Data summary: Long term trends in abundance and size of surf smelt *Hypomesus pretiosus*, Pacific herring, *Clupea pallasii,* and Pacific sand lance *Ammodytes personatus* from notes of video snorkeling surveys along the central Strait of Juan de Fuca January 2004-August 2019.

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Synopsis

Herring (*Clupea pallasii)*, sand lance, (*Ammodytes personatus)*, and surf smelt (*Hypomesus pretiosus)*, are critical components of northeast pacific marine systems. These forage fish have complex life histories that include seasonal migratory patterns to and from nearshore spawning grounds. These fish are also iteroparous (they spawn more than once), making long term monitoring important for understanding their health in Salish Sea. Here we summarize 15 years of observations of herring, surf smelt and sand lance size and abundance at two of our long term monitoring sites along the central Strait of Juan de Fuca (SJdF), a well-documented migration corridor for these species (Simenstad et al.1977, Miller et al. 1980, MESA studies)

This report is a synopsis of observed average school size and fish length for herring, surf smelt, and sand lance observed during regular video survey transects at Freshwater and Crescent Bays of the central southern Strait of Juan de Fuca (Figure 1).

Methods

Data were compiled from notes of video snorkeling surveys of Crescent and Freshwater Bays, Central Strait of Juan de Fuca from 2004-2019 as described in Shaffer et al. 2019. The video surveys followed the same path, and were done during daylight hours. Visibility was a minimum of 3 meters. During the video survey shoal size for surf smelt, sand lance and herring were estimated by counting fish in schools, and then binning the estimated counts (Table 1). Fish size was also estimated visually and then binned to the nearest 10 mm. If more than one shoal and/or fish size were recorded for a species the observations were averaged for the survey, by species. Fish were opportunistically collected and measurements taken during snorkel video surveys to confirm fish size. Notes summarizing observations were recorded along with visibility, survey time within an hour of the survey. Videos (minimum of 4k 30fps) from each survey are archived available for confirmation.

Binned shoal size and fish size for each species were averaged for each survey and then month, and analyzed for significant changes by year using one way ANOVA.

Results

A total of 321 surveys over fifteen years met the minimum criteria for visibility and are included in this synopsis (Table 2). Surf smelt and herring in general were observed beginning in May and are present until October. For surf smelt, the majority of fish observed were juveniles prior to 2013. After 2013 fish size appears to increase, and dramatically in the last five years (Figure 2). Shoal size for surf smelt changed significantly with year ($P<0.001$; Figure 3, Table 4 and 5). In contrast, herring shoal size differed significantly with year ($P<0.05$; Table 3), with juvenile herring consistently appearing in June on odd years but not until July in even years. Overall herring numbers appear to decrease (Figure 3). Herring fish size consistently increased by month annually , but over the course of the 15 years of surveys became smaller. In contrast, sand lance were most months of the year appearing as early as March and staying thru November. The majority of sand lance were also juvenile (less than 120mm). Sand lance fish shoal size was variable, but not significantly different with year ($P<0.60$ Figure 2-3, Table 4). While not significant, it the sand lance shoal size tended to decrease in the last five years.

Discussion

Our observations confirm that all three species of fish use the nearshore seasonally, and the dominant use is by juvenile fish (less than 120 mm) , indicating that migration and rearing are important roles for central SJdF shorelines. This is consistent with earlier assessments (see MESA studies including Simenstad et al. 1977, Miller et al. 1980; Shaffer and Ritchie 2008, Shaffer et al. 2012). Of the three forage fish species, sand lance appear to be the most common throughout the year and are present along the nearshore central Strait all months except absent November thru March. These months include sand lance spawning season (November thru February; Penttila 2007). Sand lance are particularly complex in their nearshore habitat use. In addition to intertidal spawning in winter, sand lance have a burrowing phase during which they burrow in sand substrate (Penttila 2007, Haynes et al. 2007 and 2008, Baker 2019). Haynes and Robinson 2011 documented that young of the year sand lance use the same area within a season for burrowing, but have a higher variability in reuse between years. This seasonal fidelity and but higher interannual variability in site fidelity are consistent with the sand lance shoal size and fish size of this study. Recent work by Baker et al. 2019 supports the hypothesis that sand lance seasonal migration to and from the area may be occurring.

