Monthly Distribution and Catch Trends of Eulachon (Thaleichthys pacificus) from Juan de Fuca Strait to the Fraser River, British Columbia, October 2017 to June 2018

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MONTHLY DISTRIBUTION AND CATCH TRENDS OF EULACHON (*Thaleichthys pacificus*) FROM JUAN DE FUCA STRAIT TO THE FRASER RIVER, BRITISH COLUMBIA, OCTOBER 2017 TO JUNE 2018

by

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ABSTRACT

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There is uncertainty and a lack of data associated with life history traits and seasonal trends in marine distribution of Fraser River Eulachon (*Thaleichthys pacificus*). A monthly bottom trawl study was funded by Fisheries and Oceans Canada's National Rotational Survey Fund from October 2017 to June 2018 to sample Eulachon in three regional strata in Juan de Fuca Strait and the Strait of Georgia. The goal of this study was to gain insights into the biology, distribution, and migration timing of Eulachon to the Fraser River by observing their spatial and temporal occurrence and biological condition over a wide survey region and over a series of months.

Eulachon catch per unit effort, size distributions, sex ratios, and maturity observations varied over time and space, as did the occurrence of stomach contents and presence/absence of teeth. Highest catches of Eulachon occurred in Juan de Fuca and lowest near the Fraser River. Mean catch rates at sites near the Fraser River plume corresponded with expected peak spawning periods in the Fraser River. The sex ratio of Eulachon sampled throughout the study region in all months was approximately 1:1 although most samples in the Strait of Georgia in May and June were female. The presence of Eulachon with maturing gonads increased in frequency from west to east in January to April before sharply decreasing throughout the survey region in May and June. Stomach contents and teeth decreased in frequency with proximity to the Fraser River.

Future work will involve analysis of DNA from tissue samples collected during this study to characterize natal stock; histological analysis to discern whether iteroparity or disease is associated with atypical ovaries prominent in May and June samples; and exploration of environmental and habitat features associated with Eulachon catch observations.

RÉSUMÉ

Dealy, L.V. and Hodes, V.R. 2019. Monthly distribution and catch trends of Eulachon (*Thaleichthys pacificus*) from Juan de Fuca Strait to the Fraser River, British Columbia, October 2017 to June 2018. Can. Manuscr. Rep. Fish. Aquat. Sci. 3179: viii + 39 p.

Une incertitude et un manque de données ont été constatés à l'égard des caractéristiques du cycle biologique et des tendances saisonnières de la répartition marine de l'eulakane (*Thaleichthys pacificus*) du fleuve Fraser. Un relevé mensuel au chalut de fond a été financé par le Fonds national de relevé par rotation de Pêches et Océans Canada d'octobre 2017 à juin 2018 pour échantillonner l'eulakane dans trois strates régionales du détroit de Juan de Fuca et du détroit de Géorgie. L'objectif de cette étude était de mieux comprendre la biologie, la distribution et la période de migration de l'eulakane dans le fleuve Fraser en observant sa présence spatiale et temporelle et son état biologique dans une vaste région pendant plusieurs mois.

Les prises d'eulakane par unité d'effort, la répartition des tailles, le rapport des sexes et les observations liées à la maturité ont varié au fil du temps et selon l'endroit, tout comme le contenu de l'estomac et la présence ou l'absence de dents. Les prises d'eulakane les plus importantes ont été enregistrées dans le détroit de Juan de Fuca alors que les plus faibles ont été enregistrées près du fleuve Fraser. Les taux de prises moyens enregistrés aux sites situés près du panache du fleuve Fraser correspondaient aux périodes de pointe de fraie prévues dans le fleuve Fraser. Le rapport de sexes échantillonné pour l'eulakane dans l'ensemble de la région pendant toute la durée de l'étude était d'environ 1:1, même si la plupart des échantillons prélevés dans le détroit de Géorgie en mai et en juin étaient composées de femelles. La présence d'eulakanes avec gonades en maturation a augmenté en fréquence d'ouest en est de janvier à avril avant de diminuer fortement dans toute la région étudiée en mai et en juin. Plus l'on s'approchait du fleuve Fraser et plus le contenu de l'estomac et la présence de dents diminuait chez les spécimens étudiés.

Les travaux futurs comprendront l'analyse de l'ADN des échantillons de tissus prélevés au cours de cette étude afin de caractériser le stock natal, l'analyse histologique visant à déterminer si l'itéroparité ou la maladie est associée à la présence d'ovaires atypiques proéminents dans les échantillons de mai et juin, ainsi que l'examen des caractéristiques environnementales et des habitats associés aux observations des prises d'eulakanes.

INTRODUCTION

Eulachon (*Thaleichthys pacificus*, Osmeridae) is an anadromous smelt that occurs only in the eastern north Pacific Ocean from California to the Bering Sea (Schweigert et al. 2012). Eulachon are lipid rich compared to other north-eastern Pacific forage fish (Payne et al. 1999). As such, they constitute a nutritious prey item for many fish, mammal, and avian predators (Schweigert et al. 2012) and have past and current value to First Nation cultures as an imporant food, social and ceremonial fisheries resource.

Eulachon spawn in coastal rivers that typically have a distinct spring freshet (Hay and McCarter 2000) and spawn timing varies over the species range but is distinct within specific river drainages (Beacham et al. 2005; Hay and McCarter 2000). Spawning begins as early as January and February in southern rivers such as the Columbia River and as late as June in northern Alaskan rivers (Beacham et al. 2005; Moody 2008). Although there is seasonal variability in spawner migration and abundance, in the Fraser River, peak spawning typically occurs in April and May (Hay and McCarter 2000).

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed three Eulachon designatable units: Fraser River as Endangered, Central Pacific Coast as Endangered (COSEWIC 2011), and Nass/Skeena rivers as Special Concern (COSEWIC 2013). Data and knowledge gaps identified by Schweigert et al. (2012) for Fraser River Eulachon relate to their general biology and ecology and include life history parameters, population structure, genetics, and habitat use and requirements, particularly outside of the Fraser River.

Genetic studies investigating Eulachon population structure in British Columbia (BC) waters have indicated that Eulachon display genetic differentiation between spawning aggregations at several major river drainages (Beacham et al. 2005) and recently-developed single nucleotide-polymorphisms (SNPs) confirmed robust regional stock structure (Candy et al. 2015). Eulachon are observed in marine waters of BC including the West Coast of Vancouver Island (WCVI), the Central Coast (CC), and the North Coast (NC). Genetic assignment of Eulachon spawning stock to marine collected samples from WCVI have been attributed to mainly Columbia River and Fraser River Eulachon spawning stocks as well as some smaller stocks along the coast (Beacham et al. 2005).

Age of maturity and repeat spawning potential are two aspects of Eulachon life history that remain unclear (Clarke et al. 2007) and there is currently no validated method to age Eulachon. Evidence for semelparity includes a lack of change of strontium to calcium (Sr:Ca) ratio (a freshwater signal) within the otolith, the presence of a single size class of spawners in a river, and a lack of teeth in spawning adults (Clarke et al. 2007; Hay and McCarter 2000).

A monthly bottom trawl study was funded by the Fisheries and Oceans Canada (DFO) National Rotational Survey Fund from October 2017 to June 2018 to sample Eulachon in three regional strata in Juan de Fuca Strait and the Strait of Georgia. The goal of this study was to gain insights into the distribution, ecology and migration timing of Eulachon to the Fraser River by observing their spatial and temporal occurrence and biological condition over a wide survey region and over several months. Eulachon were sampled for information on length, weight, sex, maturity, stomach contents, dentition, and DNA. Environmental data such as bottom depth and bottom water temperature during fishing sets were also collected and considered in summary results.

METHODS

SURVEY DESIGN

The study area (Figure 1) was overlain with a survey grid using Microsoft SQL Server to create 2x2 km blocks for fishing. The survey grid was divided into three regional strata denoted as A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River. Each month, 40 blocks were randomly selected from those in the survey grid. The number of blocks in each stratum was proportional to its surface area to allow for even coverage of the study area. An additional 40 blocks were selected when required; for example, when poor weather prohibited fishing in certain regions. When a block was rejected after sounding due to rocky substrate or hazardous objects, it was removed from the survey grid on subsequent surveys.

The survey grid contained only blocks of the target depth range, 80-200 m, based on DFO's WCVI small-mesh multispecies research surveys (Boutillier et al. 1999a; 1999b) to reflect commercial shrimp trawl grounds. Eulachon appear to be closely associated with shrimp and are common incidental catch in the shrimp trawl fishery (Levesque and Therriault 2011). When available, commercial shrimp trawl locations were helpful in determining soft bottom type and allowed for more efficient towing.

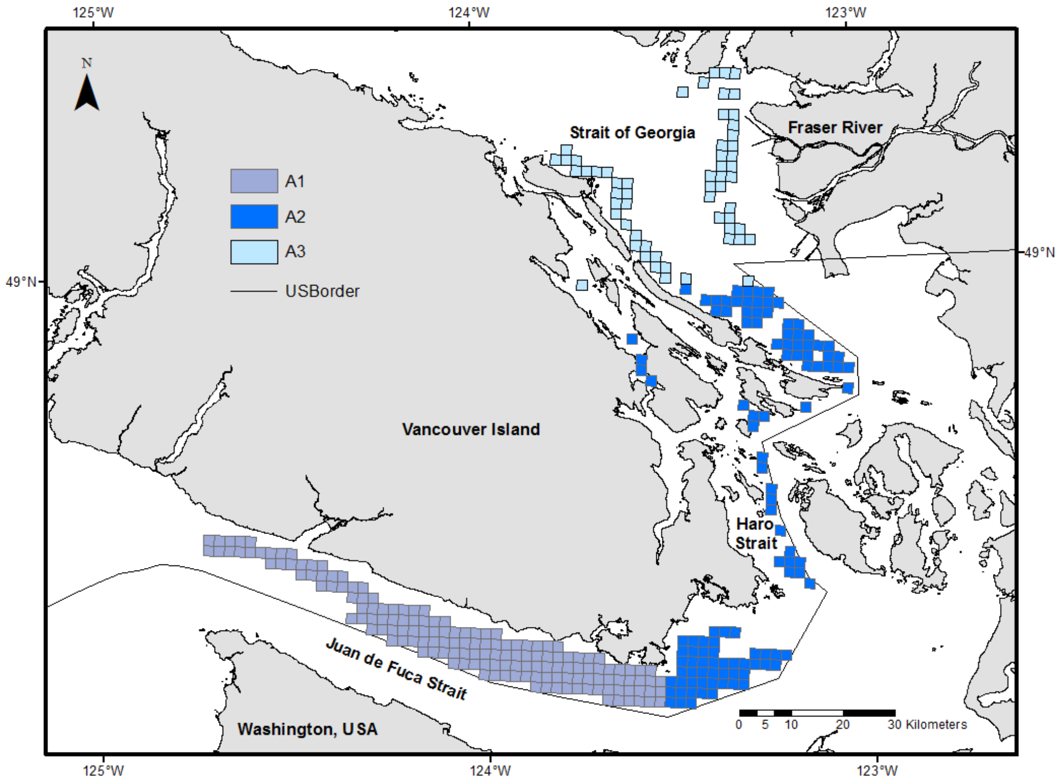

Figure 1. Study area for Eulachon bottom trawl surveys (October 2017–June 2018) with potential fishing blocks (2x2 km) identified in three strata: A1–Juan de Fuca = Juan de Fuca Strait between Swiftsure Bank and Race Rocks; A2–Haro Strait = Race Rocks to mid-Galiano Island including Haro Strait; and A3–Fraser River = mid-Galiano Island to Howe Sound in the north and Gabriola Island in the west.

FISHING AND ENVIRONMENTAL DATA

Fishing was conducted using the Nearshore Fishery Research Vessel CCGS *Neocaligus* to tow an American shrimp trawl net (Cantrawl Nets Ltd., Richmond, BC). The horizontal opening of the polypropylene net was estimated to be 34 to 37 ft (10 to 11 m), while the center of the opening had a vertical height of approximately 7 to 9 ft (2 to 3 m). A 0.4” (10 mm) liner was used in the codend. The net was configured with roller gear and 72” (1.8 m) Thyboron Type 2 trawl doors. The vessel was equipped with a Notus® trawl net mensuration system. These sensors were attached to the net to provide the Fishing Master with real-time net geometry including headline height and depth as well as door spread. To determine appropriate substrate and potential hazards, survey blocks were sounded by the Fishing Master prior to setting the net. Tow duration was typically 20 minutes but was shortened when necessary (e.g. the net hung up or the substrate changed). Standard hours of fishing operations were 0700 H to 1700 H, but these times varied throughout the year depending on sunrise and sunset.

Fishing event data was collected and stored in GFBioField, the Pacific Region’s at-sea data acquisition system for DFO Groundfish Surveys (Olsen 2010). The net deployment and retrieval times and positions, bottom depth, vessel speed and warp length were recorded for every tow. Bottom sounder and GPS data were logged continuously for the duration of each survey. During fishing sets, depth and water temperature were recorded every 10 seconds by a Star-Oddi® DST centi-TD temperature-depth logger mounted on the headline. This study includes some preliminary analyses investigating relationships between Eulachon catch rates and environmental data representing bottom depth, water temperature and time of day by fishing event.

