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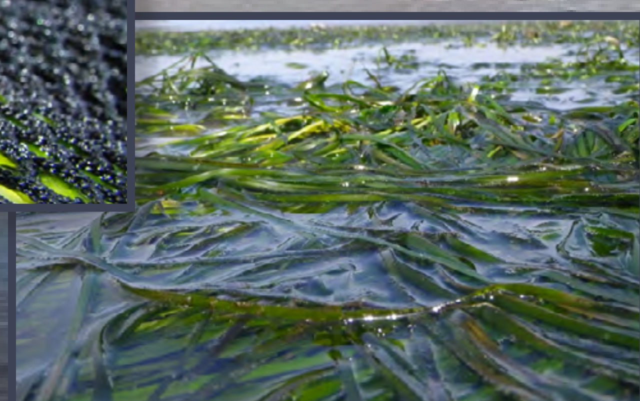
Fish Assemblages in Eelgrass Beds of Bellingham Bay, Washington, Northern Puget Sound, 2019



Data Series 1131

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Cover. Background: Field crew deploying a beach seine in Puget Sound, Washington. Photograph by Theresa Liedtke, U.S. Geological Survey, September 25, 2019.

Left: Crescent gunnel (*Pholis laeta*). Photograph by Dave Ayers, U.S. Geological Survey, July 13, 2012.

Bottom right: Common eelgrass (*Zostera marina*) at low tide in Puget Sound, Washington. Photograph by Dave Ayers, U.S. Geological Survey, May 7, 2012.

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U.S. Department of the Interior
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U.S. Geological Survey
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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Abbreviations

BPN	Boulevard Park North
BPW	Boulevard Park West
CHIPS	Coastal Habitats in Puget Sound
MP	Marine Park
PCB	Polychlorinated Biphenyl
TB	Taylor Bridge
USGS	U.S. Geological Survey

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Abstract

Puget Sound is a critical part of the Pacific Northwest, both culturally and economically. Eelgrass beds are an important feature of Puget Sound and are known to influence fish assemblages. As part of a larger site-characterization effort, and to gain a better understanding of the fish assemblages in Bellingham Bay, Washington, four eelgrass beds (*Zostera marina*) along the shoreline were surveyed. Fish were captured from 24 through 26 September 2019 by using three beach-seine hauls per eelgrass bed. In total, 12 hauls yielded 2,135 fish that comprised 20 species from 14 families. Shiner perch (*Cymatogaster aggregata)* accounted for 52 percent of the total catch. The other common species included three-spine stickleback (*Gasterosteus aculeatus*), bay pipefish (*Syngnathus leptorhynchus*), saddleback gunnel (*Pholis ornata*), Pacific staghorn sculpin (*Leptocottus armatus*), and Pacific sand lance (*Ammodytes personatus*). Total catch and species richness were highest at the two locations closest to the urban center of Bellingham; however, species diversity and evenness were highest at the two eelgrass beds farthest from the city center. Descriptions of fish assemblages in eelgrass beds are expected to be useful in the development of future process-based investigations by study partners and will focus on the movements of sediments and contaminants and their influence on biota.

Introduction

Puget Sound, in northwestern Washington, is culturally and economically important to the Pacific Northwest. This iconic water body is bounded by more than 2,000 kilometers (km) of shoreline and faces a range of challenges related to population growth and development. One of the primary threats is pollution that delivers toxic chemicals to Puget Sound. Historical contamination from past industrial or commercial efforts remains in the system with ongoing potential to affect biota. The highest concentrations of toxic pollutants are generally found near large urban centers, where heavy residential and industrial activity is concentrated along the shoreline.

The U.S. Geological Survey's (USGS) multi-disciplinary Coastal Habitats in Puget Sound (CHIPS) project addresses the need for scientific understanding of the physical and biological processes that support vital nearshore habitats and ecosystems. In 2019, the CHIPS team began investigating the physical processes that influence the movements of sediments, such as deposition from river plumes and resuspension from wave action. Hydrophobic contaminant compounds, for example, polychlorinated biphenyls (PCBs), preferentially partition to organic carbon-rich sediments that are suspended in the water or have settled rather than remain dissolved in the water. In areas where toxic compounds are present, processes that disrupt and move sediment may be transporting contaminants, potentially making them more accessible to biota. For the initial phases of this investigation, the CHIPS team focused on Bellingham Bay as one example of an urbanized embayment in Puget Sound from which contaminants such as PCBs may enter the system and be mobilized by physical processes.