The observation that juvenile herring arrive on/before June during odd years (primarily beginning in 2013) is interesting. The drivers and ecological ramifications of this observed biennial trend in juvenile herring arrival is worthy of additional study.

It is beyond the resources of this report to quantify the linkage between the observations trends, of this study, including increase in surf smelt abundance, and the shoreline restoration actions of the adjacent Elwha delta and across the Salish Sea. However given the large scale of the Elwha restoration, and the well documented migratory corridor function of the Strait of Juan de Fuca, it is likely that observations of this study are related to restoration events in these other areas. Specifically, our observations clearly indicate that surf smelt size and numbers have increased significantly over the last five years, which we hypothesize is a response to shoreline restoration, including (but not limited to) rock removal from almost a mile of shoreline just east of the Elwha delta (Michel et al. in prep). This theory is supported by an increase in the distribution of surf smelt eggs along the Elwha shoreline (Michel in prep).

The decrease in both fish and shoal size for sand lance may also be a response to restoration actions. Warrick et al. 2019 documented significant increases in potential sand lance habitat along the Elwha draft cell and we have incidentally observed large numbers of juvenile and adult sand lance along these same shorelines. It may be that sand lance have migrated/shifted to these newly hospitable shorelines for shoaling and burrowing. Additional monitoring for sand lance along the drift cell, and continued monitoring of surf smelt and sand lance spawning along the restoring Elwha shoreline, will provide more information on possible linkages to these life history stages.

And finally, changes in herring fish and shoal size may reflect regional stressors. There appears to be an overall decreasing trend in herring shoal size. This would be consistent with decreases in herring spawn biomass in the Salish Sea (Stick et al. 2014, WDFW 2019). Shaffer et al. 2019 postulate that high density of parasites on young of the year herring are one driver that continues to challenge herring. This could explain consistent long term declining trends of both number and size of juvenile herring. Identifying, and if possible, eliminating the sources of these ecto-parasites as well as other sources of disease is recommended by Shaffer et al. 2019, and echoed here as a precautionary management action. The biennial pattern in juvenile herring arrival is also worthy of additional consideration.

In summary then, these long term observations, while observational instead of quantitative, provide reliable and valuable information in forage fish abundance and size for over a decade along a critical migration and rearing corridor of the Salish Sea. These observations provide the first such field observations of long term trends for these forage fish for the Salish Sea, and should be an informative guide for further quantitative study to test hypotheses offered. They also the basis for precautionary management recommendations to guard against loss of these critical cornerstones of our coastal ecosystems.

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Figures and Tables

Figure 1. Video transect locations, south central Strait of Juan de Fuca, Washington state. Figure printed with permission from Shaffer et al. 2019.

