13-19 and 28-29), at two sites in Barkley Sound, and one site in Queen Charlotte Sound. Too few plots were sampled in SA 12, 13, 28 and 29 for statistical comparison.

Statistical Area (SA) 23 had significantly higher egg mass densities than in SA 15, 16 and 17, but not 14, 18, and 19. SA 23 also had significantly higher lingcod density than SA 15-19, but not different from SA 14 (Table 1, Figure 2). SA 23 is located on the west coast of Vancouver Island. The other plots completed outside the Strait of Georgia in SA 12 also had high egg mass and lingcod densities, but this difference was not statistically tested due to the small sample size (3). Data for each sampling plot can be found in Appendix 3 and 4.

The overall mean density of egg masses and lingcod in the Strait of Georgia is 0.2 nest/m^2 and 0.3 lingcod/m^2; though very high variability exists for both density estimates (Table 1).

We also compared egg mass and lingcod density among years surveyed. Snake Island has the longest time series and was the only site to show significant differences over time. Egg mass density was compared for the following years: 1990, 1991, 1994, 2001, 2002, 2004, 2005 and 2006; but lingcod density was only compared among surveys in the 2000's because non-guarding lingcod counts were not recorded in the 1990's. Egg mass density was greater in 1994 than it was in 1991, 2001, 2005 and 2006 (Figure 3a). Lingcod density observed in 2006 was significantly lower than it was in 2001, 2002 or 2004. The 2001 lingcod density was also significantly greater than it was in 2005. There was no difference between 2005 and 2006 (Figure 3b). No difference in egg mass density was found among years at Entrance island (2004, 2005, and 2006) or at Maud, Discovery, or Mackenzie Bight (2005, 2006).

Data on a total of 97 different egg masses were collected by DFO and volunteers (Table 2). Egg masses were categorized as small, medium, large or very large (Table 2) and the size was compared among statistical areas. SA 12 had significantly larger egg masses than SA 14, 17 or 19 (Kruskal Wallis test statistic=34.4 p=0.0001, df=8).

Discussion

Including volunteer data collectors allowed a much broader geographic area to be surveyed, and a greater number of plots to be completed at more numerous sites. In the past, Fisheries & Oceans Canada staff were only able to complete lingcod egg mass density surveys at one or a few sites near Nanaimo (Haggarty et al 2005, King and Haggarty 2004, King and Winchell 2002, King and Beaith 2001). This year, a total of 27 sites around the Strait of Georgia, Queen Charlotte Strait and Barkley Sound were surveyed. The contribution from all of the volunteer divers is greatly appreciated.

Although overall effort was great, the number of plots sampled at some sites was quite low (1-3 plots), due to weather and time constraints. However, some volunteers commented that they found the plot methodology a bit cumbersome and found it difficult to complete more than one plot. In some cases, the importance of completing multiple plots per site was not understood. Lingcod egg masses are distributed patchily and therefore numerous plots need to be completed to adequately assess the density of a site. Perhaps in the future, the plot method should be combined with a roving diver technique, such as the method used in the Vancouver Aquarium Lingcod Egg Mass Survey (Malcolm and Marliave 2005), to ensure adequate coverage of a reef.

Inclement weather also affected the sites that could be surveyed. Unfortunately, stormy weather did not allow the Powell River divers to access sites in Desolation Sound. Instead they sampled two sites in the more sheltered Okeover Inlet. King *et al*. (2004) found that egg mass density in inlets in Clayoquot sound was lower than it was at exposed sites on the open coast. The egg mass density in SA 15 may, as a result, be underestimated. Inclement weather also restricted the number of dives that could be done in SA 12 and 13. The low number of plots completed in some statistical areas limits the area comparisons and also makes comparisons among sites within statistical areas difficult.

None the less, sites sampled in statistical areas outside of the Strait of Georgia appear to have greater lingcod and egg mass density than most sites within the Strait of Georgia.

For numerous years, volunteer SCUBA divers in British Columbia have been participating in a lingcod egg mass survey through the Vancouver Aquarium. Many divers were also very willing to work with Fisheries & Oceans Canada to collect lingcod egg mass density data in a slightly more intensive manner. Volunteers also commented that they enjoyed learning more about the life history of lingcod and conservation issues in the Strait of Georgia.

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Table 1. Descriptive statistics (mean and standard deviation; median and range) for lingcod egg mass density (nests/100 m^2) and fish density (non guarding and guarding lingcod/100 m^2) by site and Statistical Area. Sites with 3 or less number of samples (N) are omitted from the statistical area calculation.

Statistical Area	Site	Site Code	N	Egg Mass Density Mean (SD)	Egg Mass Density Median (Range)	Lingcod Density Mean (SD)	Lingcod Density Median (Range)
13			4	0	0	0.4 (0.3)	0.5 (0-0.6)
	Discovery Passage	DP	3	0.2 (0.4)	0 (0-0.6)	0.2 (0.2)	0.3 (0-0.3)
	Maud Island	MI	4	0	0	0.4 (0.3)	0.5 (0-0.6)
14			10	0.3 (0.4)	0.2 (0-1.0)	0.8 (0.8)	0.5 (0-2.5)
	Eagle Rock	ER	6	0.1 (0.1)	0 (0-0.3)	0.3 (0.4)	0.3 (0-1.0)
	Norris Rock	NR	4	0.7 (0.2)	0.6 (0.6-1.0)	1.4 (0.8)	1.3 (0.6-2.5)
15			16	0	0	0.1 (0.2)	0 (0-0.6)
	Cochrane Island	CO	9	0	0	0.2 (0.2)	0 (0-0.6)
	Coode Island	CI	7	0	0	0.04 (0.1)	0 (0-0.3)
16			10	0.1 (0.3)	0 (0-1.0)	0.1 (0.1)	0 (0-0.3)
	Agamemnon	AC	1	0.6 (-)	0.6 (-)	1.3 (-)	1.3 (-)
	Cooper's Group	CG	1	0.3 (-)	0.3 (-)	0	0
	Tuwanek	TU	10	0.1 (0.3)	0 (0-1.0)	0.1 (0.1)	0 (0-0.3)
17			30	0.2 (0.3)	0 (0-1.0)	0.3 (0.3)	0.3 (0-1.0)
	Entrance Island	EI	4	0	0	0.2 (0.2)	0.3 (0-0.3)
	Indian Reef	IR	6	0.2 (0.4)	0 (0-1.0)	0.1 (0.2)	0 (0-0.3)
	Snake Island	SI	16	0.3 (0.3)	0.3 (0-1.0)	0.5 (0.3)	0.3 (0-1.0)
	Vesuvius	VB	4	0.1 (0.2)	0 (0-0.3)	0.2 (0.3)	0 (0-0.6)
18			8	0.3 (0.4)	0.2 (0-1.3)	0.4 (0.8)	0.2 (0-2.2)
	Burial Island	BI	4	0.1 (0.2)	0 (0-0.3)	0.1 (0.2)	0 (0-.3)
	Patey Rock	PR	4	0.5 (0.6)	0.3 (0-1.3)	0.8 (1.0)	0.5 (0-2.2)
19			16	0.2 (0.4)	0 (0-1.3)	0.2 (0.3)	0 (0-1.3)
	Clover Point	CP	6	0	0	0	0
	Mackenzie Bay	MB	10	0.4 (0.4)	0.3 (0-1.2)	0.3 (0.4)	0.3 (0-1.3)
	N. Cod Reef	NC	3	0.1 (0.2)	0 (0-0.3)	0.8 (0.8)	1.0 (0-1.6)
	Wain Rock	WR	1	0.6 (-)	0.6 (-)	0.3 (-)	0.3 (-)
28							
	Ansell Point	AP	1	0	0	1.0 (-)	1.0 (-)
	S. Bowyer	SB	2	0.2 (0.3)	0.2 (0-0.3)	0.6 (0.9)	0.6 (0-1.3)
	Whytecliff	WC	2	0	0	0.2 (0.2)	0.2 (0-0.3)
29							
	White Islets	WI	2	0.5 (0.2)	0.5 (0.3-0.6)	1.6 (0.5)	1.6 (1.3-1.9)
13-19, 28, 29	Strait of Georgia		110	0.2 (0.3)	0 (0-1.3)	0.3 (0.5)	0.3 (0-2.5)
12							
	Five Fathoms	FF	3	1.3 (0.3)	1.3 (1.0-1.6)	1.6 (1.1)	1.0 (1.0-2.9)
23			11	1.2 (1.1)	0.7 (0-3.8)	2.5 (2.4)	1.9 (0.6-8.9)
	Keyen Pt.	KP	5	1.0 (0.9)	0.6 (0-2.0)	1.4 (1.1)	1.0 (0.6-3.3)
	Renata's Reef	RR	6	1.4 (1.3)	1.0 (0.3-3.8)	3.5 (2.8)	2.3 (1.6-8.9)

Table 2. Data recorded for each lingcod egg mass observed at each site including the Depth (m) of the egg mass; Egg Mass Position: 0=Open, 1= under rock, 2= horizontal crevice, 3= vertical crevice; Egg Colour: 1=cream, 2=white, 3=grey, 4=eyed, 5=hatched; Egg Mass Size category: 1=small (grapefruit), 2=medium (cantaloupe), 3=large (watermelon), 4=very large. The presence of a male guarding one, two or three egg masses (M1, M2, M3), or an unguarded egg mass (M0). Boxes are drawn around egg masses that were guarded by a single male. Fisheries & Oceans Canada staff recorded the length of guarding males (when possible) and the egg mass volume.