CATCH RECORDING AND EULACHON CPUE

Catch was sorted to the lowest possible taxonomic classification and weighed to the nearest 0.01 kg on a 30 kg Marel® M1100 marine scale. Catch weights were entered into GFBioField using a Panasonic® Toughbook CF-31 computer. In the event of a large catch, several baskets of mixed fish were randomly selected to be sorted by species and weighed; these species' weight proportions were later extrapolated to the unsorted catch weight. For each tow, Eulachon were sorted from the total catch and sampled, but occasionally it was not feasible to separate every Eulachon from the total catch in which case a sub-sample was examined.

To obtain a relative measure of Eulachon abundance, catch per unit effort (CPUE) was calculated using the weight of Eulachon caught per hour of bottom tow time. Unsuccessful tows, such as when the net hung up on the seafloor or caught a large log, were not included in calculations of CPUE. Monthly maps of set locations with Eulachon CPUE represented by proportional symbols were created in ArcGIS 10.4.1 (APPENDIX 1). Cumulative catch and species composition was summarized for the entire study (APPENDIX 2).

BIOLOGICAL SAMPLING

After the total mass of Eulachon in a set was recorded, individual Eulachon were sampled. When the quantity of Eulachon exceeded ~50 individuals, a random sample of approximately 50 Eulachon was taken. When less than ~50 Eulachon were landed, all were sampled.

The following attributes were recorded in GFBioField:

- standard length (mm) (maximum n=50)
- round weight (g) (maximum n=50)
- sex (maximum n=30)
- maturity (maximum n=30)
- stomach contents – species, volume, and digestion state (maximum n=30)
- presence of teeth in three areas of the mouth (maximum n=30)
- tissue sample for DNA analysis (maximum n=10)

Length was measured to the nearest millimeter (mm) using an Ichthystick electronic measuring board connected to a Panasonic Toughbook CF-31 computer. Weight was measured to the nearest gram on a 3 kg Marel® M1100 marine scale. Sex and maturity were assessed based on the descriptions in Table 1. Stomach contents were determined by cutting the bottom of the stomach and pushing the contents out with the flat edge of the knife from the top of the esophagus. A visual estimate of prey species, volume of content in cm^3 and digestion state on a scale of 1-5 with 5 being fully digested and 1 fresh was conducted. Teeth presence was determined by running a bare finger along the inside of the Eulachon's mouth, top and bottom, and along the tongue. Presence or absence was noted at each of these locations. For the first ten fish in a sample, a small (5x5 mm) piece of operculum was clipped and stored on Whatman paper for genetic analysis. The results of the genetic sampling were not completed at time of reporting and are not included in this report.

After observing in February 2018 that some female Eulachon had unusual looking ovaries (Figure 2), often accompanied by a more slender external appearance (Figure 3), a selection of typical and atypical ovaries was retained from each survey conducted from February to June 2018. Ovarian tissue was preserved in 10% formalin for histological analysis and muscle and gonadal tissue were frozen for fatty acid profile work. Fish were not randomly selected for these analyses but rather opportunistically selected.

Throughout the study, whole Eulachon were frozen for future ageing analyses.

Table 1. Descriptions of Eulachon gonadal development by sex and maturity stage.

Sex	Maturity stage		Macroscopic description of gonads
Unknown	0 -	Immature	too small to determine
Male	1 -	Immature	clear to whitish in colouration; knife-edged (not rounded); thickness and width of dental floss
	2 -	Immature	width < 1 cm; whitish, shiny, and very smooth; knife-edged (not rounded)
	3 -	Developing	width nearing 1 cm; whitish, shiny, and very smooth; knife-edged (not rounded)
	4 -	Developing	width > 1 cm; white; milt is secreted when pressure is applied with knife
	5 -	Mature (ripe)	width >> 1 cm; white; milt flows from vent with slight pressure to abdomen
Female	1 -	Immature	clear; string-like; rounded (not knife-edged)
	2 -	Immature	width < 1 cm; clear to pinkish; rounded (not knife-edged)
	3 -	Developing	width nearing 1 cm; cream to white in colouration; beginning to appear lumpy (not perfectly smooth); vascularization present and eggs are visible (but very small)
	4 -	Developing	width > 1cm; eggs can be dislodged by gently scraping surface with knife
	5 -	Mature (ripe)	width >> 1 cm; eggs fill nearly all of body cavity; eggs flow from vent with slight pressure to abdomen
	6 -	Atypical (post-spawn?)	dark pink, thickened walls; often flaccid with residual eggs sparsely distributed

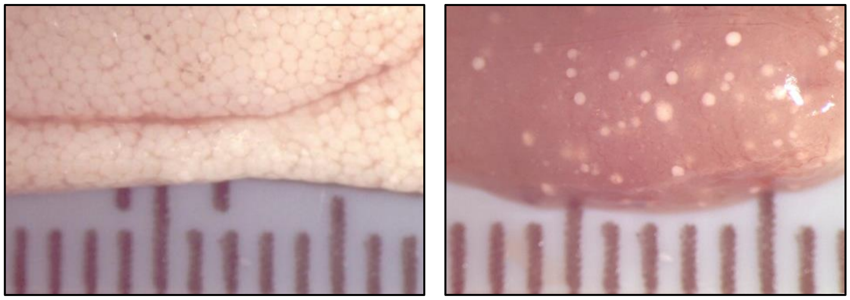

Figure 2. Ovaries from two Eulachon specimens sampled in February 2018 and photographed with a Leica® microscope camera. Left image: typical developing ovary (stage 4). Right image: atypical ovary (stage 6). Each tick on the scale bar represents one millimetre.

Figure 3. Comparison of two female Eulachon (both ~170 mm SL) sampled in February 2018. The above fish yielded ovaries with typical developing eggs (maturity stage 4). The fish below, appearing externally more slender, had atypical, flaccid ovaries containing what appeared to be residual eggs (maturity stage 6).

RESULTS

EULACHON CATCH AND CPUE

Between October 2017 and June 2018, 227 successful fishing events were made in the survey region and Eulachon were caught in 169 tows, comprising 0.44% of the cumulative catch by weight.

In total, 217 kg of Eulachon was caught in A1, 29 kg in A2, and 25 kg in A3. There was variability in Eulachon CPUE between strata and months but catch rates were highest in A1–Juan de Fuca compared to the other two strata (Table 2; Figure 4).

Table 2. Total number of sets, number of sets containing Eulachon, total catch of Eulachon (kg), mean CPUE (kg/hr), and standard error (SE) from bottom trawl surveys conducted in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018.

Stratum	Month	Total sets	Sets with Eulachon	Total Eulachon catch (kg)	Mean CPUE (kg/hr)	SE
A1	October	11	11	32.3	9.0	2.7
	November	7	5	6.1	3.1	2.0
	December	5	2	0.1	0.1	0.0
	January	3	3	3.7	4.1	1.4
	February[1]	0	-	-	-	-
	February[2]	11	11	23.0	5.8	1.8
	March	9	9	20.5	7.1	1.2
	April	18	16	20.7	3.7	1.7
	May	18	17	35.5	8.1	2.5
	June	9	9	75.0	36.1	15.6
	All	91	83	217	8.6	3.6
A2	October	4	0	0	0	0
	November	5	0	0	0	0
	December	9	4	0.2	0.1	0.0
	January	9	6	1.5	0.5	0.3
	February[1]	8	8	2.1	0.8	0.3
	February[2]	4	4	1.5	1.1	0.6
	March	12	12	12.3	3.4	1.0
	April	10	10	9.3	3.3	0.7
	May	9	5	0.9	0.3	0.1
	June	8	2	1.0	0.4	0.3
	All	78	51	29	1.0	0.4
A3	October	3	0	0	0	0
	November	0	-	-	-	-
	December	7	4	1.3	0.5	0.3
	January	6	6	8.9	4.5	1.6
	February[1]	13	8	2.1	0.5	0.2
	February[2]	0	-	-	-	-
	March	11	9	10.6	3.1	1.0
	April	0	-	-	-	-
	May	9	6	1.9	0.8	0.4
	June	9	2	0.1	0.0	0.0
	All	58	35	25	1.3	0.7
Total		227	169	271	3.7	1.4

[1] = February 1-7

[2] = February 17-22

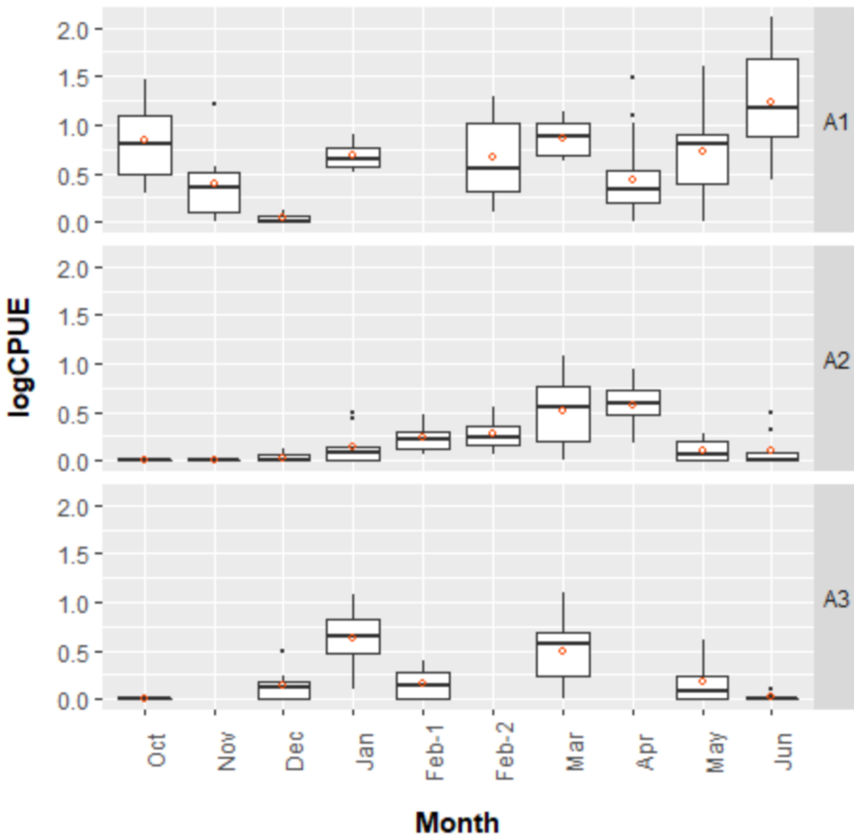

Figure 4. Log-transformed Eulachon CPUE (kg/hr) for bottom trawl sets in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Boxes represent the interquartile range (IQR) (top line = 75th percentile (Q3), middle = median (Q2), and bottom = 25th percentile (Q1)), whiskers extend to the largest value within 1.5 times the IQR above Q3 and to the smallest value within 1.5 times the IQR below Q1, and outside values (black points) are > 1.5 times the IQR beyond either end of the box. Red circles represent mean CPUE by month.

In A1–Juan de Fuca, Eulachon were present each month from October to June. Mean CPUE was lowest in December (0.1 kg/hr, SE=0.0 kg/hr) and highest in June (36.1 kg/hr, SE=15.6 kg/hr).

In A2–Haro Strait, no Eulachon were caught in October or November. Mean CPUE in A2 peaked in March (3.4 kg/hr, SE=1.0 kg/hr) and April (3.3 kg/hr, SE=0.7 kg/hr).

In A3–Fraser River, no Eulachon were caught in October. Mean CPUE was highest in January and March (4.5 and 3.1 kg/hr, SE=1.6 and 1.0 kg/hr); due to poor weather, fishing did not occur in A3 in November, late February, or April.

BIOLOGICAL SAMPLING

During the study period, 4,589 Eulachon were sampled from tows in Juan de Fuca and the Strait of Georgia (Table 3). Of these, 4,580 were measured for total length and

3,246 were weighed. Sex was determined for 3,801 of the 4,589 sampled fish; 3,364 of the 3,801 fish were also assessed for maturity. Stomach contents of approximately half of the sampled fish (2,246 of 4,589) were determined. Between January and June 2018, 1,996 of the 4,589 fish sampled were examined for presence of teeth. DNA was collected from 1,372 of 4,589 individuals.

Table 3. Number of Eulachon attributes recorded or collected during bottom trawl surveys conducted each month from October 2017 to June 2018 in Juan de Fuca and the Strait of Georgia.

Month	Length	Weight	Sex	Maturity	Stomach	Teeth	DNA
October	540	528	106	0	91	0	101
November	99	30	105	46	39	0	43
December	40	40	40	40	38	0	34
January	272	230	251	245	122	61	129
February[1]	101	101	100	92	92	91	101
February[2]	510	383	473	362	156	158	151
March	1,003	915	921	894	591	595	264
April	679	503	636	523	420	385	218
May	817	0	662	655	422	426	220
June	519	516	512	511	275	280	111
Total	4,580	3,246	3,806	3,368	2,246	1,996	1,372

[1] = February 1-7

[2] = February 17-22

LENGTH AND WEIGHT

Standard length was recorded for 4,580 Eulachon, 3,246 of which were weighed (Figure 5). The standard length of Eulachon samples ranged from 60 to 216 mm and weighed between 1 and 99 g.