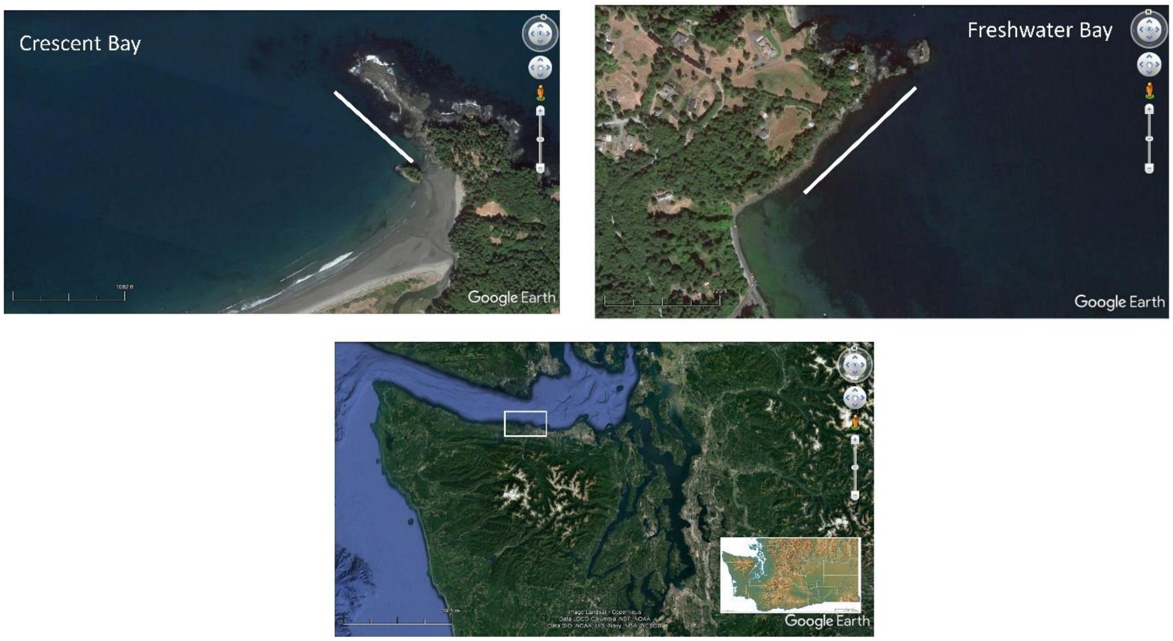
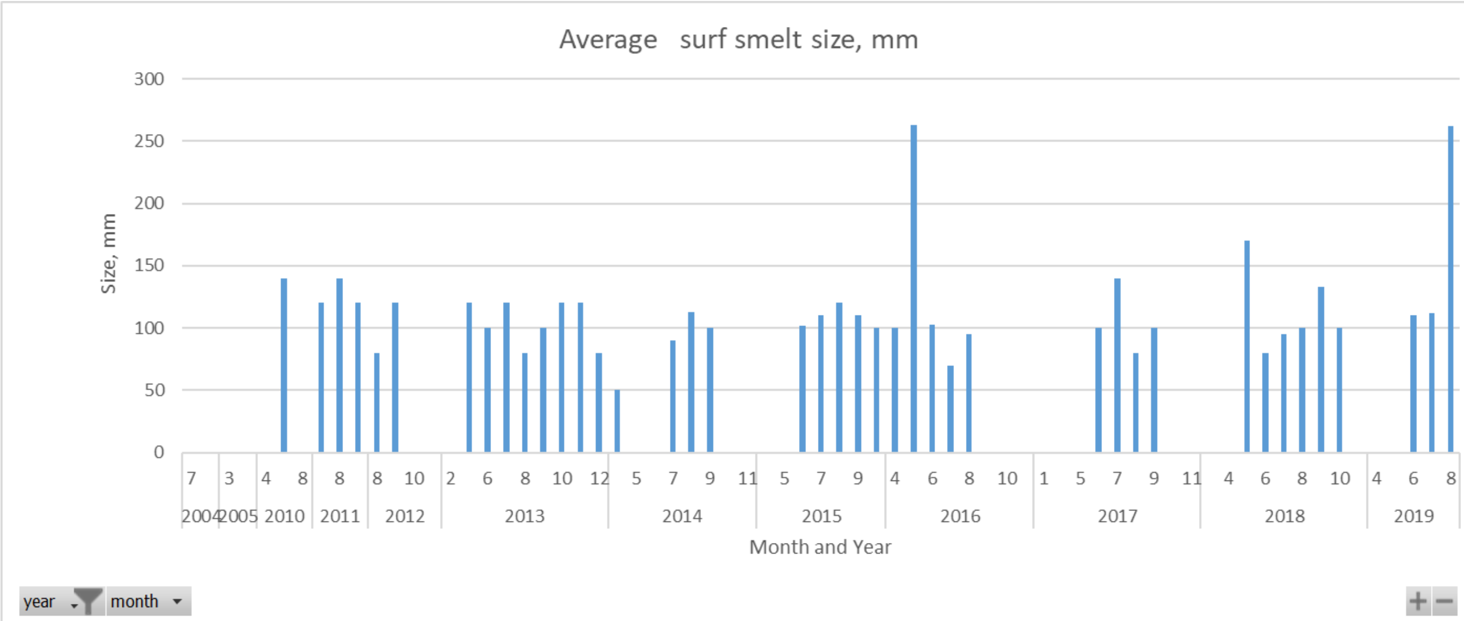
