British Columbia 2021 Lingcod Egg Mass Survey

Photo: Pat Terfloth

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A Brief History of Lingcod in British Columbia

Lingcod have an extensive history of commercial and recreational exploitation and were once the fourth largest commercial fishery in British Columbia (Cass et al. 1990). Throughout the last century, lingcod have undergone biomass reduction from commercial fishing. In the late 1980s, lingcod stocks in the Strait of Georgia collapsed to approximately 3-5% of original biomass, with Howe Sound stocks reaching a low 1% of original biomass (Martell and Wallace, 1998). As a result, the Strait was closed to commercial fishing in 1990, with sport fishing regulations established in 1992. Even with these precautionary actions implemented, the depressed state of lingcod abundance was still a concern and thus Porteau Cove and Whytecliff Park were designated as a no-take closure area in 1993 under the Fisheries Act of Canada. In 2002, all sport fishing for lingcod was banned in the Strait of Georgia and surrounding waters. This ban was lifted on the east coast of Vancouver Island in 2006 but remains in place for the Vancouver area (area 28 and 29-1, 29-4 and 29-6 to 29-17).

In 2007 the Department of Fisheries and Oceans Canada (DFO) established 164 Rockfish Conservation Areas (RCAs) in British Columbia, in order to provide protection for B.C.'s inshore rockfish populations (Yamanaka and Logan 2010), which are severely depleted following decades of unsustainable harvesting. These RCAs also provide protection for, and assist in the recovery of, local lingcod populations. Owing to extreme low abundance of lingcod in Howe Sound and Burrard Inlet, all hook-and-line fishing for groundfish (lingcod and rockfish) was banned in summer of 2007.

Lingcod spawn from December through to early April in the Strait of Georgia, with peak egg mass abundance in late February. The males guard the egg masses, for over a month until hatching. The behavior of the guarding male and the distinctive appearance of the egg masses are easily identified by SCUBA divers. Dives logged during the annual Lingcod Egg Mass Survey are performed by recreational divers as well as Ocean Wise® staff. Divers are enlisted through a variety of sources including dive organizations, stores, charters, magazines, and personal contacts. For the most part, dives by Ocean Wise® staff have been limited to Howe Sound.

Biology of Lingcod

Lingcod spawn primarily in January/February in crevices on rocky shores of western North America where strong currents allow for egg respiration (Cass et al., 1990). Eggs are adhesive to each other and resemble a clump of styrofoam. Females can begin to spawn at three years old and their egg masses are approximately one liter volume. A four-year female will lay an egg mass of about 2-2.5 liters, and then beyond five-years old, the fish lay much larger egg masses (Giorgi 1981). In 1995 reference sizes were created based on whether the egg mass resembled the size of a grapefruit (under one liter, from a 3-yr female), a cantaloupe (ca. two liters, from 4-yr female), or watermelon (5-yr or older). Most lingcod spawning occurs within a depth range safe for scuba diving (often between 15-60 ft).

Most nests are guarded by the male parent, although smaller males tend to flee temporarily when approached by seals or divers. Smaller males may sneak in and partially fertilize eggs during spawning, so a spawning reef often has more male lingcod than nests. The guarding male is the fish that attracted the female and initiated courtship and spawning and is usually the principal sire of the egg mass. A dominant male may guard two or three adjacent egg masses, usually separately by no more than 1m (Cass et al., 1990). The

guarding behavior of the male parent tends to indicate the location of the eggs, which vary from white when newly laid to dark gray toward hatching. If the egg mass remains lodged in a crevice where currents force water flow through the eggs, and the male remains to prevent predation, embryos survive to the hatching stage of development.

