NOAA Contract Report NMFS-NWFSC-CR-2024-02

https://doi.org/10.25923/g2ac-xm81

Naval Station Everett East Waterway Fish Presence and Shoreline Use, 2020–22

Contract **N6874220GTC3651**

January 2024

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

NOAA Contract Report Series NMFS-NWFSC-CR

Recommended citation:

(Frick and Kagley 2024)[1]

[1] Frick, K. E., and A. N. Kagley. 2024. Naval Station Everett East Waterway Fish Presence and Shoreline Use, 2020–22. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC-CR-2024-02.

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Executive Summary

We conducted a study to improve upon the existing knowledge of nearshore fish occurrence in the Naval Station Everett East Waterway. Regular beach seine sampling was conducted at eight sites in the study area between February 2020 and September 2022. Results are intended to inform the Naval Station Everett's *Integrated Natural Resources Management Plan,* and avoidance and minimization measures for potential in-water work. Project objectives included:

1. Describe fish community species composition in the nearshore study area on a monthly basis, with more intensive focus on the period of peak juvenile salmonid occurrence and the designated in-water work window.
2. Provide a brief characterization of physical nearshore habitat and water quality conditions.
3. Compare the East Waterway fish community to that of the lower Snohomish River and estuary using data available from previous monitoring of juvenile salmonids *Oncorhynchus* spp. conducted by the National Marine Fisheries Service, the U.S. Geological Survey, Snohomish County, and the Tulalip Tribe.

Due to the coronavirus disease (COVID-19) pandemic, sampling events were curtailed in 2020; therefore, sampling was not contiguous. Sampling was rescheduled, and the resumed schedule encompassed both a migration year (2022) and a non-migration year (2021) for juvenile pink salmon. A total of 56,760 individual fish were captured, representing 22 species. Patterns of catch related directly to individual species' life histories. Seasonal variations were observed in all of the water quality metrics but they remained fairly consistent among sites.

Contents

Introduction

Nearshore marine ecosystems featuring intertidal and shallow subtidal habitats play a key role in the life cycle of many fishes, including juvenile salmonids, forage fish, and other commercially and ecologically important species (Bizzarro et al. 2022). The location of these ecosystems along coastal shorelines often leads to anthropogenic modification, including construction of bulkheads, erection of piers and docks, dredging and filling, and removal of riparian vegetation. To understand the dynamics of local populations and the potential impact of work in these habitat areas, monitoring and recording individual fish use of nearshore ecosystems is critical. Such monitoring is also essential for rigorous evaluations to ensure the efficacy of actions to mitigate these impacts (Cereghino et al. 2012).

The East Waterway is an industrialized body of water situated at the mouth of the Snohomish River immediately west of downtown Everett, Washington (Figure 1). This waterway is surrounded on three sides by armored shorelines with structures associated with U.S. Naval Station Everett, the former Kimberly-Clark property, and the Port of Everett.

Figure 1. Map of the overall study region (left) and East Waterway study area in Everett, Washington.

Investigations of juvenile salmonid habitat use within the freshwater Snohomish River system have been conducted by state and federal resource agencies, Snohomish County, private entities, and tribes (Rice et al. 1999; Haas 2001; SBSRF 2005). However, few studies have focused on fish occurrence and distribution within the estuary (Chamberlin et al. 2022), including the East Waterway.

In April and May 1997, a shoreline observational study was conducted along portions of the Port of Everett waterfront (Pentec 1997; City of Everett 2001). In 2015 the Washington Department of Fish and Wildlife (WDFW) conducted a short study of the East Waterway (Frierson et al. 2017). They combined two survey days using a remotely operated vehicle (ROV) with one day using hydroacoustics (sonar) and five days of monthly beach seine sampling at four locations from May to September. Both of these studies provided useful information about habitat type and fish distribution, but neither was designed to capture a full calendar year of fish occurrence within nearshore habitats, nor capture the variation between pink salmon outmigration and non-outmigration years.

Habitat remediation projects in the adjacent Snohomish River have included monitoring that has produced consistent data about salmonid densities and lower river fish communities over time (Haas et al. 2001; Chamberlin 2022; Greene et al. 2023; WCET 2022). Status and monitoring studies have also shown that many salmonid species in the Snohomish River Basin continued to decline for the past few decades (Pess et al. 2002; Hahn et al. 2010; SBSRF 2019), increasing the urgency to obtain knowledge of nearshore habitat use by these species.

For the present study, our goal was to improve upon existing knowledge of nearshore fish presence in the East Waterway. Beach seine surveys were initiated to assess spatial and temporal patterns in presence and abundance of forage fish and salmonids in marine nearshore habitats off Naval Station Everett. Sampling was conducted at eight sites in the study area between February 2020 and September 2022 for a total of 40 sampling days (Table 1; Appendix Table A) that encompassed two juvenile salmon migration seasons from the Snohomish River.

Due to a work hold implemented during the COVID-19 pandemic, sampling was not contiguous in 2020, the first year of the study. Therefore, data from sampling efforts during 2020-2022 comprised the equivalent of collections from a two-year study. Results will be used to enhance the Naval Station Everett *Integrated Natural Resources Management Plan* and to inform avoidance and minimization measures for in-water work in the area, such as dock/pier construction or demolition, dredging, etc. that may not be planned in the future.

Table 1. Number of sampling dates by month, with the number of sites visited on each sampling date shown in parentheses (out of 8 maximum). Details for sampling dates in Appendix A.

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020		1 (7)	1 (7)							2 (8, 8)	1 (7)	1 (8)
2021		2 (8, 7)	2 (8, 8)	2 (8, 7)	2 (8, 8)	2 (8, 8)	1 (8)	2 (7, 7)	2 (8, 8)	2 (8, 6)	1 (7)	1 (8)
2022	1 (8)	1 (8)	2 (8, 8)	2 (8, 7)	2 (4, 8)	2 (8, 8)	1 (8)	2 (7, 7)	2 (8, 8)			

Project objectives include:

1. Describe fish community species composition in the East Waterway nearshore study area on a monthly basis with intensive focus on periods of peak juvenile salmonid occurrence and the designated in-water work period.
2. Provide a brief characterization of physical nearshore habitat and water quality conditions in the East Waterway.
3. Compare the East Waterway fish community to that of the lower Snohomish River and estuary using data from juvenile salmonid monitoring previously conducted by National Marine Fisheries Service, the U.S. Geological Survey, Snohomish County, and the Tulalip Tribe.

Methods

Survey methods followed comprehensive recommendations in Hahn et al. (2007) and Midway et al. (2022) to give a basic understanding of the fish community and habitat in the East Waterway.

Beach Seine Surveys

Nearshore fish surveys were conducted at eight beach seine sites in the East Waterway study area (Figures 2-3) targeting tidal heights of 5-9 ft mean lower low water (MLLW). Three of these sites (EW1, EW4, and EW5) were consistent with the 2015 WDFW survey (Frierson et al. 2017). Of the eight sampling sites, seven were located within the East Waterway, whereas the eighth was in the lower Snohomish River (EW1).

Surveys were conducted using a 37 m Puget Sound beach seine (Hahn et al. 2007), which ranges from a depth of 0.9 m at the wing ends to 2.4 m at the bag (Figure 3). Mesh size was 13 mm in the wings and 6 mm knotless nylon in the bag. During deployment, one end of the seine was held onshore, and a 21 ft motorboat was used to set the net in a shallow alongshore arc to a second point approximately 20-25 m down the shore.

To retrieve the beach seine, the wing ends were pulled together, creating a semi-circular net shape, entrapping the fish, which were then forced toward the cod-end for collection. This net design is ideally suited for capturing surface-oriented fishes like juvenile salmonids and various forage fish species over smooth substrate, but may miss an unknown proportion of benthic fishes (e.g., flatfishes, sculpins) and others in areas where the beach profile drops off steeply or is high relief (e.g. armored shorelines).

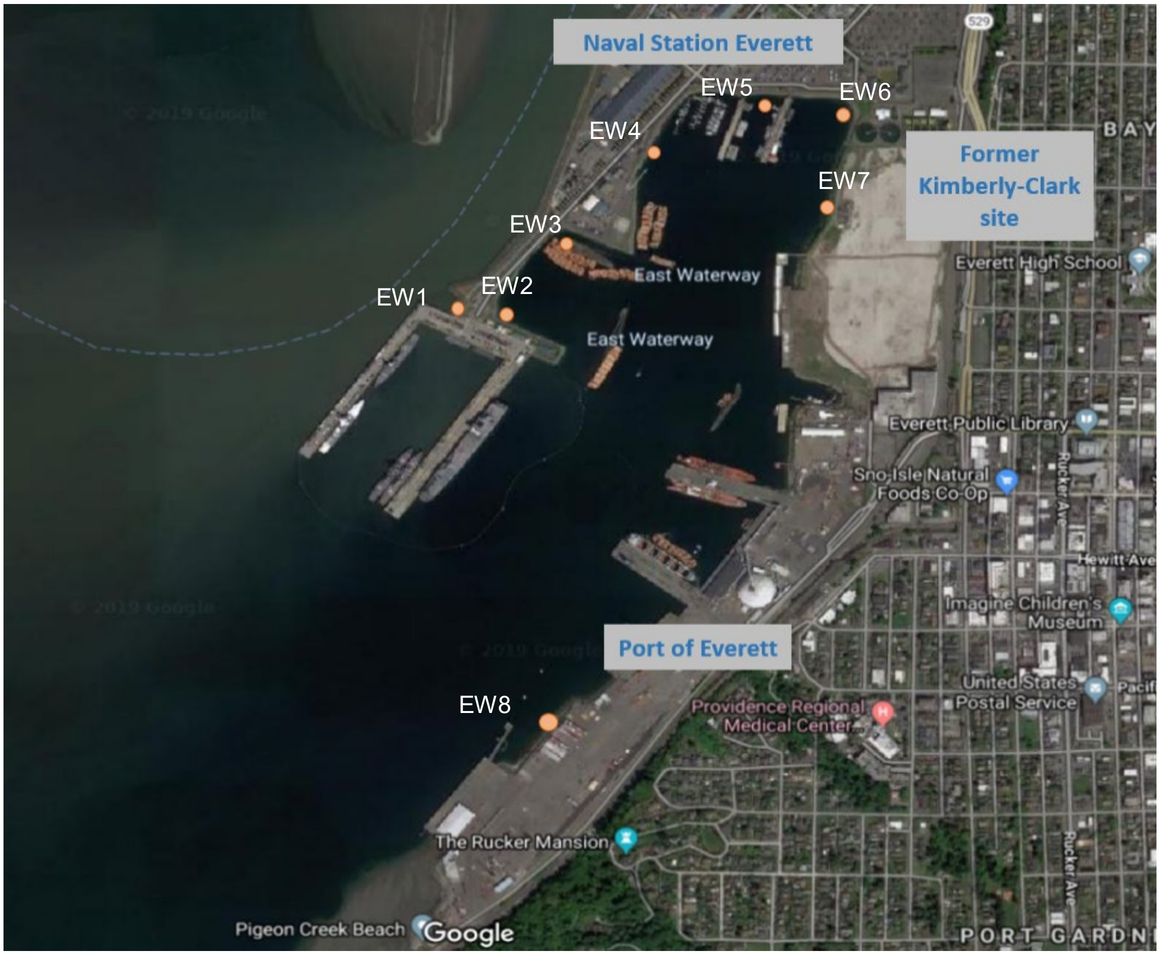


Figure 2. Beach seine sampling sites within the East Waterway (orange dots).

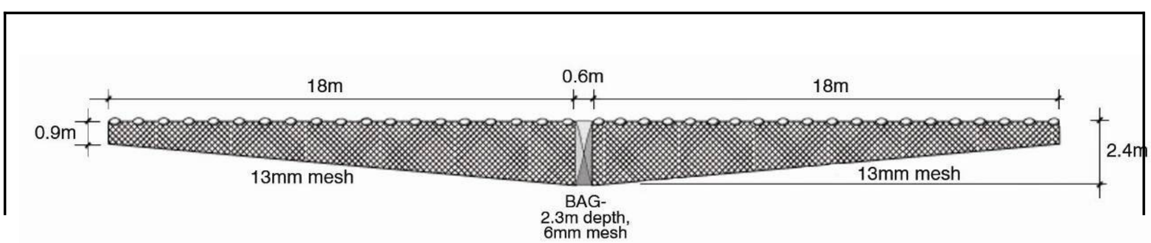


Figure 3. Dimensions of the Puget Sound beach seine used for sampling (from Hahn et al. 2007).

Assessment of Fish Community Composition

All fish collected from the cod-end upon net retrieval were identified and enumerated. If more than 20 individuals of any species were captured in a set, the first 20 fish were measured for fork length (FL), while the remaining fish were enumerated and immediately released in the vicinity of their capture location. This action met analytical power needs and minimized handling stress. For any large catches of fish (>500 individuals), we estimated the total catch via volumetric subsample to minimize handling and mortality.

In addition, salmonids were visually inspected for adipose fin clips and scanned with a magnetic wand for the presence of coded wire tags (CWTs). A subset of coded-wire-tagged fish were retained for assessment of origin. We limited these lethal collections to one individual per day in each of two categories: CWT with an intact adipose fin, or CWT and adipose fin-clipped.

Descriptions and plots of the East Waterway fish community were completed for each sampling effort. These included reporting of total catch and calculation of catch per unit effort (CPUE) as the average catch of each species per beach seine set. These calculations were pooled by month and site for the most commonly captured species. We plotted the relative categorical abundance by sampling site for salmonids and forage fish. Fish size was also plotted in year-independent length distributions by calendar date for these groups.

We compared CPUE of Chinook salmon captured by beach seine between sites at Naval Station Everett (this study) and sites in the nearby Snohomish River estuary in 2019 and 2022 (unpublished data from the National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center). We summarized monthly mean Chinook salmon counts in these samples, with data from March to September and 3-59 seine samples available per area/month combination. A significant data consideration for this comparison was that many of the samples (386 out of 519 = 74.4%) had sampled counts of 0 Chinook salmon. The remainder were "patchy," or scattered throughout samples, comprising 1-99 Chinook salmon per set.