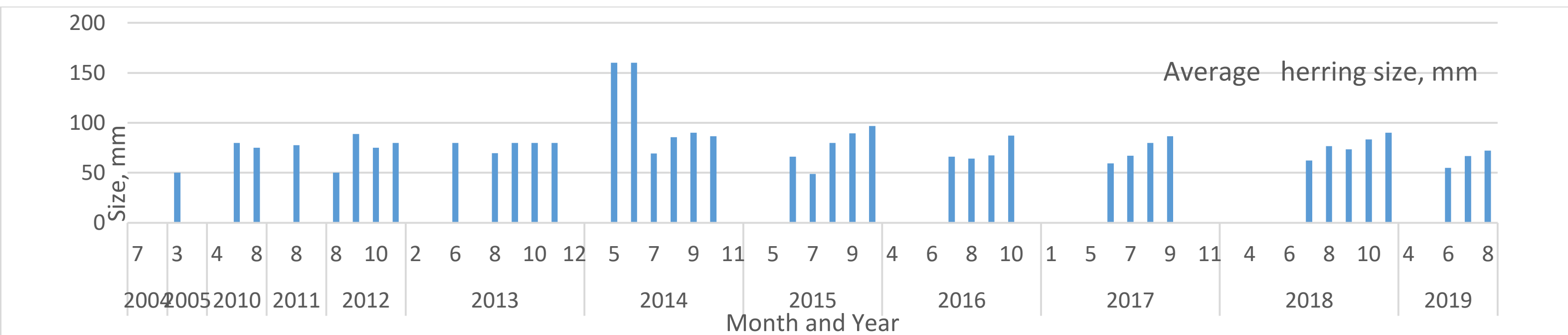