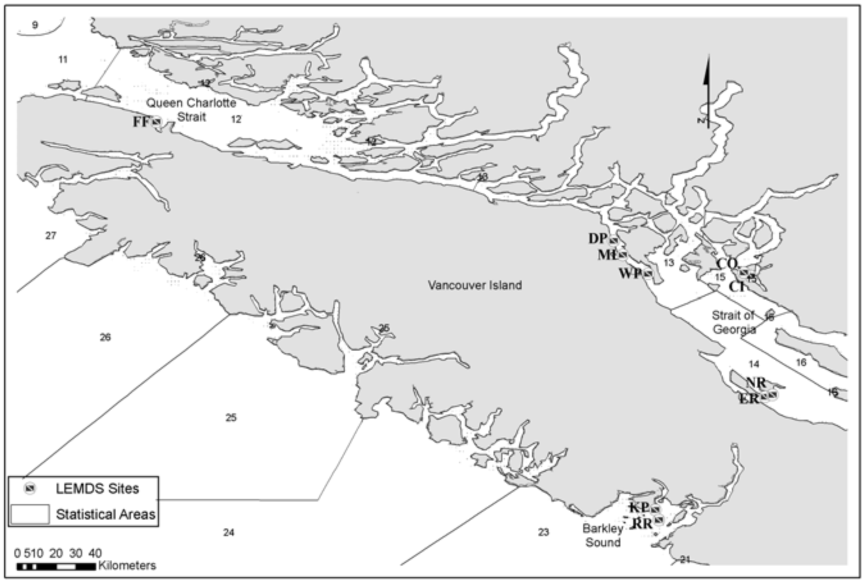
Site	Stat Area	Plot#	Depth (m)	Egg mass Position	Egg Colour	Egg Mass Size	Egg Mass Volume (L)	Guardian Male Present	Length (cm)
Five Fathom	12	1	10.7	1	1, 2	2		M1	
Five Fathom	12	1	10.7	1	1, 2	4		M1	
Five Fathom	12	1	11.3	1	1, 3	4		M1	
Five Fathom	12	1	11.0	1	1, 3	4		M1	
Five Fathom	12	1	11.6	1	2	3		M1	
Five Fathom	12	2	12.5	2	2, 3	3		M1	
Five Fathom	12	2	13.1	1	2, 3	3		M1	
Five Fathom	12	2	12.8	2	2	3		M0	
Five Fathom	12	3	17.7	1	3, 4, 5	3		M1	
Five Fathom	12	3	17.4	1	1, 2	3		M1	
Five Fathom	12	3	14.6	0	1, 2, 3	4		M2	
Five Fathom	12	3	14.6	1	2	3		M2	
Discovery	13	6	11.6	1	2, 3	3	9.6	M2	64
Discovery	13	6	11.6	1	3	1		M2	64
Eagle	14	6	7.6	1	2	2		M0	
Norris	14	1	7.6	1	2	1		M2	
Norris	14	1	7.6	1	2	3		M2	
Norris	14	1	7.6	0	2	1		M0	
Norris	14	2	11.0	0	1	1		M0	
Norris	14	2	8.5	0	2	1		M1	
Norris	14	3	12.2	1	1	1		M0	
Norris	14	3	9.2	0	2	1		M0	
Norris	14	4	8.8	0	3, 4	2		M1	
Norris	14	4	12.8	1	2	3		M1	
Agamemnon	16	1	7.6	0	1	1		M1	
Agamemnon	16	1	10.4	2	1	1		M0	
Cooper's G.	16	1	8.8	1	1	2		M0	
Tuwanek	16	7	19.5	3	1	3		M3	
Tuwanek	16	7	19.5	3	1	2		M3	
Tuwanek	16	7	16.5	3	1	2		M3	
White Islets	16	1	15.3	1	1, 2	3		M1	
White Islets	16	1	7.6	1	1, 2	2		M1	
White Islets	16	2	9.2	0	1, 2	2		M1	
Indian Reef	17	1	11.3	2	1	1		M0	

Table 2. Continued.

Site	Stat Area	Plot#	Depth (m)	Nest Position	Colour	Egg Mass size	Egg Mass Volume (L)	Guardian Male Present	Length (cm)
Indian Reef	17	1	11.6	3	3, 4	3		M2	
Indian Reef	17	1	9.8	3	3	2		M2	
Indian Reef	17	2	9.2	2	3	1		M1	
Snake	17	1	9.5	2	4	2	4.4	M1	
Snake	17	2	10.4	1	3	3	10.5	M1	56
Snake	17	4	9.8	3	3	3	7.9	M1	48
Snake	17	5	5.8	0	1	3	12.3	M1	71
Snake	17	6	8.2	2	4	2	2.8	M1	43
Snake	17	6	8.2	1	4	1	0.8	M0	
Snake	17	6	8.2	1	3	1	2.2	M0	
Snake	17	9	12.8	0	1	2	3.8	M0	
Snake	17	9	12.8	1	4	1	1.1	M1	69
Snake	17	10	13.7	1	3	3	10.2	M1	64
Snake	17	15	12.2	2	3, 4	1	1.6	M3	80
Snake	17	15	12.2	2	3, 4	1	1.8	M3	80
Snake	17	15	12.8	2	3, 4	2	2.8	M3	80
Snake	17	16	7.9	1	0	2	3.0	M0	
Snake	17	16	7.6	1	3, 4	3	6.4	M1	62
Vesuvius	17	1	12.2	3	2	2		M1	
Burial I.	18	2	14.6		1	3		M1	
Patey I.	18	1	19.8	3	2	3		M1	
Patey I.	18	2	6.1	2	1	3		M1	
Patey I.	18	2	7.0	0	3	2		M0	
Patey I.	18	2	8.5	1	3	3		M0	
Patey I.	18	2	7.6	3	3	3		M1	
Patey I.	18	3	12.2	1	1	3		M1	
MacKenzie	19	1	22.3	3	5	2		M0	
MacKenzie	19	1	17.1	3	5	2		M0	
MacKenzie	19	2	19.5	3	2	2		M0	
MacKenzie	19	2	21.4	1	2	2		M1	
MacKenzie	19	2	20.1	3	3	2		M1	
MacKenzie	19	2	20.1	0	3	3		M1	
MacKenzie	19	5	14.6	0	2	1		M0	
MacKenzie	19	6	19.8	3	1	2		M1	
MacKenzie	19	9	22.9	3	2	2		M1	
MacKenzie	19	10	19.8	2	2	2		M3	
MacKenzie	19	10	16.8	3	2	2		M3	
MacKenzie	19	10	15.9	3	2	2		M3	
N. Cod Reef	19	3	7.0	2	2	3		M1	

Table 2. Continued.

Site	Stat Area	Plot#	Depth (m)	Nest Position	Colour	Egg Mass size	Egg Mass Volume (L)	Guardian Male Present	Length (cm)
Wayne Rock	19	1	10.7	3	3	1		M2	
Wayne Rock	19	1	12.2	3	3	2		M2	
Keyen Pt.	23	1	8.8	3	1	2		M0	
Keyen Pt.	23	2	7.9	3	1	3		M1	
Keyen Pt.	23	2	8.8	2	1	3		M1	
Keyen Pt.	23	3	5.5	3	1	3		M1	
Keyen Pt.	23	3	7.6	0	1	4		M1	
Keyen Pt.	23	3	9.2	3	2	2		M0	
Keyen Pt.	23	5	8.5	3	2	2		M1	
Keyen Pt.	23	5	7.0	2	1	2		M2	
Keyen Pt.	23	5	7.0	2	2	3		M2	
Renate Reef	23	1	13.1	3	1	3		M1	
Renate Reef	23	2	12.8	2	2	3		M1	
Renate Reef	23	2	13.7	2	1	2		M1	
Renate Reef	23	2	15.9	2	2	3		M1	
Renate Reef	23	3	13.1	2	1, 5	2		M1	
Renate Reef	23	3	13.1	2	1	1		M1	
Renate Reef	23	3	13.1	0	1	3		M2	
Renate Reef	23	4	16.5	3	1, 5	3		M1	
Renate Reef	23	4	17.4	3	1, 3	2		M1	
Renate Reef	23	5	16.5	2	1	3		M1	
Renate Reef	23	6	14.3	3	1, 3	3		M1	
S. Bowyer	28	1	13.4	1	2, 5	1		M1	