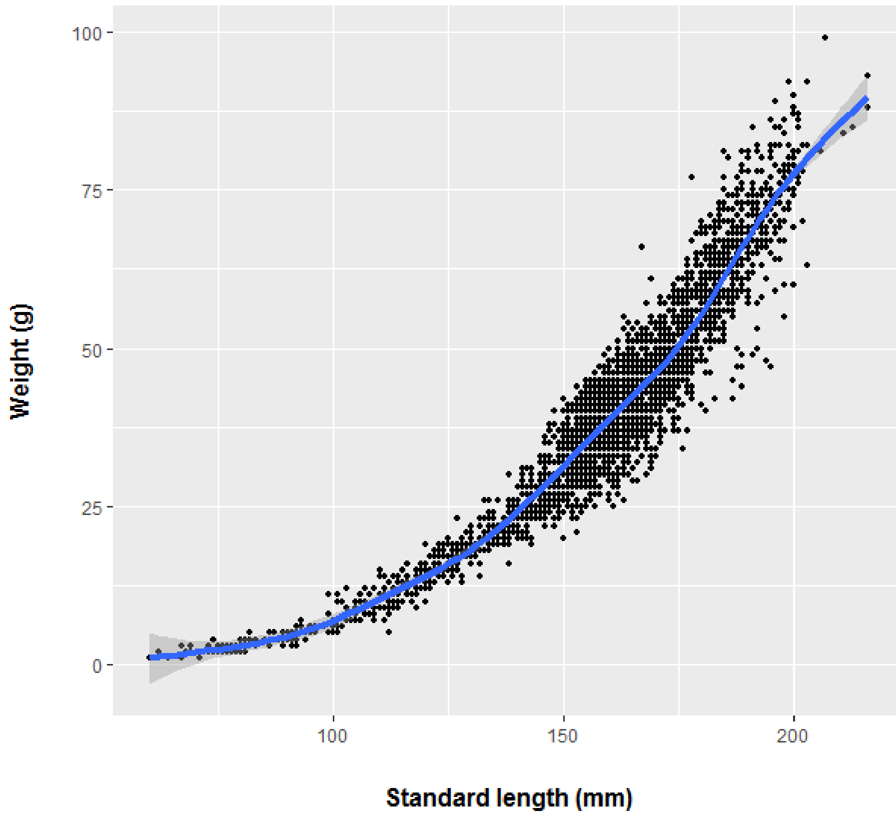

Figure 5. Cumulative length-weight relationship of Eulachon (n=3,246) sampled during bottom trawl surveys conducted in Juan de Fuca Strait and the Strait of Georgia from October 2017 to June 2018. Blue line represents the LOESS regression smoother and grey ribbon indicates a 95% confidence interval.

Each month of the survey, Eulachon sampled from A1–Juan de Fuca had a multi-modal length distribution. This trend was less apparent in A2–Haro Strait or A3–Fraser River where relatively few Eulachon measured less than 100 mm (Figure 6).

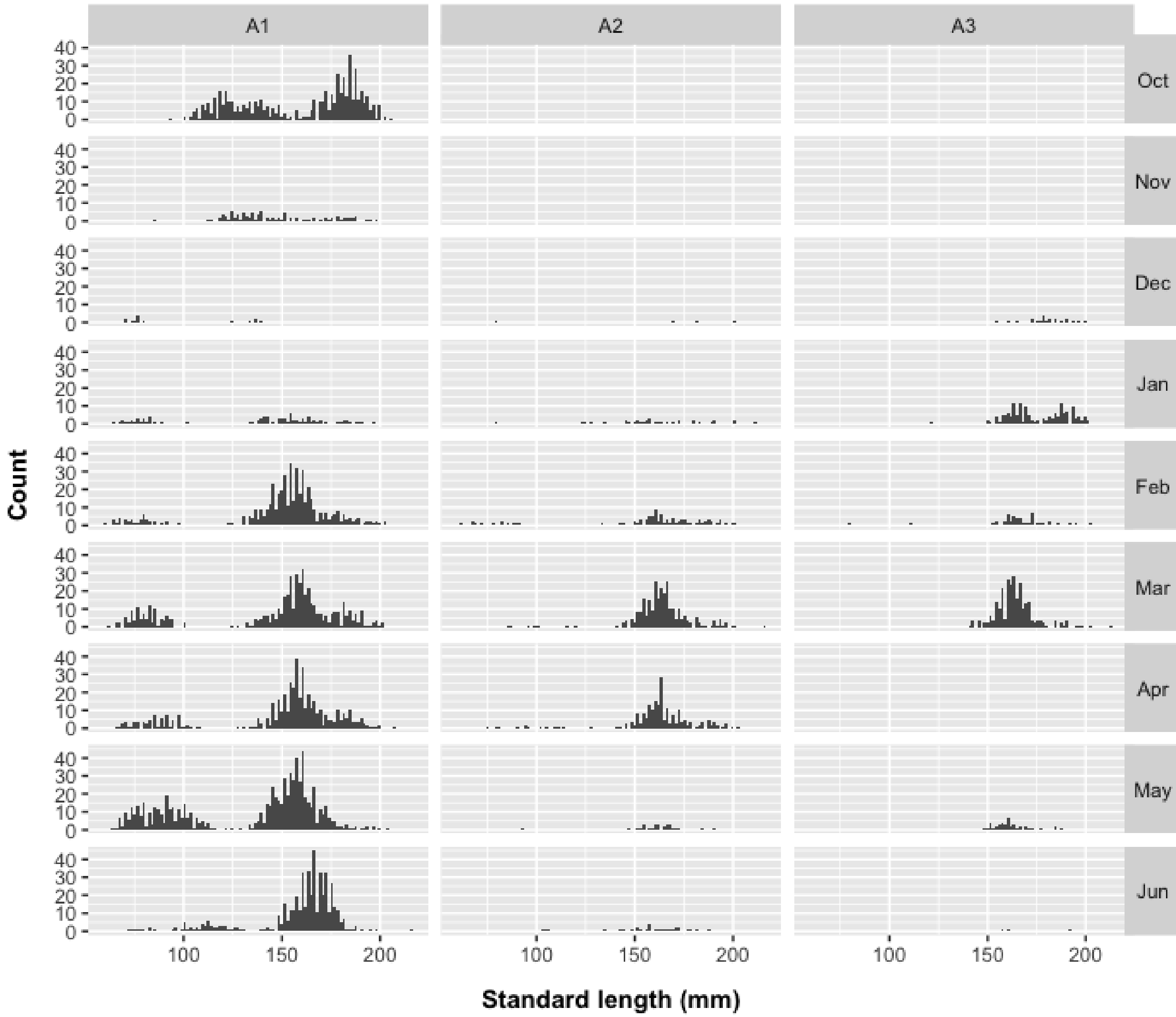

Figure 6. Standard length distribution of Eulachon sampled during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Length data from two February surveys are pooled. Note that no fishing occurred in A1 in early February 2018 or in A3 in November 2017, late February 2018, or April 2018 due to poor weather.

The effect of catch location (i.e. strata) on mean body length of Eulachon was significant (Kruskal-Wallis ranked sum test, $x^2(2)=285.26$, $p<0.001$) when length measurements from all months were pooled. A post-hoc pairwise comparison using Mann-Whitney tests with Bonferroni correction showed significant differences in mean lengths between all combinations of strata A1, A2, and A3 ($p<0.001$). The mean, median, and minimum length of Eulachon increased from furthest away from the Fraser River (A1) to closest (A3) (Table 4).

Table 4. Summary of length measurements including count, minimum length, 25th percentile (Q1), median length, mean length, 75th percentile (Q3), maximum length, and standard error (SE) of Eulachon sampled during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018.

			Standard length (mm)						
Stratum	Month	Count	Min.	Q1	Median	Mean	Q3	Max.	SE
A1	October	540	93	131	171	159	184	206	1.3
	November	99	86	129	140	147	166	198	2.4
	December	14	71	75	77	96	132	139	7.9
	January	87	64	88	150	136	163	196	4.1
	February[1]	NF	NF	NF	NF	NF	NF	NF	NF
	February[2]	474	60	146	155	151	163	203	1.2
	March	490	62	142	158	146	165	201	1.6
	April	471	66	148	158	151	166	207	1.4
	May	747	63	97	150	134	160	204	1.3
	June	486	72	156	165	159	171	216	1.0
	All	3,408	60	138	157	148	168	216	0.5
A2	October	0	-	-	-	-	-	-	-
	November	0	-	-	-	-	-	-	-
	December	4	80	147	176	158	187	201	26.8
	January	34	79	150	158	161	178	211	4.4
	February[1]	54	67	157	163	156	178	201	5.0
	February[2]	36	62	155	161	158	174	200	5.0
	March	261	85	158	164	163	168	216	0.9
	April	208	75	157	163	162	171	202	1.4
	May	28	93	157	162	161	168	190	3.1
	June	30	103	151	159	156	171	188	3.9
	All	655	62	157	163	161	170	216	0.8
A3	October	0	-	-	-	-	-	-	-
	November	NF	NF	NF	NF	NF	NF	NF	NF
	December	22	154	176	180	180	187	200	2.4
	January	151	121	164	173	176	189	201	1.2
	February[1]	47	80	161	165	166	173	202	2.7
	February[2]	NF	NF	NF	NF	NF	NF	NF	NF
	March	252	141	158	163	164	168	213	0.6
	April	NF	NF	NF	NF	NF	NF	NF	NF
	May	42	149	156	160	162	165	188	1.4
	June	3	158	159	160	170	176	192	11.0
	All	517	80	160	165	168	174	213	0.6

[1] = February 1-7

[2] = February 17-22

NF = no fishing occurred

SEX AND MATURITY

Over all tows over all surveys, a total of 1,740 males and 1,885 females were observed. For 181 individuals sex could not be determined macroscopically as the gonads were too small. In May and June, females dominated A2–Haro Strait and A3–Fraser River (1:25 and 1:43 male-to-female ratios in May; 7:23 and 0:3 in June) (Table 5). Sex observations by stratum and month are provided in Figure 7.

Table 5. Sexes assigned to Eulachon sampled during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Total males sampled: n=1,740; total females sampled: n=1,885; undetermined: n=181.

Stratum	Month	% Male (n)	% Female (n)	% Undetermined (n)
A1	October	58 (61)	34 (36)	8 (9)
	November	35 (37)	40 (42)	25 (26)
	December	14 (2)	21 (3)	64 (9)
	January	52 (34)	38 (25)	11 (7)
	February[1]	NF	NF	NF
	February[2]	52 (229)	43 (188)	5 (24)
	March	55 (222)	43 (173)	3 (12)
	April	39 (170)	57 (245)	4 (17)
	May	39 (233)	53 (311)	8 (48)
	June	54 (258)	45 (215)	1 (6)
	Total	47 (1,246)	47 (1,238)	6 (158)
A2	October	(0)	(0)	(0)
	November	(0)	(0)	(0)
	December	25 (1)	50 (2)	25 (1)
	January	56 (19)	38 (13)	6 (2)
	February[1]	35 (19)	48 (26)	17 (9)
	February[2]	38 (12)	63 (20)	0 (0)
	March	38 (100)	60 (158)	2 (4)
	April	42 (85)	55 (113)	3 (6)
	May	4 (1)	96 (27)	0 (0)
	June	23 (7)	77 (23)	0 (0)
	Total	38 (244)	59 (382)	3 (22)
A3	October	(0)	(0)	(0)
	November	NF	NF	NF
	December	50 (11)	50 (11)	0 (0)
	January	56 (84)	44 (67)	0 (0)
	February[1]	41 (19)	57 (26)	2 (1)

Stratum	Month	% Male (n)	% Female (n)	% Undetermined (n)
	February[2]	NF	NF	NF
	March	54 (135)	46 (117)	0 (0)
	April	NF	NF	NF
	May	2 (1)	98 (41)	0 (0)
	June	0 (0)	100 (3)	0 (0)
	Total	48 (250)	51 (265)	0 (1)
Total		46 (1,740)	50 (1,885)	5 (181)

[1] = February 1-7

[2] = February 17-22

NF = no fishing occurred

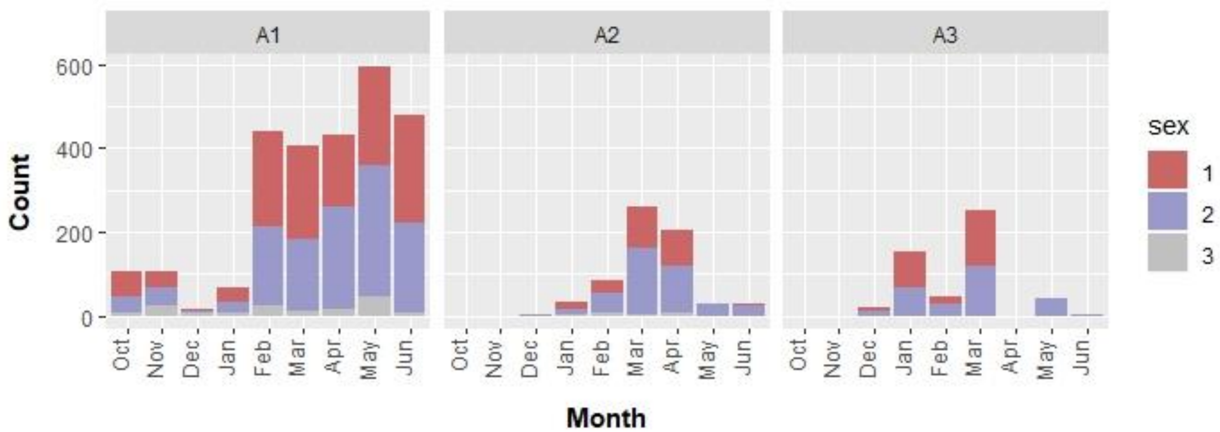

Figure 7. Frequency of sex codes (1=male; 2=female; 3=undetermined) assigned to Eulachon samples (n=3,806) during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Data from two February surveys are pooled.