Figure 2. Average fish size of surf smelt, herring and sand lance observed by month 2004-2019. Note fish size was not recorded for surf smelt beginning in 2004.





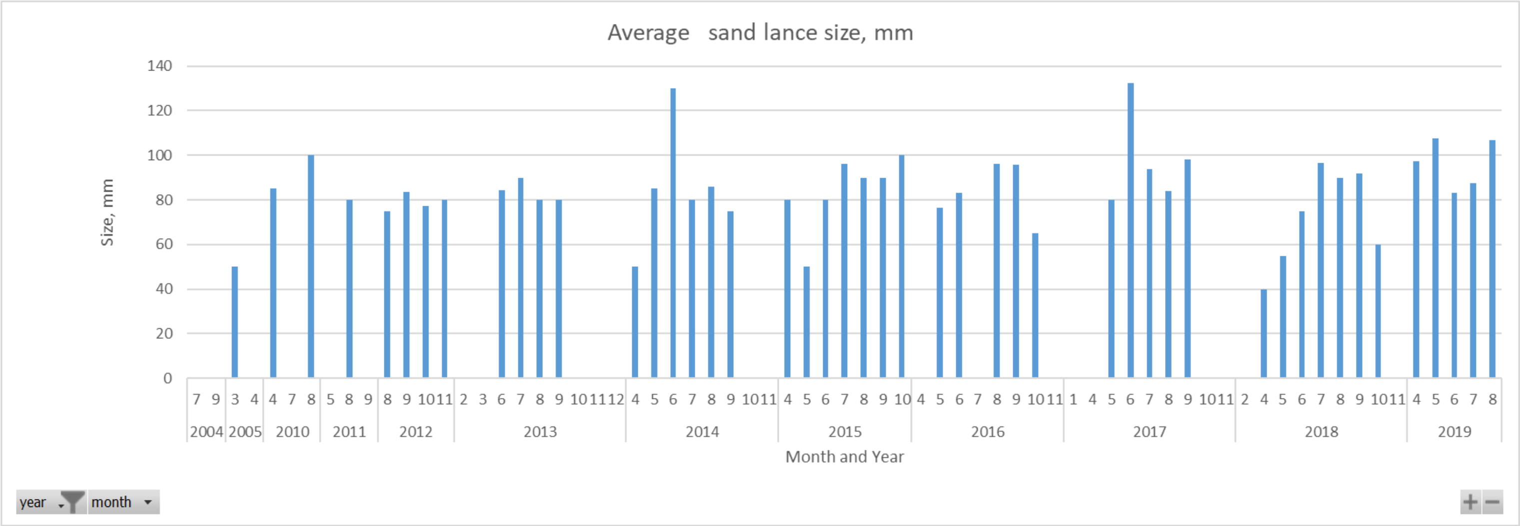


Figure 3. Average shoal size, number of fish, for surf smelt, sand lance, and herring central Strait of Juan de Fuca 2005-2019.

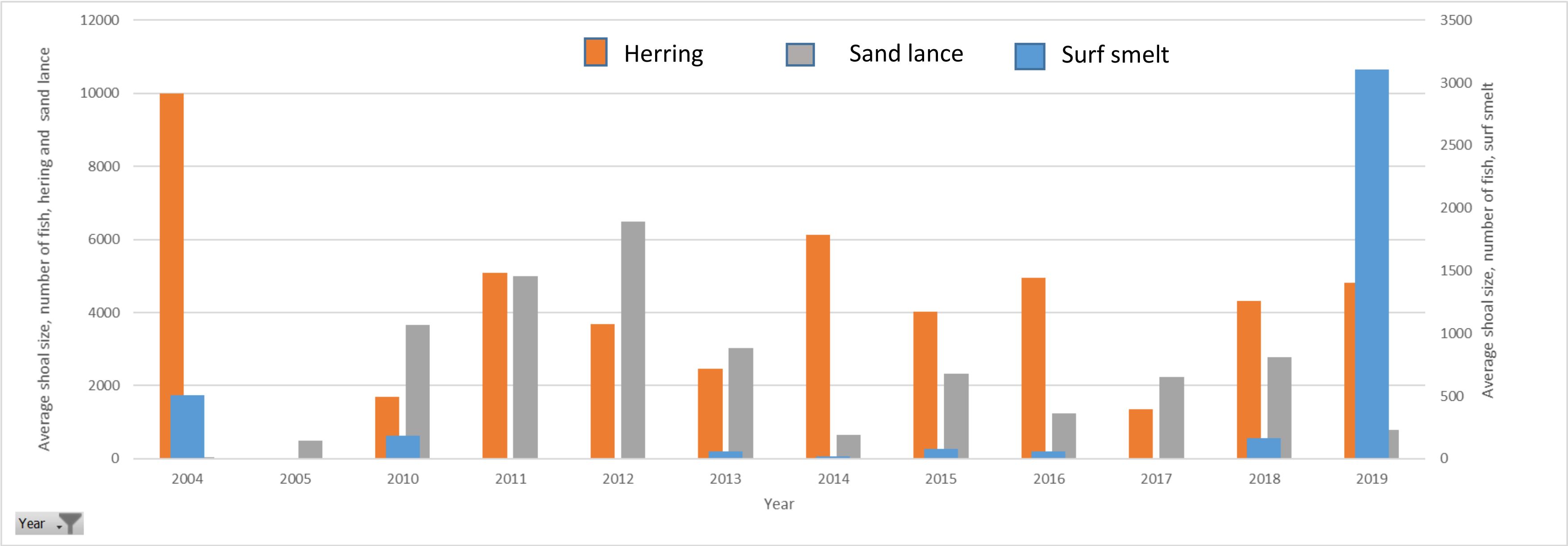

Herring
Sand lance
Surf smelt
Average shoal size, number of fish, hering and sand lance
Average shoal size, number of fish, surf smelt
12000
10000
8000
6000
4000
2000
0
3500
3000
2500
2000
1500
1000
500
0
2004
2005
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Year