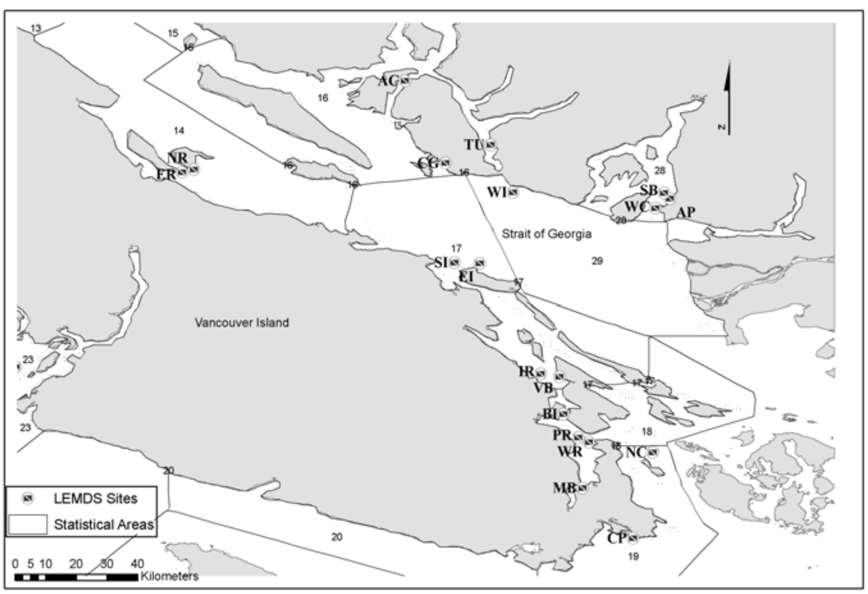
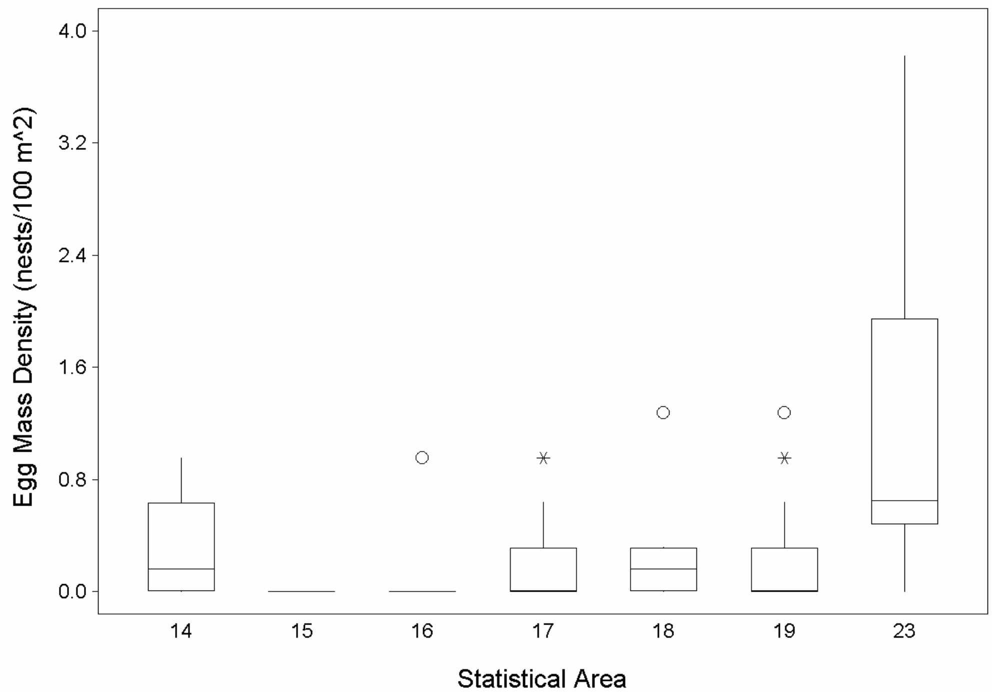


Figure 1.Sites surveyed during the lingcod egg mass density survey (LEMDS) February 12-March 21, 2006. Statistical Areas are also shown. See Table 1 for a list of the site names and site codes. Sites were surveyed by volunteers except for SI, EI (in SA 17), and DP, and MI (in SA 13).

a)



b)

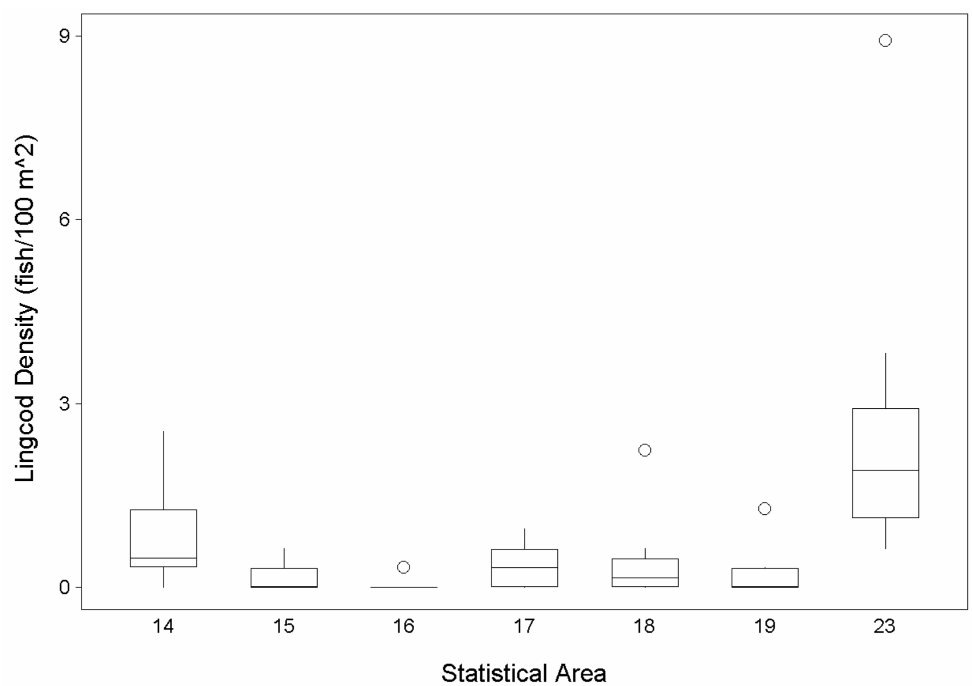
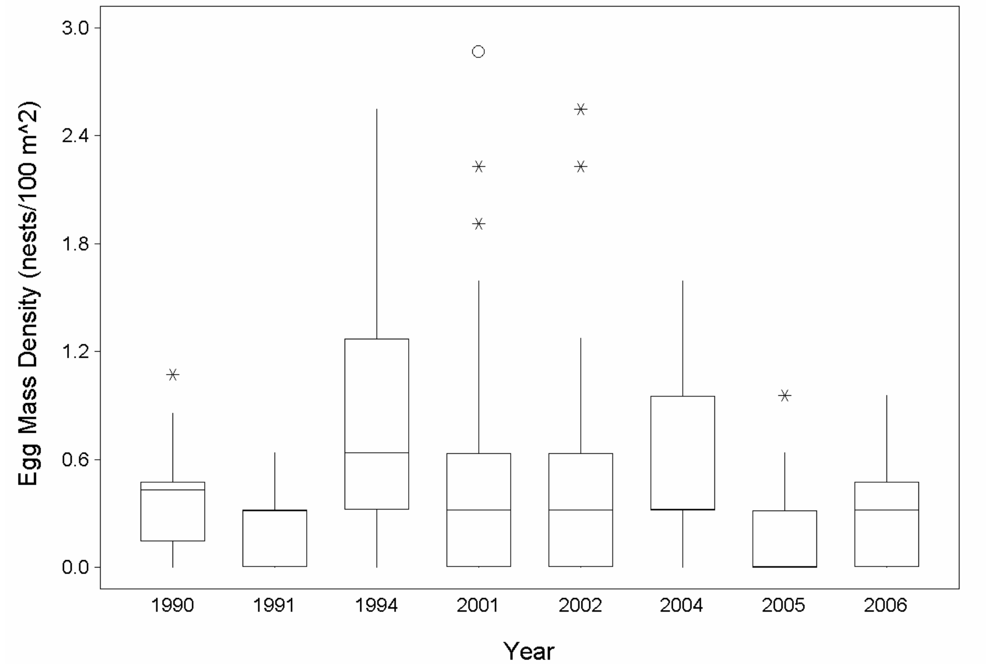
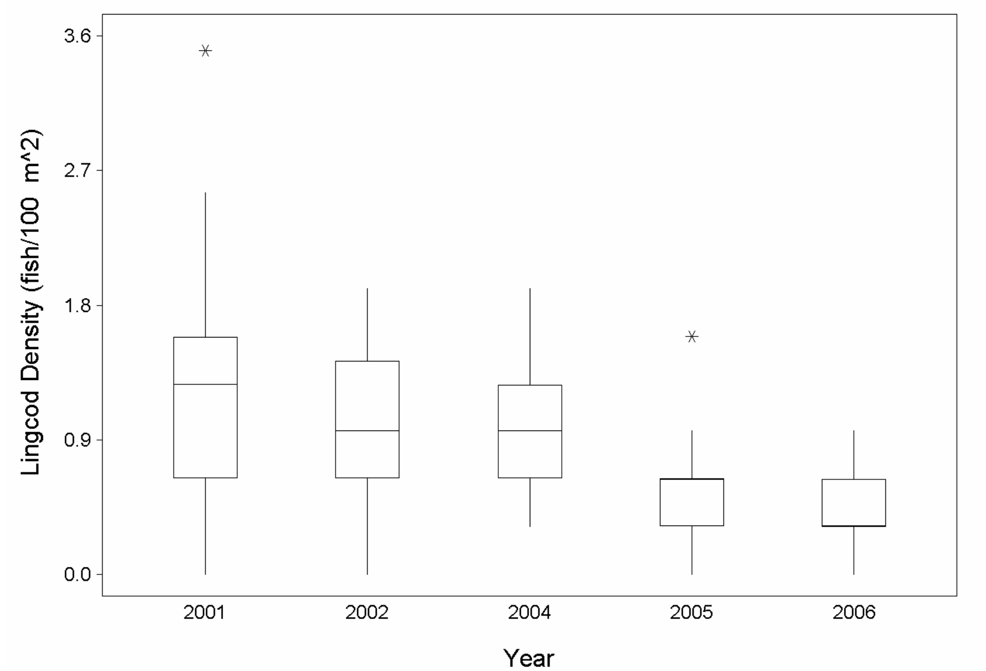