The sexual maturity of 3,368 Eulachon was assessed using criteria in Table 1. Maturity stage observations by stratum and month are provided in Figure 8. A summary of results by stratum is described below.

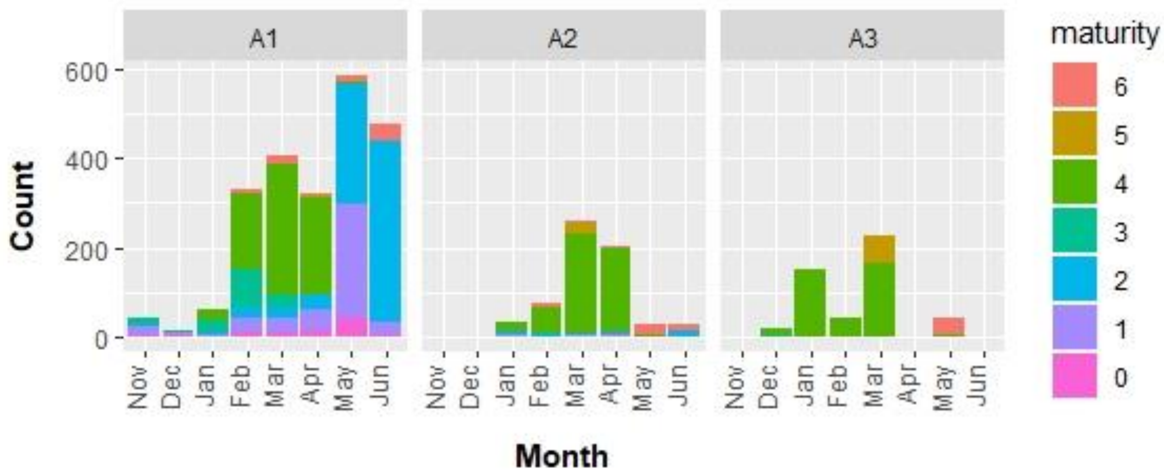

Figure 8. Frequency of maturity stages assigned to Eulachon samples (n=3,359) during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Data from two February surveys are pooled. Male and female results are combined. Maturity stages are described in Table 1 (0-2 = immature, 3-4 = developing, 5 = mature (ripe), 6 = atypical).

In A1–Juan de Fuca, immature Eulachon (stages 0-2) were found in all survey months but were at relatively high proportions in November and December (~60%) as well as in May and June (>90%) and at low proportions from January to April, when most fish sampled were observed to have developing gonads (stages 3 and 4). In A1, mature fish (stage 5) were only observed in April and in relatively low proportions (<2%) and atypical ovaries (stage 6) were observed each month from February through June at relatively low proportions (<10%).

In A2–Haro Strait, immature Eulachon were found in all survey months but compared to A1, they were at lower proportions (3-50%) with the lowest levels observed over February to May. Developing Eulachon represented the majority of samples collected December to April (65-91%) and mature fish were only observed in March and April at relatively low proportions (<10%), whereas atypical ovaries were observed at relatively low levels from Febrary to April (2-12%) and at relatively high levels in May and June (≥50%).

In A3–Fraser River, immature Eulachon were observed December, February, March, and May but at relatively low levels (<1%) whereas developing Eulachon comprised the majority of samples from December to March. Some mature Eulachon were observed in March (~25%) and similar to A2 observations, atypical ovaries were at relatively low levels in February (~7%) and relatively high levels in May and June (88-100%).

Maturity stage had a significant effect on mean body length of Eulachon samples (Kruskal-Wallis rank sum test, $x^2(6)$ =842.36, p<0.001). A post-hoc pairwise comparison using Mann-Whitney test with Bonferroni correction showed significantly different mean lengths between all maturity stages except between stages 2 and 3 (p=1.00), stages 4 and 5 (p=0.03), stages 4 and 6 (p=1.00), and stages 5 and 6 (p=0.03). In other words, the mean body length of Eulachon increased with stage of maturation from stage 0 to 2 but beyond stage 2, differences in mean lengths between stages were undetectable as length ranges overlapped one another (Table 6; Figure 9).

Table 6. Standard length measurements of Eulachon (n=3,359) for each maturity stage assigned during bottom trawl sets in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Summary statistics include minimum length (min.), 25th percentile (Q1), median length, mean length, 75th percentile (Q3), maximum length (max.), standard error (SE), and count. Maturity stages are described in Table 1 (0-2 = immature, 3-4 = developing, 5 = mature (ripe), 6 = atypical).

		Standard length (mm) by maturity stage						
Stratum		**0**	**1**	**2**	**3**	**4**	**5**	**6**
A1	Min.	69	75	84	99	127	166	144
	Q1	79	130	150	151	157	173	160
	Median	94	149	160	156	162	185	165
	Mean	101	141	157	158	166	182	169
	Q3	117	159	168	164	176	190	175
	Max.	197	198	199	198	207	197	216
	SE	2.55	1.24	0.61	1.08	0.50	5.63	1.41
	Count	106	414	766	151	696	5	93
A2	Min.	75	93	101	133	141	145	142
	Q1	86	112	147	156	159	164	157
	Median	96	128	157	158	163	170	162
	Mean	98	125	155	159	166	172	164
	Q3	104	140	173	165	171	182	170
	Max.	150	151	191	177	216	195	200
	SE	5.34	5.56	4.56	3.12	0.55	2.49	1.50
	Count	14	11	31	13	485	29	56
A3	Min.	111	143	152	161	121	154	149
	Q1	111	143	157	173	161	162	157
	Median	111	143	160	178	166	166	161
	Mean	111	143	162	176	170	168	163
	Q3	111	143	165	182	178	171	167
	Max.	111	143	178	184	213	198	192
	SE	NA	NA	4.43	2.96	0.71	1.21	1.51
	Count	1	1	5	8	372	59	43

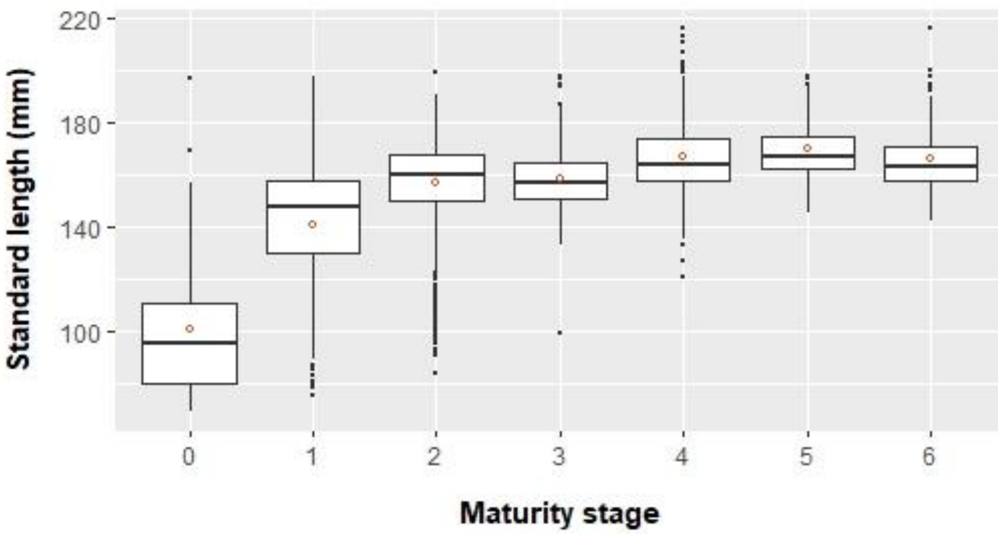

Figure 9. Body lengths of each maturity stage assigned to Eulachon sampled from October 2017 to June 2018 in Juan de Fuca Strait and the Strait of Georgia (n=3,359). Boxes represent the interquartile range (IQR) (top line = 75th percentile (Q3), middle = median (Q2), and bottom = 25th percentile (Q1)), whiskers extend to the largest value within 1.5 times the IQR above Q3 and to the smallest value within 1.5 times the IQR below Q1, and outside values (black points) are > 1.5 times the IQR beyond either end of the box. Red circles represent mean length for each maturity stage. Maturity stages are described in Table 1 (0-2 = immature, 3-4 = developing, 5 = mature (ripe), 6 = atypical).

STOMACH CONTENTS

The majority of Eulachon stomachs examined (1,764 of 2,245) were empty. The relative frequency of empty stomachs increased spatially from Juan de Fuca towards the Fraser River – 68% of stomachs were empty in A1–Juan de Fuca, 88% in A2–Haro Strait, and 99% in A3–Fraser River (Table 7). Eulachon stomachs that were sampled never contained more than one species. The most common item was Euphausiid, occurring in 30% of stomachs in A1, 8% in A2, and <1% in A3. Euphausids were present in stomachs most frequently in A1 in October 2017 and May 2018, occurring in 68% and 47% of stomachs respectively.

Table 7. Number of Eulachon stomachs by stomach content category. Each stomach contained only one type of content. Eulachon stomachs (n=2,245) were sampled during bottom trawl sets in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018.

Stratum	Stomach contents	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Relative Freq. (%)
A1	Empty	28	27	11	25	95	190	172	183	204	935	68.1
	Euphausiid	62	8	2	5	23	35	71	165	35	406	29.6
	Uniden. remains	0	4	1	3	4	3	4	5	2	26	1.9
	Glass shrimp	0	0	0	0	0	1	0	0	0	1	0.1
	Shrimp	0	0	0	0	0	0	1	0	0	1	0.1
	Uniden. fishes	1	0	0	0	0	0	0	0	1	2	0.1
	Uniden. worm	0	0	0	0	0	1	0	0	0	1	0.1
	Total	91	39	14	33	122	230	248	353	242	1,372	
A2	Empty	0	0	2	32	72	159	147	25	21	458	88.4
	Euphausiid	0	0	2	1	3	10	25	0	2	43	8.3
	Uniden. remains	0	0	0	0	4	1	0	0	1	6	1.2
	Pacific sandlance	0	0	0	0	0	0	0	0	5	5	1.0
	Shrimp	0	0	0	0	0	2	0	0	0	2	0.4
	Uniden. fishes	0	0	0	1	0	0	0	0	1	2	0.4
	Glass shrimp	0	0	0	0	0	1	0	0	0	1	0.2
	Pink shrimp	0	0	0	0	1	0	0	0	0	1	0.2
	Total	0	0	4	34	80	173	172	25	30	518	
A3	Empty	0	0	20	55	45	186	0	43	3	352	99.2
	Uniden. remains	0	0	0	0	0	1	0	1	0	2	0.6
	Glass shrimp	0	0	0	0	1	0	0	0	0	1	0.3
	Total	0	0	20	55	46	187	0	44	3	355	

TEETH

Teeth were sampled on each survey from January to June 2018 (Table 8). Eulachon samples were assessed as having teeth present (Figure 11), absent (Figure 12), or in a state of reduced dentition. Eulachon with no teeth ("toothless") were caught in all three strata. Most toothless Eulachon were caught in March and April in A2–Haro Strait and in March in A3–Fraser River. Overall, the percent of toothless Eulachon increased with proximity to the Fraser River (A1 = 1%, A2 = 14%, and A3 = 31%). In June, all Eulachon examined had teeth. Teeth observations by stratum and month are provided in Figure 10.

Table 8. Counts of Eulachon sampled for presence of teeth by category in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River by month (January–June 2018). Categories: None=no teeth; TMB=teeth present on the top, tongue, and bottom of the mouth; TM=top and tongue only; TB=top and bottom only; MB=tongue and bottom only; M=tongue only; and T=top only.

Stratum	Month	None	TMB	TM	TB	MB	M	T	Total
A1	Jan	3	1	1	0	1	0	0	6
	Feb	1	95	20	0	2	8	0	126
	Mar	2	178	23	0	1	27	2	233
	Apr	5	160	8	0	1	40	0	214
	May	1	352	0	0	2	1	0	356
	Jun	0	240	2	0	1	4	0	247
	Total	12	1,026	54	0	8	80	2	1,182
A2	Jan	5	12	2	4	0	1	0	24
	Feb	16	23	13	0	0	24	2	78
	Mar	25	44	52	1	2	50	2	176
	Apr	26	60	22	0	0	63	0	171
	May	1	10	11	0	0	6	0	28
	Jun	0	26	1	0	3	0	0	30
	Total	73	175	101	5	5	144	4	507
A3	Jan	1	22	4	0	0	4	0	31
	Feb	16	5	7	1	0	15	1	45
	Mar	77	12	24	0	2	66	5	186
	Apr	NF	NF	NF	NF	NF	NF	NF	NF
	May	0	19	10	0	0	13	0	42
	Jun	0	0	0	0	2	1	0	3
	Total	94	58	45	1	4	99	6	307

NF = no fishing occurred

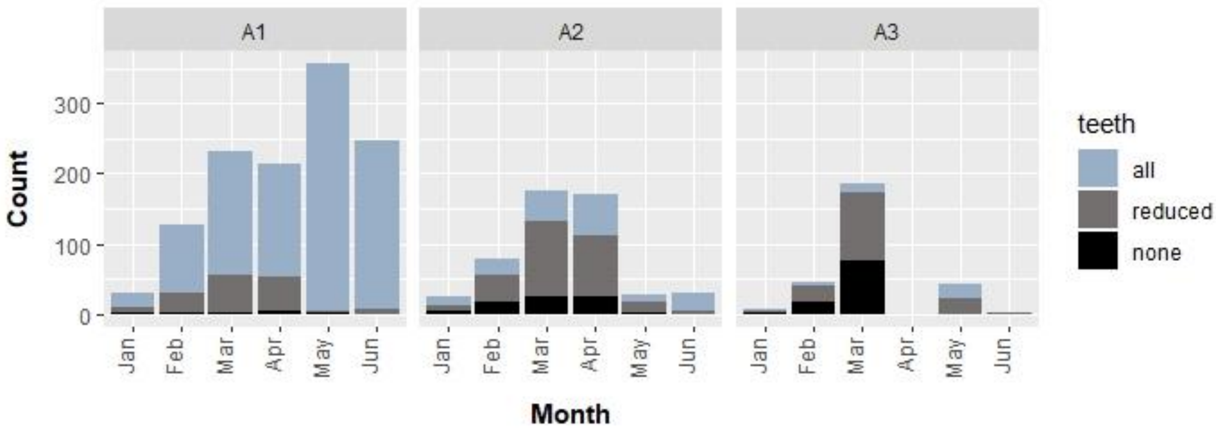

Figure 10. Frequency of teeth observations for Eulachon (n=1,996) sampled during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from January to June 2018. Categories: all=teeth present on top, tongue, and bottom of mouth; reduced=teeth found on top only, on top and tongue only, on tongue and bottom only, on top and bottom only, or on tongue only; none=no teeth in mouth.