Seagrasses are a key component of Puget Sound, providing habitat, forage, and protection for many marine species (Thayer and Phillips, 1997). Globally, seagrass beds are some of the most prolific, extensive, and valuable elements of coastal environments (Duffy, 2006; Krause-Jensen and others, 2011). Two dominant eelgrass species are found in Puget Sound – the native common eelgrass (*Zostera marina*) and the nonnative dwarf/Japanese eelgrass (*Zostera japonica*). Eelgrasses provide many ecosystem services and are commonly used as ecological-health indicators on the basis of their fast response to water quality and substrate changes (Duarte, 2000; Spalding and others, 2003; Mumford, 2007). Ecosystem services provided by eelgrass include fueling nearshore food webs, serving as nurseries for juvenile fish, and providing habitat complexity in areas that would otherwise be mostly two-dimensional (Duarte, 2000; Duffy, 2006; Mumford, 2007). Many of the fish species in Puget Sound rely on eelgrasses habitats at some point in their lifecycle. For example, Pacific herring use eelgrass as a substrate for spawning (Penttila, 2007; Thom and others, 2014), and juvenile rockfish use it for rearing (Murphy and others, 2000). Therefore, fish and eelgrass are intertwined, playing a central role in marine-ecosystem dynamics (Hughes and others, 2002; Johnson and others, 2003; Hyndes and others, 2018). In Puget Sound, fish commonly found in eelgrass beds consist of both non-commercial and commercially valuable species such as Pacific salmonids *(Oncorhynchus spp*.) and forage fish. The most prevalent families of forage fish in Puget Sound are Ammodytidae (sand lances), Clupeidae (herrings, shads, sardines), and Osmeridae (smelts) (Penttila, 2007), and the CHIPS team is interested in forage fish as indicators of ecosystem health. Robust eelgrass meadows have a positive influence on both commercial fisheries and nearshore-ecosystem resilience (Blandon and Ermgassen, 2014). Eelgrass and other submerged vegetation can influence sediment dynamics in nearshore habitats by attenuating waves and currents and changing patterns of sediment erosion, deposition, retention, and resuspension (Lacy and Wyllie-Echeverria, 2011), potentially trapping and concentrating sediment-born contaminants in important fish habitats.

Vegetated coastal environments are influenced by shoreline development and are one of the marine ecosystems most affected by humans (Johnson and others, 2003; Waycott and others, 2009; Coll and others, 2011). Major losses of eelgrass beds have been documented along the industrialized shores of Bellingham Bay (Gaeckle, 2009), throughout Puget Sound, and worldwide because of a combination of anthropogenic pressures such as nutrient overloading, aquaculture, climate change, dredge and fill practices, and the spread of disease (Waycott and others, 2009; Coll and others, 2011; Blandon and Ermgassen, 2014). As part of the CHIPS program's investigations in Bellingham Bay, several eelgrass beds were sampled to describe fish species, with an emphasis on forage fish. These surveys were of limited scope and were intended to be part of a site-characterization effort, providing the basic information upon which more process-based investigations could be developed and executed by the CHIPS team or others. This report describes the results of surveys conducted to document fish-species assemblages at four locations where eelgrass was present in Bellingham Bay.

Methods

Study Locations

The study was conducted in Bellingham Bay, Washington, in the northernmost section of Puget Sound (fig. 1). The city of Bellingham is located directly adjacent to the bay (fig. 2), 145 km north of Seattle, Washington, and 84 km southeast of Vancouver, Canada. Along the shoreline south of the urban center, four intertidal eelgrass beds were selected for sampling to address the CHIPS team's research questions about sediment movements in the bay. Beginning closest to the city center and moving away from it, the study locations were Boulevard Park North (BPN), Boulevard Park West (BPW), Taylor Bridge (TB), and Marine Park (MP; fig. 2).