Figure 2. Boxplot depicting lingcod egg mass density (a) and lingcod density (b) by statistical area. SA 12, 13, 28 and 29 are not shown due to too few samples and sites with three or fewer samples are omitted. The median is indicated by the horizontal line in the box, while box edges depict the 1st and 3rd quartiles. The typical range of the data are represented by the whiskers, while outliers are represented by * and º. Egg Mass density is significantly higher in SA 23 than it is in SA 15, 16 or 17 (Kruskal Wallis test statistic=30.9, p=0.0001, df=6). Lingcod density is significantly higher in SA 23 than it is in SA 15-19 but not different from 14 (Kruskal Wallis test=42.4, p=0.0001, df=7).

a)





b)

Figure 3. Boxplot representing lingcod nest density (a) at Snake Island in 1990, 1991, 1994, 2001, 2002, 2004-2006; and lingcod density (b) at Snake Island in 2001, 2002, 2004-2006. Non-guarding lingcod were not recorded in the 1990's so total lingcod density can not be calculated for those years. The median is indicated by the horizontal line in the box, while box edges depict the 1st and 3rd quartiles. The typical range of the data are represented by the whiskers, while outliers are represented by * and º. Egg mass density was greater in 1994 than it was in 1991, 2001, 2005 and 2006 (Kruskal-Wallis test statistic=25.8, p=0.0004, df=7). Lingcod density observed in 2006 was significantly lower than it was in 2001, 2002 or 2004, and the 2001 lingcod density was also significantly greater than 2005's (Kruskal-Wallis test statistic=22.0, p=0.0002, df=4).

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Appendix 1. Instruction Manual

Lingcod Egg Mass Density Survey 2006

Introduction

This year, volunteer divers will take part in the lingcod egg mass density dive survey in the Strait of Georgia. Lingcod inhabit rocky reefs and spawn in the winter. The eggs are laid in crevices on rocky reefs and are aggressively guarded by male lingcod until the larvae hatch in early spring (Figure 1). Studies have shown that only a single female lays each egg mass and that spawning locations are returned to year after year by the same males. A male lingcod can guard more than one egg mass and eggs that are not guarded usually succumb to predation.

Figure 1. A male lingcod guarding an egg mass. The egg mass is the white mass to the right of the fish. The size of the egg mass relates to the size of the female that laid it.

The lingcod population in the Strait of Georgia has been severely depressed for numerous years, but is starting to recover. Biologists at Fisheries & Oceans Canada have been conducting lingcod egg mass density surveys over the years as one estimate of relative abundance of lingcod. In 2005, we conducted a pilot project with a small group of recreational divers in order to expand the number of sites surveyed. The Vancouver Aquarium Marine Science Centre also conducts lingcod egg mass surveys with volunteer divers. They have done great work in raising awareness within the diving community about lingcod natural history and conservation.

This year, with your involvement, we will build on this work by collecting data on lingcod spawning sites throughout the Strait of Georgia. The data we collect will be used to calculate an egg mass density at each site surveyed. Densities at different sites and in different regions of the Strait of Georgia will be compared to each other and to sites outside of the Strait. We hope to collect data at enough sites around the Strait of Georgia to allow us to make an estimate of the number of spawning lingcod in the Strait of Georgia. This is exciting work. Thank you for choosing to be involved!

Materials Supplied:

UW Data Sheets: can be attached to personal dive slates (such as the Ultimate Dive Slate) or used with a clipboard provided
Clipboards with pencils on lines, rubber bands, clips
10-m plot line with 1 m marks

Divers must supply their own dive gear and underwater lights. Each buddy team will also require an extra dive weight (5-10 lbs) or cannonball to attach to the plot line.

Methods.

Each dive coordinator/team leader will work with the lingcod biologist to choose study sites and to arrange the dates and logistics of each survey. At the dive site, the dive coordinator will organize the divers so that each site is adequately surveyed and to ensure sampling plots do not overlap.

Egg masses are counted within circular plots with a radius of 10 meters. Divers can usually complete 2 plots per dive. We aim to complete a total of 6-10 plots per site.

Divers will work in buddy teams and should stay in close communication throughout the dive. The dive coordinator will direct each buddy team as to where they will survey, and what direction they will swim if they are able to complete more than one plot in a dive. Divers should always follow a safe, non-decompression limit dive plan.

One diver (Diver A), will descend with the plot line attached to a weight. Diver B descends with the clipboard and datasheet. Once the divers have adjust their personal buoyancy, they will signal the start of the dive with the OK sign. The dive team then finds suitable lingcod spawning habitat (rocky areas with a minimum of sand/mud). Diver A places the weight in a location where it will not move easily and then swims to the end of the 10 m line. Using the known length of the plot line (10 m), Diver B estimates and records the water visibility. Note that the plot line is marked at every meter and flagged at 5 m.

Diver B then follows Diver A, swimming down the radius line searching for lingcod and egg masses. When Diver B reaches Diver A, Diver A moves the plot line ahead and Diver B will search the next wedge-shaped area of the plot by swimming back up the line to the center of the plot. In addition to controlling the plot line, Diver A can help to search the edge of the plot (see Figure 2). The size of the wedge should be no larger than would allow a thorough inspection, dependant on habitat complexity and visibility.

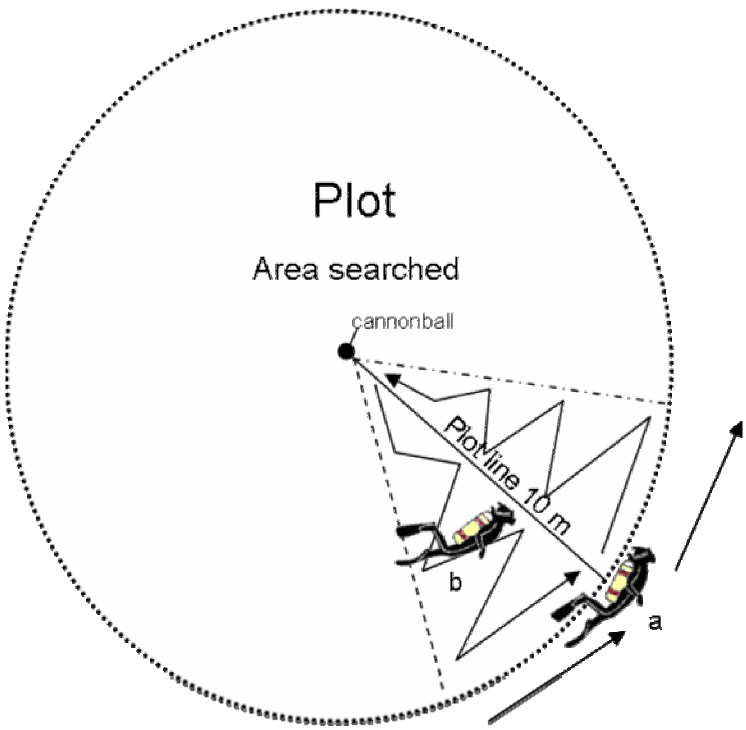

Figure 2. Diagram of a lingcod egg mass density survey sampling plot. Diver A holds and moves the plot line while Diver B inspects each wedge of the circle for lingcod and egg masses. Once Diver B has finished searching the wedge, Diver A advances the line and Diver B searches the next wedge until the entire circle is searched. Diver A must keep track of the start position. The size of each wedge and search pattern used by Diver B will depend of the complexity of the terrain.

When an egg mass is located, Diver B records the following information on the data sheet:

- Depth of the egg mass (measured with depth gauge)
- Nest position: where the egg mass is located:
    - 0 = open
    - 1 = under rock
    - 2 = horizontal crevice
    - 3 = vertical crevice

- Egg Colour (use your dive light)
    - 1 = cream
    - 2 = white
    - 3 = grey
    - 4 = eyed (black eyes of larvae are visible)
    - 5 = hatched (remainder of gelatinous mass, no larvae)
- Egg Mass Size: estimate if it is closest to the size of a:
    - G = grapefruit,

  - C = cantaloupe, or
  - W = watermelon

- Guardian Male Lingcod present:
  - M0 = none
  - M1 = guarding 1 nest
  - M2 = guarding 2 nests
  - M3 = guarding the 3 nests

Diver B should also **count non-guarding lingcod**. Tally the count of additional lingcod in the column “lingcod count.” Try to make sure you don’t count the same lingcod twice. Total the number after the dive.