Therefore, the distribution of calculated mean Chinook salmon counts for each area/month combination were not assumed to follow a normal (Gaussian) distribution, or any other typical theoretical distribution. We therefore compared them using resampling methods (i.e. bootstrapping), where we let the means of a large number of resampled (with replacement) cohorts "define" their own empirical distributions (Efron and Tibshirani 1993). To compare months, we calculated the resample distribution for the difference between Naval Station Everett and Snohomish River estuary in each month using 100,000 resamples. Then we calculated a mean difference with 95% confidence intervals where the endpoints of the intervals were the 2.5 and 97.5% values of the ordered distribution of differences.

To determine a *P*-value for the null hypothesis that the catch of Chinook salmon at Naval Station Everett and in the Snohomish River estuary were equal in a given month, we calculated the proportion of values less than or equal to 0 and doubled it, as this was a two-sided test, and observed values were only calculated in one direction. However, if this proportion (undoubled) was greater than 0.5 we did a similar calculation for the values greater than or equal to 0. All analyses were done in the R statistical software environment (R Core Team 2021).

Habitat Location and Characterization

For each sampling site, the survey team recorded a position (latitude/longitude) of the approximate center point of the net to the shoreline. The same position was visited for each sampling event at each site. During the survey, a brief characterization of the physical habitat at each site was recorded, including remarks about beach slope, substrate makeup, and degree of anthropogenic development.

Water quality metrics of temperature, pH, conductivity, and dissolved oxygen were collected concurrent with each beach seine set using instrumentation from YSI (Yellow Springs Instrument Company).[1] Collected environmental data values from the East Waterway were compared with those sampled in the top two meters of water at Gedney Island (WSDE 2021, location ID PSS019; also known as Hat Island; monthly averages from 1999-2017), the geographically closest water quality station. This station in a fully marine location that is located 3.69 nm NW from the East Waterway, which is directly influenced by output from the Snohomish River. SigmaPlot 12.5 statistical software was used for comparing groups using a *t*-test unless the data did not satisfy a normality test. If the data failed tests of normality or equal variance, a Mann-Whitney test was used to make the comparison.

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Results

Habitat Characterization

The area surrounding and including Naval Station Everett has been extensively armored, dredged, and filled, both historically and currently. Shoreline areas consisted of highly modified riprap or bulkheads leading to soft bottoms below the tide lines. Site EW6 was the only site with a gravel beach at low tide. Site EW8 was backed by a bulkhead with large riprap aggregate scattered at the base. The remaining sites were all backed by riprap, resulting in steep drop-offs within several meters of the shore. Habitat features such as eelgrass, kelp beds, and natural, unmodified shorelines associated with robust fish communities are absent from the area within the naval station waterfront (Frierson et al. 2017).

Water quality measures varied monthly but were fairly consistent among sites (Table 2). Numerous monthly values were significantly different from those sampled in the top two meters of water at Gedney Island, particularly for salinity and dissolved oxygen.

Table 2. Monthly average water quality measures collected during East Waterway fish surveys, 2020-2022. Standard errors shown in parentheses. Values shown in boldface are significantly higher and blue italicized values are significantly lower than Gedney Island values (WSDE 2021).

	Water temperature (°C)	Conductivity (µs)	Salinity (ppt)	Dissolved oxygen (mg/L)
January	**8.0 (0.2)**	*19316 (2460)*	*17.5 (2.2)*	8.94 (0.79)
February	7.7 (0.6)	**22956 (3052)**	21.3 (3.0)	*9.48 (0.72)*
March	*8.2 (1.1)*	18427 (5200)	*16.7 (5.2)*	*10.59 (1.04)*
April	10.1 (1.2)	24493 (3399)	21.3 (3.1)	*10.33 (1.05)*
May	12.2 (0.9)	*19679 (3709)*	*15.8 (3.3)*	*9.14 (1.17)*
June	13.8 (1.1)	20684 (3419)	*16.0 (3.3)*	*9.50 (0.70)*
July	**16.8 (2.1)**	*24113 (4946)*	*17.6 (2.8)*	*8.43 (0.99)*
August	**17.8 (0.7)**	*31524 (2464)*	*23.2 (2.3)*	*7.90 (0.81)*
September	14.7 (1.4)	*32314 (1242)*	*25.8 (0.9)*	*8.49 (1.20)*
October	**12.2 (0.8)**	27531 (4119)	*23.0 (3.7)*	*6.87 (1.07)*
November	9.7 (0.7)	20191 (8989)	17.8 (8.4)	*8.28 (1.33)*
December	7.8 (1.3)	21828 (3474)	20.0 (2.8)	*8.65 (0.93)*

Fish Community Composition

Among the eight sample sites, we conducted 303 total seine sets on 40 sampling dates between 28 February 2020 and 20 September 2022 (Table 1, Appendix Table A). A total of 56,760 individuals were captured, representing 22 identified species (Table 3) among six functional groups (Figure 4). Fish were captured in 199 seine sets (65.7%) and at all sampling sites over the course of the study.

Table 3. Seine catch summary: species and total number caught during February 2020-June 2022.

Functional group/ Common name	Scientific name	No. sets with catch (of 303)	Total count	CPUE (rounded)
Salmonids				
Chinook salmon	*Oncorhynchus tshawytscha*	34	269	1
Chum salmon	*Oncorhynchus keta*	63	5,248	17
Coho salmon	*Oncorhynchus kisutch*	13	82	0
Cutthroat trout	*Oncorhynchus clarki*	1	1	0
Pink salmon	*Oncorhynchus gorbuscha*	35	10,836	36
Sockeye salmon	*Oncorhynchus nerka*	1	1	0
Forage fish				
Northern anchovy	*Engraulis mordax*	1	1	0
Pacific herring	*Clupea pallasii*	13	24,827	82
Pacific sand lance	*Ammodytes personatus*	21	10,438	34
Surf smelt	*Hypomesus pretiosus*	38	544	2
Sculpins				
Buffalo sculpin	*Enophrys bison*	2	2	0
Pacific staghorn sculpin	*Leptocottus armatus*	14	57	0
Sharpnose sculpin	*Clinocottus acuticeps*	12	27	0
Tidepool sculpin	*Oligocottus maculosus*	9	13	0
Greenling				
Kelp greenling	*Hexagrammos decagrammus*	4	4	0
Surfperches				
Shiner perch	*Cymatogaster aggregata*	31	928	3
Striped seaperch	*Embiotoca lateralis*	1	2	0
Flatfish				
English sole	*Parophrys vetulus*	2	2	0
Other				
Bay pipefish	*Syngnathus leptorhynchus*	13	24	0
Plainfin midshipman	*Porichthys notatus*	1	1	0
Saddleback gunnel	*Pholis ornata*	1	2	0
Threespine stickleback	*Gasterosteus aculeatus*	87	3,447	11
Unidentified		3	4	0

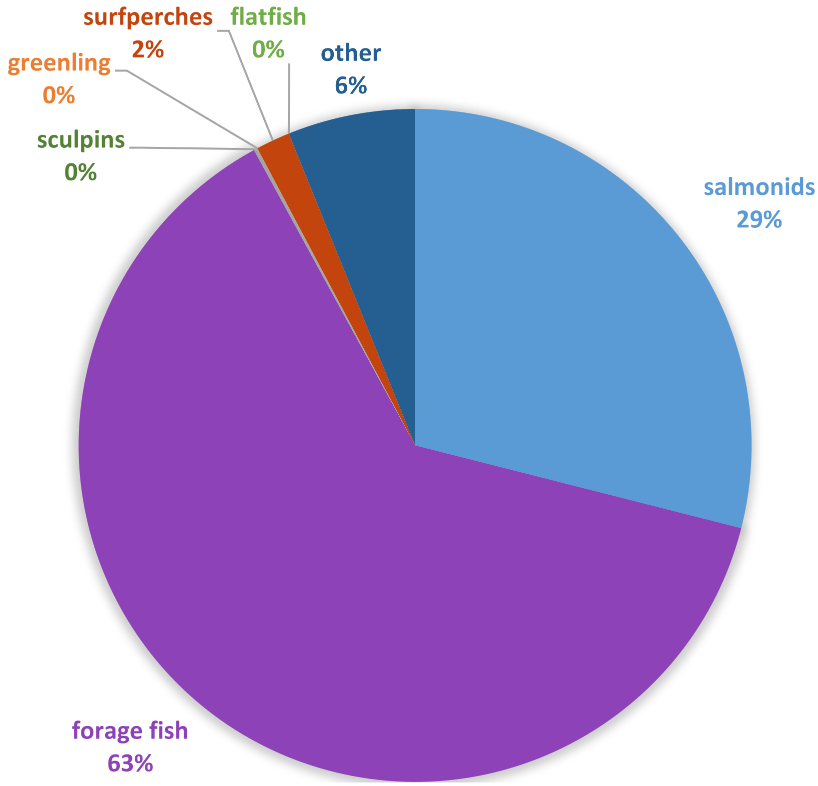


Figure 4. Proportional catch of fish among functional groups across the entire study (all categories included though some comprised too small a fraction to be visible).

Average catch per unit effort (CPUE) was 187 fish per set over the entire sampling period. This average was driven by a few large capture events and varied considerably when calculated by date or site (Tables 4, 5). The species-independent median catch per haul was two (2) individuals across all sites and sampling dates. Monthly total and average catches reflected species' seasonal use of the East Waterway (Tables 4, 5; Appendix Table B2).

Spatially, captured fish were not distributed evenly among sampling sites (Tables 4, 5). The sites at EW3 and EW4 had the greatest total catches, primarily driven by a couple of large sets of Pacific herring, pink salmon, and Pacific sand lance in May 2022. These species tended to be caught in large groups when present. Threespine stickleback was captured across the sampling timeline, in every month of sampling (Table 4). Shiner perch was also common.

Table 4. Total catch and catch per unit effort (CPUE; in parentheses) numbers by species and sample month for the most prevalent species across the study time frame.

		Salmonids				Forage Fish			Other	
Month	Number of sets	Chinook	Coho	Chum	Pink	Pacific sand lance	Pacific herring	Surf smelt	Threespine stickleback	Shiner perch
Jan	8	0	0	0	0	0	0	5 (1)	3 (0)	0
Feb	30	0	8 (0)	1 (0)	3 (0)	1 (0)	0	3 (0)	16 (1)	0
Mar	39	20 (1)	10 (0)	881 (23)	2,012 (52)	5 (0)	0	6 (0)	1 (0)	1 (0)
Apr	30	3 (0)	0	3,330 (111)	6,172 (206)	4,789 (160)	0	11 (0)	15 (1)	0
May	28	38 (1)	10 (0)	983 (35)	2,626 (94)	5,585 (199)	24,691 (882)	3 (0)	36 (1)	346 (12)
Jun	32	80 (3)	47 (1)	53 (2)	23 (1)	4 (0)	1 (0)	0	653 (20)	2 (0)
Jul	16	113 (7)	5 (0)	0	0	1 (0)	2 (0)	49 (3)	198 (12)	28 (2)
Au	28	10 (0)	1 (0)	0	0	1 (0)	130 (5)	132 (5)	891 (32)	354 (13)
Sep	32	1 (0)	0	0	0	0	2 (0)	167 (5)	1,575 (49)	182 (6)
Oct	30	0	0	0	0	50 (2)	1 (0)	152 (5)	21 (1)	15 (1)
Nov	14	0	1 (0)	0	0	2 (0)	0	16 (1)	32 (2)	0
Dec	16	4 (0)	0	0	0	0	0	0	6 (0)	0

Table 5. Total catch and catch per unit effort (in parentheses) numbers by species and sample month for the most prevalent species (Note: total catch is not scaled for effort). The upper set represents monthly average catch in 2020 and 2022, in which juvenile pink salmon were present based on life history. The lower set in gray represents catch in 2021, which was not a pink salmon juvenile migration year.

		Salmonids				Forage fish			Other	
Month	Number of sets	Chinook	Coho	Chum	Pink	Pacific sand lance	Pacific herring	Surf smelt	Threespine stickleback	Shiner perch
January	8	0	0	0	0	0	0	5 (1)	3 (0)	0
February	23	0	0 (0)	0	3 (0)	1 (0)	0	3 (0)	1 (0)	0
March	23	0	10 (0)	689 (30)	2,012 (87)	5 (0)	0	6 (0)	0	1 (0)
April	15	0	0	792 (53)	6,172 (411)	197 (13)	0	11 (1)	9 (1)	0
May	12	38 (3)	2 (0)	637 (53)	2,626 (219)	5,302 (442)	24,691 (2,058)	0	35 (3)	346 (29)
June	16	19 (1)	11 (1)	11 (1)	23 (1)	3 (0)	0	0	41 (3)	2 (0)
July	8	18 (2)	2 (0)	0	0	1 (0)	2 (0)	0	195 (24)	28 (4)
August	14	5 (0)	1 (0)	0	0	0	130 (9)	5 (0)	599 (43)	272 (19)
September	16	1 (0)	0	0	0	0	2 (0)	0	1,540 (96)	177 (11)
October	16	0	0	0	0	0	1 (0)	2 (0)	12 (1)	14 (1)
November	7	0	0	0	0	0	0	1 (0)	7 (1)	0
December	8	1 (0)	0	0	0	0	0	0	1 (0)	0
January	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	7	0	8 (1)	1 (0)	0	0	0	0	15 (2)	0
March	16	20 (1)	0 (0)	192 (12)	0	0	0	0	1 (0)	0
April	15	3 (0)	0	2,538 (169)	0	4,592 (306)	0	0	6 (0)	0
May	16	0	8 (1)	346 (22)	0	283 (18)	0	3 (0)	1 (0)	0
June	16	61 (4)	36 (2)	42 (3)	0	1 (0)	1 (0)	0	612 (38)	0
July	8	95 (12)	3 (0)	0	0	0	0	49 (6)	3 (0)	0
August	14	5 (0)	0	0	0	1 (0)	0	127 (9)	292 (21)	82 (6)
September	16	0	0	0	0	0	0	167 (10)	35 (2)	5 (0)
October	14	0	0	0	0	50 (4)	0	150 (11)	9 (1)	1 (0)
November	7	0	1 (0)	0	0	2 (0)	0	15 (2)	25 (4)	0
December	8	3 (0)	0	0	0	0	0	0	5 (1)	0

Table 6. Site-specific catch information for East Waterway sampling sites. Total catch per site is included for common species, along with the number of sets with catch of that species in parentheses. CPUE, catch per unit effort.