Figure 11. Lateral and anterior view of the mouth of an Eulachon sampled during the 2017-18 Eulachon bottom trawl study with teeth present on top, tongue, and bottom of mouth.

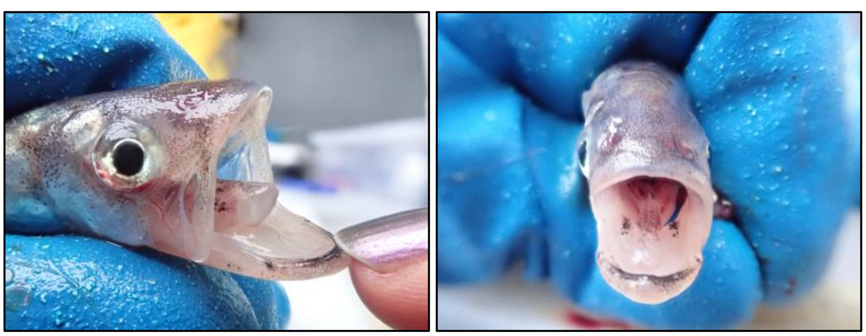

Figure 12. Lateral and anterior view of the mouth of an Eulachon sampled during the 2017-18 Eulachon bottom trawl study with teeth entirely absent on top, tongue, and bottom of mouth.

DNA

Operculum tissue samples were collected from 1,372 Eulachon in Juan de Fuca and the Strait of Georgia between October 2017 and June 2018. These results will be reported in future publications.

ENVIRONMENTAL OBSERVATIONS

BOTTOM DEPTH

Fishing sets were made at bottom depths ranging from 79 to 227 m. Eulachon were caught at depths of 81 to 227 m. Highest CPUE (>25 kg/hr) occurred at bottom depths between 117 and 170 m (Figure 13) as did the largest catches (>5 kg) of Eulachon.

TEMPERATURE

Water temperatures at fishing depths (81 to 227 m) ranged from 6.9 to 9.6 ºC in sets where Eulachon were present. Highest CPUE (>25 kg/hr) occurred in waters between 7.1 and 7.8 ºC (Figure 13) as did the largest catches (>5 kg) of Eulachon.

TIME OF DAY

Eulachon were caught at all hours of day ranging from 0700 H to 1700 H. Highest CPUE (>25 kg/hr) occurred between the hours of 0800 and 1400 H (Figure 14) as did the largest catches (>5 kg) of Eulachon.

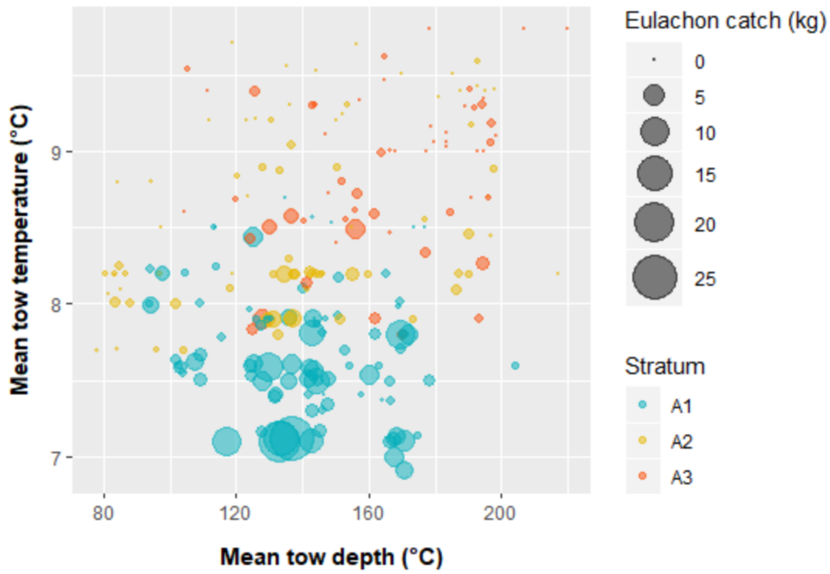

Figure 13. Eulachon catch size (kg) in each set in relation to mean tow temperature and depth of bottom trawl survey sets in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Data from all months are combined.

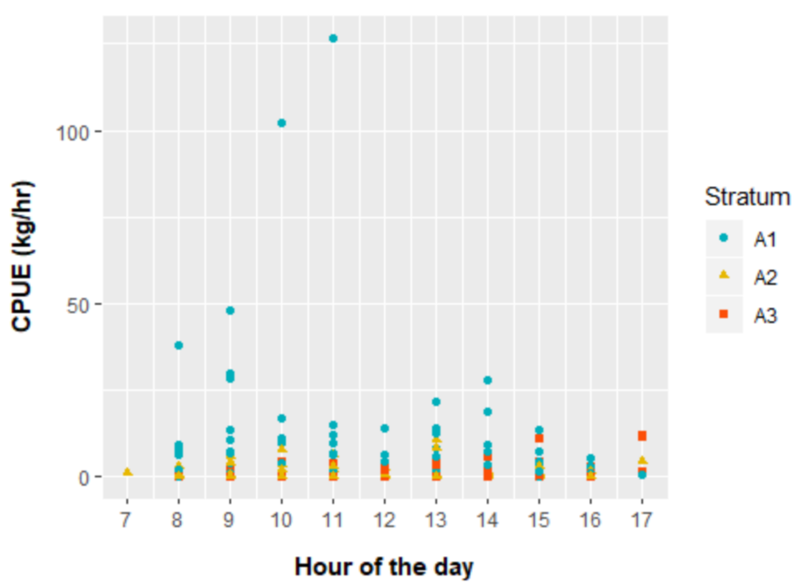

Figure 14. Eulachon CPUE (kg/hr) in relation to the time the set was completed (hour of the day) during bottom trawl surveys in A1–Juan de Fuca, A2–Haro Strait, and A3–Fraser River from October 2017 to June 2018. Data from all months are combined.

DISCUSSION

This is the first directed study of its kind known to have been conducted in British Columbia and elsewhere. The study was successful in developing and applying methods to observe and characterize Eulachon ecology in the marine environment in a region extending from the Fraser River Estuary towards the southwestern coast of Vancouver Island in Juan de Fuca Strait. Key trends observed in this study and their interpretations are discussed below in association with ecological uncertainties, sampling limitations, and future investigations into Fraser River Eulachon ecology and migration.

Results of this study demonstrate that Eulachon CPUE varied spatially and temporally as expected of a migratory species. There was variability in Eulachon CPUE among strata and months but catch rates were highest in A1–Juan de Fuca compared to the other two strata which had relatively high rates in January (A3), March (both A2 and A3), and April (A2). Seasonal variation in catches in the Strait of Georgia strata (A2 and A3) are consistent with a pre-spawning migration pattern of Fraser River bound Eulachon moving from Juan de Fuca during winter to mid-spring months. Furthermore, trends in CPUE, fish length, and maturity stage in strata A2 and A3 are consistent with when Eulachon would be expected to be present in the nearby marine environment before and during spawning periods in the Fraser River, especially peaks typical in April-May (Hay and McCarter 2000). Given when peak CPUE levels were observed in the A2 and A3 and the relatively uniform distribution of fish lengths greater than 150 mm observed in these strata compared to the Juan de Fuca samples, these findings could be interpreted to suggest that most of the fish sampled were likely Fraser River bound Eulachon moving inward from Juan de Fuca Strait.

Trends in CPUE, fish length, presence of teeth, and stomach contents demonstrate that Juan de Fuca Strait likely provides an important year-round marine habitat for Eulachon feeding and growth as well as being a migration corridor to and from the west coast of Vancouver Island, which offers a large range of additional Eulachon habitat for foraging, growth habitat and mixing of stocks (Beacham et al. 2005; Chandler et al. 2018).

It is uncertain if or when the large (>150 mm) Eulachon with developing gonads caught near the Fraser River in December and January would have entered the Fraser River to spawn. It has been reported that Eulachon hold outside the estuary as they prepare to migrate up the river using the tidal salt-wedge just before spawning (Clarke et al. 2007). According to Indigenous knowledge, up to three spawning runs occur in the Fraser River including an early run near the end of February (LFFA 2015). Historical gillnet test fishing and the 2017 LFFA survey show that Eulachon can be in the river February onwards (L. Flostrand 2019, pers. comm.). Currently DFO's Fraser River Eulachon egg and larval survey, conducted annually to estimate the relative abundance of the associated spawning stock (Hay et al. 2002; Schweigert et al. 2012; Flostrand et al. in Chandler et al. 2018), involves sampling April to June and would not capture observations from early spawning events before early March.

No validated method currently exists for determining Eulachon ages as there is high degree of uncertainty interpretating growth patterns on otoliths; therefore, there is also a high degree of uncertainty associated with assigning ages to ranges in fish length. Although length distributions from this study appear somewhat multi-modal with two dominant peaks in some cases, more than two size and age distributions may be overlapping, confounding the ability to distinguish them. Observations showing wide ranges in variability between fish lengths and maturity stages demonstrate that maturing and spawning Eulachon may be comprised of different ages. Variability in length by maturity stage may be due to factors such as differences in ages or hatch timing, natal sources, growth rates, and habitat conditions. Fish length distributions for maturity stages 3 to 5 had such overlap that differences are not clearly detectable, thus limiting the use of length data as a proxy for sexual maturity and age.

Limitations of the study may have introduced unknown levels of uncertainty and bias. For example, there was considerable variability between the number of effective sets conducted in each stratum by month (ranging from 0 to 18 sets) due to weather conditions preventing fishing. Furthermore, the overall 9-month duration of the survey bracketed only one spawning season, therefore providing a limited snapshot of Eulachon distribution and biological condition.

Ongoing investigations

There is uncertainty with what natal river(s) and/or spawning river(s) the observed Eulachon are associated with, as stocks from different river sources can mix in their marine distribution. Additional work is recommended and planned to analyze DNA from tissue samples collected during this study using methods to detect SNPs.

Histological analyses of Eulachon ovaries are underway to investigate the cause of the maturity stage six atypical ovary observations prominent in the May and June samples of A2 and A3 that appeared flaccid and contained residual eggs. Discerning whether iteroparity or disease is associated with these observations will be highly informative as there has been a general understanding that Eulachon die after spawning.

Preliminary analyses reported on CPUE relationships with each of fishing depth, temperature and time of day show no major trends when pooled by stratum. Investigations are ongoing to explore potential relationships between environmental variables and Eulachon catch observations collected during this study.