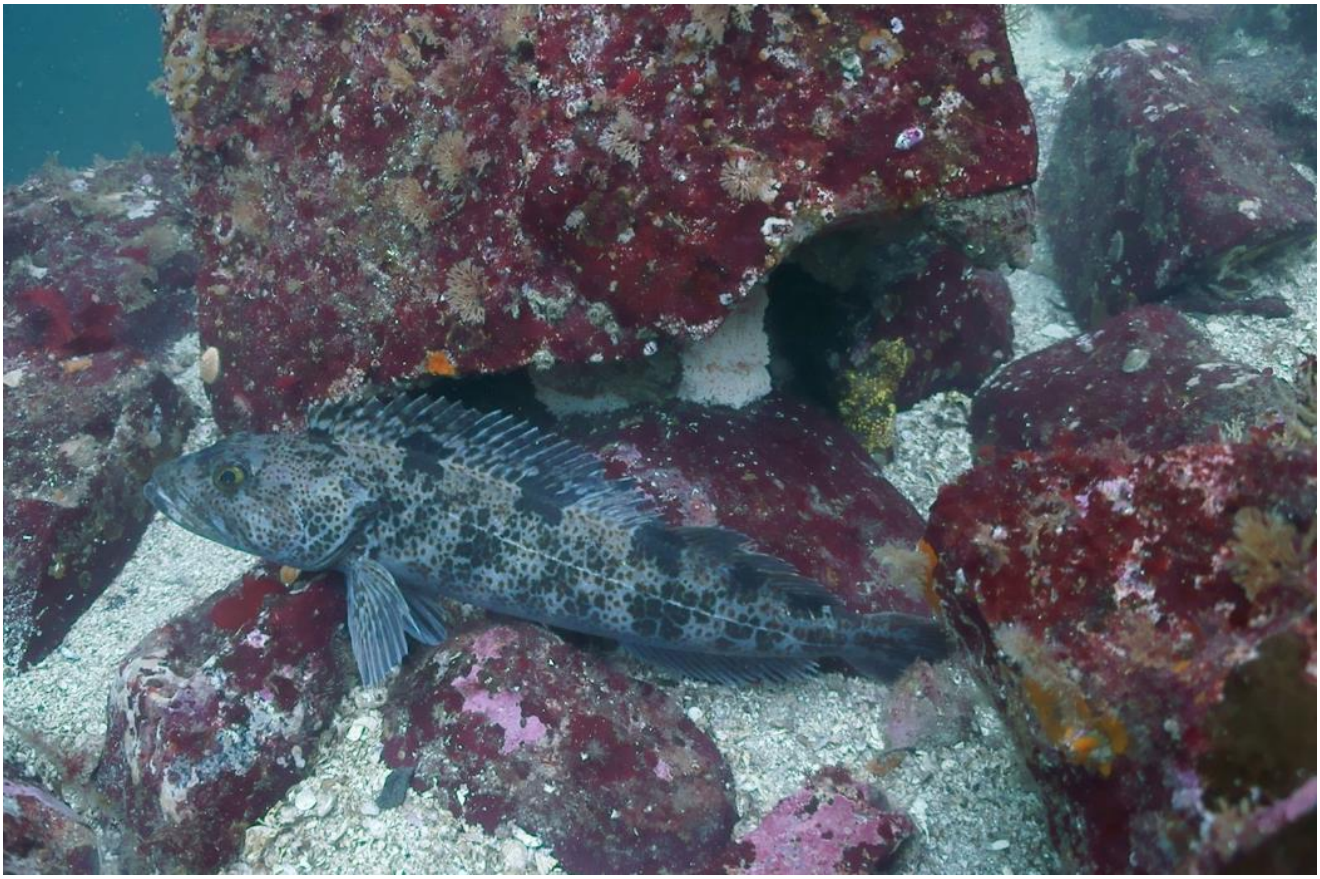

Photo of male lingcod guarding egg mass.

Eggs incubate for 5-11 weeks depending on temperature and current flow (Cass et al., 1990). Hatch success varies with strength of currents: egg mortality occurs from respiratory failure in low flows. Newly hatched larvae swim rapidly to the surface, orient into currents and swim offshore by selecting stronger currents. This takes them into tidal current drift and rapidly disperses them through the spawning area. Little is known about the extent of larval dispersal, but over-fished areas do not seem to receive any rescue effect from spawning populations in remote areas. Adults are relatively sedentary, with only the females showing a seasonal depth migration for summer feeding.