Site name	Number of sets	Total fish caught	Average CPUE	Median catch per set	*Salmonids* Chinook	*Salmonids* Coho	*Salmonids* Chum	*Salmonids* Pink	Forage fish Pacific sand lance	Forage fish Pacific herring	Forage fish Surf smelt	Other Threespine stickleback	Other Shiner perch
EW1	34	8,824	260	0	24 (9)	3 (1)	2,589 (9)	1,287 (3)	4,853 (3)	3 (3)	5 (3)	29 (8)	25 (4)
EW2	38	5,227	138	0	20 (6)	7 (2)	456 (9)	3,011 (6)	466 (3)	42 (1)	152 (8)	658 (8)	347 (2)
EW3	40	16,377	409	0	33 (2)	3 (2)	415 (7)	73 (4)	4,384 (2)	11,328 (1)	27 (6)	99 (12)	7 (1)
EW4	38	17,573	462	0	10 (5)	0	386 (6)	3,255 (6)	467 (3)	13,320 (1)	111 (7)	22 (5)	0
EW5	38	1,712	45	0	3 (2)	2 (1)	127 (7)	463 (5)	196 (2)	127 (2)	55 (4)	721 (15)	11 (3)
EW6	39	2,841	73	0	145 (19)	57 (9)	544 (8)	1,097 (4)	9 (5)	2 (2)	156 (7)	433 (12)	378 (9)
EW7	39	1,756	45	0	18 (8)	10 (1)	172 (9)	63 (4)	3 (2)	4 (3)	32 (4)	1,367 (17)	78 (2)
EW8	37	2,450	66	0	16 (5)	0	559 (8)	1,587 (3)	60 (5)	1 (1)	6 (5)	118 (10)	82 (10)

Forage Fish

Forage fish presence and abundance were patchy, as reflected by the most common species in the category (Pacific sand lance, Pacific herring, and surf smelt) (Tables 4, 5, 6; Figure 5). Patterns in presence of these species were seasonally constrained. They were sequential in dominating abundance, transitioning from Pacific sand lance to Pacific herring to surf smelt (Figure 6).

Pacific sand lance

Pacific sand lance was most abundant at EW1 and EW3 (Table 6, Figure 5), sites closest to the Snohomish River channel. These fish were captured primarily in April and May, though the month was dependent on the year of study (Table 5, Figure 6). Post-larval fish (<50 mm) dominated catch early in the year, with no post-larval individuals and only larger larval fish (50-120 mm) captured as the year progressed (Figure 7).

Pacific herring

Pacific herring was primarily caught at sites EW3 and EW4 (Table 6, Figure 5). May 2022 brought an influx of large numbers of Pacific herring juveniles (24,691 individuals) unlike observations in any other month of sampling (Tables 4, 5). Aside from that event, they were mostly present in August, although not abundant (Figure 6). The size of Pacific herring captured increased across sampling months, with small post-larval fish comprising all catch in May and larger juvenile fish being captured in late summer and fall (Figure 7).

Surf smelt

Surf smelt was the least abundant of the common forage fish, but was captured at all sites and throughout the year (Tables 4, 6). Surf smelt was most abundant in fall (Table 4, Figure 6). Except for one sampling event in July, we caught almost exclusively post-larval sized surf smelt (Figure 7). A few larval-sized fish (50-120 mm) were present late in the year.

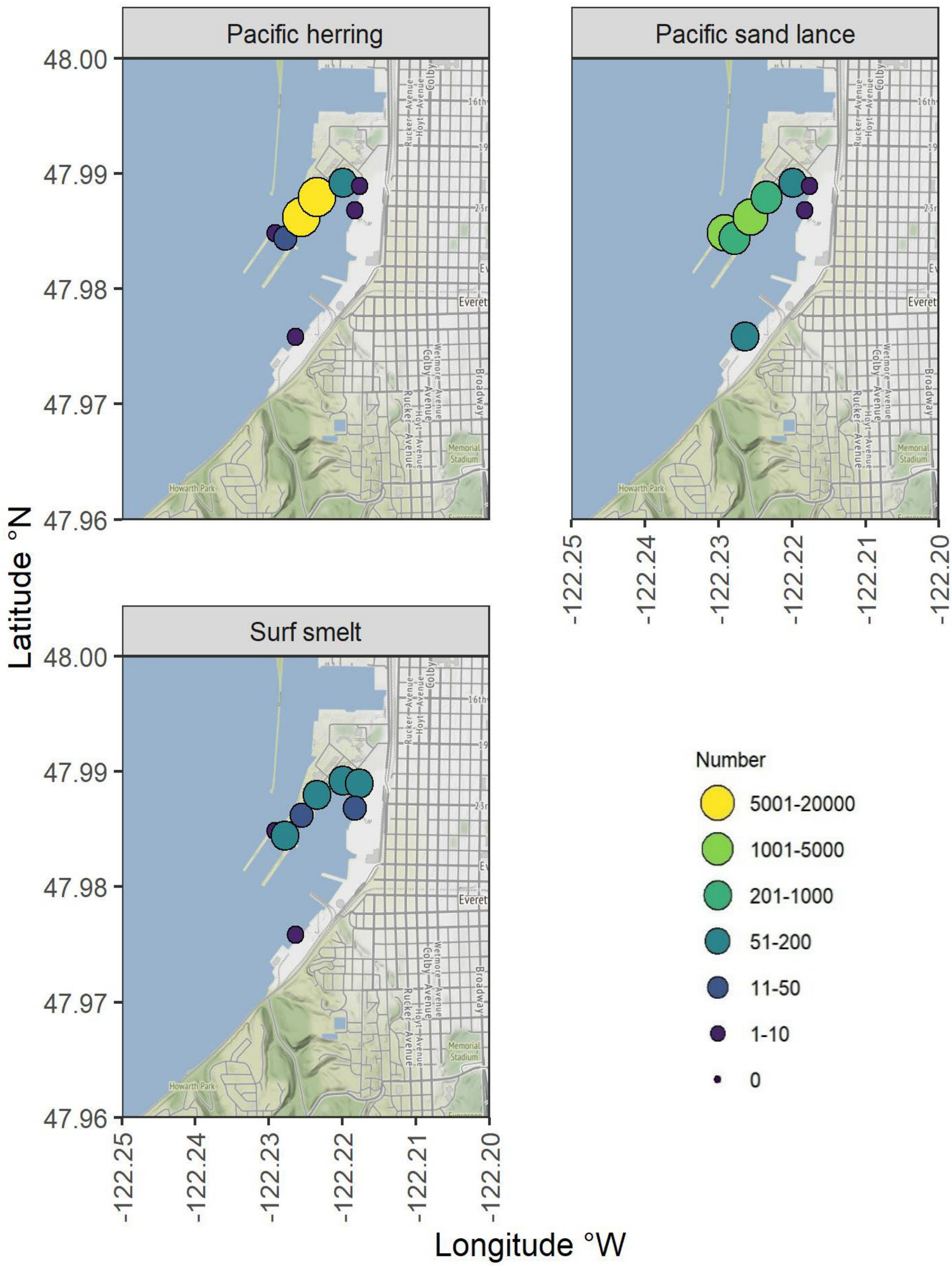


Figure 5. Categorical abundance of forage fish species at sampling sites within the East Waterway. Abundance values not scaled to level of effort.

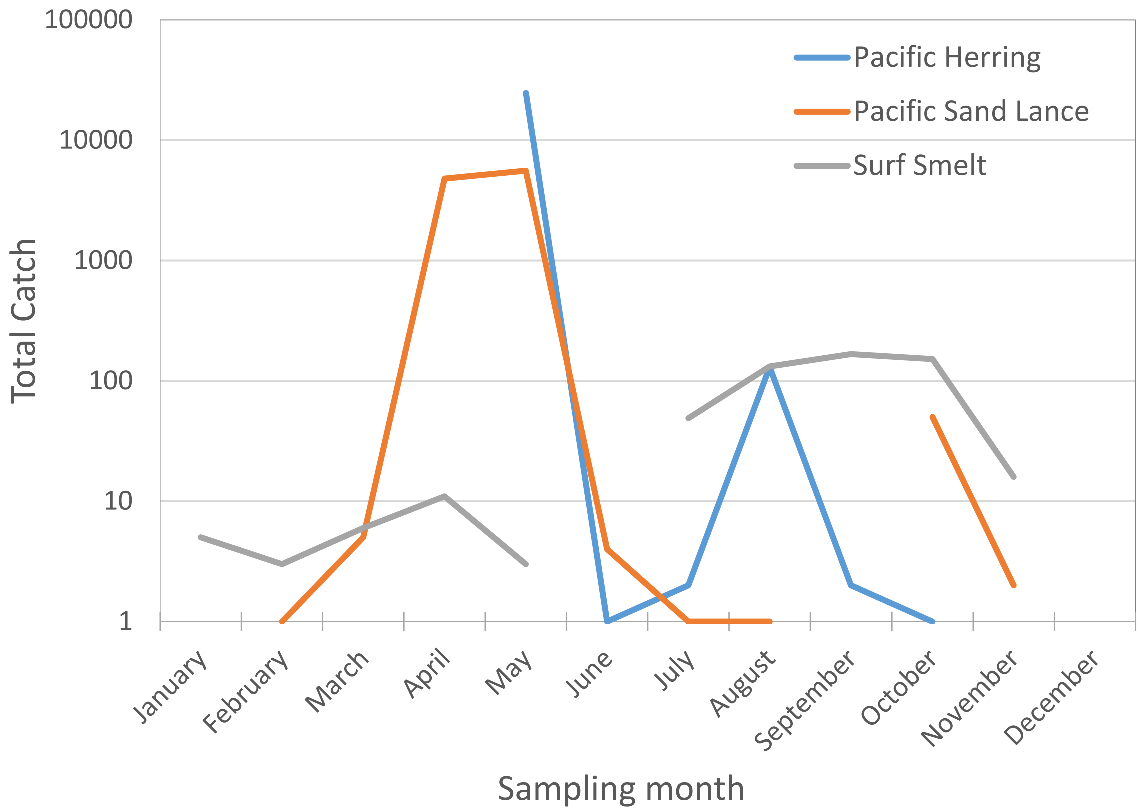


Figure 6. Total catch by month (presented on log scale) for the most prevalent forage fish species.

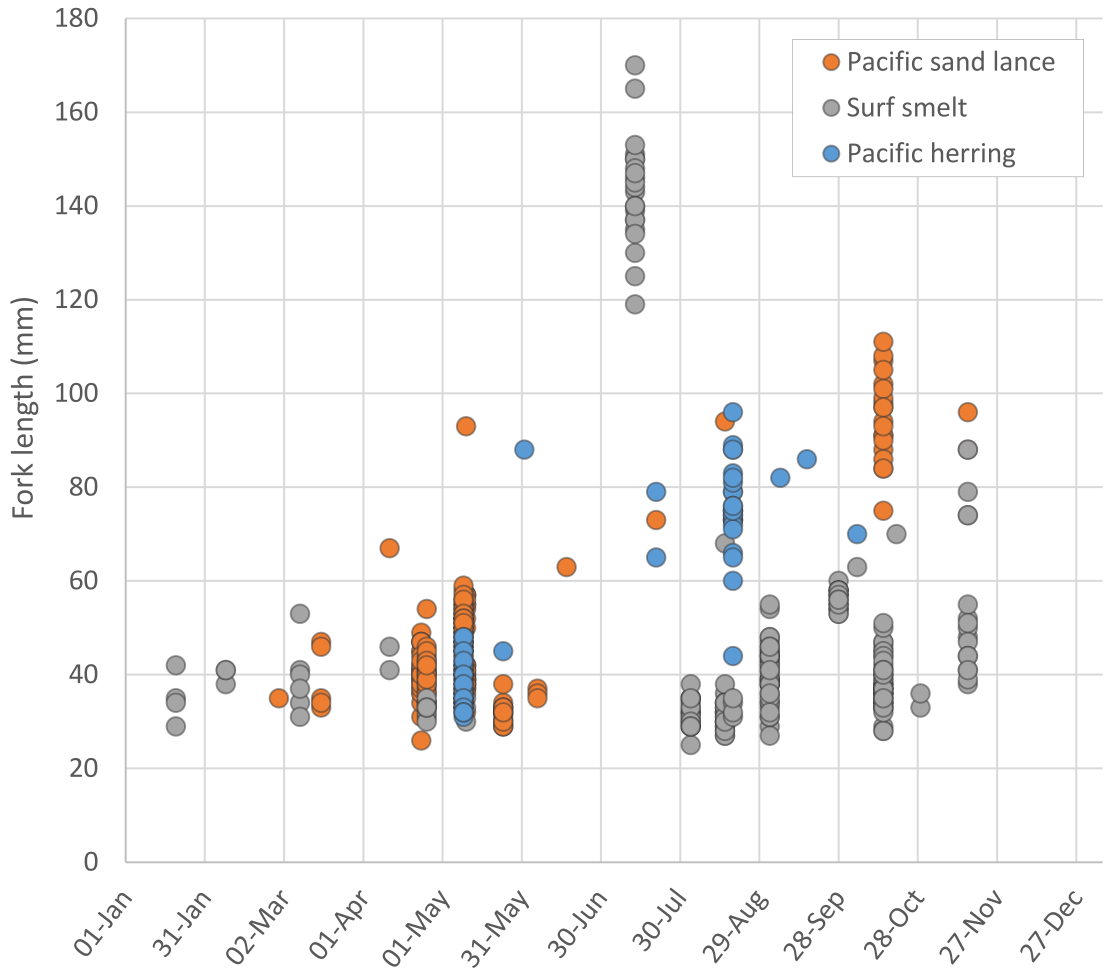


Figure 7. Year-independent length distribution by calendar date for the primary species of forage fish caught in the East Waterway.

Salmonids

The four primary species of salmonids encountered (Chinook, coho, chum, and pink salmon) were spread across all sampling sites. Their distributions in space and time were species-specific. There were many similarities in timing and prevalence between chum and pink salmon and between coho and Chinook salmon. Additionally, we captured a single sockeye salmon, and a single cutthroat trout. No steelhead were captured during our sampling.