At the completion of the plot, Diver B records the following information about the habitat in the plot:

- Depth (ft): at the center of the plot and the min and max (Diver B should verify this information with Diver A after the dive)
- Complexity:
  - Simple: smooth rock, no crevices.
  - Low: less than 25% crevices
  - Medium: 25-50% crevices
  - High: greater than 50% crevices
- Relief of the quadrat:
  - Flat: less than a 2 ft difference in depth.
  - Low: 2 to 7 ft difference in depth
  - High: Over 7 ft difference in depth, less than 45 degree slope
  - Wall: greater than 45 degree slope
- Substrate: estimate the percentage of the plot that is:
  - Rock: hardpan, bedrock or boulders
  - Coarse: cobble, gravel, shell
  - Fine: sand or mud
- Flora: estimate the % of the plot covered by kelp (of any type).

If bottom time, air and safe diving limits permit, the divers may be able to complete a second plot. If that is so, both divers should swim to the edge of the plot and then swim at least another 10 meters away before placing the weight to do another plot (See Figure 3). Proceed as for Plot 1.

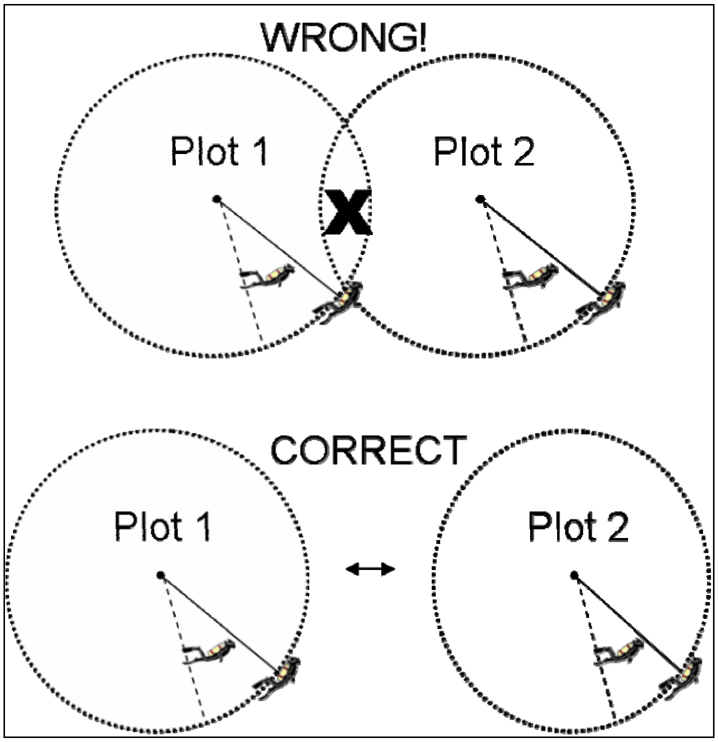

Figure 3. If a second plot is completed on a dive, divers must swim to the edge of the plot and then at least another 10 m away (20 fin kicks) to avoid overlapping the plots (shown by the X above) and recounting the same area twice. There should be no overlap between the plots.

At the conclusion of the dive, both divers should look over the data sheets to ensure all information has been recorded. Data sheets are submitted to the dive coordinator, who will send all of the data sheets to the lingcod biologist in the envelope provided.

If you have any questions or comments that your dive coordinator can not answer, please contact:

Dana Haggarty
Research Biologist, Lingcod Program
Marine Ecosystem and Aquaculture Division
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC
V9T 6N7
Tel: 250-756-7050
haggartyd@pac.dfo-mpo.gc.ca

Appendix 2. Name, affiliation and location of each “dive team” who took part in the 2006 lingcod egg mass density survey. Dive coordinators are marked with an asterisk (*).

Name	Affiliation	Location
Owen Robertson	UBC Aqua Society	Vancouver
Christopher Brandt	UBC Aqua Society	Vancouver
Nadia Vitacic	UBC Aqua Society	Vancouver
Gregory Wittig	UBC Aqua Society	Vancouver
Jess Schultz*	UBC Aqua Society	Vancouver
Shawn Penson	UBC Aqua Society	Vancouver
Frank Berghaus	UBC Aqua Society	Vancouver
Caitlin Riebe	UBC Aqua Society	Vancouver
Nicholas Baal	UBC Aqua Society	Vancouver
Leigh Beamish	UBC Aqua Society	Vancouver
Adrian Vester	UBC Aqua Society	Vancouver
Emma Preston	UBC Aqua Society	Vancouver
Linda Monk	Duncan Divers	Duncan
Christine Hind*	Duncan Divers	Duncan
Alexa Counsell	Duncan Divers	Duncan
Harvey Popplestone	Duncan Divers	Duncan
Terry Hind	Duncan Divers	Duncan
John Hind	Duncan Divers	Duncan
Tom Whitney	Duncan Divers	Duncan
Ken Sharp	Duncan Divers	Duncan
Fred Demchuk	Duncan Divers	Duncan
Carol Demchuk	Duncan Divers	Duncan
Rian Dickson	Bamfield Marine Science Centre	Bamfield
Arin Yeomans-Routledge	Bamfield Marine Science Centre	Bamfield
Tom Bird*	Bamfield Marine Science Centre	Bamfield
Jenn Provencher*	Bamfield Marine Science Centre	Bamfield
Sheryl Mass	Bamfield Marine Science Centre	Bamfield
Sid Allman	Alpha Dive Service	Powell River
Tammy Norgard*	Alpha Dive Service	Powell River
Ron Cochrane	Alpha Dive Service	Powell River
Ann Snow	Alpha Dive Service	Powell River
Don Carto	Alpha Dive Service	Powell River
Karen King*	Alpha Dive Service	Powell River
Cheri Ayers	Alpha Dive Service	Powell River
Hal Ross	Powell River Dive Club	Powell River
Mike Delaney*	Edge Diving Centre	Vancouver
Mandy Hengeveld	Edge Diving Centre	Vancouver
Andrea Burns	Edge Diving Centre	Vancouver
David Campbell	Edge Diving Centre	Vancouver
Skylar Albrecht	Edge Diving Centre	Vancouver
Creig Statz	Union Bay Dive and Kayak	Union Bay/Comox
Tyler Statz	Union Bay Dive and Kayak	Union Bay/Comox
Kaylee Statz	Union Bay Dive and Kayak	Union Bay/Comox
Kevin Driver	Union Bay Dive and Kayak	Union Bay/Comox
Mike Driver	Union Bay Dive and Kayak	Union Bay/Comox
Paul Von Schilling	Union Bay Dive and Kayak	Union Bay/Comox

Name	Affiliation	Location
Tim O'Leary	Union Bay Dive and Kayak	Union Bay/Comox
Sean Smyrichinsky*	Union Bay Dive and Kayak	Union Bay/Comox
Paul Lee	Union Bay Dive and Kayak	Union Bay/Comox
Taylor Knott	Union Bay Dive and Kayak	Union Bay/Comox
Christine Leveille	Union Bay Dive and Kayak	Union Bay/Comox
Amanda Allen	Union Bay Dive and Kayak	Union Bay/Comox
Ryan Baker	Union Bay Dive and Kayak	Union Bay/Comox
Doug Biffard*	Victoria Dive Club	Victoria
Bev Biffard	Victoria Dive Club	Victoria
Mike Kalina*	Victoria Dive Club	Victoria
Mick Harvey	Victoria Dive Club	Victoria
Carol Vaulkenier	Victoria Dive Club	Victoria
Ian Pope	Victoria Dive Club	Victoria
James Dranchuk	Victoria Dive Club	Victoria
Dan Bauer*	Sidney Dive N’ Surf	Sidney
Linda Bishop*	Suncoast Diving	Sechelt
Jared Simpson	Suncoast Diving	Sechelt
Sarah Park	Capilano College	Sechelt
Elise Hatton	Capilano College	Sechelt
Jim Rossi*	Capilano College	Sechelt
Jesse Bueckert	Capilano College	Sechelt
Kris Bouma	Capilano College	Sechelt
Matt Cairns	Capilano College	Sechelt
David Lee	Capilano College	Sechelt
Bryan McWilliams	Capilano College	Sechelt
Siobhan Gray	Capilano College	Sechelt
Tina Kuiack*	Capilano College	Sechelt
Kal Helyar	Porpoise Bay Charters	Sechelt
Glen Dennison*	Underwater Council of BC	Vancouver
Primo Seriosa	Underwater Council of BC	Vancouver
Paul Sim	Underwater Council of BC	Vancouver
Ray Gascon*	Esquimalt Dive Club	Victoria
Mike Greensill	Esquimalt Dive Club	Victoria
Damen McKinty	Esquimalt Dive Club	Victoria
Jacquie Engell*	Top Island Econauts	Port MacNeill
Andy Hanke	Top Island Econauts	Port MacNeill
Kevin Bates	Campbell River Tiderippers	Campbell River

Appendix 3. Habitat, depth, lingcod and nesting information for plots completed by volunteers.