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APPENDIX 1

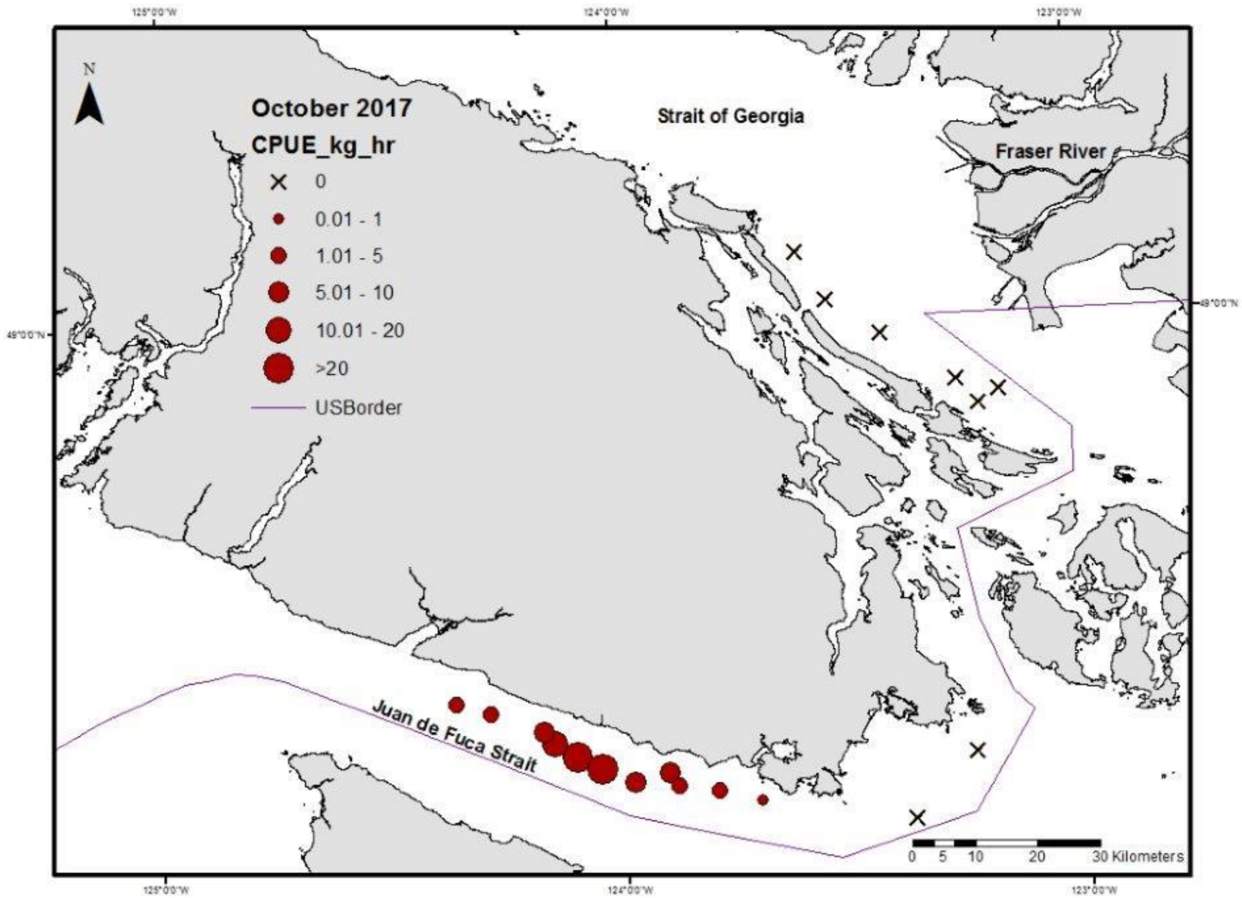

Figure 15. October 4-6, 2017 Eulachon bottom trawl survey set locations with Eulachon catch per unit effort (CPUE) represented by proportional symbols.

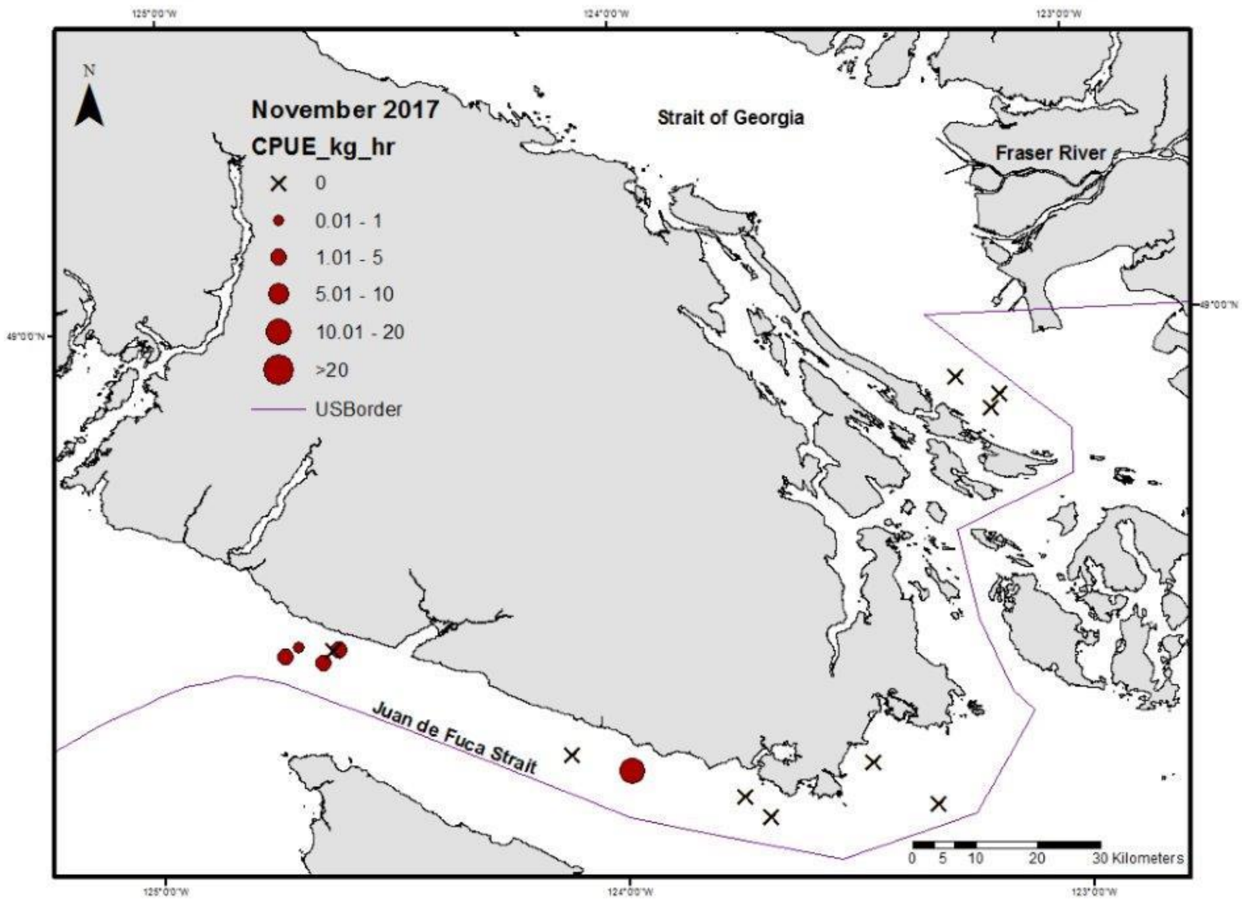

Figure 16. November 12-14, 2017 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

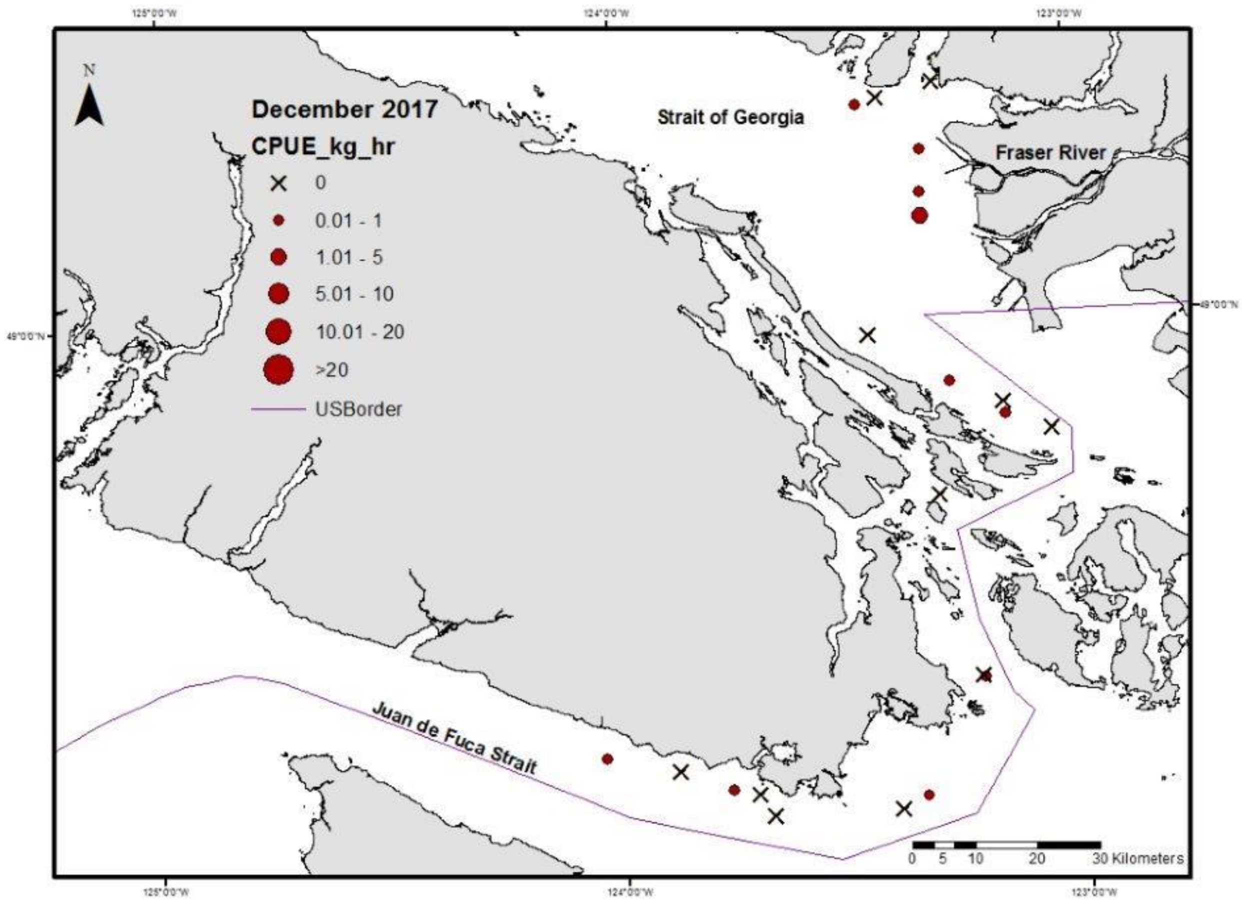

Figure 17. December 2-5, 2017 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