Chinook salmon

Chinook salmon was most prevalent at EW6 (Table 6, Figure 8), the only sampling location within the East Waterway with a cobble beach instead of rip-rap. The period from May through July saw the most individuals captured, with few to none from September to April. Early fish, captured from March through May, were all small (parr) and unmarked (Figure 10). Both known hatchery and unmarked fish were larger and of similar size between origins later in the year. The majority of Chinook salmon caught, 66.2%, were marked hatchery fish (Table 7). We retained six individuals with CWTs from different sampling events. All CWTs in Chinook salmon indicated fish had originated in the Snohomish River basin (Table 8), and were captured 2 weeks to 2 months post-release from their hatcheries of origin (Regional Mark Processing Center).

Areas in the lower Snohomish River estuary and at nearby Howarth Park have been sampled with beach seines by the National Marine Fisheries Service, the Tulalip Tribe, and Snohomish County (Appendix Figure B1; Chamberlin 2022; Greene et al. 2023). Chinook salmon data from March through September 2019 and 2022 were used for comparison with CPUE from Naval Station Everett (Appendix Table B1). Resampled distributions of mean Chinook salmon count for each area/month and the differences between Naval Station Everett and estuary sites varied widely in width and skewness (Appendix Figures B2, B3). Patterns of abundance between the East Waterway and nearby sites appear similar (Figure 11), though CPUE consistently trended lower at Naval Station Everett. Catch was significantly lower in three of the seven months: April, August, and September (Figure 11; Appendix Figures B2, B3).

Coho salmon

Coho salmon was also captured almost exclusively at EW6 (Table 6, Figure 8). Individuals were present sporadically throughout sampling but were most abundant in June (Tables 4, 5; Figure 9). The majority of captured coho salmon, 87.5%, were unmarked fish (Table 7). Known hatchery fish were captured on two sampling dates and trended larger than unmarked fish captured at the same time (Figure 10). Two CWTs were retained from coho salmon (Table 8). One of these originated in the Snohomish River basin (captured within 4 days of release from the hatchery), while the other was from the Cowlitz River in the Lower Columbia River region (an ESA-threatened ESU: Lower Columbia River Coho Salmon), captured 2 months post-release.

Table 7. Numbers of unmarked and marked hatchery (CWT and/or adipose-clipped) Chinook and coho salmon.

	Unmarked	Marked Hatchery	Percent Known Hatchery Origin
Chinook	91	178	66.2
Coho	72	10	12.5

Table 8. Source and capture information for CWT fish from the East Waterway. All captured Chinook salmon and the coho salmon from the Cowlitz River belong to ESUs listed as Threatened under the ESA.

Sample date	Site	CWT	Source	Basin	Region
			Chinook		
21 Jul 2022	EW1	638353	Wallace R. Hatchery	Snohomish	N Puget Sound
14 Dec 2021	EW6	211448	Bernie Gobin Hatchery	Snohomish	N Puget Sound
13 Jul 2021	EW1	211526	Bernie Gobin Hatchery	Snohomish	N Puget Sound
17 Jun 2021	EW8	637766	Wallace R. Hatchery	Snohomish	N Puget Sound
1 Jun 2021	EW6	637821	Wallace R. Hatchery	Snohomish	N Puget Sound
1 Jun 2021	EW6	211526	Bernie Gobin Hatchery	Snohomish	N Puget Sound
			Coho		
6 Jun 2022	EW2	637968	Cowlitz Salmon Hatchery	Cowlitz	Lower Columbia R
13 Jul 2021	EW1	211381	Bernie Gobin Hatchery	Snohomish	N Puget Sound

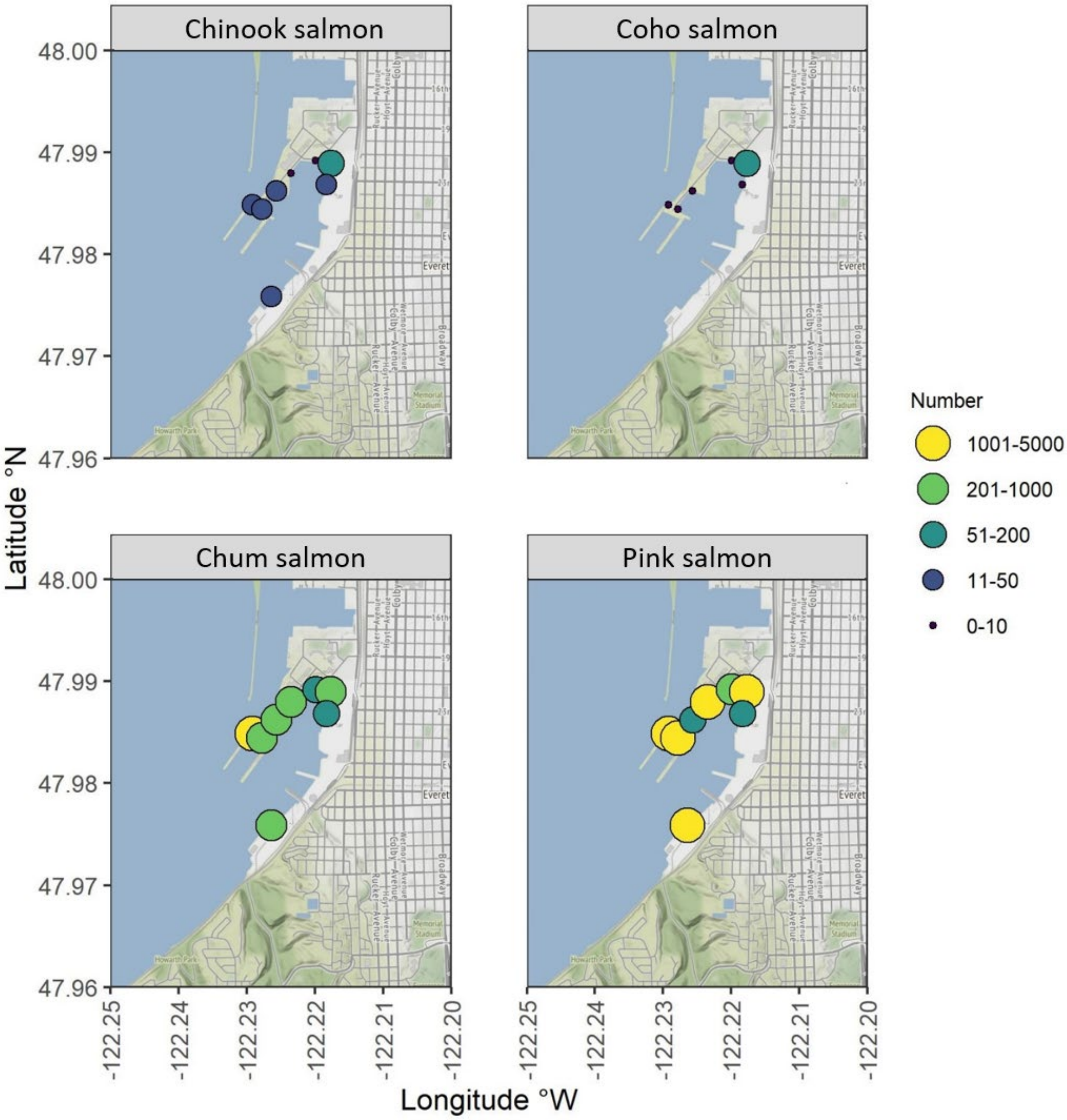


Figure 8. Categorical abundance of salmonid species at sampling sites within the East Waterway. Abundance values not scaled to level of effort.

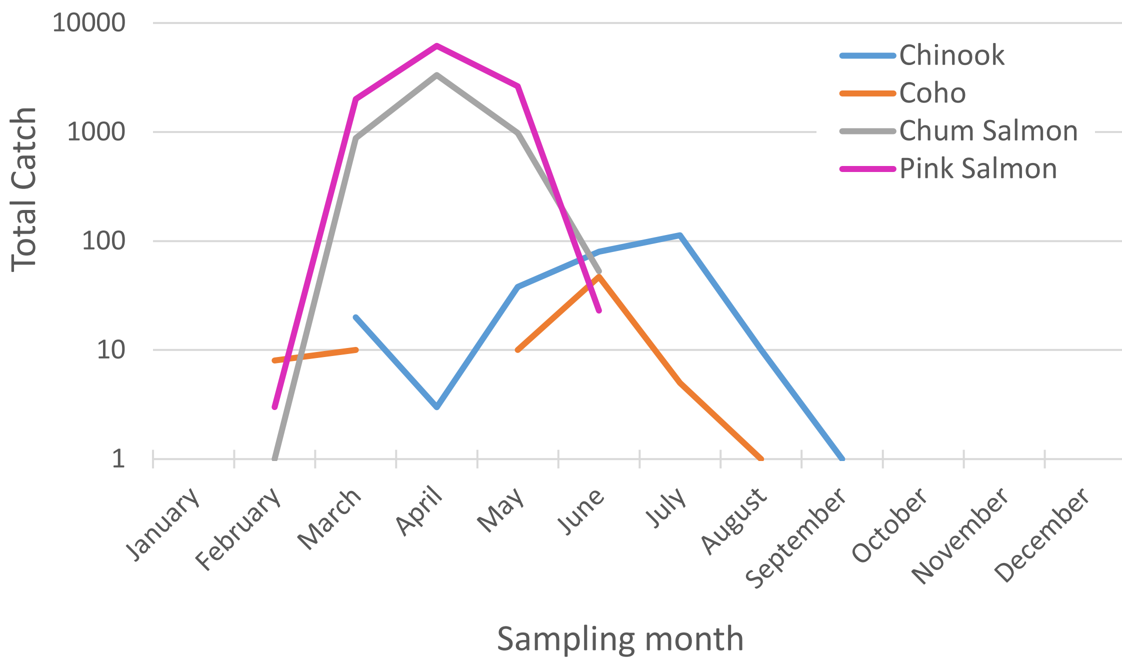


Figure 9. Total catch by month (log scale) for salmonid species across the entire study. For pink salmon, catch only occurred in 2022.

Pink salmon

Pink salmon has an every-other-year life history (Litz et al. 2019; Kendall et al. 2020), with juveniles migrating in even years. Individuals were caught in 2022 and were abundant from March to May (Table 5). Pink salmon was present at all sample sites within the East Waterway and was most abundant at EW2 and EW4 (Table 6, Figure 8). These fish tended to be caught together in groups and were concurrent in space and time with chum salmon (Figure 9). All individuals were recent juvenile migrants with fork lengths less than 80 mm. Early fish were especially small, less than 40 mm, though this size category persisted throughout the seasonal capture of pink salmon (Figure 10).

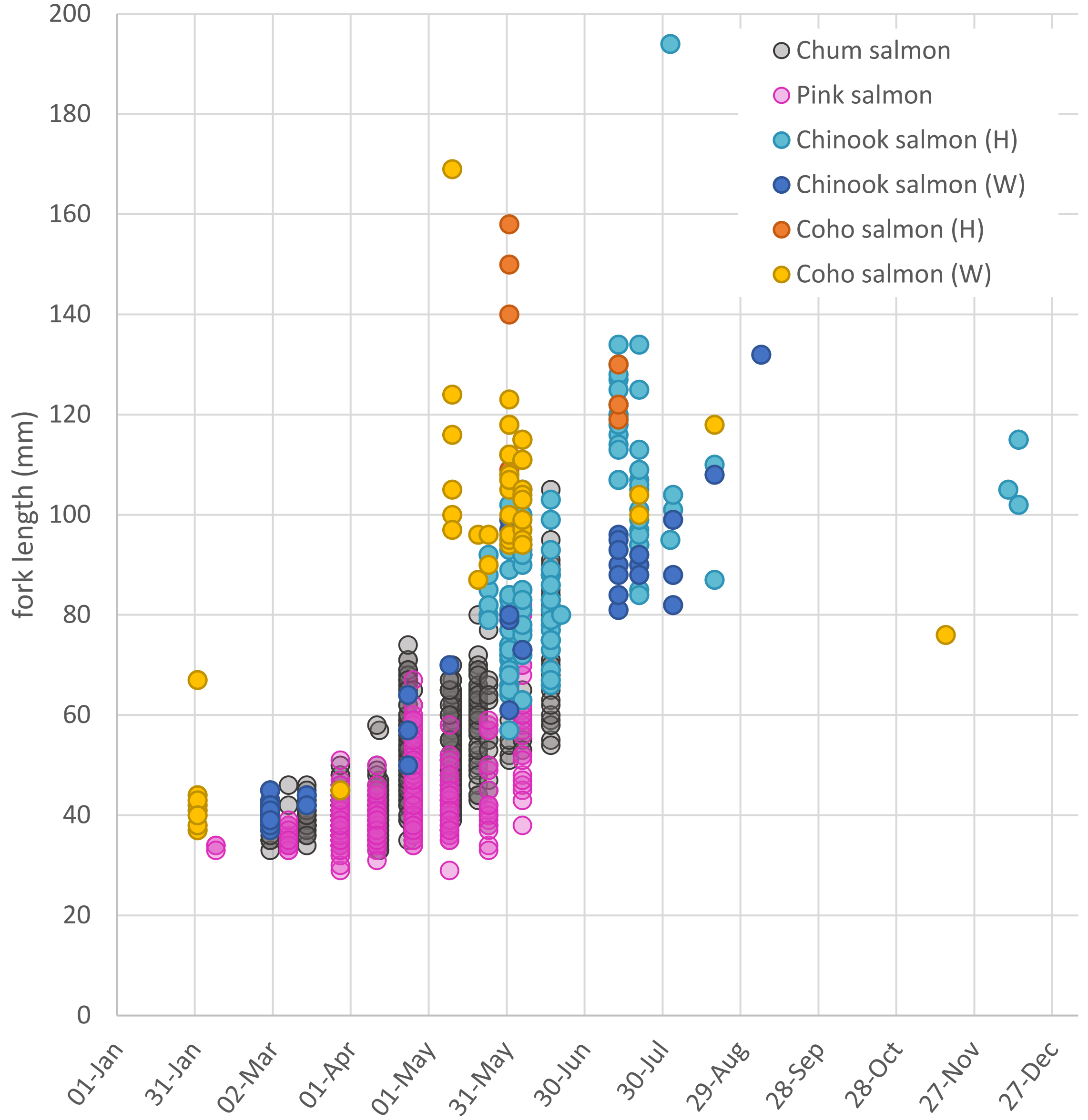


Figure 10. Year-independent length distribution by calendar date for salmonids caught in the East Waterway, with differentiation for known hatchery (H) and unmarked (W) Chinook and coho salmon.