Beach Seining

Each of the four eelgrass beds was sampled by using a 37 m long beach seine (fig. 3) that tapered from 2.5 m wide at the center of the net to 1 m wide at the ends. The net was black and without knots with a 36-by-1 cm stretched 6 mm hole-size mesh on the main body of the net and a black, center bag without knots made of 59-by-1 cm stretched 3 mm hole-size mesh. The top float line was composed of floats at 31 mm centers, and a lead line in the bottom webbing enabled the seine to contact the substrate while the top floated. A full bridle system was secured with rings to the end breast lines for easy attachment to the haul lines. The seine was deployed by using a "round-haul" approach. That is, one end of the seine was held by a person on the beach or in shallow water near the beach while the opposing end was pulled away from shore and around the target sampling area by boat. Personnel pulling both ends of the seine onto the shore completed the operation. Using the boat to deploy the net allowed the seine to reach farther offshore and into deeper water and thus to sample a larger area of the eelgrass bed.

Sampling began at MP on 24 September 2019 at 7:30 am, when the tide was out by 0.05 m. BPW was sampled on 25 September 2019 at 7:00 am with a tide of 0.14 m, and BPN was sampled later that same day at 9:00 am with a tide of -0.09 m. On the last day of sampling, 26 September 2019, beach seining began at 8:00 am at TB when the tidal elevation was 0.15 m. The maximum tidal elevation during the combined sampling periods was 0.15 m, and the minimum was -0.09 m; all sampling occurred within two hours of low tide. Three beach-seine hauls were made in each eelgrass bed in rapid succession. Overall, 12 beach-seine hauls were conducted for the study. The species of captured fish were identified, and fork length (the length of a fish measured from the tip of the snout to the notch in the tail fin) was measured to the nearest millimeter for the first 30 fish of each species at each site. Fish that were not identifiable in the field were photographed and later identified in the laboratory.

Data Analysis

The three individual hauls per location were combined to represent an overall catch at each location. The total catches at every location were pooled to represent total overall catch. Species richness was summarized as the total number of species found at a given location. A diversity index was calculated to provide more information about community composition than the simple expression of species richness provides. Species diversity was calculated by using Shannon's diversity index (H'), which is defined as:

$$\mathbf{H} = -\sum_{i=1}^{S} (pi)(\ln pi),$$

where

pi is the number of individuals of a species divided by the total number of individuals of all species, and

S is the number of species (Shannon and Weaver, 1963).

This equation considers two components of diversity: the number of species and evenness. Evenness was calculated by using Pielou's evenness index (J') defined as:

$$J' = \frac{H(s)}{H(max)},$$

where

J' is Pielou's index,

H (*s*) is Shannon's index value, and

H (*max*) is the maximum diversity possible if every species were to be captured in equal numbers and is calculated by taking the natural log of the total number of species (Pielou, 1966).

J' is constrained between 0 and 1and lower values represent a less even distribution of species (for example, when one or several species dominate the catch.).

Figure 1. Location of the study area in Bellingham Bay, Washington.

Figure 2. The four eelgrass beach-seining locations in Bellingham Bay, Washington. All four sites were south of Bellingham's urban center and included Boulevard Park North, Boulevard Park West, Taylor Bridge, and Marine Park. Imagery by Landsat for Marine Park on August 8, 2011, and all other sites on July 7, 2018.

Figure 3. Beach seine being pulled onto shore by personnel in Puget Sound, Washington. Photograph by Dave Ayers, U.S. Geological Survey, July 18, 2012.

Results

Overall, 12 beach-seine hauls at four study locations yielded 2,135 fish that comprised 20 species from 14 families (table 1). Shiner perch (*Cymatogaster aggregata*) made up 52 percent of the total catch and represented the largest proportion of fish captured at three of the four locations: BPN (45 percent), BPW (70 percent), and MP (39 percent). The three-spine stickleback (*Gasterosteus aculeatus*) was the most prevalent species at TB, contributing 43 percent of the total catch at this site (table 2). Following shiner perch, the most common species in the total catch (all sites combined) included three-spine stickleback (17 percent), bay pipefish (*Syngnathus leptorhynchus*; 10 percent), saddleback gunnel (*Pholis ornata*; 9 percent), Pacific staghorn sculpin (*Leptocottus armatus*; 4 percent), and Pacific sand lance (*Ammodytes personatus;* 3 percent). Five of the six most common species were found in each study location. The exception was that three-spine stickleback were not captured at MP but composed 6–43 percent of the catch at the other three sites (table 2). There were no Pacific salmonids captured at any of the sample locations

We calculated the mean fork length (all sites combined) for commonly captured species (fig. 4). Means were 83 mm (range 33–148 mm, n=79) for shiner perch; 40 mm (range 27–50 mm, n=49) for three-spine stickleback; 148 mm (range 47–245 mm, n=51) for bay pipefish; 114 mm (range 45 –165 mm, n=60) for saddleback gunnel; 105 mm (range 49–230 mm, n=69) for Pacific staghorn sculpin; and 85 mm (range 69–101 mm, n=63) for Pacific sand lance (fig. 4).