Within two to three months of hatching, larvae settle at about 70 mm length and start feeding on juvenile herring. Lingcod reach 21 cm length in their first year, 30 cm at 20 months age, and 45 cm (0.8 kg weight) in their third year. Males grow rapidly until 8 years of age and live to a maximum of approximately 14 years. Females grow until 12-14 years of age and live to approximately 20 years. An age 13 male averages 84 cm and 6.1 kg, versus an age 13 female that averages 103 cm and 11.9 kg. The size record is 150 cm and 32 kg. Female lingcod of 10-12 years age are about twice the weight of males that age.

Survey Instructions

This year marked the 28th anniversary of the Lingcod Egg Mass Survey (LEMS). Initiated in the winter of 1994 by the Marine Life Sanctuaries Society (MLSS), the survey encourages divers from the community to census spawning of lingcod along the B.C. coast. Since 1996, Ocean Wise® has promoted and collated data for the census, encouraging a record number of participants.

The Lingcod Egg Mass Survey occurs over a six-week period centered on the third weekend in February, a time when most lingcod egg masses have been spawned but not much hatching has occurred. Divers are given instructions with all the pertinent information to complete the census; the instructions are available online (https://research.ocean.org/survey/lingcod) or by contacting Ocean Wise® (biodiversityresearch@ocean.org). For each dive the following information is recorded:

Date - The month/day/year.

Diver Information - The first and last names of both divers and all pertinent contact information.
Area - There are 31 polygon areas we have divided the coast into; please note the appropriate area. Map provided on the website.
Dive Site - Divers often identify sites by local names, which can make it difficult for us to know where the data were collected. Identify the specific location you are diving in and provide a GPS point if possible (ex: Whytecliff Park – Marker).
Bottom Time - Note the bottom time for your dive and if only a portion of the dive was spent looking for egg masses, note that time.
Comments - Be sure to record if no egg masses are found or if the dive was primarily on soft bottom (versus bedrock or boulders).
Nest Information
Depth – Note the depth where you found the egg mass in feet.
Size – Estimate if the egg mass is roughly the size of a Grapefruit, Cantaloupe or Watermelon (G, C, W).
Condition – You may want to bring a dive light along with you, this will aid in determining the condition of the egg mass. Recently extruded eggs will generally be white/pink (N=New). Older eggs will be eyed/dark grey (E=Eyed), or rotten (R=Rotten).
Situation – Note how the egg mass is situated, either loose (L) in a crevice, secure (S) in a crevice, or loose in the open (O).
Nest Guarding Male – Often one male may guard more than one egg mass. If the male is guarding only one egg mass, indicate so with a "P". If the male is guarding multiple egg masses, indicate so with "P2". If this is observed, record each egg mass as an individual egg mass and be sure to indicate the nest guarding male as "P2" for each egg mass. If there is an egg mass without a guarding male, indicate the absence of the male with "A".

Sample dive slate with nest information:

Nest #	Depth (ft)	Size	Condition	Situation	Nest Guarding Male
1	18	W	N	S	P2
2	18	W	E	S	P2
3	20	C	R	O	A
4	35	G	E	L	P
5	32	W	N	O	A
6	33	C	E	S	P

All data are sent to Ocean Wise® or entered online. Once we have sorted the data we calculate the index of abundance by using a Count Per Unit Effort (CPUE). The CPUE is the number of egg masses sighted per hour and is calculated by multiplying the number of egg masses by 60 to get an hourly sighting rate, divided by the dive time.

Figure 1. Geographic area breakdown for British Columbia south coast and Washington, comprised of 31 unique polygons. Areas are defined based on patterns from long-term biodiversity records.

Results and Discussion

The 28th annual lingcod egg mass survey was conducted between January 30th and March 14th, 2021. Divers from all across British Columbia undertook 74 dives, totaling over 70 hours of underwater surveying, finding 111 egg masses (Table 1). This is the lowest number of dives conducted for this survey since 2012, a direct impact from COVID-19. In a typical year, dive operators would provide upwards of 70 additional survey submissions; however, many diving companies have been closed since early 2020, not allowing them to participate in this years' survey. Ocean Wise staff have similarly halted all dive operations, so all sightings in this year's report are from citizen scientists, highlighting the importance of their contributions to research.