Figure 4 Typical images of large schools of adult gravid surf smelt, juvenile herring, and sand lance along the central Strait of Juan de Fuca nearshore 2019. Photos by Anne

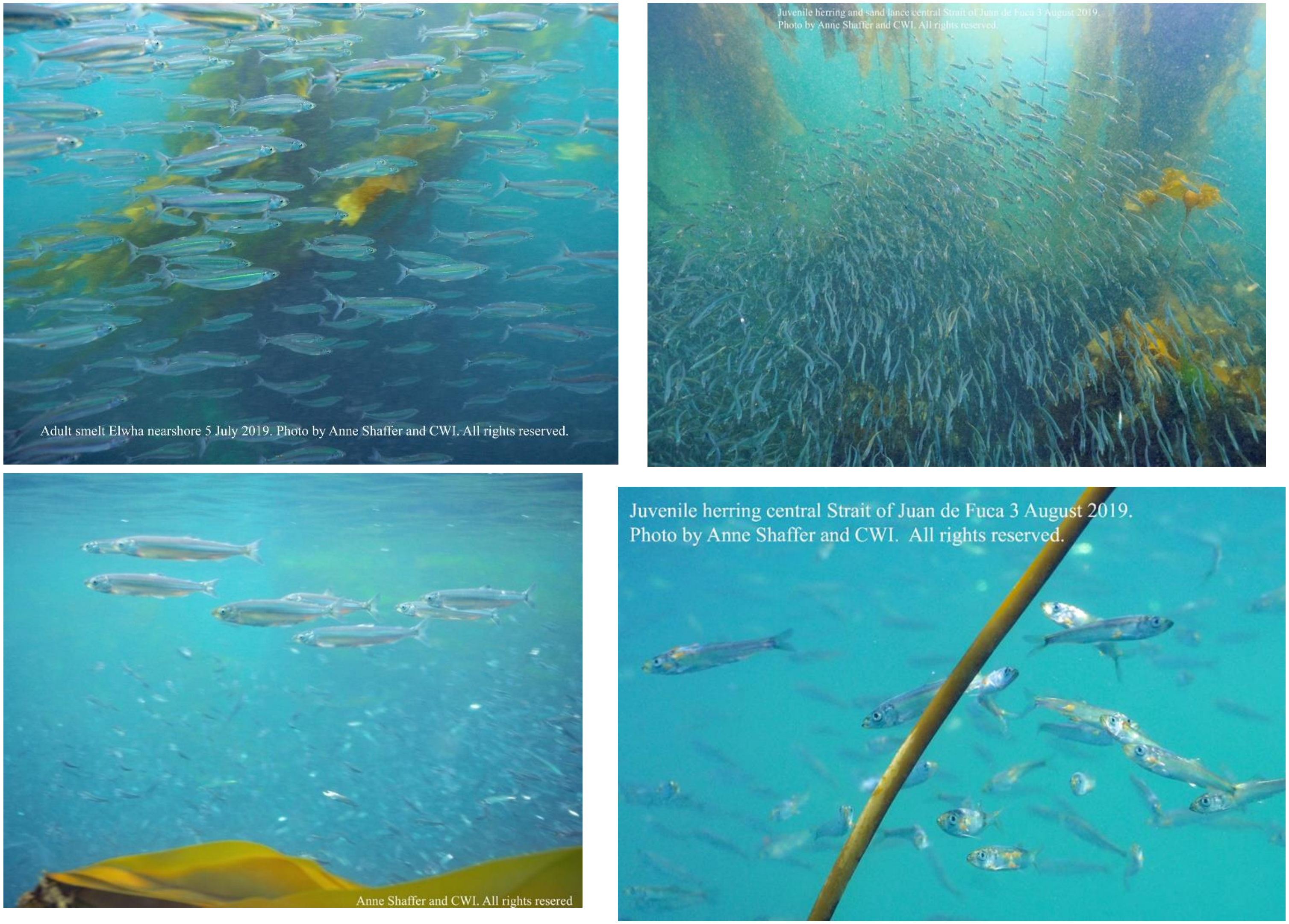


Table 1. Bins for relative estimated abundance of juvenile forage fish school size (number of fish), by species, recorded during visual transect surveys 2004-201.9