The abundance of forage fish such as Pacific sand lance, surf smelt (*Hypomesus pretiosus*), and Pacific herring (*Clupea pallasii*) differed among the four eelgrass beds. Pacific sand lance were captured at each of the four locations. The highest abundance of Pacific sand lance was observed at TB with 26 individuals, and the lowest catch–a single individual–was at MP. A total of three surf smelt were captured at BPN and BPW. Two Pacific herrings were observed at BPN, and none were captured at the other locations (table 1).

Several species were captured at only a single location. These limited-capture species included the striped surfperch (*Embiotoca lateralis*), buffalo sculpin (*Enophrys bison*), rock sole (*Lepidopsetta bilineata*), Pacific herring, silver spotted sculpin (*Blepsias cirrhosus*), and plainfin midshipman (*Porichthys notatus*; table 1). Five striped surfperch and two silver spotted sculpin were collected at MP. One buffalo sculpin was captured at BPN and one rock sole and one plainfin midshipman at TB. Other species captured at low frequencies included the crescent gunnel (*Pholis laeta*), tidepool sculpin (*Oligocottus maculosus*), starry flounder (*Platichthys stellatus*), whitespotted greenling (*Hexagrammos stelleri*), and snake prickleback (*Lumpenus sagitta*). At MP, penpoint gunnels (*Apodichthys flavidus*) and tubesnouts (*Aulorhynchus flavidus*) were captured in higher quantities than at any other site. The number of Penpoint gunnels was 23 at MP compared to 0–6 elsewhere, and the number of tubesnouts at MP was 19 compared to 0–8 elsewhere (table 1).

Catch characteristics expressed as total catch, species richness, species diversity, and evenness appeared to define two groups from the four study sites; BPN and BPW were similar to each other but differed with respect to the characteristics of the grouping of TB and MP. The first group, BPN and BPW, was closest to the city center, and the second group, TB and MP, was farthest from the city center. Total catch and species richness were highest in the first group, but species diversity and evenness were highest in the second group. The highest total catch among the four sites occurred at BPW, with 844 individuals and a species-richness value of 13, including 10 families (table 1). At BPN, the total catch included 595 fish, and the species richness was 13, including 11 families. The total catch was lowest at TB, with 294 individuals and a species richness of 11, representing nine families. At MP, the species richness was 12 and comprised nine families, with a total catch of 402 fish (table 1). Species diversity and evenness were highest for the second group of sites, TB and MP, which were located farthest from the city center (table 3). Shannon's diversity index for MP was the highest (1.64) of the values at all four sites. The lowest diversity index was 1.11 at BPW. The mean diversity index for TB and MP combined was 1.61, compared to the mean index for BPN and BPW, which was 1.25. Evenness was 0.66 at both TB and MP and 0.43 and 0.54 at the other two sites (table 3). The lower evenness values at BPN and BPW suggest that species were captured in equal numbers but were influenced by high captures of a relatively few number of species.

Table 1. Scientific and common names of fish captured at four sampling locations in Bellingham Bay, Washington, and for tabulating total catch.

[Species are listed under their family names by common, genus, and species names, and in order from highest to lowest total-catch frequency for families. –, no fish were captured.]