Area	# of Dives	Total Minutes	Total Egg Masses	CPUE	%W	%C	%G	% Secured	% Guarded
Burrard Inlet	1	5	1	12	0	100	0	100	100
Howe Sound	13	792	17	1.29	58.8	35.3	5.9	76.5	76.5
Inside Southern Gulf Islands	9	637	0	0	0	0	0	0	0
NE Vancouver Island	3	146	38	15.62	94.7	5.3	0	100	86.8
Parksville	27	1870	46	1.48	65.2	34.8	0	84.8	82.6
Saanich Inlet	10	429	5	0.70	40	60	0	60	100
SE Mainland	2	10	2	12	0	100	0	100	50
Strait of Juan de Fuca	3	123	1	0.49	100	0	0	100	100
Victoria	6	232	1	0.26	0	100	0	100	100
all	74	4244	111	1.57	71.2	27.9	0.9	88.3	83.8

Table 1. Summary, by area, of lingcod egg mass sightings along the British Columbia south coast in winter 2021.

The last decade has seen a downward trend in lingcod abundance along British Columbia's south coast. The 28-year average abundance of egg masses across all areas surveyed on B.C.'s south coast was 4.09 egg masses h^{-1} (Fig. 2). The 2021 results were far below the long-term average with divers recording an average of 1.57 egg masses h^{-1} (Fig. 2). This is the first time in the survey's history that a yearly average has reached below 2 egg masses h^{-1}.

Five areas had repeated surveys from 2020 – Howe Sound, Inside Southern Gulf Islands, NE Vancouver Island, Parksville and Saanich Inlet. Of these areas, only Howe Sound showed an increase in average egg mass abundance from 1.06 egg masses h^{-1} in 2020 to 1.29 egg masses h^{-1} in 2021. For the second year in a row, the Inside Southern Gulf Islands area had 0 egg masses observed. While it can be explained that the locations surveyed in the Inside Southern Gulf Islands area were not the same as 2020 or 2019, this decline in egg mass abundance is concerning and further investigation will be needed to understand why lingcod are not spawning in this area. Consistent with previous years, NE Vancouver Island had the highest average egg mass abundance at 15.62 egg masses h^{-1}. Although NE Vancouver Island typically reports high egg mass abundances and is usually above the 28-year average for all areas, their egg mass abundance still declined from 2020. Reports

from Saanich Inlet also provide further insight into their observations and low egg mass abundance of 0.70 egg masses h^{-1}. We were informed that other divers who were in the area during the survey period, but did not submit a survey, did not see any egg masses over multiple dives. With this information, it is possible that the egg mass abundance may be less than reported. We would also like to highlight Burrard Inlet and SE Mainland which each had a reported egg mass abundance of 12 egg masses h^{-1}. The dive time for these areas was low, which would account for the high abundances. Longer surveys are needed in both areas in the future to get a more accurate depiction of egg mass abundance.