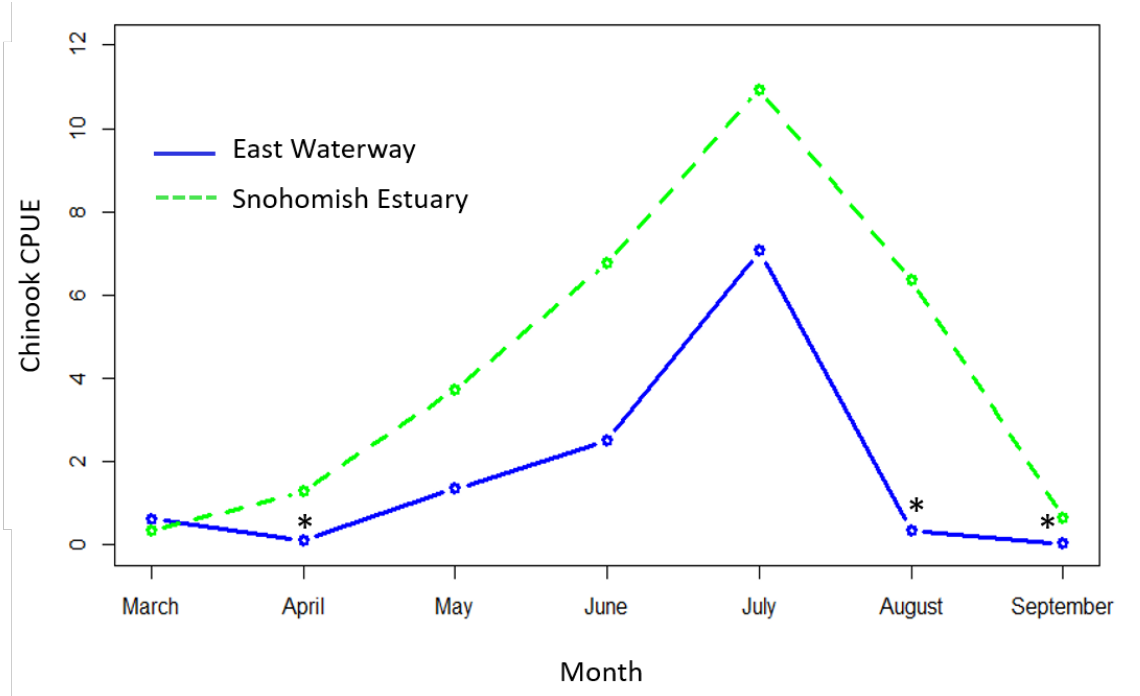


Figure 11. Year-independent comparison of Chinook salmon CPUE by month between East Waterway sites and nearby estuarine sites from 2019 and 2022 (labeled Snohomish Estuary; NOAA unpublished data). Asterisks (*) denote significantly different monthly values.

Chum salmon

Chum salmon was most abundant at EW1, which is directly adjacent to the Snohomish River channel (Table 6, Figure 8). Individuals were present at all other sampling sites and distributed fairly evenly within the East Waterway. Chum salmon was primarily captured from March to May, with a few individuals caught in February and June (Table 4, 5); none were caught in other months of the year. Lengths of captured individuals increased from March to June (Figure 10). Chum salmon directly overlapped with pink salmon in size and timing, but had similar overall abundance patterns regardless of the presence of pink salmon.

Discussion

Habitat Characterization

The shoreline along the waterfront at Naval Station Everett was created when the upland salt marsh area of the installation was originally filled. This shoreline and adjacent areas are highly developed, with armoring and structures including piers, docks, seawalls, debris deflectors, and boomed areas. The nearshore area of Naval Station Everett provides very little natural habitat, reflecting its industrial past and character. The area consists primarily of highly modified channels and limited shallow subtidal and intertidal habitat. Littoral habitats are largely associated with fill and bordered by riprap or bulkheads.

Prior to development, the nearshore area likely resembled the extensive mud and sand flats and emergent marshes that persist north of the naval station. These areas are associated with the mainstem mouth of the Snohomish River and with Ebey, Steamboat, and Union Sloughs.

Water quality is an important component of the physical habitat. Fish health and survival, particularly for salmonids, can be greatly influenced by water quality parameters such as temperature, salinity, dissolved oxygen, and conductivity (Midway et al. 2022). The comparisons made were between readings taken in conjunction with seine-sampling events in the East Waterway and with environmental data values from surface water samples at Gedney Island. Geographically, these were the closest available water quality data, but they presented an imperfect comparison as the Gedney Island data reflect Puget Sound saltwater values, while the East Waterway has a strong riverine influence due to its location at the mouth of the Snohomish River. Furthermore, due to the geography and man-made structures, there is incomplete and tide-dependent mixing between the East Waterway and Puget Sound at large.

Seasonal variations were observed in all of the water quality metrics but remained fairly consistent among sites (Table 2). Mean temperatures in the East Waterway ranged from as low as 7.7 degrees C in February to as high as 17.8 degrees C in August (Table 2). Summer month temperatures in the East Waterway were significantly higher than those collected at Gedney Island (Table 2), and exceeded preferred temperature tolerances for juvenile salmonids (Piper 1982). While the higher East Waterway temperatures corresponded to periods of decreased salmon presence, such high estuarine temperatures exceed thresholds for salmonids (Richter and Kolmes 2005) and may reduce the time that salmon spend in this geographic rearing area.

In general, salinity, conductivity, and dissolved oxygen were less variable than temperature throughout our sampling period (Table 2). Salinity ranged 15.8-25.8 ppt, with values consistently lower than those at Gedney Island explained by riverine influence in the East Waterway. Salinity values were more similar to typical marine metrics in late summer and fall, when riverine output was low, but were still significantly different from values at Gedney Island. Conductivity measurements act as a proxy for turbidity, and were lower in the East Waterway than at Gedney Island for much of the year. However, salt water is more conductive than freshwater, accounting for much of this discrepancy. Dissolved oxygen values were also consistently lower in the East Waterway, which indicated limitations in water exchange (limited flushing). Levels such as those recorded in October (6.87 mg/L; Table 2) have the potential to stress salmonids (Piper 1982; Carter 2005).

While we noted many instances of significant differences in our environmental data comparisons, the majority appeared due to inherent geographical differences in marine versus riverine influences between available datasets. In most cases, both migrating juvenile salmon and resident fish species have the osmoregulatory capacity to handle the fluctuations and ranges that we observed (Piper 1982, Midway et al. 2022). Without more continuous monitoring of temperature and other environmental variables, we cannot say whether there are periods when conditions may negatively impact the fish community. Netting activity increases stress in fishes, and can exacerbate negative outcomes of environmental stress during sampling.

Fish Community Composition

Habitats associated with robust and complex fish communities such as eelgrass, kelp beds, and natural unmodified shorelines are absent from the area within the East Waterway (Frick and Kagley 2021). This increased urban gradient is known to negatively impact biodiversity and ecosystem functioning (Samhouri et al. 2022). However, due to its location near the mouth of Snohomish River, the site supports use by a variety of fish species for rearing and migration at some times of the year (Frierson et al. 2017; Frick and Kagley 2021).

The sampling results of this study represent a fairly simple community (Long 1983; Simenstad 1991), as the catch was comprised of 22 individual species representing 6 functional groups (Table 3; Figure 4). This community was similar to that described at Naval Station Everett in 2015-2016 by Frierson et al. (2017) based on their sampling results. The two dominant groups (Figure 4), forage fish and salmonids, reflect the regionally dominant taxa (Greene et al. 2012; Boldt et al. 2022; Frick et al. 2022). Species in these two groups made up the majority of our catches (Figure 4; Table 4), but were transient inhabitants of nearshore habitat, using it for spawning, rearing, and refuge (Bizzarro et al. 2022; Chamberlin 2022; Quinn and Losee 2022).

There were also seasonal/periodic pulses of the reasonably common threespine stickleback and shiner perch, which tend to have higher site fidelity (Odenweller 1975; Miller et al. 1980; Ward et al. 2013). Threespine stickleback were caught throughout the year with highest abundances during the summer (Table 4) and were distributed across sites (Table 6) in the East Waterway, showing less responsiveness to sampling site characteristics. Monitoring of such species can be important for gauging habitat suitability for salmonids as a function of carrying capacity (Greene et al. 2012; Chamberlin 2022).

Forage Fish

Numerically, forage fish dominated our catch, as they do in surveys around the Salish Sea (Miller et al. 1980; Long 1983; Greene et al. 2012; Frick et al. 2022). The sheer number of forage fish caught during this project (Tables 4-6; Figure 5) was notable due to the fact that there is no optimum spawning habitat or documented spawning beds within or immediately adjacent to the area sampled. Our data demonstrated a wide range of sizes, from post-larval to large juveniles for the dominant forage fish species present: Pacific sand lance, Pacific herring, and surf smelt. It was assumed that the post-larval forage fish observed were recruiting from nearby areas (Greene et al. 2023). However, the patchy nature of presence and abundance of forage fish necessitates frequent and long-term sampling to see trends, and these patterns may or may not persist with more sampling effort.

We observed an increase in the size of Pacific herring and Pacific sand lance across the sampling year (Figure 7). Without direct information on residence time within the area, we cannot infer direct growth of individuals within the East Waterway. However, the area is used by juveniles of these species as they increase in size across their growing seasons, so they are present in the surrounding area as they grow and move. For surf smelt, only post-larval-sized fish were consistently captured (save one sampling event, Figure 7). While spawning of this species is not documented in the area of the East Waterway, the consistent influx of post-larval individuals indicates that there is recruitment from nearby. The July capture event of a number of spawning-size adult individuals would support that potential.

Applying monthly/periodic sampling and CPUE metrics to abundance patterns did not capture the extreme variability in forage fish presence. Variation ranged from single digits to thousands in a single set of the net. Regarding patterns of presence, forage fish dominated the catch in sequential groups. Early in the year we caught small numbers of surf smelt, followed by a pulse of Pacific sand lance, then Pacific herring, concluding with a second pulse of surf smelt (Figure 6). It can be assumed that patterns in the presence of these species were seasonally constrained and linked to each species' life history patterns in the immediate vicinity, such as nearby spawning or rearing areas.

Patterns of forage fish presence described in the East Waterway varied somewhat from those reported for the same species in the Strait of Juan de Fuca (Miller et al. 1980; Long 1983; Frick et al. 2022). There, the probability of capturing Pacific herring increased in late summer while surf smelt capture rates fell. These patterns were opposite of those we observed in the East Waterway. Pacific sand lance capture decreased in late summer in both regions. Patterns were similar to those described in the East Waterway for 2015-2016 (Frierson et al. 2017), though in those years CPUEs for surf smelt and Pacific herring were higher during the May-September period of study overlap, and the two forage species were captured more consistently over time. Pacific sand lance was also captured in a late summer pulse in 2015-2016, although such a pulse was absent during our study.

Collectively, the consistent presence of these three forage fish species (Pacific herring, surf smelt, and Pacific sand lance) represents a dependable prey source for a diversity of predators, including salmon. They may also serve as alternate prey for marine mammals and thus decrease predation pressure on salmon (Duffy et al. 2010; Rivers et al. 2022; Crewson, Tulalip Tribe, pers. comm). Since the East Waterway hosts a large Harbor seal population, the interplay between forage fish presence and abundance should be examined more fully in light of predation pressure on listed salmonids.

Acoustics may be one tool to examine forage fish occurrence in adjacent areas that are difficult to sample by beach seine (Thayne et al. 2019). Broader knowledge gaps for assessing the robustness of Salish Sea forage fish populations include unknowns about the egg and larval life history stages and juveniles of non-commercial species, diets of forage fish generally, migration patterns and survival, and effects of large-scale climatic pressures (Duffy et al. 2005; Reum and Essington 2008; Weitkamp et al. 2012; Boldt et al. 2022; Greene et al. 2023). An alternative to direct interventions in the East Waterway that would support fish communities would be to support research on these topics, which could improve conservation of forage fish on a landscape scale.

Salmonids

The Snohomish River produces all native species of Pacific salmonid (Quinn and Losee 2022). Given its position at the mouth of the Snohomish River, the East Waterway has the potential to be an important area for refuge, growth, and marine adaptation for each of these species (Pess et al. 2002; Frick and Kagley 2021; Chamberlin 2022; Greene et al. 2022). The habitat demands of individual species, and thus their potential to use East Waterway resources, depend on their life histories, which vary both within and among species. However, with limited habitat for refuge and likely a poor quality benthic community with limited suitable forage (e.g., zooplankton), the East Waterway offers reduced value relative to more natural estuarine areas.

Differences in migration timing among salmonid species impact growth rates and exposure to altered habitats, predators, fisheries, and contaminants (Greene et al. 2012; Quinn and Losee 2022). However, in the highly modified Snohomish River Estuary, including the East Waterway, exposure to these factors is high for all salmonids as they migrate out of the Snohomish River. This section will document which salmonids are most prevalent both spatially and temporally, as a benchmark to reduce or mitigate future exposure risk. A review of Snohomish River system abundance and production of fishes is available in Frick and Kagley (2021).

Generally speaking, the timing of salmonid presence in the East Waterway is consistent with abundance patterns at lower Snohomish River sites (Haas 2001; Hahn et al. 2010; Chamberlin 2022). Source-identified CWT fish took 4 days to 2 months from release to capture in the East Waterway, indicating the outmigration timing relationship is not especially tight. Furthermore, we cannot directly relate East Waterway catch as a proportion of riverine output density due to the periodic sampling regime employed in this study and inaccessibility of complete outmigrant and hatchery release information. Therefore, this direct sampling information is critical to understanding site-specific patterns of use within the East Waterway. Patterns of salmonid presence for this study were similar to those reported by Frierson et al. (2017) with respect to timing and fish sizes; however, abundance data differed. Pink salmon were captured at similar rates, while we saw substantially lower CPUE for Chinook, coho, and chum salmon than in 2015-2016, particularly in the months of May and June.

Pink & Chum—Pink and chum salmon were present in expected patterns within the East Waterway, including the pattern of pink salmon presence only in the even years (Table 5). When present, these species showed very similar patterns of abundance, with similar timing and size at capture (Figure 9). Both pink and chum salmon were small upon capture, initially less than 50 mm, with some individuals of this size at every capture event. Chum salmon reached larger sizes (> 100 mm) within the East Waterway by early June, but both pink and chum utilized the area for a relatively short time. Pink salmon in particular is known to have short estuarine residence time, and the perpetually small size of captured individuals agrees with the expected short-term use of the area by new groups of fish over the migration season (Litz et al. 2019; Kendall et al. 2020).