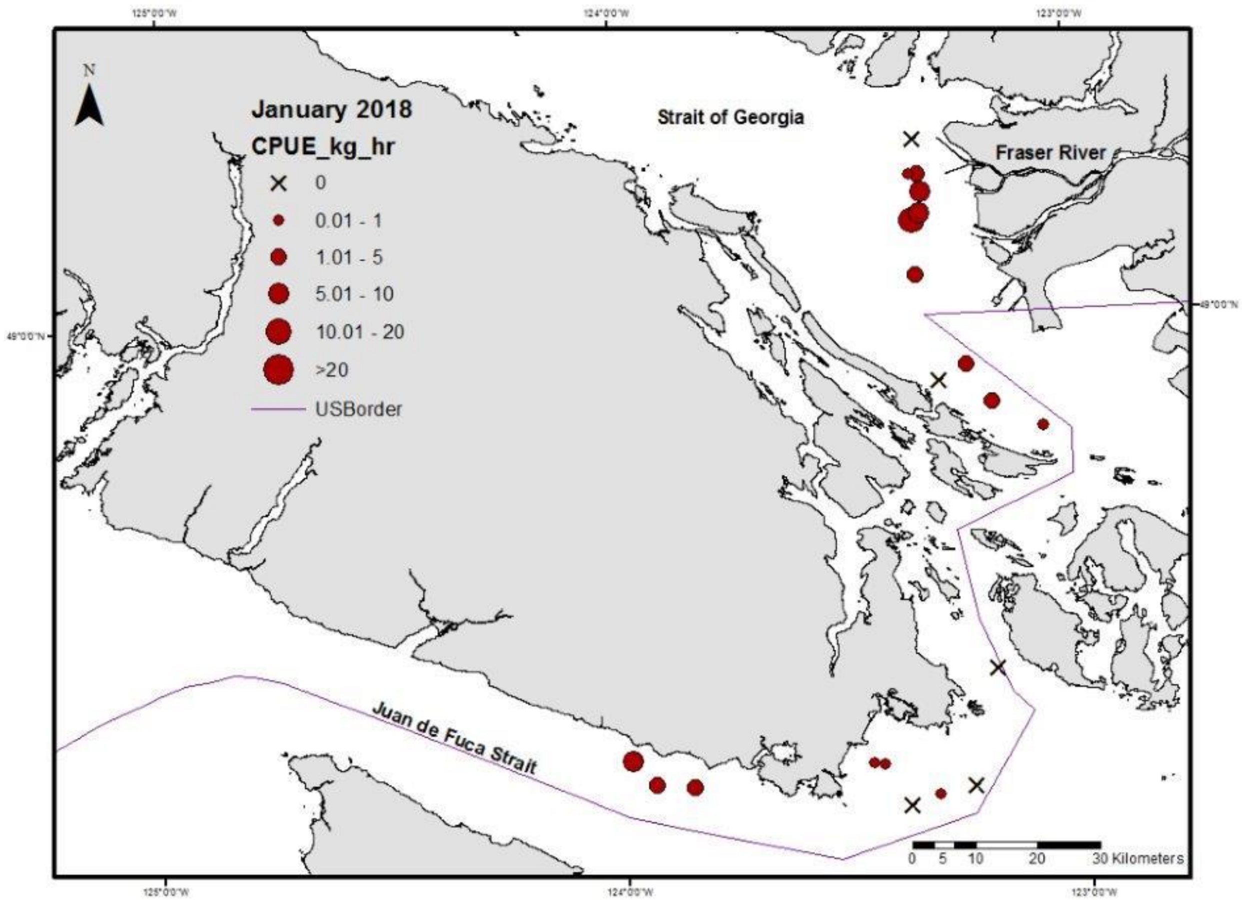

Figure 18. January 3-7, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

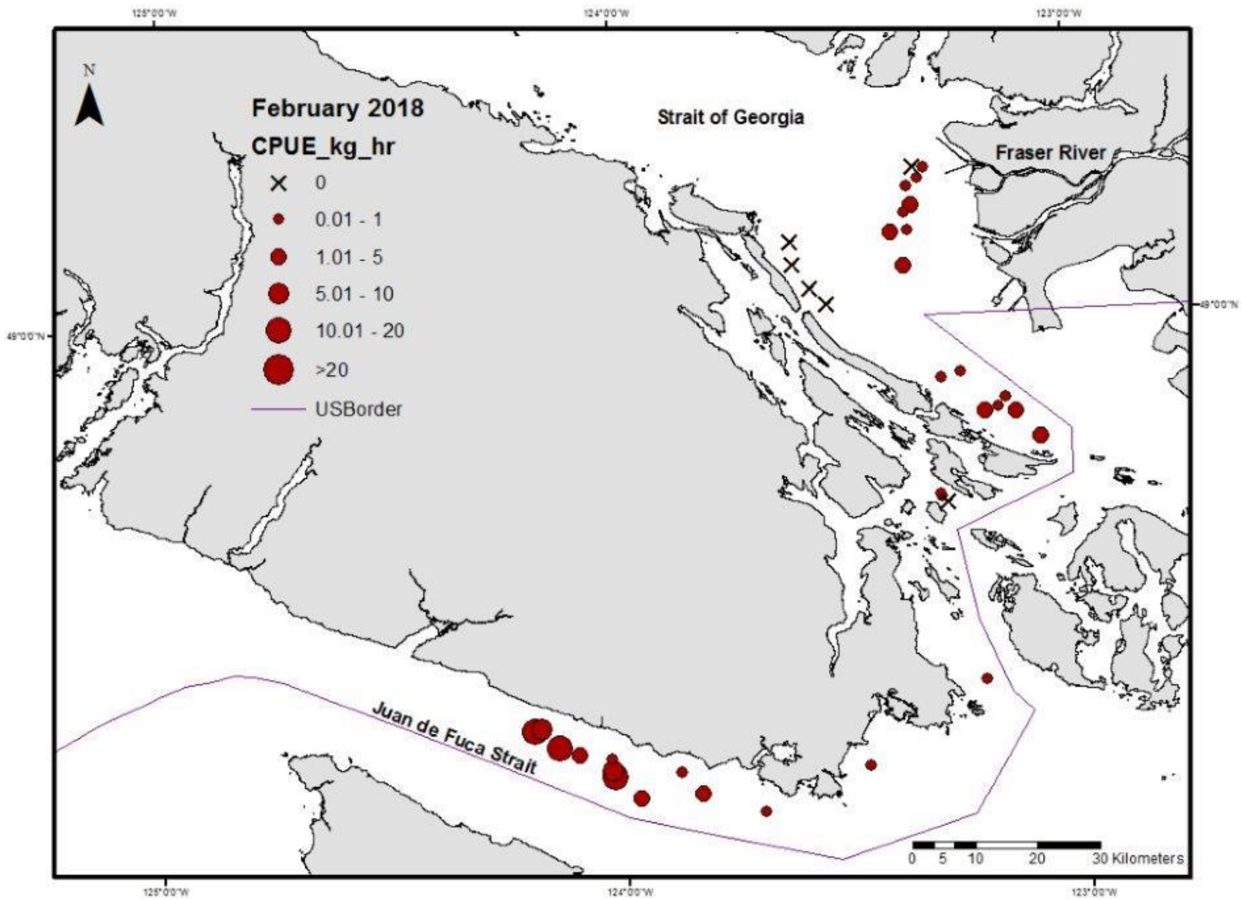

Figure 19. February 1-3 and February 17-21, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