Herring	Smelt	Sand lance
0-10	0-10	0-10
11- 75	11-100	11- 75
75-500	100-500	75-500
1000	500	1000
10000	10000	10000

Table 2. Summary of number of video surveys by month and year 2004-2019

Year and month	Number of surveys	Year and month	Number of surveys	Year and month	Number of surveys
2004	**2**	**2015**	**48**	**2019**	**31**
7	1	4	1	3	1
9	1	5	3	4	2
2005	**2**	6	10	5	6
3	1	7	9	6	5
4	1	8	7	7	8
2010	**6**	9	10	8	9
4	1	10	8	**Grand Total**	**321**
7	2	**2016**	**42**		
8	3	4	3		
2011	**4**	5	5		
5	1	6	9		
8	2	7	6		
9	1	8	7		
2012	**17**	9	7		
8	1	10	4		
9	6	11	1		
10	7	**2017**	**41**		
11	3	1	1		
2013	**33**	4	2		
2	1	5	2		
3	1	6	11		
6	10	7	10		
7	1	8	7		
8	9	9	6		
9	4	10	1		
10	3	11	1		
11	3	**2018**	**38**		
12	1	2	1		
2014	**41**	4	1		
4	2	5	4		
5	5	6	2		
6	1	7	9		
7	6	8	11		
8	12	9	6		
9	10	10	3		

Table 3. Average length (mm) and standard deviation for surf smelt , herring, and sand lance by month observed along central Strait of Juan de Fuca, during video snorkeling surveys 2004-2019. Blank cells indicate no size for that species that month

	Sand lance		Surf smelt		Herring	
Year/month	**Size (mm)**	**St dev**	**Size (mm)**	**St dev**	**Size (mm)**	**St dev**
2004						
7						
9						
2005	50	0			50	0
3	50	0			50	0
4						
2010	93	8	140	0	77	21
4	85	0				
7			140	0	80	0
8	100	0			75	25
2011	80	0	127	9	78	8
5			120	0		
8	80	0	140	0	78	8
9			120	0		
2012	79	6	107	19	79	13
8	75	0	80	0	50	0
9	84	4	120	0	89	2
10	77	7			75	9
11	80	0			80	0
2013	83	11	98	16	74	20
2						
3			120	0		
6	84	15	100	0	80	0
7	90	0	120	0		
8	80	0	80	0	70	26
9	80	0	100	0	80	0
10			120	0	80	0
11			120	0	80	0
12			80	0		
2014	83	17	102	25	88	23
4	50	0	50	0	0	0
5	85	0			160	0
6	130	0			160	0
7	80	0	90	10	69	12
8	86	12	113	21	85	9

9	75	5	100	0	90	10
10					87	5
11						
2015	88	14	106	13	75	28
4	80	0				
5	50	0				
6	80	0	101	16	66	10
7	96	6	110	10	49	40
8	90	10	120	0	80	0
9	90	0	110	10	89	5
10	100	0	100	0	97	5
2016	86	22	113	77	69.5	12
4			100	0		
5	77	17	263	90		
6	83	18	102	60	0	0
7			70	27	66	12
8	96	10	95	9	64	7
9	95	5			68	7
10	65	38			87.25	8
11						
2017	95	26	105	22	68	13
1						
4						
5	80	0				
6	132	68	100	0	59	6
7	94	13	140	0	67	9
8	84	5	80	0	80	0
9	98	4	100	0	87	9
10						
11						
2018	83	28	106	25	73	10
2						
4	40	0				
5	55	9	170	0		
6	75	25	80	0		
7	97	29	95	7	62	7
8	90	23	100	8	77	7
9	92	24	133	24	73	7
10	60	0	100	0	83	5
11					90	0
2019	95	15	196	105	67	18