While there is evidence of short-term competitive dominance of juvenile pink salmon over other salmonid species (Ruggerone and Nielson 2004; Litz et al. 2019; Kendall et al. 2020), we did not see an effect of pink on chum salmon catch in this study;

chum salmon abundance was similar in pink and non-pink migration years. However, these species did show some separation in use of sites within the East Waterway. Both were caught at all sampling sites, but a smaller proportion of chum than pink salmon appeared to enter the East Waterway from the Snohomish River. Chum salmon were much more prevalent at EW1 on the Snohomish River channel side of Naval Station Everett. Pink salmon juveniles were seen more commonly at sites in the East Waterway proper (Table 6). This distribution pattern may reflect competition or resource partitioning between the species within the East Waterway.

Pink salmon has been shown to decrease Chinook salmon survival in Puget Sound (Kendall et al. 2020). We saw little overlap in the timing of catch between pink and Chinook salmon during even years, although in 2021, Chinook juveniles were present during the March and April time frame, when pink juveniles were absent. Due to the episodic nature of our sampling, we could not draw conclusions as to possible effects of pink salmon on Chinook salmon in the East Waterway, but we did not capture any early parr migrant Chinook during the pink migration year (Table 5, Figure 10). This observation could relate to the presence of pink juveniles.

Coho and Chinook—Both Chinook and coho salmon utilized the East Waterway, particularly in summer months. Most individuals of both species were caught at EW6, which represents the only beach-type habitat available to sample with cobble beach instead of rip-rap. There is also a small patch of eelgrass sub-tidally adjacent to this area of shoreline. These habitat differences likely influenced the presence of these salmonids at the EW6 site.

Based on known-source fish identified by CWTs (Table 8), the East Waterway appears to be used primarily by locally produced Chinook and coho salmon from the Snohomish River Basin (in agreement with Rice et al. 2011). However, we had only a few known-source fish. Salmonids from other river systems also have access to the East Waterway. While unexpected given the geographical distance, the presence of a tagged coho salmon from the Cowlitz River shows that nearshore habitat such as that in the East Waterway can be utilized by fish other than the immediate local population (Rice et al. 2011).

The Snohomish River has large numbers of hatchery-produced and naturally produced Chinook and coho salmon (Duffy et al. 2005). Not all hatchery fish in Puget Sound are marked, which makes distinction and related analyses more difficult. While our sampling showed patterns in abundance over time, we could not assess the proportion of juvenile migrant fish as a function of the Snohomish River run based on our sampling schedule. Noting fin-clip status and presence of CWTs provided us an index of proportional assignment between coho and Chinook groups in the East Waterway (Table

7) and confirmed the presence of ESA-listed stocks. However, these proportions were unreliable for assigning river-run proportions with confidence, as no systemic marking was conducted for these fish or for our study. Nevertheless, we did note some consistent patterns in size distribution.

Marked hatchery coho were consistently larger than unmarked coho salmon (Figure 10), possibly reflecting hatchery feed supplementation and release regimes (Rice et al. 2011). For Chinook salmon, marked and unmarked size classes overlapped. However, early Chinook salmon migrants (March-early May) were all fry-sized and unmarked, representing a natural life history strategy that is common in the Snohomish River (Healy 1982; Quinn and Losee 2022; Chamberlin 2022; Chamberlin et al. 2022). These Chinook fry are likely more prevalent than was reflected in our samples, as our gear is not optimized for this size class. Regardless, our data show that wild juvenile Chinook salmon with this life history are present, and should be considered in decisions about work in the East Waterway during early spring.

The lower Snohomish River has been the focus of recent remediation activities aimed at improving salmon habitat (Haas 2001) and includes lower river work as part of the *Quilceda Watershed Enhancement* effort (Murdoch and Adopt a Stream Foundation 2023). This particular effort has targeted the West Fork Quilceda, Middle Fork Quilceda, and Olaf Strab Creek sites with activities including planting trees to improve the riparian zone, removal of canary grass, and setting of in-stream logs. These enhancements are proving beneficial, at least for coho salmon in the system (Pess et al. 2002; Murdoch and Adopt a Stream Foundation 2023). However, as juvenile salmonids that have benefitted from restoration efforts upstream move into the Snohomish River estuary, productive premium habitat can become scarce.

The degree of anthropogenic perturbation in the Snohomish River estuary makes it difficult to utilize information from adjacent areas. Nonetheless, CPUE data from geographically appropriate areas in the lower Snohomish River estuary and at nearby Howarth Park have been sampled with beach seines by the National Marine Fisheries Service, Tulalip Tribe, and Snohomish County. Beach seine data from March through September 2019 and 2022 were used for comparison (Figure 11; Appendix B).

While Chinook salmon CPUE consistently trended lower at Naval Station Everett, the few instances of significant differences were all months affected by the prevalence of zero-catch hauls, which resulted in minimal capture events and reduced probability of capture in bootstrap distribution models (Appendix Figure B2, B3). Inclusion of additional years of data (new or existing from Frierson et al. 2017) could bring these statistical differences in CPUE into closer statistical alignment so that they agree with the visibly similar patterns we observed.

Conclusions and Recommendations

Significant progress has been made on ecosystem restoration efforts designed to increase salmon abundance, either planned or in progress, in the Snohomish River upstream of Naval Station Everett (Rice et al. 1999; Haas 2001; Murdoch and Adopt a Stream Foundation 2023). This project was established to inform the *Integrated Natural Resources Management Plan* and inform avoidance and minimization measures for potential in-water work in the East Waterway; these results also provide valuable information on resource use in the lower Snohomish estuary by salmonids produced upstream in the Snohomish River.

There are myriad factors that influence the estuarine habitat resources upon which fish populations depend (Able et al. 2022; Bizarro et al. 2022). These factors are often grouped within functional categories such as *geomorphology and hydrology*, *physio-chemical variables*, and *ecological contexts* (Appendix Figure C; Able et al. 2022). For this project, we presented data that can be informative for all of these categories in the Snohomish River estuary. Our direct observation of lack of premium habitat within the research area, along with findings from other long-term monitoring efforts (Rice et al. 1999; Greene et al. 2012, 2023; Chamberlin 2022; Hall et al. 2023), suggest that density dependence acts as one of many impediments for salmonid success in this lower portion of the estuary.

These impediments are not specific to the East Waterway ecosystem, and when considering salmon recovery, there are documented approaches for improved conditions relevant across Puget Sound that also apply to the Snohomish River estuary. These include habitat goals, indicator metrics (a combination of physical and biological attributes), life-cycle implementation, and monitoring of vital signs (Dethier 1990; Cereghino et al. 2012; Midway et al. 2022; Greene et al. 2023). Such approaches are currently supported by the Puget Sound Partnership and detailed in recovery planning documents such as the *Puget Sound Ecosystem Monitoring Program and Action Agenda* (www.psp.wa.gov; see *Summarizing Salmon Recovery Data* ArcGIS StoryMaps), and the *Snohomish Basin Salmon Recovery Forum* (SBSRF 2005, 2019).

Naval Station Everett is situated at a critical estuarine location for migrating salmonids from the Snohomish River. Nearshore habitat improvement could provide great benefit for those fish, although some of the approaches referenced above may not be feasible within the East Waterway due to security and marine safety concerns. Among other alternatives, the *2022-2026 Action Agenda for Puget Sound* (PSP 2022) includes additional and potentially more feasible ways to improve habitat that could be applied to the East Waterway, such as planting eelgrass, refining best practices to lower toxins and pollution, runoff control, and creosote removal. Increasing eelgrass meadow area in the East Waterway would be a good first step, as this has proven to be an even more effective strategy than armor removal for optimizing salmon and forage fish habitat (Frances et al, 2022).

Predation can also play a large role in juvenile survival. Naval Station Everett offers abundant habitat for marine mammals that prey on salmon, such as harbor seals and California sea lions. Reducing the appeal or availability of haul-out structures for these animals could lessen the impact to migrating salmonids (Nelson 2020; WSAS 2022).

Puget Sound-based habitat classification tools may be especially useful when considering fish habitat improvement projects (Dethier 1990; Simenstad et al. 1991; Bizarro et al. 2022; PMEP 2023). Any effort to increase or improve estuary habitat within Naval Station Everett has the potential to strengthen the foodweb and increase the limited carrying capacity for Chinook salmon in the lower Snohomish River (Chamberlin 2022; Chamberlin et al. 2022; Hall et al. 2023; Greene et al. 2012, 2023).

Suggestions for additional habitat improvements within East Waterway include:

- Transplant eelgrass where active channel dredging is not required (Kennedy et al. 2018)
- Enhancement of natural shoreline functionality (such as removing bulkheads, culverts, and rip rap; Toft et al. 2007; Munsch et al. 2017)
- Shoreline planting to provide riparian buffer that includes shade and structure and providing in-water habitat such as large woody debris and engineered log jams (Leavitt 1998; Pess et al. 2012; Fullerton et al. 2022)
- Removal and/or modification of log rafts and other structures that provide convenient and appealing haul out locations for fish predators like harbor seals and California sea lions (Nelson 2020; WSAS 2022)
- Manage detrimental marine inputs such as stormwater runoff and reduce/control pollution from ship maintenance and construction projects (Feist et al. 2011)

Implementing recovery and restoration actions in urban waterways is challenging and some may argue that such actions are impractical or will have limited impact. However, small and incremental changes and localized habitat availability can have outsized effect (Francis et al. 2022) and as illustrated by some of the data summarized here. Alternatively, where actions at Naval Station Everett are infeasible, support could be given to nearby estuarine habitat improvements with fewer logistical constraints.

In addition to habitat improvements, we suggest continued monitoring of salmonid and forage fish populations within the East Waterway. The consistency of patterns between sites within the East Waterway may indicate that regular sampling of fewer sites would show the same patterns. However, continued efforts (spatially, temporally, and with expanded gear types) could provide more data that can be applied in life-cycle models (Kendall et al. 2020) to identify the most sensitive life stages and to optimally prioritize the recommended remediation actions.

Acknowledgments

Sampling was regularly dependent on the valuable assistance of Steve Corbett of the Northwest Fisheries Science Center and Kolten Ollom of the Veterans Conservation Corps. Alicia Higgs and Rebecca Johnson of the Naval Facilities Engineering Systems Command Northwest (NAVFAC NW) were instrumental to project management and coordination, as well as field work. Additional field help was provided by NAVFAC NW, including Matt Ridgway and Paul Rudell. Ben Sandford and JoAnne Butzerin with the Northwest Fisheries Science Center provided valuable statistical analyses and editing work, respectively.

References

Able, K.W., C.A. Simenstad, N.A. Strydom, M. Bradley, and M. Sheaves. 2022. Chapter 4. Habitat Use and Connectivity. Pp. 188-254 *In* Whitfield, A.K., K.W. Able, S. J. M. Blaber, and M. Elliott. *Fish and Fisheries in Estuaries: A Global Perspective, Volume I*, First Edition. Edited by John Wiley & Sons Ltd. 10.1002/9781119705345.ch4.

Bizzarro, J.J., J. Selleck, K. Sherman, J. Drinkwin, V.C. Hare and D.S. Fox. 2022. State of the knowledge: U.S. West Coast nearshore habitat use by fish assemblages and select invertebrates. Report to Pacific Marine & Estuarine Fish Habitat Partnership, Portland, OR. pacificfishhabitat.org/assessment-reports/

Boldt, J.L., H.M. Murphy, J.M. Chamberland, A. Debertin, S. Gauthier, B. Hackett, P.S. Hagel, A.R. Majewski, J.L. McDermid, D. Merette and C.L. Robinson. 2022. Canada's forage fish: an important but poorly understood component of marine ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 79(11):1911-1933. 10.1139/cjfas-2022-0060.

Carter, K. 2005. The effects of dissolved oxygen on steelhead trout, coho salmon, and chinook salmon biology and function by life stage. California Regional Water Quality Control Board, North Coast Region, 10.

Cereghino, P., J.D. Toft, C.A. Simenstad, E. Iverson, and J. Burke. 2012. Strategies for nearshore protection and restoration in Puget Sound. Puget Sound Nearshore Report No. 2012-01. Report to the Washington Department of Fish and Wildlife, and the U.S. Army Corps of Engineers. wdfw.wa.gov/publications/02182 (March 2021).

Chamberlin, J. 2022. Chinook salmon use of tidal delta habitats: synthesis for Snohomish recovery plan revision. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC-CR-2022-01. 10.25923/nafn-jp23.

Chamberlin, J.W., J. Hall, W.T. Zackey, F. Leonetti, M. Rustay and C. Rice. 2022. Spatial and temporal variability in Chinook salmon abundance reflects opportunity to support life history diversity in an estuarine landscape. Estuaries and Coasts 45(3):866-881.

City of Everett. 2001. Salmon overlay to the Snohomish Estuary wetland integration plan (SEWIP). Prepared by City of Everett and Pentec Environmental. 348 pp. https://salishsearestoration.org/wiki/File:City_of_Everett_2001_snohomish_estuary_wetland_salmon_overlay.pdf

Dethier, M.N. 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Dept. Natural Resources, 56.

Duffy, E.J., D.A. Beauchamp and R.M. Buckley. 2005. Early marine life history of juvenile Pacific salmon in two regions of Puget Sound. Estuarine, Coastal and Shelf Science 64(1):94-107. 10.1016/j.ecss.2005.02.009.

Duffy, E.J., D.A. Beauchamp, R.M. Sweeting, R.J. Beamish and J.S. Brennan. 2010. Ontogenetic diet shifts of juvenile Chinook salmon in nearshore and offshore habitats of Puget Sound. Transactions of the American Fisheries Society 139(3)803-823. 10.1577/T08-244.1.

Efron, B. and R.J. Tibshirani. 1993. An Introduction to the Bootstrap. New York: Chapman and Hall.

Feist, B.E., E.R. Buhle, P. Arnold, J.W. Davis and N.L. Scholz. 2011. Landscape ecotoxicology of coho salmon spawner mortality in urban streams. PLoS One 6(8):e23424. 10.1371/journal.pone.0023424.