				Depth (m)				Nests		Lingcod				Substrate				Plot		Density	
Date	Site	Stat Area	Plot#	Center	Min	Max	Visibility (m)	Total	Guarded	Guarding	Non-guarding	Complexity	Relief	Rock	Coarse	Fine	Algae	Radius	Area	Nest	Lingcod
04/03/2006	Five Fathom	12	1	10.8	10.5	11.1	12	5	5	5	4	high	Low	100	0	0	0	10.0	314.0	1.592	2.866
04/03/2006	Five Fathom	12	2	12.6	12.3	12.9	12	3	2	2	1	low	Low	60	40	0	0	10.0	314.0	0.955	0.955
04/03/2006	Five Fathom	12	3	15.0	13.5	17.4	12	4	4	3	0	low	High	30	0	70	0	10.0	314.0	1.274	0.955
19/02/2006	Eagle	14	1	12.9	12.0	13.2	25	0	0	0	3	simple	Low	10	90	0		10.0	314.0	0.000	0.955
19/02/2006	Eagle	14	2	11.4			10	0	0	0	0	low	Low	90	10	0	0	10.0	314.0	0.000	0.000
19/02/2006	Eagle	14	3	7.5	6.0	7.5	20	0	0	0	1	simple	Low	90	10	0		10.0	314.0	0.000	0.318
19/02/2006	Eagle	14	4	9.9		10.5	20	0	0	0	1		Flat	90	10	0	0	10.0	314.0	0.000	0.318
19/02/2006	Eagle	14	5	9.9	9.0	13.5	10	0	0	0	1	low	Low	0	100	0		10.0	314.0	0.000	0.318
19/02/2006	Eagle	14	6	7.5	7.5	8.4	25	1	0	0	0	simple	Flat	70	30	0		10.0	314.0	0.318	0.000
19/02/2006	Norris	14	1	7.5	7.5	7.5	20	3	2	2	0			0	0	0		10.0	314.0	0.955	0.637
19/02/2006	Norris	14	2	10.5	7.5	13.5	20	2	1	1	3	med	High	80	15	5		10.0	314.0	0.637	1.274
19/02/2006	Norris	14	3	10.5	7.5	13.5	15	2	0	0	4	med	High	90	10	0		10.0	314.0	0.637	1.274
19/02/2006	Norris	14	4	11.4	0.6	13.5	20	2	2	2	6	med	High	80	15	5	0	10.0	314.0	0.637	2.548
04/03/2006	Cochrane	15	1	12.0	6.0	15.0	20	0	0	0	1	low	High	95	5	0	10	10.0	314.0	0.000	0.318
04/03/2006	Cochrane	15	2	12.0	12.0	15.0	20	0	0	0	0	low	High	50	50	0	10	10.0	314.0	0.000	0.000
04/03/2006	Cochrane	15	3	12.0	12.0	18.3	20	0	0	0	1	low	Low	95	5	0	10	10.0	314.0	0.000	0.318
04/03/2006	Cochrane	15	4	12.0	12.0	18.0	20	0	0	0	2	low	Low	80	20	0	10	10.0	314.0	0.000	0.637
04/03/2006	Cochrane	15	5	15.3	12.0	19.5	15	0	0	0	0	med	High	95	5	0	10	10.0	314.0	0.000	0.000
04/03/2006	Cochrane	15	6	13.8	10.2	19.2	20	0	0	0	0	med	High	95	5	0	20	10.0	314.0	0.000	0.000
04/03/2006	Cochrane	15	7	9.6	6.3	10.2	20	0	0	0	1	low	High	60	20	20	25	10.0	314.0	0.000	0.318
04/03/2006	Cochrane	15	8	15.0	12.0	18.0	20	0	0	0	0	med	High	95	5	0	0	10.0	314.0	0.000	0.000
04/03/2006	Cochrane	15	9	18.0	15.0	21.0	20	0	0	0	0	low	High	95	5	0	5	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	1	12.0	13.5	11.4	20	0	0	0	0	simple	Low	80	20	0	0	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	2	8.4	6.6	10.5	20	0	0	0	0	med	High	99	1	0	0	10.0	314.0	0.000	0.000
04/02/2006	Coode I.	15	3	12.0	9.0	15.0	20	0	0	0	0	low	High	90	10	0	40	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	4	9.9	6.0	12.9	20	0	0	0	0	low	High	90	10	0	40	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	5	10.5	12.0	9.9	0	0	0	0	0	low	High	100	0	0	25	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	6	8.7	4.5	12.6	20	0	0	0	0	low	High	60	40	0	15	10.0	314.0	0.000	0.000
04/03/2006	Coode I.	15	7	9.6	6.6	15.6	20	0	0	0	1	med	High	90	10	0	20	10.0	314.0	0.000	0.318
17/02/2006	Agamemnon	16	1	15.9	6.0	22.2	15	2	1	1	3	med	Wall	90	10	0		10.0	314.0	0.637	1.274
18/02/2006	Coopers Green	16	1	11.4	7.5	12.9	8	1	0	0	0	med	High					10.0	314.0	0.318	0.000
04/03/2006	Tuwanek	16	1	13.5	11.4	15.6	8	0	0	0	0	low	High	100	0	0	0	10.0	314.0	0.000	0.000
04/03/2006	Tuwanek	16	2	17.7	13.5	21.6	15	0	0	0	0	low	High	100	0	0	40	10.0	314.0	0.000	0.000
04/03/2006	Tuwanek	16	3	15.0	9.0	19.5	15	0	0	0	1	simple	High	10	80	10	2	10.0	314.0	0.000	0.318
04/03/2006	Tuwanek	16	4	4.8	3.9	6.0	6	0	0	0	0	med	Low	90	5	5	0	5.0	78.5	0.000	0.000
08/03/2006	Tuwanek	16	5	21.0	18.6	27.0	15	0	0	0	0	high	High	100	0	0	0	10.0	314.0	0.000	0.000
08/03/2006	Tuwanek	16	6	15.0	14.4	17.4	15	0	0	0	0	high	High	100	0	0	0	10.0	314.0	0.000	0.000
04/03/2006	Tuwanek	16	7	18.6	16.2	20.1	20	3	3	1	0	med	Low	75	15	10	0	10.0	314.0	0.955	0.318
08/03/2006	Tuwanek	16	8	9.6	9.0	14.1	12	0	0	0	0	low	Low	25	75	0	0	10.0	314.0	0.000	0.000

Appendix 3.

Date	Site	Stat Area	Plot#	Depth (m) Center	Min	Max	Visibility (m)	Nests Total	Guarded	Lingcod Guarding	Non-guarding	Complexity	Relief	Substrate Rock	Coarse	Fine	Algae	Plot Radius	Area	Density Nest	Lingcod
08/03/2006	Tuwanek	16	9	9.3	7.5	10.8	12	0	0	0	0	low	Low	10	90	0		10.0	314.0	0.000	0.000
08/03/2006	Tuwanek	16	10	9.0	9.0	12.0	12	0	0	0	0	low	High	30	70	0		10.0	314.0	0.000	0.000
16/02/2006	White Isl	16	1	18.0	7.5	24.0	13	2	2	2	4	med	High	75	25	0	0	10.0	314.0	0.637	1.911
16/02/2006	White Isl	16	2	15.0	4.5	21.0	13	1	1	1	3	med	High	75	25	0	0	10.0	314.0	0.318	1.274
05/03/2006	Indian Reef	17	1	10.5	8.4	12.0	10	3	2	1	0	low	Low	0	100	0	5	10.0	314.0	0.955	0.318
05/03/2006	Indian Reef	17	2	10.5	8.4	12.0	12	1	1	1	0	low	Low	0	100	0	5	10.0	314.0	0.318	0.318
05/03/2006	Indian Reef	17	3	6.0	4.5	8.4	10	0	0	0	0	low	Low	50	50	0	0	10.0	314.0	0.000	0.000
05/03/2006	Indian Reef	17	4					0	0	0	0	low	Low	50	50	0	0	10.0	314.0	0.000	0.000
05/03/2006	Indian Reef	17	5					0	0	0	0							10.0	314.0	0.000	0.000
05/03/2006	Indian Reef	17	6					0	0	0	0							10.0	314.0	0.000	0.000
05/03/2006	Vesuvius	17	1	13.5	6.0	19.5		1	1	1	1	med	High	50	50	0	0	10.0	314.0	0.318	0.637
05/03/2006	Vesuvius	17	2					0	0	0	0							10.0	314.0	0.000	0.000
05/03/2006	Vesuvius	17	3					0	0	0	0							10.0	314.0	0.000	0.000
05/03/2006	Vesuvius	17	4					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Burial	18	1	10.5	6.0	15.0	7	0	0	0	0	med	High	100	0	0	5	10.0	314.0	0.000	0.000
26/02/2006	Burial	18	2					1	1	1	0							10.0	314.0	0.318	0.318
26/02/2006	Burial	18	3					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Burial	18	4					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Patey	18	1	13.5	9.0	21.0	8	1	1	1	0		Wall	50	0	50		10.0	314.0	0.318	0.318
26/02/2006	Patey	18	2	7.5	21.0	9.0	7	4	2	2	5	high	High	100	0	0	20	10.0	314.0	1.274	2.229
26/02/2006	Patey	18	3	9.0	6.0	12.0	7	1	1	1	1	med	High	50	50	0	10	10.0	314.0	0.318	0.637
26/02/2006	Patey	18	4					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	1	6.0	3.0	8.4	10	0	0	0	0	high	Low	100	0	0	0	10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	2	10.5	9.0	12.0	10	0	0	0	0	low	Low	60	40	0	0	10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	3	9.0	7.8	10.5	10	0	0	0	0	high	Low	100	0	0	0	10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	4					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	5					0	0	0	0							10.0	314.0	0.000	0.000
26/02/2006	Clover Point	19	6					0	0	0	0							10.0	314.0	0.000	0.000
21/03/2006	MacKenzie	19	1	19.5	23.4	11.1	10	2	0	0	0	med	Wall	70	10	20	0	10.0	314.0	0.637	0.000
12/03/2006	MacKenzie	19	2	19.2	17.1	22.5	10	4	3	3	1	high	High	90	10	0	0	10.0	314.0	1.274	1.274
12/02/2006	MacKenzie	19	3	16.5	12.0	19.5	7	0	0	0	1	low	High	65	0	55	0	10.0	314.0	0.000	0.318
12/02/2006	MacKenzie	19	4	15.6	12.0	19.8	8	0	0	0	0	med	High	75	15	10	5	10.0	314.0	0.000	0.000
12/02/2006	MacKenzie	19	5	13.2	9.6	16.8	8	1	0	0	0	high	High	90	10	0	10	10.0	314.0	0.318	0.000
12/02/2006	MacKenzie	19	6	19.8	16.2	22.5	8	1	1	1	0	med	High	50	50	0	0	10.0	314.0	0.318	0.318
12/02/2006	MacKenzie	19	7	16.8	15.0	19.5	8	0	0	0	1	low	High	60	10	30	0	10.0	314.0	0.000	0.318
12/02/2006	MacKenzie	19	8	13.2	9.3	16.5	8	0	0	0	0	med	High	70	20	10	10	10.0	314.0	0.000	0.000
03/03/2006	MacKenzie	19	9	22.5	19.8	27.9	8	1	1	1	0	med	High	80	20	0	0	10.0	314.0	0.318	0.318
03/03/2006	MacKenzie	19	10	13.2	11.4	20.1	10	3	3	1	0	high	High	75	25	0	0	10.0	314.0	0.955	0.318
12/02/2006	N. Cod Reef	19	1	18.0	15.0	23.1	5	0	0	0	3	low	High	90	10	0	5	10.0	314.0	0.000	0.955
12/02/2006	N. Cod Reef	19	2				5	0	0	0	0							10.0	314.0	0.000	0.000
12/02/2006	N. Cod Reef	19	3	6.9	4.8	10.2	5	1	0	1	4	med	High	100	0	0	1	10.0	314.0	0.318	1.592