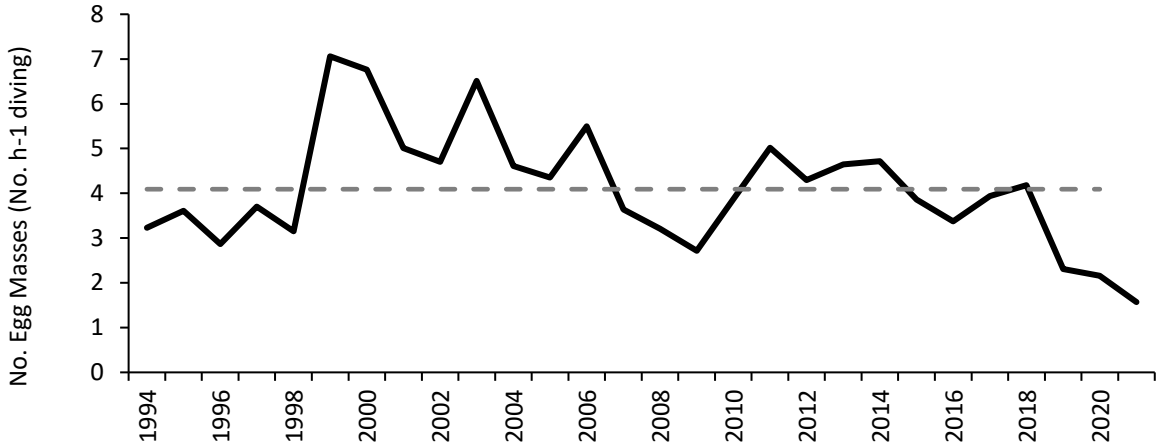

Figure 2. Abundance of lingcod throughout British Columbia's south coast since 1994, measured as the number of egg masses seen per hour diving. Solid line indicates average for each survey year. Dashed line indicates average egg masses over the past 28-years (4.09 egg mass h^{-1}).

Taking a closer look at the egg masses themselves, over the last 28 years the older females on average have produced about 50% of total egg masses (Fig. 3). This year, egg masses from the oldest females comprised 71% of egg masses observed, the highest ever for that age group. Four-year-old females contributed 28% of egg masses, and the youngest females only comprised 1% of total egg masses. The large increase in watermelon sized egg masses can likely be explained by looking at the observations from 2020. Last year the four-year-old females produced the most egg masses, and assuming most survived to 2021, we would have expected a large increase in watermelon sized egg masses. Similar instances have taken place in 1998/1999 and 2007/2008. This is the first time that the youngest age group of spawning females has produced such a low percentage of egg masses (1%) and only in one area (Howe Sound). There is no clear indication why this has happened.

Looking at the geographic data can provide more clues as to the health of the lingcod populations. Three areas had at least ten surveys contributed in 2021 to provide a sufficient sample size for comparison: Howe Sound, Parksville and Saanich Inlet. None of these three areas had an abundance of lingcod egg masses above the 28-year average (Table 1). Compared to previous years, both Parksville and Saanich Inlet saw decreases in average egg mass abundance. Additionally, Saanich Inlet has been steadily decreasing in egg mass abundance every year since 2018 when it was at 5.2 egg masses h^{-1}. Both Parksville and Howe Sound have been fluctuating in egg mass abundance over the years. This was the first year egg masses were reported on the HMCS Annapolis in Howe Sound, indicating that younger lingcod may be expanding their territory in the Sound.

Another indicator of population viability is looking at the presence of a guarding male at a nest site. All but one site (SE Mainland) had at least 75% of egg masses guarded by a male (Table 1). At four sites (Burrard Inlet, Saanich Inlet, Strait of Juan de Fuca and Victoria) all egg masses were observed to be guarded by a male. SE Mainland was only surveyed for 10 minutes over two surveys so it is likely that there were more egg masses

in the area which could have been guarded by a male. More surveys in this area in the future are necessary to get a better overview of lingcod abundance and guarding. The absence of a male lingcod guarding an egg mass greatly reduces the likelihood of eggs reaching the hatching stage. Without the male, it is likely that the eggs would be consumed by predators such as urchins or sea stars.