Francis, T.B., G.H. Sullaway, B.E. Feist, A.O. Shelton, E. Chui, C. Daley, K.E. Frick, N. Tolimieri, G.D. Williams and J.F. Samhouri. 2022. Equivocal associations between small-scale shoreline restoration and subtidal fishes in an urban estuary. Restoration Ecology 30(8):e13652.

Frick, K.E. and A.N. Kagley. 2021. Naval Station Everett East Waterway fish presence and shoreline use. Report of NOAA Fisheries Northwest Fisheries Science Center to the Naval Facilities Engineering Systems Command Northwest. Silverdale, Washington. 20p.

Frick, K.E., A.N. Kagley, K.L. Fresh, J.F. Samhouri, L.S. Ward, J.T. Stapleton, and A.O. Shelton. 2022. Spatiotemporal variation in distribution, size, and relative abundance within a Salish Sea nearshore forage fish community. Marine and Coastal Fisheries 14:e10202. 10.1002/mcf2.10202.

Frierson, T., W. Dezan, D. Lowry, L. LeClair, L. Hillier, R. Pacunski, J. Blaine, A. Hennings, A. Phillips, and P. Campbell. 2017. Final assessment of threatened and endangered marine and anadromous fish presence adjacent to the NAVSTA Everett: 2015-16 beach seine survey results. Final report to NAVFAC NW. Washington Department of Fish and Wildlife. Olympia, Washington. pacific.navfac.navy.mil/Portals/72/Northwest/Documents/nw_Everett_seine_2017_FINAL.pdf.

Fullerton, A.H., N. Sun, M.J. Baerwalde, B.L. Hawkins and H. Yan. 2022. Mechanistic simulations suggest riparian restoration can partly counteract climate impacts to juvenile salmon. Journal of the American Water Resources Association 58(4):525-546.

Greene, C.M., C.A. Rice, L.D. Rhodes and S. Naman. 2012. Evaluating the status of Puget Sound's nearshore pelagic foodweb: final report: November 28, 2012. Internal report of the National Marine Fisheries Service Northwest Fisheries Scienc Center. Available from researchgate.net/publication/281113936_Evaluating_the_status_of_Puget_Sound's_nearshore_pelagic_foodweb_Final_report_November_28_2012

Greene, C.M., S. Munsch, J. Chamberlin, and M. Liermann. 2023. Trophic linkages between zooplankton, herring, and salmon vital sign indicators. Puget Sound Environmental Monitoring Program final report. 58 pp.

Haas, A. 2001. Ecosystem restoration opportunities in the Snohomish River Valley, Washington. Report of the Tulalip Tribes and Snohomish County Department of Public Works. Everett, Washington. Available at https://snohomishcountywa.gov/Archive/ViewFile/Item/2096 (March 2021)

Hahn, P.K.J, R.E. Bailey, and A. Ritchie. 2007. Beach seining. pp. 267-324 *in* H. Johnson, D.H., B. Shrier, J. O'Neal, J. Knutzen, X. Augerot, T. O'Neil, and T. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Hahn, P.K., D. Lowry and M.C. Mizell. 2010. Abundance estimation of Snohomish system Chinook salmon via mark-recapture: 2009-10 sentinel stock monitoring. Report of the Washington Department of Fish and Wildlife to the Sentinel Stock Committee of the Pacific Salmon Commission. Available at https://www.psc.org/download/495/chinook-sentinel-stocks/2539/ssp-9-abundance-estimation-of-snohomish-system-chinook-salmon-via-mark-recapture-2009-sentinel-stock-monitoring.pdf (March 2021).

Hall, J., P. Roni, K. Ross, M.J. Camp, J. Nuckols and C. Ruffing. 2023. Estimating juvenile salmon estuarine carrying capacities to support restoration planning and evaluation. Estuaries and Coasts 46(4):1046-1066.

Healey, M.C. 1982. Juvenile Pacific salmon in estuaries: the life support system. Pp. 315-341 *In* Kennedy, V.S. Estuarine Comparisons. Proceedings of the Sixth Biennial International Estuarine Research Conference. Gleneden Beach, Oregon, 1-6 November 1981 10.1016/b978-0-12-404070-0.50025-9.

Kendall, N.W., B.W. Nelson and J.P. Losee. 2020. Density-dependent marine survival of hatchery-origin Chinook salmon may be associated with pink salmon. *Ecosphere* 11(4):e03061. 10.1002/ecs2.3061.

Kennedy, L.A., F. Juanes and R. El-Sabaawi. 2018. Eelgrass as valuable nearshore foraging habitat for juvenile Pacific salmon in the early marine period. Marine and Coastal Fisheries 10(2):190-203.

Leavitt, J. 1998. The functions of riparian buffers in urban watersheds. PhD dissertation, University of Washington. digital.lib.washington.edu/researchworks/handle/1773/17063

Litz, M.N., A.M. Dufault, A.M. Claiborne, J.P. Losee, and T.J. Garber. 2019. Competitive interactions between natural populations of pink and chum salmon from Puget Sound and coastal Washington, USA. North Pacific Anadromous Fish Commission Technical Report No. 15:120-125.

Long, E.R. 1983. A synthesis of biological data from the Strait of Juan de Fuca and Northern Puget Sound (Vol. 1). Report of the U.S. Environmental Protection Agency and U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Seattle, Washington.

Midway, S.R., C.T. Hasler, and P. Chakrabarty, editors. 2022. Methods for Fish Biology, 2nd edition. American Fisheries Society, Bethesda, MD.

Miller, B., C. Simenstad, J. Cross, K. Fresh and S. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of the common nearshore fish: Final report of three years' sampling, 1976-1979. Report of the U.S. Environmental Protection Agency. Washington, D.C. EPA/600/7-80/027 (NTIS PB81212466).

Munsch, S.H., J.R. Cordell and J.D. Toft. 2017. Effects of shoreline armouring and overwater structures on coastal and estuarine fish: opportunities for habitat improvement. Journal of Applied Ecology 54(5):1373-1384.

Murdoch, Tom and Adopt a Stream Foundation. 2023. Quilceda watershed enhancement: coho salmon spawn a new generation. Press release available at heraldnet.com/news/in-arlington-a-stream-is-born-giving-fish-a-new-route/

Nelson, B.W. 2020. Predator-prey interactions between harbour seals (*Phoca vitulina*) and Pacific salmon (*Oncorhynchu*s spp.) in the Salish Sea. PhD dissertation, University of British Columbia.

Odenweller, D.B. 1975. Aspects of the biology of the shiner perch in a Southern California estuary. Transactions of the Western Section of the Wildlife Society 11:93-101.

Pentec. 1997. Movement of juvenile salmon through industrialized areas of Everett Harbor. Report to the Port of Everett. 24 pp.

Pess, G.R., D.R. Montgomery, E.A. Steel, R.E. Bilby, B.E. Feist and H.M. Greenberg. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., USA. Canadian Journal of Fisheries and Aquatic Sciences 59(4):613-623.

Pess, G.R., M.C. Liermann, M.L. McHenry, R.J. Peters and T.R. Bennett. 2012. Juvenile salmon response to the placement of engineered log jams (ELJs) in the Elwha River, Washington State, USA. River Research and Applications 28(7):872-881.

Piper, R.G. 1982. Fish hatchery management (No. 2175). U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C. 517pp. https://pubs.usgs.gov/publication/95209

PMEP (Pacific Marine and Estuarine Fish Habitat Partnership). 2023. Data products to conserve and restore estuarine and nearshore fish habitat along the West Coast. PMEP data products web page, available at Pacificfishhabitat.org/data.

PSP (Puget Sound Partnership). 2022. 2022-2026 Action Agenda for Puget Sound. Report of the PSP available from psp.wa.gov/2022AAupdate.php.

Quinn, T.P. and J.P. Losee. 2022. Diverse and changing use of the Salish Sea by Pacific salmon, trout, and char. Canadian Journal of Fisheries and Aquatic Sciences 79(6):1003-1021. 10.1139/cjfas-2021-0162.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Regional Mark Processing Center. 2022. Regional Mark Information System (RMIS), A fisheries data project of the Pacific States Marine Fisheries Commission. www.rmpc.org

Reum, J.C. and T.E. Essington. 2008. Seasonal variation in guild structure of the Puget Sound demersal fish community. Estuaries and Coasts 31(4):790-801.

Rice, C.A., C.M. Greene, P. Moran, D.J. Teel, D.R. Kuligowski, R.R. Reisenbichler, E.M. Beamer, J.R. Karr 1, and K.L. Fresh. 2011. Abundance, stock origin, and length of marked and unmarked juvenile Chinook Salmon in the surface waters of greater Puget Sound. Transactions of the American Fisheries Society 140(1):170-189. 10.1080/00028487.2010.550253.

Rice, C., P. Roni, J. Hall, J. Chamberlin, G. Hood, G. Guntenspergen, L. Johnson, H. Imaki, M. Calvi, A. Portinga and C. Crandell. 1999. Monitoring Plan for the Qwuloolt Restoration Project. Report of the National Marine Fisheries Service, NOAA. citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.443.9262&rep=rep1&type=pdf (October 2023).

Richter, A. and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13(1):23-49.

Rivers, J.W., J. Bailey Guerrero, R.D. Brodeur, G.K. Krutzikowsky, L.J. Adrean, S.A. Heppell, K.C. Jacobson, K. Milligan, S.K. Nelson, D.D. Roby and W.J. Sydeman. 2022. Critical research needs for forage fish within inner shelf marine ecosystems. Fisheries 47(5):213-221. 10.1002/fsh.10725.

Ruggerone, G.T. and J.L. Nielsen. 2004. Evidence for competitive dominance of pink salmon (*Oncorhynchus gorbuscha*) over other salmonids in the North Pacific Ocean. Reviews in Fish Biology and Fisheries 14:371-390.

Samhouri, J.F., A.O. Shelton, G.D. Williams, B.E. Feist, S.M. Hennessey, K. Bartz, R.P. Kelly, J.L. O'Donnell, M. Sheer, A.C. Stier and P.S. Levin. 2022. How much city is too much city? Biodiversity and ecosystem functioning along an urban gradient at the interface of land and sea. Frontiers in Marine Science 9:931319. 10.3389/fmars.2022.931319.

Simenstad, C.A., C.D. Tanner, R.M. Thom and L.L. Conquest. 1991. Estuarine habitat assessment protocol. Report to the U.S. Environmental Protection Agency, Region 10, Seattle, Washington. hdl.handle.net/1773/4121

SBSRF (Snohomish Basin Salmon Recovery Forum). 2005. Snohomish River Basin salmon conservation plan. Report of the Snohomish County Department of Public Works, Surface Water Management Division. Everett, WA. https://www.snohomishcountywa.gov/ArchiveCenter/ViewFile/Item/2153

SBSRF (Snohomish Basin Salmon Recovery Forum). 2019. Snohomish River Basin salmon conservation plan status and trends. Report of the Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA. https://www.snohomishcountywa.gov/DocumentCenter/View/71060/SnohomishBasin10YearReport_2019-12-30_reduced

Thayne, M.W., J.A. Santora, B. Saenz, P. Warzybok and J. Jahncke. 2019. Combining seabird diet, acoustics and ecosystem surveys to assess temporal variability and occurrence of forage fish. Journal of Marine Systems 190:1-14. 10.1016/j.jmarsys.2018.08.006.

Toft, J.D., J.R. Cordell, C.A. Simenstad and L.A. Stamatiou. 2007. Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management 27(2):465-480.

Ward, A.J.W., R. James, A.D.M. Wilson and M.M. Webster. 2013. Site fidelity and localized homing behaviour in three-spined sticklebacks (*Gasterosteuaculeatus*). Behaviour 150(14):1689-1708.

WCET (Whidbey Cumulative Effects Team). 2022. The cumulative effects of nearshore habitat recovery actions on juvenile salmonids in the Whidbey Basin: Study development report. Report to the Puget Sound Partnership, Olympia, WA.

Weitkamp, L.A, P.J. Bentley and M.N.C. Litz. 2012. Seasonal and interannual variation in juvenile salmonids and associated fish assemblage in open waters of the Lower Columbia River Estuary. Fishery Bulletin 110(4):426-450.

WSAS (Washington State Academy of Sciences). 2022. Pinniped predation on salmonids in the Washington portions of the Salish Sea and Outer Coast. Report to the Washington State Department of Fish and Wildlife, Seattle, WA.

WSDE (Washington State Department of Ecology). 2021. Long-term marine water and sediment data. Online dataset available at ecology.wa.gov/Research-Data/Monitoring-assessment/Puget-Sound-and-marine-monitoring/Water-column-data (March 2021).

Appendix A

Appendix Table A. Sampling summary and notes by date.