4	97	3				
5	107	12				
6	83	5	110	10	55	4
7	88	19	112	45	67	25
8	107	9	262	93	72	10

Table 4. Average shoal size (number of fish) and standard deviation

Year/Month	herring		sand lance		surf smelt	
	Ave	St dev	Ave	St dev	Ave	St dev
2004	**10000**	**0**	**50**	**50**	**505**	**495**
7	10000	0	0	0	1000	0
9	10000	0	100	0	10	0
2010	**2030**	**3985**	**2400**	**3826**	**220**	**392**
7	5000	5000	5000	5000	550	450
8	50	41	667	471	0	0
2011	**6767**	**4573**	**6667**	**4714**	**3**	**5**
8	10000	0	5000	5000	0	0
9	300	0	10000	0	10	0
2012	**5900**	**4742**	**4314**	**4924**	**3**	**5**
8	10000	0	10000	0	10	0
9	5217	4792	3367	4691	2	4
2013	**2979**	**4509**	**3725**	**4308**	**68**	**197**
6	20	0	5180	4825	0	0
7	0	0	1000	0	100	0
8	3478	4621	4000	3830	43	36
9	10000	0	153	204	288	411
2014	**7355**	**4292**	**1548**	**3464**	**36**	**99**
6	0	0	1000	0	0	0
7	8500	3354	1690	3716	0	0
8	7600	4162	1100	2840	78	141
9	7110	4421	2010	3995	10	30
2015	**3610**	**4604**	**2253**	**3976**	**82**	**159**
6	7500	4330	1263	3303	143	209
7	2641	4260	6875	4285	64	95
8	2212	3900	480	293	100	200
9	1790	3273	11	31	33	94
2016	**6079**	**4875**	**1601**	**3373**	**70**	**188**
6	0	0	2489	4023	182	302
7	8333	3727	0	0	45	70

8	8600	3429	371	410	19	34
9	10000	0	3061	4391	0	0
2017	**1802**	**3510**	**2804**	**3897**	**1**	**4**
6	5667	4243	133	313	0	0
7	145	167	6750	4257	0	0
8	0	0	2170	3530	3	7
9	17	37	2183	2098	0	0
2018	**5019**	**4427**	**3037**	**2956**	**181**	**214**
6			1000	0	50	0
7	9000	2828	5040	3099	121	109
8	4136	3932	1667	1491	157	49
9	667	670	3417	3271	440	412
2019	**4810**	**3829**	**880**	**1045**	**3104**	**3591**
6	4000	4243	100	0	68	45
7	5263	4038	555	835	353	534
8	4678	3417	1833	943	5644	3235

Table 5. Single factor ANOVA shoal size (average number of fish) by year 2004-2019 for surf smelt, herring, and sand lance

Species	SUMMARY						
Surf smelt	Groups	Count	Sum	Average	Variance		
	Year	291	586469	2015.357388	6.782178		
	Surf smelt	288	65955	229.0104167	1306482		
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between Groups	461889988.7	1	461889988.7	710.7662	1E-102	3.85763
	Within Groups	374962309.8	577	649848.0239			
	Total	836852298.5	578				
Herring	Groups	Count	Sum	Average	Variance		
	Year	291	586469	2015.357388	6.782178		
	herring	291	1081662	3717.051546	21353850		
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between Groups	421333517.6	1	421333517.6	39.46205	7E-10	3.85754
	Within Groups	6192618509	580	10676928.46			
	Total	6613952027	581				
Sand lance	Groups	Count	Sum	Average	Variance		
	Year	291	586469	2015.357388	6.782178		
	Sand lance	291	571422	1963.649485	12876276		
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between Groups	389024.4141	1	389024.4141	0.060425	0.8059	3.85754
	Within Groups	3734122053	580	6438141.471			
	Total	3734511077	581				

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