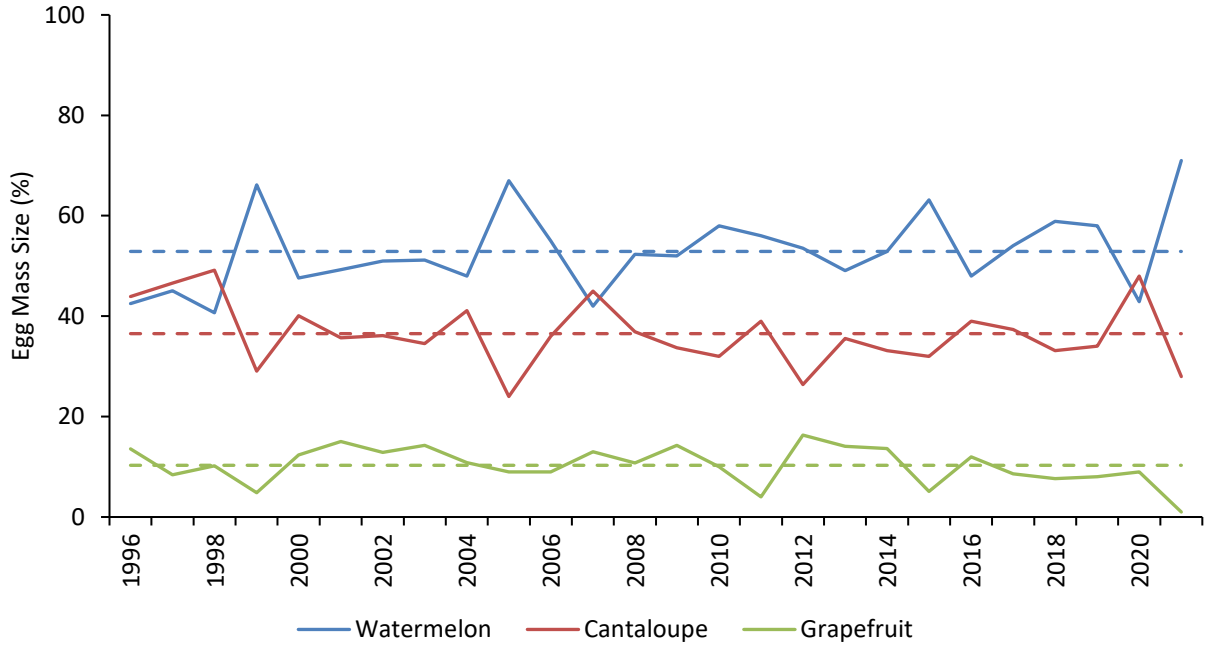

Figure 3. Percentage of egg masses produced by 5+ year old females (blue), 4-year-old females (red), and 3-year-old females (green) throughout British Columbia's south coast since 1996. The dashed lines represent the average percentage of egg masses for each size over the past 28-years.

Selected sites

Lingcod have large home ranges but are unlikely to stray more than 10 km from where they settle as juveniles (Cass et al., 1990). Examining lingcod population abundance and spawning population structure at specific sites provides an opportunity to understand year-over-year changes on a much smaller geographic scale. We have selected four sites where data for this survey have been collected for at least ten years, representing three areas with an extensive survey history (Fig. 4).

At Whytecliff Park – designated as an MPA in 1993 – the average egg mass abundance increased slightly from 0.95 egg masses h^{-1} in 2020 to 1.39 egg masses h^{-1} (Fig. 4a). Apart from two years (2000 and 2019), Whytecliff Park has always been below the 28-year average. Watermelon sized egg masses comprise the majority of sightings every year, pointing to an older female population. Additionally, no grapefruit sized egg masses have been seen since 2013, which could indicate low survivorship or high dispersal of lingcod larvae. By comparison, the other MPA in Howe Sound – Porteau Cove – has historically seen between 5-10 egg masses h^{-1} since surveys began there in 1996 (Fig. 4b). The last two years have seen a decline in egg mass abundance well below average, which is concerning should this trend continue. Porteau Cove has always had a strong egg mass abundance, so further investigation is required to understand if this change is due to a declining lingcod population or lack of survey effort.

NE Vancouver Island has consistently had the highest average egg masses of any area surveyed. Taking a closer look at one site surveyed since 2001, Five Fathom Reef, this location has a 20-year average of 21.6 egg

masses h^{-1}. The average egg mass abundance in 2021 was low at 15.62 egg mass h^{-1} (Fig. 4c), however this area still had the highest abundance of egg masses of any area surveyed this year. The majority of egg masses seen were watermelon-sized (95%), consistent with previous years' data. The qualitative data from this site however reveals an interesting shift in lingcod reproduction. Surveys were conducted towards the end of spawning season, one week after the survey period. Many female lingcod were observed to still be full of eggs, which would suggest a late breeding season. Males were also reported to be smaller with many battle scars, supporting the idea that spawning was still occurring at this site. Furthermore, watermelon-sized egg masses were observed to be smaller than previous years (typically they are the size of two watermelons). This is the first year these specific observations have been reported and it will be important to monitor this site in subsequent years.