Year	Date	Sites sampled (n)	Notes
2020	28 Feb	7	Tide too high for EW8
	16 Mar	7	Rough conditions, could not safely sample EW8
	5 Oct	8	
	20 Oct	8	
	16 Nov	7	Debris barrier closed so EW1 inaccessible
	10 Dec	8	
2021	1 Feb	8	No workable schedule/tides in January so sampled twice in February
	16 Feb	7	Debris barrier closed so EW1 inaccessible
	1 Mar	8	YSI environmental sampling instrument died, available at EW1, EW2, EW3, and EW6 only
	15 Mar	8	
	12 Apr	8	
	23 Apr	7	Dock positioned in front of EW2 making it inaccessible
	10 May	8	
	20 May	8	EW8 sampled but no emergent shore and net badly snagged; did not re-deploy due to conditions
	1 Jun	8	
	17 Jun	8	Many salmon visibly stressed in the net due to water temperature (e.g. 16.6°C at EW7).
	13 Jul	8	Hatchery Chinook appear emaciated. At EW8 Chinook dead in net upon retrieval (too hot, 17.4°C), at EW6 no Chinook lengths due to water temperature (18.5°C).
	3 Aug	7	No sampling at EW2 due to seal pups on the shore
	16 Aug	7	Tide too high for EW8
	2 Sep	8	
	28 Sep	8	
	15 Oct	8	
	29 Oct	6	Debris barrier closed so EW1 inaccessible. No sampling at EW5.
	16 Nov	7	Debris barrier closed so EW1 inaccessible
	14 Dec	8	
2022	20 Jan	8	
	8 Feb	8	
	8 Mar	8	
	28 Mar	8	
	11 Apr	8	
	25 Apr	7	Debris barrier closed so EW1 inaccessible
	9 May	4	Limited tidal window so distributed sampling at EW1, EW2, EW4, EW6 only due to constraints
	24 May	8	At EW8 approximately 30 salmonids observed in net but zero landed (escaped)
	6 Jun	8	
	21 Jun	8	
	21 Jul	8	
	2 Aug	7	No sampling at EW4 due to presence of boom and seal pups on the shore
	19 Aug	7	No sampling at EW4 due to seal pups on the shore
	6 Sep	8	
	20 Sep	8	EW8 sampled but no emergent shore and net badly snagged; did not re-deploy due to conditions

Appendix B

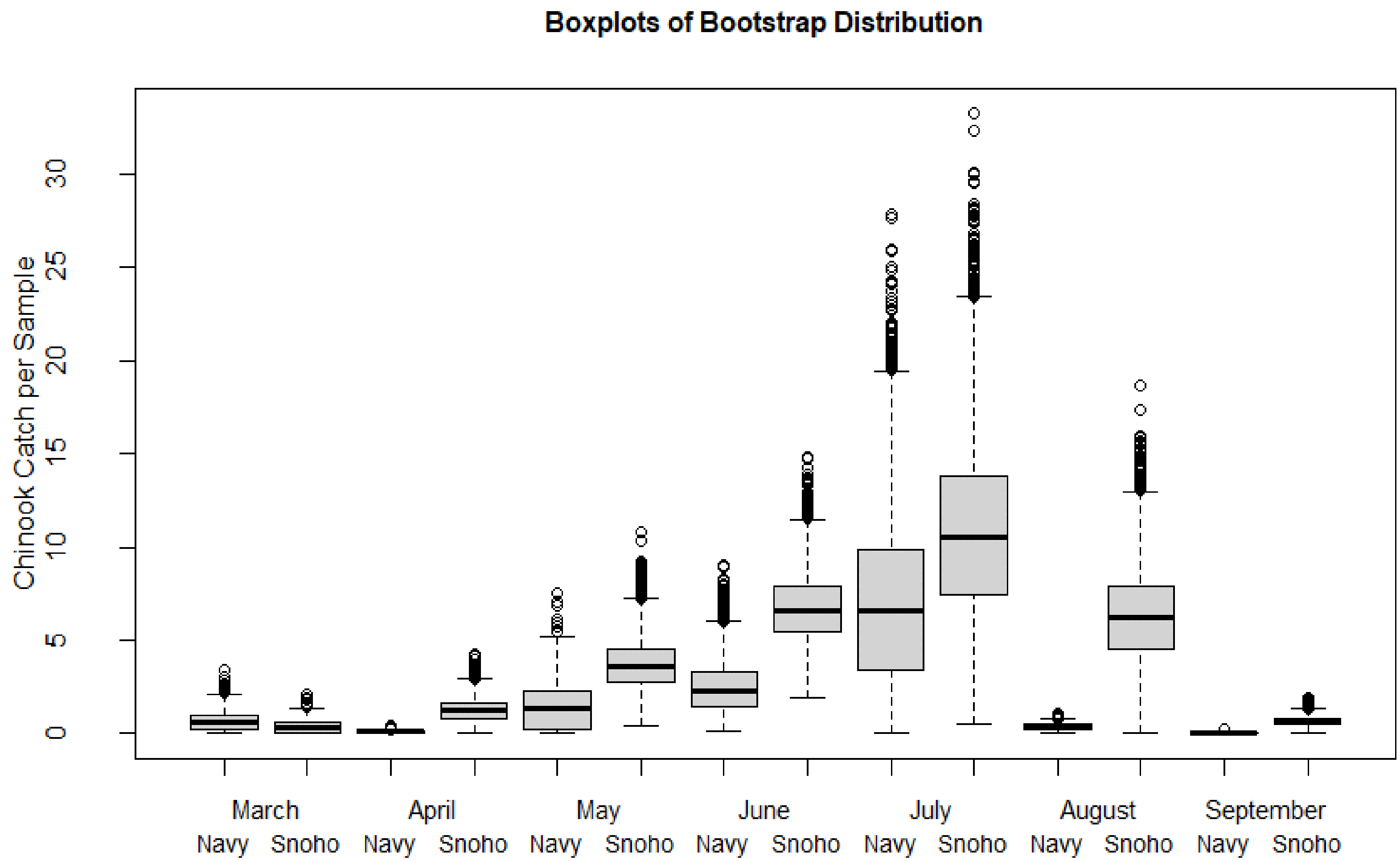
Appendix Figure B1. Map of estuarine sites (indicated with yellow star) sampled by NOAA from 2019 and 2022.

Appendix Table B1. Monthly and total catch per unit effort (CPUE) numbers by species and sample month for the most prevalent species at marine and estuarine sites sampled by NOAA Fisheries in 2019 and 2022.

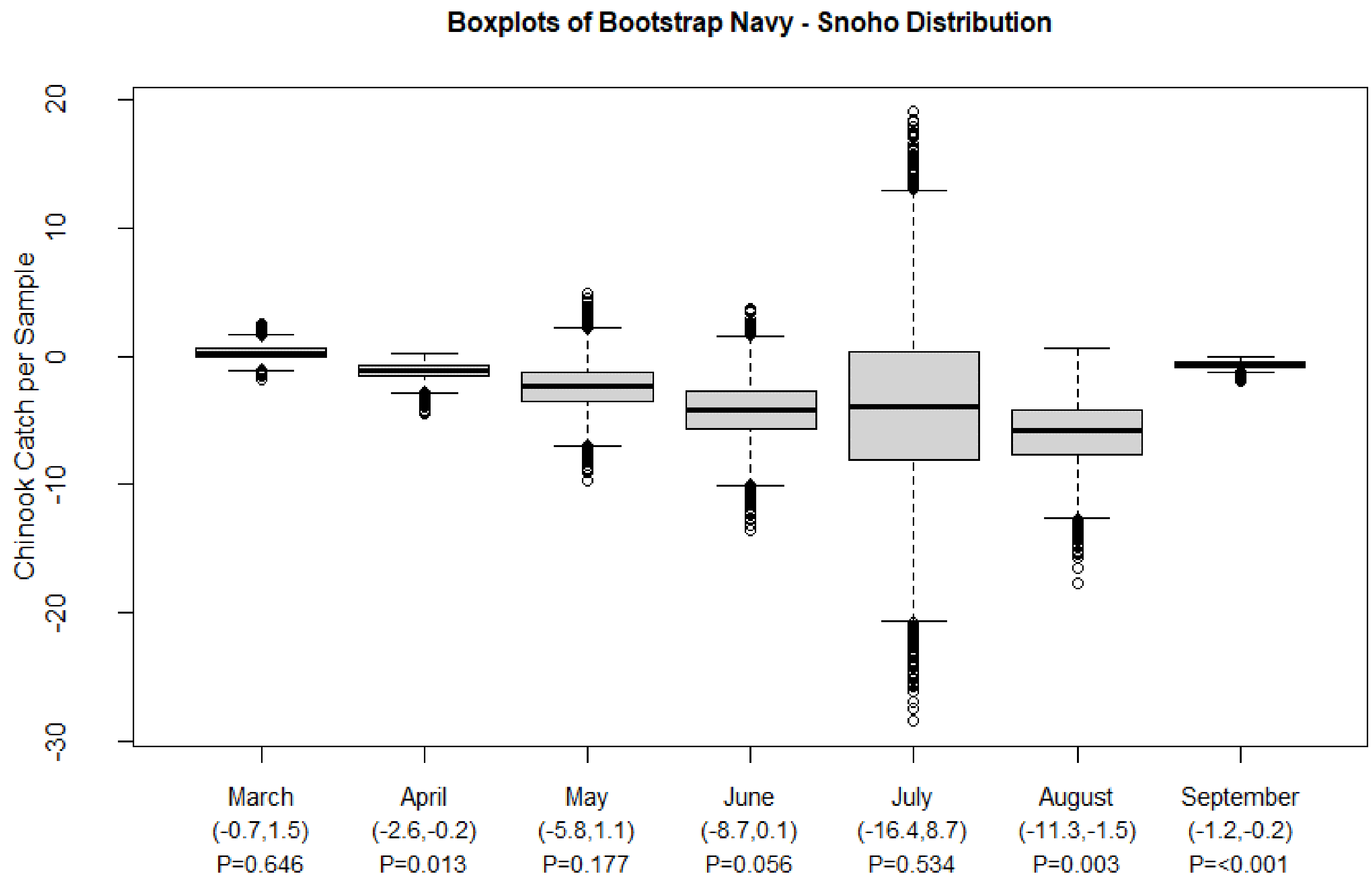
		Salmonids				Forage fish		
Month	Number of sets	Chinook	Coho	Chum	Pink	Pacific sand lance	Pacific herring	Surf smelt
January	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March	37	0	0	13	50	8	0	2
April	59	1	0	25	76	9	0	39
May	61	4	11	7	4	2	0	25
June	64	7	4	4	0	0	0	1
July	29	11	1	0	0	5	0	1
August	14	6	0	0	0	0	0	14
September	57	1	0	0	0	98	1	3
October	55	0	0	0	0	8	1	1
November	7	0	0	0	0	44	0	7
December	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overall	383	3	3	7	17	20	0	12

Appendix Table B2. Modified Table 4. East Waterway monthly and total catch per unit effort (CPUE) numbers by species and sample month for the most prevalent species across the study time frame.

		Salmonids				Forage fish		
Month	Number of sets	Chinook	Coho	Chum	Pink	Pacific sand lance	Pacific herring	Surf smelt
January	8	0	0	0	0	0	0	1
February	30	0	0	0	0	0	0	0
March	39	1	0	23	52	0	0	0
April	30	0	0	111	206	160	0	0
May	28	1	0	35	94	199	882	0
June	32	3	1	2	1	0	0	0
July	16	6	0	0	0	0	0	3
August	28	0	0	0	0	0	5	5
September	32	0	0	0	0	0	0	5
October	30	0	0	0	0	2	0	5
November	14	0	0	0	0	0	0	1
December	16	0	0	0	0	0	0	0
Overall	303	1	0	17	2	34	82	2

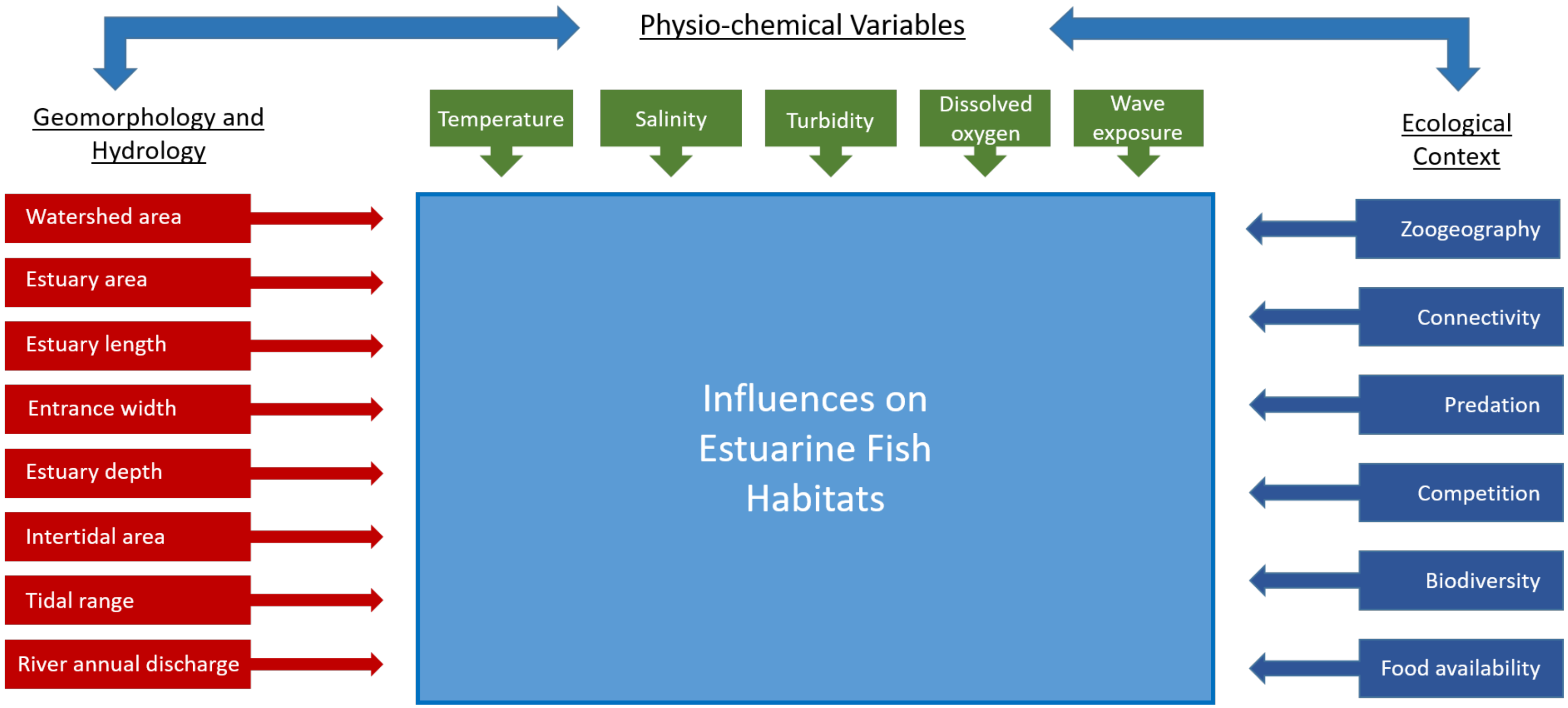


Appendix Figure B2. Box plots of bootstrap distribution of monthly Chinook salmon CPUE between sites at Naval Station Everett (labeled Navy) and nearby estuarine sites from 2019 and 2022 (labeled Snoho; NOAA unpublished data).



Appendix Figure B3. Box plots of difference between the bootstrap distribution of monthly Chinook salmon CPUE between sites at Naval Station Everett and nearby estuarine sites from 2019 and 2022 (NOAA unpublished data). Bootstrap range and level of significance (*P*-value) listed with x-axis.

Appendix C



Appendix Figure C. Schematic interpretation of the factors influencing estuarine habitats and associated fish assemblages. Ecological context is included to incorporate a broad ecosystem perspective. From Able et al. 2022.

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