Appendix 3.

				Depth (m)				Nests		Lingcod				Substrate				Plot		Density	
Date	Site	Stat Area	Plot#	Center	Min	Max	Visibility (m)	Total	Guarded	Guarding	Non-guarding	Complexity	Relief	Rock	Coarse	Fine	Algae	Radius	Area	Nest	Lingcod
06/03/2006	Wayne	19	1					2	2	1	0	med	High	50	50	0		10.0	314.0	0.637	0.318
19/02/2006	Keyen	23	1	11.4	6.6	16.5	8	1	0	0	3	high	Wall	25	70	5	5	10.0	314.0	0.318	0.955
19/02/2006	Keyen	23	2	10.8	7.8	13.8	7	2	2	2	0	high	Wall	90	5	5	5	10.0	314.0	0.637	0.637
19/02/2006	Keyen	23	3	7.5	5.4	11.4	8	3	2	2	3	high	Wall	75	25	0	10	7.0	153.9	1.950	3.250
19/02/2006	Keyen	23	4	15.0	15.0	18.0	10	0	0	0	1	med	High	100	0	0	0	7.0	153.9	0.000	0.650
19/02/2006	Keyen	23	5	9.0	9.0	12.0	10	3	3	2	0	med	High	100	0	0	25	7.0	153.9	1.950	1.300
19/02/2006	Renate Reef	23	1	14.1	12.0	18.0	10	1	1	1	3	med	High	100	0	0	0	7.0	153.9	0.650	2.600
19/02/2006	Renate Reef	23	2	12.9	12.3	15.6	10	3	3	3	0	med	High	100	0	0	0	7.0	153.9	1.950	1.950
19/02/2006	Renate Reef	23	3	14.1	12.9	15.0	7	3	3	3	0	med	High	100	0	0	5	5.0	78.5	3.822	3.822
19/02/2006	Renate Reef	23	4	16.2	15.6	17.4	6	2	2	2	3	med	High	75	20	5	0	10.0	314.0	0.637	1.592
19/02/2006	Renate Reef	23	5	15.6	13.8	17.7	7	1	1	1	5	med	High	90	10	0	5	10.0	314.0	0.318	1.911
19/02/2006	Renate Reef	23	6	12.3	11.1	15.9	8	1	1	1	6	high	Wall	100	0	0	10	5.0	78.5	1.274	8.917
26/02/2006	Ansell	28	1	9.9	3.0	15.0	6	0	0	0	3	med	High	70	30	0	10	10.0	314.0	0.000	0.955
19/02/2006	S. Bowyer	28	1	13.5	11.1	15.6	10	1	1	1	3	low	High	100	0	0	0	10.0	314.0	0.318	1.274
19/02/2006	S. Bowyer	28	2					0	0	0	0							10.0	314.0	0.000	0.000
19/02/2006	Whytecliff	28	1	21.0		27.0	3	0	0	0	0	low	High	20	0	80	0	10.0	314.0	0.000	0.000
18/02/2006	Whytecliff	28	2	17.1	15.0	20.4	2	0	0	0	1	low	Wall	0	40	60	20	10.0	314.0	0.000	0.318

Appendix 4. Habitat, depth, lingcod and nesting information for plots completed by Fisheries & Oceans Canada staff. Flora; A.=*Agarum*, N=*Nereocystis*. Radius of all plots is 10 m and Area always = 314.0 m^2.

				Depth (m)				Nests		Lingcod		Complexity						Substrate			Flora			Density	
Date	Site	Stat Area	Plot#	Center	Min	Max	Vis (m)	Total	Guarded	Guarding	Non-guarding	Simple	Low	Med	High	Category	Relief	Rock	Coarse	Fine	A.	N.o	Other	Nest	Lingcod
03/03/2006	Snake	17	1	9.3	8.7	9.6	9	1	1	1	0	50	50	0	0	low	Flat	90	10	0	0	0	0	0.32	0.32
03/03/2006	Snake	17	2	9.9	9.9	12.0	10	1	1	1	1	0	100	0	0	low	Low	85	10	5	20	0	0	0.32	0.64
03/03/2006	Snake	17	3	11.4	10.5	13.5	10	0	0	0	2	0	100	0	0	low	High	90	0	10	20	0	0	0.00	0.64
03/03/2006	Snake	17	4	10.2	9.0	12.0	10	1	1	1	0	0	100	0	0	low	Low	90	0	10	30	0	0	0.32	0.32
03/03/2006	Snake	17	5	6.0	5.7	7.5	10	1	1	1	0	30	70	0	0	low	Low	95	5	0	0	0	0	0.32	0.32
03/03/2006	Snake	17	6	8.1	7.8	9.3	10	3	1	1	0	80	20	0	0	simple	Flat	90	10	0	0	0	0	0.96	0.32
03/03/2006	Snake	17	7	7.8	6.0	9.0	10	0	0	0	1	0	0	100	0	med	high	70	20	10	20	0	0	0.00	0.32
03/03/2006	snake	17	8	12.0	9.0	15.0	10	0	0	0	0	0	0	100	0	med	High	80	10	10	10	0	0	0.00	0.00
07/03/2006	Snake	17	9	13.2	12.6	15.3	7	2	1	1	1	0	10	20	70	med	High	90	10	0	0	0	0	0.64	0.64
07/03/2006	Snake	17	10	12.0	7.5	13.5	10	1	1	1	1	0	20	80	0	med	Low	70	30	0	0	0	0	0.32	0.64
07/03/2006	Snake	17	11	13.2	12.6	13.5	9	0	0	1	2	50	0	50	0	low	Flat	50	20	30	60	0	0	0.00	0.96
07/03/2006	Snake	17	12	7.8	7.2	9.3	10	0	0	0	1	80	20	0	0	simple	Low	90	10	0	0	0	0	0.00	0.32
07/03/2006	Snake	17	13	7.5	6.6	12.0	10	0	0	0	1	0	100	0	0	low	Low	90	10	0	0	0	0	0.00	0.32
07/03/2006	Snake	17	14	10.5	9.0	15.0	8	0	0	0	0	75	20	0	0	simple	Low	90	10	0	20	0	0	0.00	0.00
07/03/2006	Snake	17	15	13.5	12.0	15.0	10	3	3	1	1	0	0	100	0	med	Low	80	20	0	60	0	0	0.96	0.64
07/03/2006	Snake	17	16	7.5	7.5	7.8	8	2	1	1	2	50	25	25	0	low	Flat	90	10	0	0	0	0	0.64	0.96
09/03/2006	Discovery	13	5	7.5	6.0	12.0	15	0	0	0	0	0	0	50	50	med	Wall	100	0	0	0	0	90	0.00	0.00
09/03/2006	Discovery	13	6	12.0	8.1	15.0	12	2	2	1	0	0	0	100	0	med	High	90	10	0	0	0	0	0.64	0.32
09/03/2006	Discovery	13	7	12.9	7.5	15.0	12	0	0	0	1	0	60	40	0	low	Wall	90	0	10	0	0	0	0.00	0.32
09/03/2006	Maude	13	1	10.5	7.8	12.3	11	0	0	0	2	0	0	0	100	high	High	100	0	0	0	0	0	0.00	0.64
09/03/2006	Maude	13	2	15.3	10.8	18.0	11	0	0	0	2	0	50	50	0	med	Wall	100	0	0	0	0	0	0.00	0.64
09/03/2006	Maude	13	3	10.2	7.2	10.2	12	0	0	0	0	0	50	50	0	med	High	50	50	0	0	10	30	0.00	0.00
09/03/2006	Maude	13	4	12.0	10.2	15.6	15	0	0	0	1	0	0	100	0	med	Wall	80	20	0	0	0	0	0.00	0.32
10/03/2006	Entrance	17	1	13.8	12.0	13.8	10	0	0	0	1	0	100	0	0	low	Low	80	15	5	0	0	0	0.00	0.32
10/03/2006	Entrance	17	2	13.8	12.0	15.0	10	0	0	0	1	0	50	0	50	med	High	85	10	5	10	0	0	0.00	0.32
10/03/2006	Entrance	17	3	13.2	10.5	13.5	15	0	0	0	1	60	40	0	0	low	Low	30	10	60	0	0	0	0.00	0.32
10/03/2006	Entrance	17	4	12.0	9.0	15.0	12	0	0	0	0	20	20	60	0	med	High	60	20	20	10	0	0	0.00	0.00

