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.

24 October 2019

J. Anne Shaffer Coastal Watershed Institute. PO Box 266 Port Angeles Washington 98362.

CWI Technical Report Number © CWI20191024:3 ISSN 2643-9697

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), but appears 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 observed 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 migration to and from the area may be occurring.

It is beyond the resources of this report to quantify the linkage between the observation of this study 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 *Coastal Watershed Institute* www.coastalwatershedinstitute.org 2 of 17

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 ectoparasites as well as other sources of disease is recommended by Shaffer et al. 2019, and echoed here as a precautionary management action.

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.

Acknowledgments

An entire generation of students and scientists have contributed to these surveys. Dave Parks provided countless hours in the water for snorkeling. Dan Penttila has provided regular and thoughtful consideration to observations. Funding for this work has been provided by the Coastal Watershed Institute, private donors, and Patagonia Inc. Thank you to all.

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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.









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

Long term forage fish monitoring central SJdF

Shaffer

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



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10 of 17

Table 1. Bins for relative estimated abundance of juvenile forage fish school size (number of fish), by species, recorded during visual transect surveys 2004-2019

| <u>Herring</u> | <u>Smelt</u> | 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 |

| <u>Year and</u> <u>month</u> | <u>Number of</u> <u>surveys</u> | <u>Year and</u> month | <u>Number of</u> <u>surveys</u> | <u>Year and</u> <u>month</u> | <u>Number of surveys</u> |
|---------------------------------|------------------------------------|--------------------------|------------------------------------|---------------------------------|--------------------------|
| 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 2. Summary of number of video surveys included in this summary by month and year 2004-2019

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12 of 17

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 <u>Size</u> | | Surf smelt | | Herring <u>Size</u> | |
|-------------------|---------------------------|---------------|------------|---------------|------------------------|--------|
| <u>Year/month</u> | <u>(mm)</u> | <u>St dev</u> | Size (mm) | <u>St dev</u> | <u>(mm)</u> | 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 |

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| 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 | 60 | 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 |
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14 of 17

| 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 | 60 | 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 | | |

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| 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 |
| 2018 6 | 5019 | 4427 | 3037 1000 | 2956 0 | 181 50 | 214 0 |
| 2018 6 7 | 5019 9000 | 4427 2828 | 3037 1000 5040 | 2956 0 3099 | 181 50 121 | 214 0 109 |
| 2018 6 7 8 | 5019 9000 4136 | 4427 2828 3932 | 3037 1000 5040 1667 | 2956 0 3099 1491 | 181 50 121 157 | 214 0 109 49 |
| 2018 6 7 8 9 | 5019 9000 4136 667 | 2828 3932 670 | 3037 1000 5040 1667 3417 | 2956 0 3099 1491 3271 | 181 50 121 157 440 | 214 0 109 49 412 |
| 2018 6 7 8 9 2019 | 5019 9000 4136 667 4810 | 4427 2828 3932 670 3829 | 3037 1000 5040 1667 3417 880 | 2956 0 3099 1491 3271 1045 | 181 50 121 157 440 3104 | 214 0 109 49 412 3591 |
| 2018 6 7 8 9 2019 6 | 5019 9000 4136 667 4810 4000 | 4427 2828 3932 670 3829 4243 | 3037 1000 5040 1667 3417 880 100 | 2956 0 3099 1491 3271 1045 0 | 181 50 121 157 440 3104 68 | 214 0 109 49 412 3591 45 |
| 2018 6 7 8 9 2019 6 7 | 5019 9000 4136 667 4810 4000 5263 | 4427 2828 3932 670 3829 4243 4038 | 3037 1000 5040 1667 3417 880 100 555 | 2956 0 3099 1491 3271 1045 0 835 | 181 50 121 157 440 3104 68 353 | 214 0 109 49 412 3591 45 534 |

| 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 | <u>Groups</u> | <u>Count</u> | Sum | <u>Average</u> | <u>Variance</u> | _ | |
| | 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 | 274062200.8 | 577 | 640949 0220 | | | |
| | Groups | 374962309.8 | 577 | 649848.0239 | | | |
| | Total | 836852298.5 | 578 | | | | |
| Herring | <u>Groups</u> | <u>Count</u> | <u>Sum</u> | <u>Average</u> | <u>Variance</u> | _ | |
| | 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 Croups | 6102619500 | 590 | 10676028 46 | | | |
| | Totoups | 0192018309 | 501 | 100/0928.40 | | | |
| <u>C 1 1</u> | Total | 6613952027 | 581 | | | | |
| Sand lance | <u>Groups</u> | Count | <u>Sum</u> | 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 | | | 2 222 2 | 0.0.00 | 0.00 = 0 | 2 1 1 1 1 |
| | Groups | 389024.4141 | I | 389024.4141 | 0.060425 | 0.8059 | 3.85754 |
| | Within Croups | 2724122052 | 590 | 6120111 171 | | | |
| | Groups | 3734122033 | J8U 701 | 0438141.4/1 | | | |
| | Total | 3/34511077 | 581 | | | | |