At Henderson Point in Saanich Inlet, surveys have been conducted on and off since 1998. For the last three years egg mass abundance has steadily declined, resulting in 0 egg masses h^{-1} this year (Fig. 4d). With the exception of 1998, 2011 and 2018, egg mass abundance has always been relatively low at less than 2 egg masses h^{-1}. These results are consistent with the whole Saanich Inlet area which had an average egg mass abundance at 0.70 egg masses h^{-1}. This is not the first time that Henderson Point has seen an egg mass abundance of 0. In 2013 and 2014 no egg masses were observed, so there is a chance that lingcod could return to spawn next year.

Lingcod egg mass abundance within and among areas is highly variable. Twenty eight years of conducting surveys along British Columbia's south coast has shown no clear indication about age population or structure. To see a significant recovery of lingcod stocks from the low reached in the 1990s, we hope to see an increase in the number of large females which produce the greatest number of, and most viable, young. Because COVID-19 prevented many citizen scientists from surveying areas they would regularly visit, it is possible that the decline we are witnessing may not be truly representative of lingcod abundance in 2021. However, if trends continue to decline in future years, more measures will need to be implemented to protect this species. As always, more targeted surveys within areas for year-to-year comparisons are needed to build a comprehensive understanding of lingcod population abundance and structure.