Appendix 5. Site name information and location sampled by volunteers and Fisheries & Oceans Canada staff during the 2006 lingcod egg mass density survey.

Site	Name Code	Stat Area	Latitude DD	Longitude DD	Location	Type	Group	# of plots completed
Five Fathoms Rock	FF	12	50.7442	-127.4868	Hardy Bay	Volunteer	Top Island Econauts	3
Discovery Pass	DP	13	50.1938	-125.3800	CR	DFO	DFO	3
Maud I.	MI	13	50.1290	-125.3383	CR	DFO	DFO	4
Whiskey Point	WP	13	50.0425	-125.2217	CR	Volunteer	CR Tiderippers	2
Eagle Rock	ER	14	49.4770	-124.6833	Hornby-Denman	Volunteer	Union Bay	6
Norris Rock	NR	14	49.4850	-124.6483	Hornby-Denman	Volunteer	Union Bay	4
Coode I.	CI	15	50.0307	-124.7490	Oekeover	Volunteer	Powell River	7
Cochrane I.	CO	15	50.0473	-124.7798	Oekeover	Volunteer	Powell River	8
Agamemnon Ch.	AC	16	49.7447	-124.0289	Sechelt	Volunteer	Suncoast	1
Coopers Green	CG	16	49.5045	-123.9108	Sechelt	Volunteer	Cap College	1
Tuwanek	TU	16	49.5570	-123.7777	Sechelt	Volunteer	Suncoast & UBC	10
White Isl	WI	16	49.4182	-123.7117	Sechelt	Volunteer	Suncoast	2
Entrance	EI	17	49.2102	-123.8093	Nanaimo	DFO	DFO	4
Indian Reef	IR	17	48.8873	-123.6308	Chemainus	Volunteer	Duncan Divers	6
Snake	SI	17	49.2117	-123.8847	Nanaimo	DFO	DFO	16
Vesuvius	VB	17	48.8788	-123.5760	Saltspring	Volunteer	Duncan Divers	4
Burial Island	BI	18	48.7695	-123.5637	Sansun Narrows	Volunteer	Duncan Divers	4
Patey Rock	PR	18	48.7008	-123.5208	Satellite Channel	Volunteer	Duncan Divers	4
Clover Point	CP	19	48.4055	-123.3602	Victoria	Volunteer	Esquimalt Dive Club	6
Mackenzie Bight	MB	19	48.5533	-123.5077	Saanich Inlet	Volunteer	Victoria SCUBA Club	10
N. Cod Reef	NC	19	48.6577	-123.3017	Sidney	Volunteer	Victoria SCUBA Club	4
Wain Rock	WR	19	48.6875	-123.4897	Saanich Inlet	Volunteer	Duncan Divers	1
Kyan Pt	KP	23	48.9535	-125.1893	Barkley Sound	Volunteer	BMSC	5
Renate's Reef	RR	23	48.9068	-125.1723	Barkley Sound	Volunteer	BMSC	6
Ansell Pt.	AP	28	49.4000	-123.2517	Howe Sound	Volunteer	UBC	1
S. Bowyer	SB	28	49.4162	-123.2688	Howe Sound	Volunteer	UCBC	2
Whytecliff	WC	28	49.3712	-123.2938	Howe Sound	Volunteer	Edge Diving	2

Appendix 6. Fish species count information per plot. Rockfish species were categorized as either greater than 15 cm (adult) or less than 15 cm (juvenile).

			Lingcod		Copper Rockfish		Quillback Rockfish		Kelp Greenling		Cabezon	Total
Site	Stat Area	Plot	Guardian	Non-guardian	Adult	Juvenile	Adult	Juvenile	Female	Male		
Discovery	13	5	0	0	3	1	3	2	3	2	0	14
Discovery	13	6	1	0	8	0	0	1	0	3	0	13
Discovery	13	7	0	1	1	1	0	0	1	1	0	5
Maud	13	1	0	2	4	2	10	5	0	1	0	24
Maud	13	2	0	2	5	0	4	0	0	0	2	13
Maud	13	3	0	0	9	0	1	0	3	0	0	13
Maud	13	4	0	1	3	0	3	0	1	0	0	8
Entrance	17	1	0	1	3	1	0	5	3	1	0	14
Entrance	17	2	0	1	9	1	0	2	2	1	0	16
Entrance	17	3	0	1	0	0	0	0	0	0	0	1
Entrance	17	4	0	0	2	0	0	16	0	2	0	20
Snake	17	1	1	0	3	3	0	0	0	0	0	7
Snake	17	2	1	1	0	0	0	0	0	1	0	3
Snake	17	3	0	2	0	1	0	0	0	0	0	3
Snake	17	4	0	0	0	1	0	0	0	0	0	1
Snake	17	5	1	0	0	0	0	0	0	0	0	1
Snake	17	6	1	0	3	2	0	0	0	1	0	7
Snake	17	7	0	1	2	0	0	1	1	1	0	6
snake	17	8	0	0	1	3	0	0	1	0	0	5
Snake	17	9	1	1	7	1	2	1	0	0	0	13
Snake	17	10	1	1	6	0	0	0	1	0	0	9
Snake	17	11	1	2	4	1	0	0	3	1	0	12
Snake	17	12	0	1	0	0	1	0	0	0	0	2
Snake	17	13	0	1	3	3	0	0	0	0	0	7
Snake	17	14	0	0	1	0	1	0	2	0	0	4
Snake	17	15	1	1	6	0	0	0	1	0	0	9
Snake	17	16	1	2	2	0	1	1	0	1	0	8

Appendix 7. Geographic coordinates (in decimal degrees) of some plots were available. The exact positions of other plots were not taken.

Site	Stat Area	Plot#	Latitude	Longitude
Discovery	13	5	50.1943	-125.3799
Discovery	13	6	50.1938	-125.3800
Discovery	13	7	50.1950	-125.3801
Maud	13	1	50.1285	-125.3385
Maud	13	2	50.1290	-125.3383
Maud	13	3	50.1298	-125.3384
Maud	13	4	50.1277	-125.3405
Eagle	14	1	49.4770	-124.6833
Eagle	14	2	49.4770	-124.6838
Eagle	14	5	49.4767	-124.6833
Eagle	14	6	49.4761	-124.6842
Norris	14	1	49.4850	-124.6484
Norris	14	2	49.4850	-124.5617
Norris	14	3	49.5004	-124.6672
Norris	14	4	49.4963	-124.6443
Entrance	17	1	49.2104	-123.8083
Entrance	17	2	49.2097	-123.8117
Entrance	17	3	49.2101	-123.8066
Entrance	17	4	49.2091	-123.8070
Snake	17	1	49.2127	-123.8845
Snake	17	2	49.2123	-123.8847
Snake	17	3	49.2121	-123.8841
Snake	17	4	49.2114	-123.8842
Snake	17	5	49.2111	-123.8848
Snake	17	6	49.2107	-123.8847
Snake	17	7	49.2102	-123.8853
Snake	17	8	49.2105	-123.8859
Snake	17	9	49.2115	-123.8856
Snake	17	10	49.2120	-123.8853
Snake	17	11	49.2126	-123.8851
Snake	17	12	49.2118	-123.8847
Snake	17	13	49.2114	-123.8850
Snake	17	14	49.2109	-123.8857
Snake	17	15	49.2099	-123.8856
Snake	17	16	49.2121	-123.8846