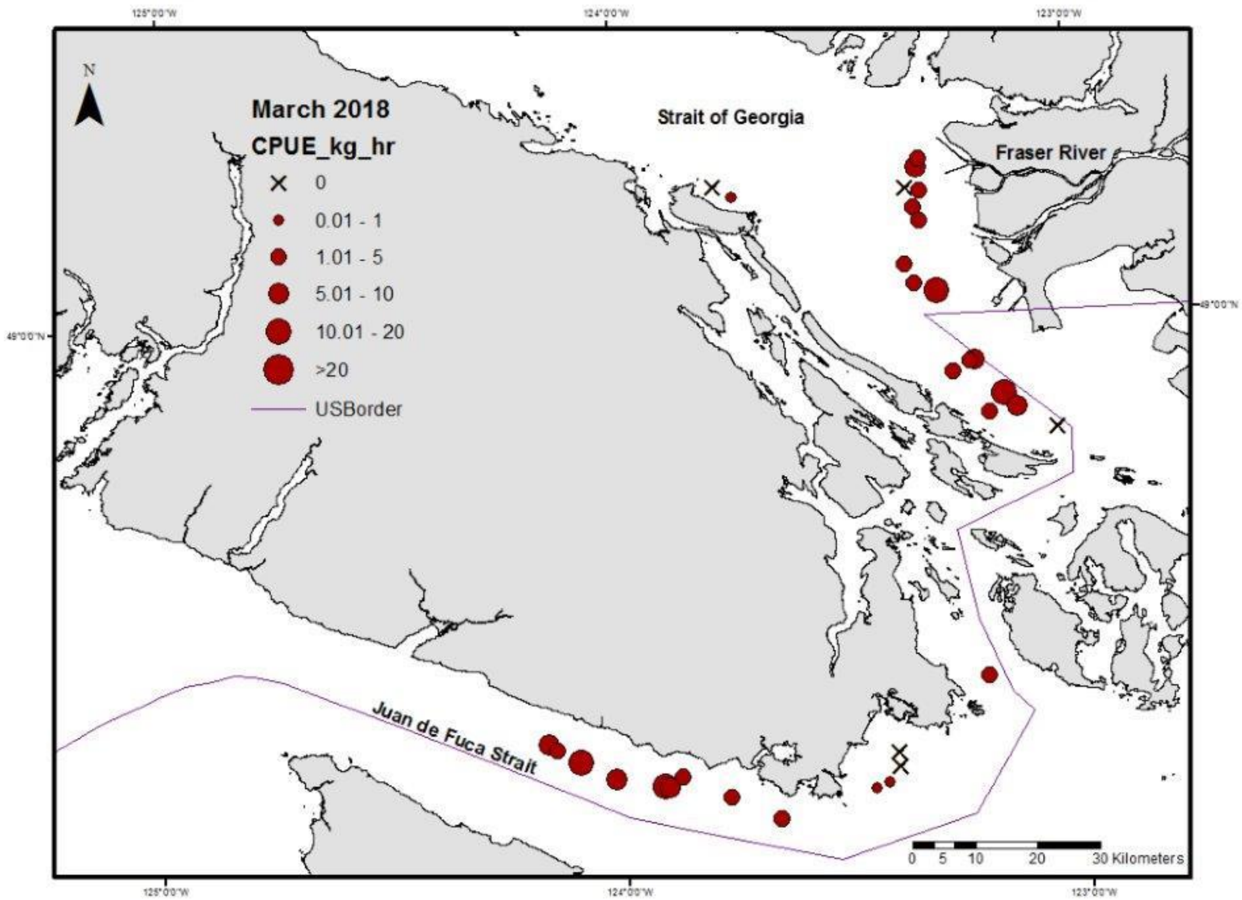

Figure 20. March 10-14, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

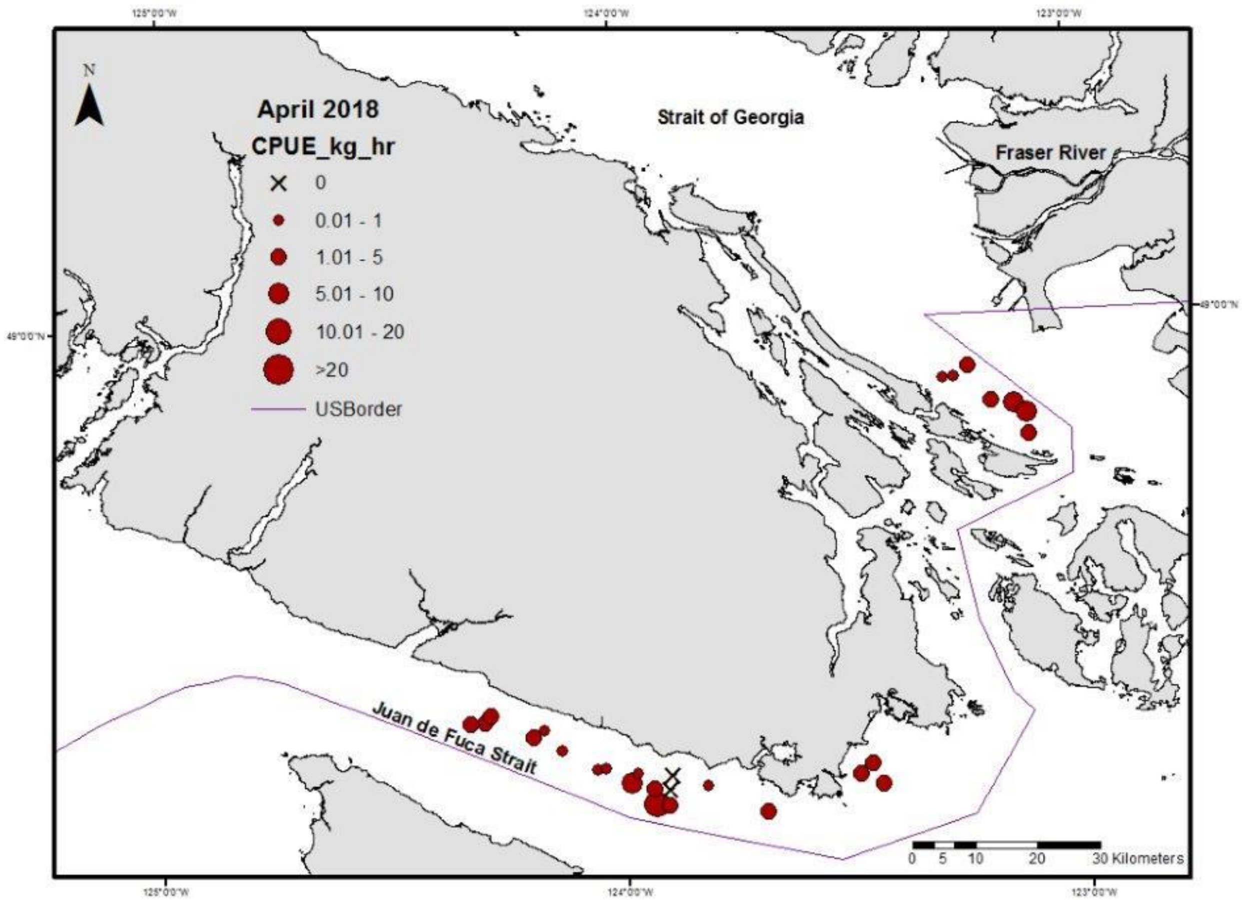

Figure 21. April 7-12, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

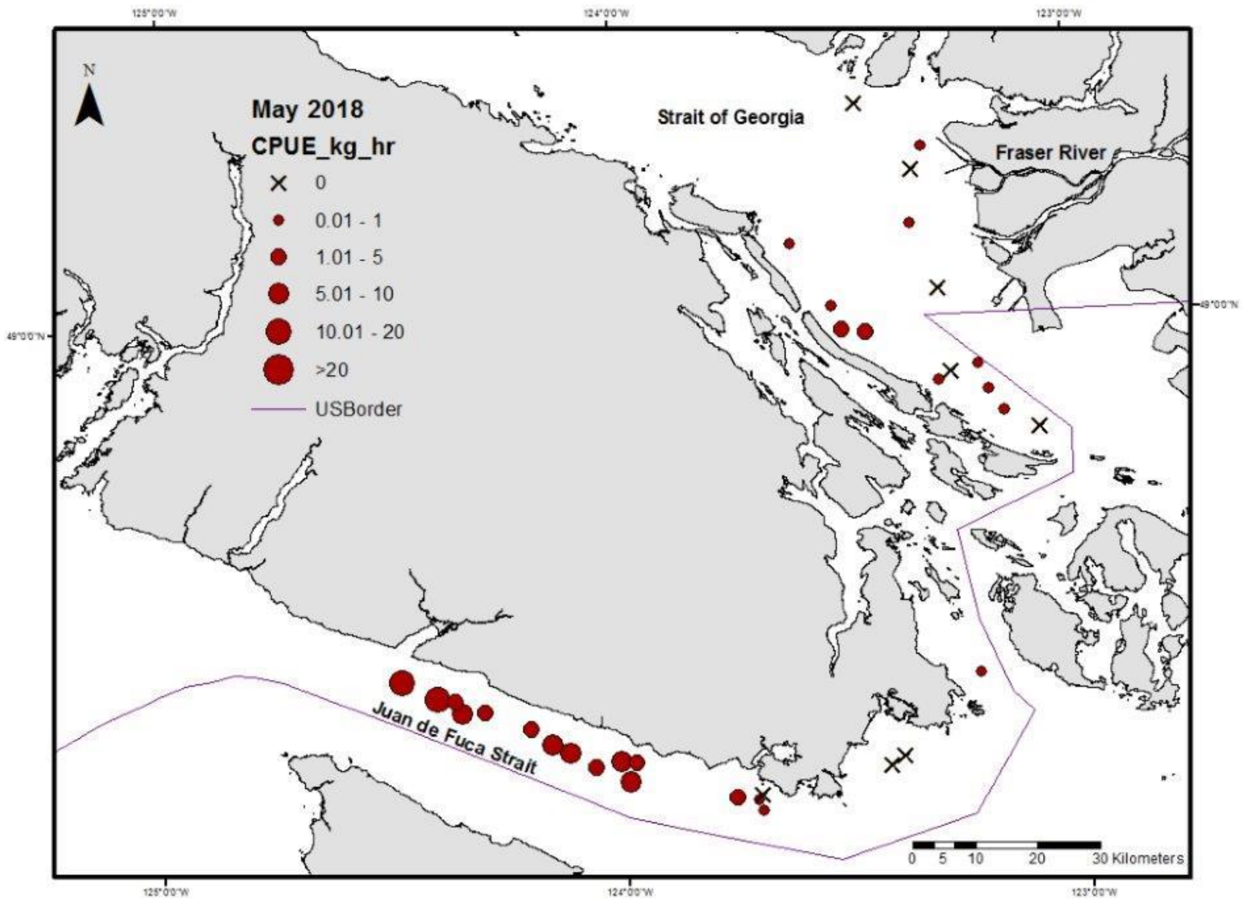

Figure 22. May 4-9, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

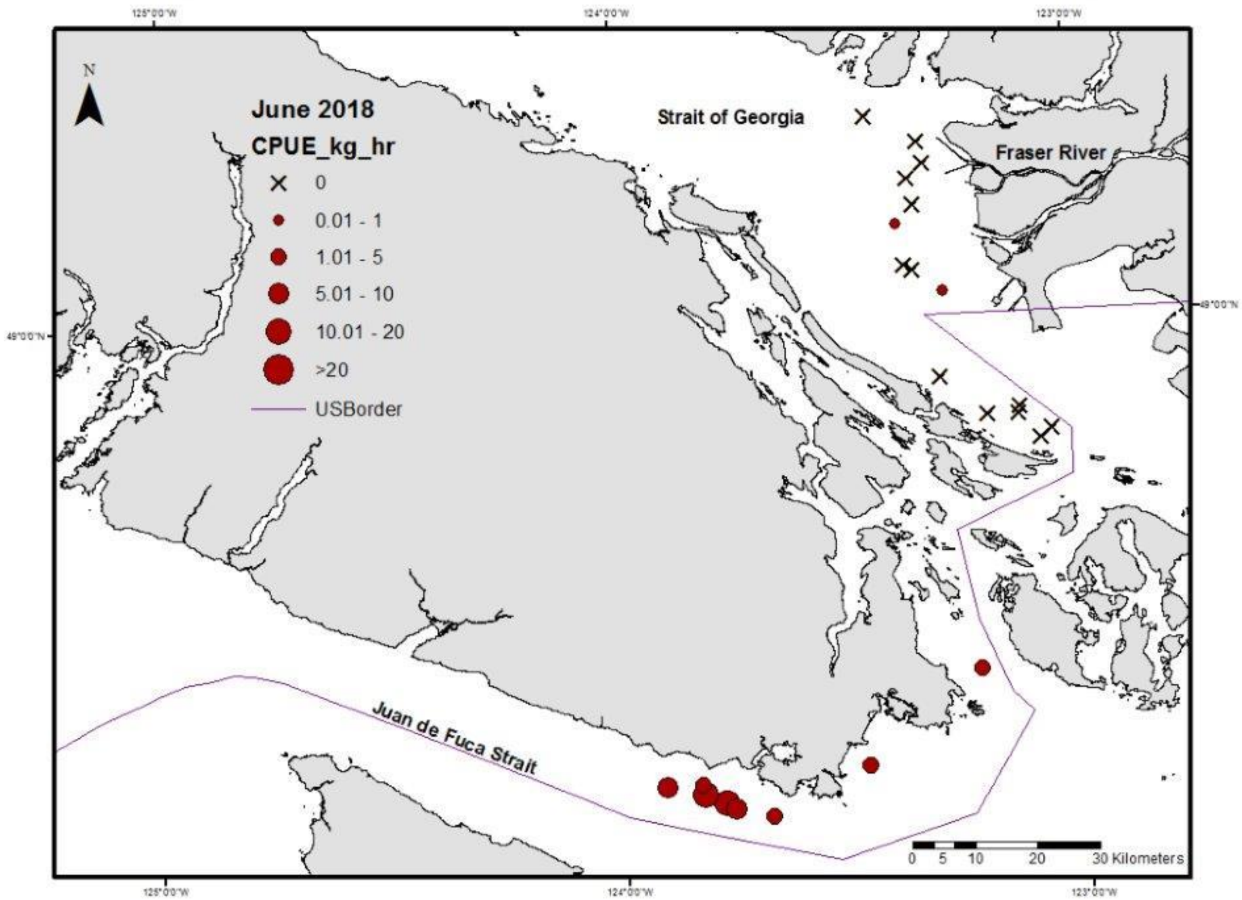

Figure 23. June 24-27, 2018 Eulachon bottom trawl survey set locations with Eulachon CPUE represented by proportional symbols.

APPENDIX 2

Table 9. Cumulative catch and species composition from bottom trawl surveys (n= 227 sets) conducted in Juan de Fuca Strait and Strait of Georgia from October 2017 to June 2018.

Common name	Scientific name	Total catch (kg)	Total catch (%)
Spotted Ratfish	*Hydrolagus colliei*	30396.80	50.04
Walleye Pollock	*Gadus chalcogrammus*	7443.33	12.25
Pacific Spiny Dogfish	*Squalus suckleyi*	5878.91	9.68
English Sole	*Parophyrus vetulus*	3910.26	6.44
Pacific Hake	*Merluccius productus*	1997.43	3.29
Longnose Skate	*Raja rhina*	1733.56	2.85
Big Skate	*Beringraja binoculata*	1474.29	2.43
Dover Sole	*Microstomus pacificus*	1191.71	1.96
Slender Sole	*Lyopsetta exilis*	771.15	1.27
Rex Sole	*Glyptocephalus zachirus*	647.20	1.07
Brittlestars	Ophiuroidea	562.33	0.93
Sidestripe Shrimp	*Pandalopsis dispar*	521.26	0.86
Pacific Herring	*Clupea pallasii*	435.50	0.72
Arrowtooth Flounder	*Artheresthes stomias*	428.69	0.71
Flathead Sole	*Hippoglossoides elassodon*	292.41	0.48
Eulachon	*Thaleichthys pacificus*	269.61	0.44
Sandpaper Skate	*Bathyraja interrupta*	269.29	0.44
Pacific Cod	*Gadus macrocephalus*	268.73	0.44
Prawn	*Pandalus platyceros*	222.07	0.37
Euphausiids	Euphausiacea	191.09	0.31
Mussels	Mytilidae	157.34	0.26
Sablefish	*Anoplopoma fimbria*	139.79	0.23
Dungeness Crab	*Metacarcinus magister*	101.58	0.17
American Shad	*Alosa sapidissima*	86.38	0.14
Pink Shrimp (Spiny)	*Pandalus borealis*	85.66	0.14
Anemone	Actiniaria	82.36	0.14
Sponges	Porifera	81.38	0.13
Plainfin Midshipman	*Porichthys notatus*	74.56	0.12
Blackbelly Eelpout	*Lycodes pacificus*	59.87	0.10
Scallop	Pectinidae	56.10	0.09
Lingcod	*Ophiodon elongatus*	55.85	0.09

Common name	Scientific name	Total catch (kg)	Total catch (%)
Sea Urchin	*Strongylocentrotus sp.*	55.20	0.09
Green Sea Urchin	*Strongylocentrotus droebachiensis*	44.84	0.07
Southern Rocksole	*Lepidopsetta bilineata*	43.51	0.07
Giant Pacific Octopus	*Enteroctopus dofleini*	41.59	0.07
Red Sea Urchin	*Strongylocentrotus franciscanus*	39.27	0.06
Greenstriped Rockfish	*Sebastes elongatus*	38.02	0.06
Shrimp	Dendrobranchiata	37.78	0.06
Quillback Rockfish	*Sebastes maliger*	35.89	0.06
Schoolmaster Gonate Squid	*Berryteuthis magister*	35.12	0.06
Coonstripe Shrimp	*Pandalus danae*	29.05	0.05
Shiner Perch	*Cymatogaster aggregata*	26.50	0.04
Inshore Tanner Crab	*Chionoecetes bairdi*	20.06	0.03
Heart Urchin	*Brisaster latifrons*	20.02	0.03
Glass Shrimp	*Pasiphaea pacifica*	19.33	0.03
Lions Mane	*Cyanea capillata*	17.83	0.03
Pacific Halibut	*Hippoglossus stenolepis*	16.23	0.03
Yellowtail Rockfish	*Sebastes flavidus*	15.92	0.03
Black Eelpout	*Lycodes diapterus*	15.18	0.02
Shortspine Thornyhead	*Sebastolobus alascanus*	14.76	0.02
Brown Cat Shark	*Apristurus brunneus*	14.73	0.02
Pacific Tomcod	*Microgadus proximus*	14.32	0.02
Fried Egg Jellyfish	*Phacellophora camtschatica*	14.32	0.02
Splitnose Rockfish	*Sebastes diploproa*	13.74	0.02
Pacific Sanddab	*Citharichthys sordidus*	13.37	0.02
Brown Box Crab	*Lopholithodes foraminatus*	13.37	0.02
Sand Star	*Luidia foliolata*	13.06	0.02
Petrale Sole	*Eopsetta jordani*	12.65	0.02
Starry Flounder	*Platichthys stellatus*	11.22	0.02
Sea Mouse	*Aphrodita sp.*	10.43	0.02
Basket Star	*Gorgonocephalus eucnemis*	10.42	0.02
Showy Snailfish	*Liparis pulchellus*	9.65	0.02
Pink Short-spined Star	*Pisaster brevispinus*	8.89	0.01
Threespine Stickleback	*Gasterosteus aculeatus*	8.83	0.01
Sunflower Star	*Pycnopodia helianthoides*	7.75	0.01
Hermit Crab	Paguroidea	7.04	0.01
Leather Star	*Dermasterias imbricata*	6.97	0.01

Common name	Scientific name	Total catch (kg)	Total catch (%)
Long-armed Sea Star	*Orthasterias koehleri*	5.51	0.01
Gunpowder Star	*Gephyreaster swifti*	5.43	0.01
Gastropods	Gastropoda	5.39	0.01
Yelloweye Rockfish	*Sebastes ruberrimus*	5.34	0.01
Giant Red Sea Cucumber	*Parastichopus californicus*	5.29	0.01
Wattled Eelpout	*Lycodes palearis*	5.00	0.01
Bluntnose Sixgill Shark	*Hexanchus griseus*	4.50	0.01
Canary Rockfish	*Sebastes pinniger*	4.33	0.01
Pallid Eelpout	*Lycodapus mandibularis*	4.25	0.01
Sturgeon Poacher	*Podothecus accipenserinus*	4.19	0.01
Vermillion Rockfish	*Mediaster aequalis*	4.03	0.01
Bluespot Shrimp	*Pandalus stenolepis*	3.77	0.01
Redstripe Rockfish	*Sebastes proriger*	3.63	0.01
Butter Sole	*Isopsetta isolepis*	3.44	0.01
Spiny Red Sea Star	*Hippasteria spinosa*	3.01	0.00
Pacific Staghorn Sculpin	*Leptocottus armatus*	2.96	0.00
Chinook Salmon	*Oncorhynchus tshawytscha*	2.92	0.00
Northern Ronquil	*Ronquilus jordani*	2.74	0.00
Northern Anchovy	*Engraulis mordax*	2.58	0.00
Pacific Lamprey	*Entosphenus tridentatus*	1.93	0.00
Snailfishes	Liparidae	1.86	0.00
Pink Shrimp (Smooth)	*Pandalus jordani*	1.79	0.00
Skates	Rajidae	1.68	0.00
Cushion Star	*Pteraster tesselatus*	1.57	0.00
Slender Bladed Shrimp	*Spirontocaris holmesi*	1.47	0.00
Common Two-spined Crangon	*Neocrangon communis*	1.37	0.00
Northern Smoothtongue	*Leuroglossus schmidti*	1.24	0.00
Copper Rockfish	*Sebastes caurinus*	1.22	0.00
Pallid Urchin	*Strongylocentrotus pallidus*	1.19	0.00
Fragile Urchin	*Allocentrotus fragilis*	1.18	0.00
Whelks	Buccinidae	1.17	0.00
Striped Sun Starfish	*Solaster stimpsoni*	1.16	0.00
Blacktip Poacher	*Xeneretmus latifrons*	1.12	0.00
Spiny Side Shrimp (Spiny Lebbeid)	*Lebbeus groenlandicus*	1.10	0.00
Sweet Potato Sea Cucumber	*Molpadia intermedia*	0.96	0.00
Spinyhead Sculpin	*Dasycottus setiger*	0.91	0.00
Sculpins	Cottidae	0.88	0.00

Common name	Scientific name	Total catch (kg)	Total catch (%)
Turban Snails	Turbinidae	0.86	0.00
Solaster Sea Star	*Solaster sp.*	0.79	0.00
Crangon	Crangonidae	0.70	0.00
Marbled Snailfish	*Liparis dennyi*	0.42	0.00
Octopus	Octopoda	0.40	0.00
Coho Salmon	*Oncorhynchus kisutch*	0.38	0.00
Red Rock Crab	*Cancer productus*	0.37	0.00
Moon Jelly	*Aurelia aurita*	0.36	0.00
Bivalve Molluscs	Bivalvia	0.27	0.00
Northern Crangon	*Crangon alaskensis*	0.25	0.00
Smoothskin Octopus	*Benthoctopus leioderma*	0.05	0.00
Nereid Worm	Nereididae	0.02	0.00