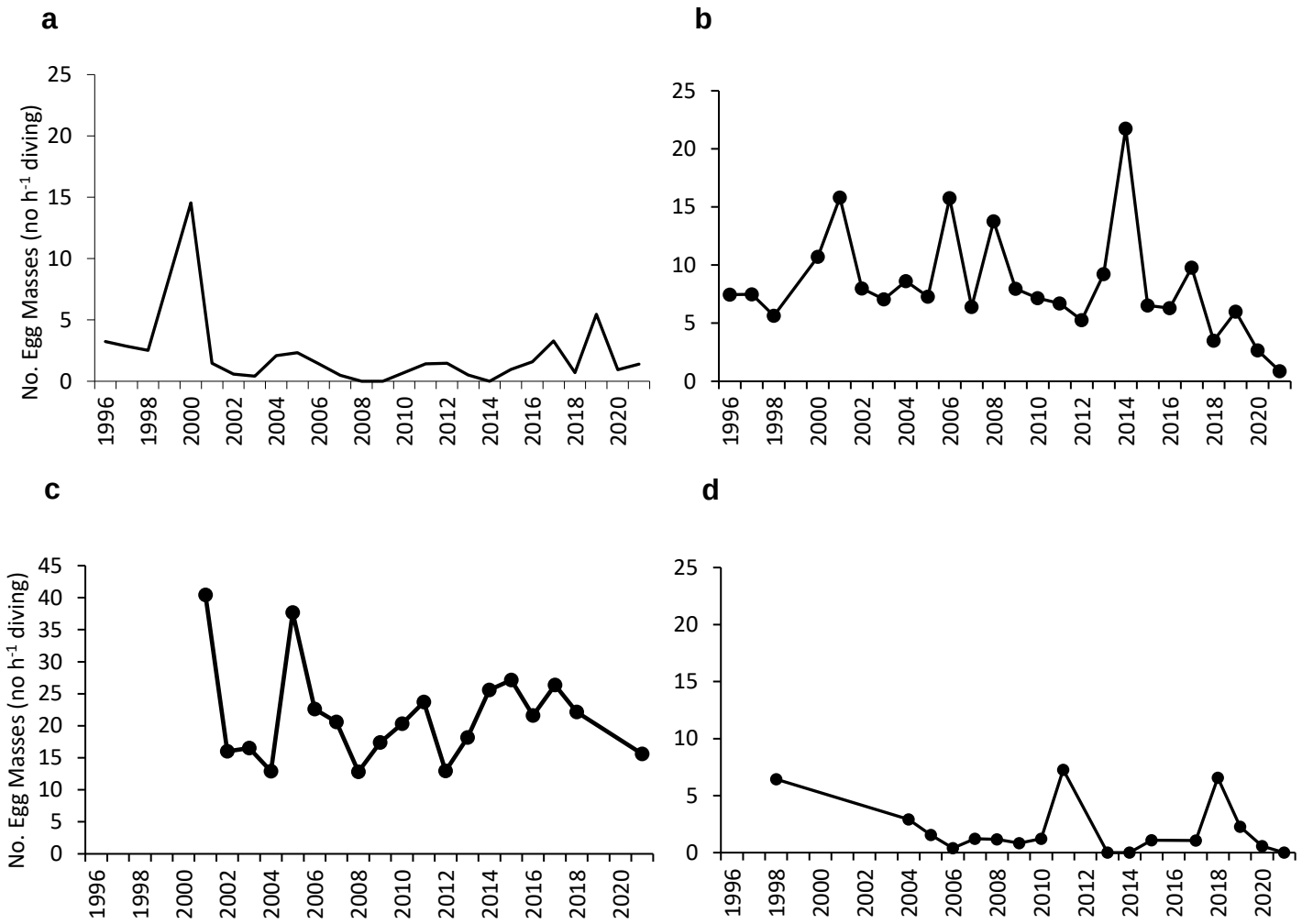

Figure 4. Abundance of lingcod egg masses (count per unit effort) since 1996 at (**a**) Whytecliff Park, and (**b**) Porteau Cove in Howe Sound, (**c**) Five Fathom Reef in NE Vancouver Island, and (**d**) Henderson Point in Saanich Inlet.

Threats

The two main threats to lingcod population recovery are illegal fishing practices and predators, including seals and sea lions. Lingcod populations face pressure from recreation fishing likely due to a combination of lack of knowledge of fishing restrictions and difficulty of enforcement by DFO. A 2005/2006 enforcement campaign along the Sea-to-Sky Highway by DFO coincided with an increase in egg mass abundance for Howe Sound in 2006. Whytecliff Park, despite being designated as an MPA in 1993, is a prime example of an area where frequent poaching has been seen. In addition to illegal fishing pressures, populations of harbor seals have increased in the past decade and are a potential contributor to the continued suppression of lingcod spawning numbers, though no analysis of seal diets has been conducted since the 1980s for areas such as Howe Sound.

Solutions

In 2007, 164 rockfish conservation areas were established along the British Columbia coast, which aim to protect B.C.'s depleted inshore rockfish stocks and lingcod. Increased awareness about the location and boundaries of these areas are needed to ensure compliance by the public. For example, these areas have yet to be added to any GPS systems used by boaters. Having these areas clearly outlined for the public would help to prevent accidental fishing activity and reduce chances of bycatch.

Continuation and expansion of the DFO enforcement campaign from 2005/2006 all along the B.C. coast would be beneficial to increase awareness and compliance. Efforts aimed at rockfish conservation on Galiano Island have shown that increased awareness can reduce fishing activity in protected areas.

Additionally, there is a complete commercial and recreational fishery closure for area 28 and parts of area 29 (Howe Sound and Burrard Inlet) for hook-and-line fishing for lingcod and rockfish. Follow the existing regulations for fishing in your area and report any violations to the Department of Fisheries and Oceans Canada (DFO: 1-800-465-4336).

How can you help?

Since its inception in 1994, the lingcod egg mass survey has been strongly dependent on divers from the community surveying rocky reefs for lingcod egg masses from January to March. What started as a citizen science initiative of the Marine Life Sanctuary Society remains largely dependent on contributions from the diving community. Divers can contribute to this survey by submitting their dives online during the annual Lingcod Egg Mass Survey (https://research.ocean.org/survey/lingcod).

The Lingcod Egg Mass Survey is not the only census the Ocean Wise Research Institute's Howe Sound Research Program conducts. Since 2002, prior to the announcement of the first Rockfish Conservation Areas (RCAs) in 2004, researchers for Ocean Wise have been conducting Rockfish Abundance Surveys. Since 2013 the majority of contributions to the survey effort have come from citizen science divers throughout British Columbia. The Ocean Biodiversity Research Program promotes the Rockfish Abundance Survey (RAS) August – October annually. For more information visit the survey webpage: https://research.ocean.org/survey/rockfish

Not a diver? You can still contribute to lingcod conservation by following local fishing regulations and reporting any violations to DFO (1-800-465-4336).

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