Family name and common names	Genus and species (scientific name)	Total catch	Boulevard Park North	Boulevard Park West	Taylor Bridge	Marine Park
Embiotocidae		1,103	270	590	86	157
Shiner perch	*Cymatogaster aggregate*	5	–	–	–	5
Striped surfperch	*Embiotoca lateralis*					
Gasterosteidae		365	189	49	127	–
Three-spine stickleback	*Gasterosteus aculeatus*					
Pholidae		195	73	70	9	43
Saddleback gunnel	*Pholis ornate*	4	–	1	–	3
Crescent gunnel	*Pholis laeta*	29	–	6	–	23
Penpoint gunnel	*Apodichthys flavidus*					
Syngnathidae		223	8	85	16	114
Bay pipefish	*Syngnathus leptorhynchus*					
Cottidae		89	24	19	13	33
Pacific staghorn sculpin	*Leptocottus armatus*	1	1	–	–	–
Buffalo sculpin	*Enophrys bison*	5	1	1	3	–
Tidepool sculpin	*Oligocottus maculosus*					
Ammodytidae		63	18	18	26	1
Pacific sand lance	*Ammodytes personatus*					
Aulorhynchidae		28	–	1	8	19
Tubesnout	*Aulorhynchus flavidus*					
Pleuronectidae		10	5	1	4	–
Starry flounder	*Platichthys stellatus*	1	–	–	1	–
Rock sole	*Lepidopsetta bilineata*					
Hexagrammidae		4	1	2	–	1
Whitespotted greenling	*Hexagrammos stelleri*					
Osmeridae		3	2	1	–	–
Surf smelt	*Hypomesus pretiosus*					
Clupeidae		2	2	–	–	–
Pacific herring	*Clupea pallasii*					
Stichaeidae		2	1	–	–	1
Snake prickleback	*Lumpenus sagitta*					
Hemitripteridae		2	–	–	–	2
Silver-spotted sculpin	*Blepsias cirrhosus*					
Batrachoididae		1	–	–	1	–
Plainfin midshipman	*Porichthys notatus*					
	Total	2,135	595	844	294	402

Table 2. Species of fish captured at four sampling locations in Bellingham Bay, Washington, listed by common and scientific names, by the percentage of each species caught at each study location (Boulevard Park North, Boulevard Park West, Taylor Bridge, and Marine Park) and by the total catch combined across all locations.

[The table is ordered from the largest to the smallest proportions of total catch; dashes indicate that no fish were captured. Boulevard Park North (BPN), Boulevard Park West (BPW), Taylor Bridge (TB), and Marine Park (MP); <, less than]

Common name	Scientific name	Proportion of total catch (percent)	BPN (percent)	BPW (percent)	TB (percent)	MP (percent)
Shiner perch	*Cymatogaster aggregata*	52	45	70	29	39
Three-spine stickleback	*Gasterosteus aculeatus*	17	32	6	43	–
Bay pipefish	*Syngnathus leptorhynchus*	10	1	10	5	28
Saddleback gunnel	*Pholis ornata*	9	12	8	3	11
Pacific staghorn sculpin	*Leptocottus armatus*	4	4	2	4	8
Pacific sand lance	*Ammodytes personatus*	3	3	2	9	<1
Penpoint gunnel	*Apodichthys flavidus*	1	–	1	–	6
Tubesnout	*Aulorhynchus flavidus*	1	–	<1	3	5
Starry flounder	*Platichthys stellatus*	<1	1	<1	1	–
Striped surfperch	*Embiotoca lateralis*	<1	–	–	–	1
Tidepool sculpin	*Oligocottus maculosus*	<1	<1	<1	1	–
Crescent gunnel	*Pholis laeta*	<1	–	<1	–	1
White-spotted greenling	*Hexagrammos stelleri*	<1	<1	<1	–	<1
Surf smelt	*Hypomesus pretiosus*	<1	<1	<1	–	–
Pacific herring	*Clupea pallasii*	<1	<1	–	–	–
Silver-spotted sculpin	*Blepsias cirrhosus*	<1	–	–	–	1
Snake prickleback	*Lumpenus sagitta*	<1	<1	–	–	<1
Buffalo sculpin	*Enophrys bison*	<1	<1	–	–	–
Plainfin midshipman	*Porichthys notatus*	<1	–	–	<1	–
Rock sole	*Lepidopsetta bilineata*	<1	–	–	<1	–

Table 3. Total catch, number of species, diversity index, and evenness values for four sampling sites in Bellingham Bay, Washington.

[Sites are listed in the order of distance (closest to farthest) from the urban center of Bellingham, Washington.]

Site	Total catch	Number of species	Diversity index	Evenness
Boulevard Park North	595	13	1.39	0.54
Boulevard Park West	844	13	1.11	0.43
Taylor Bridge	294	11	1.58	0.66
Marine Park	402	12	1.64	0.66

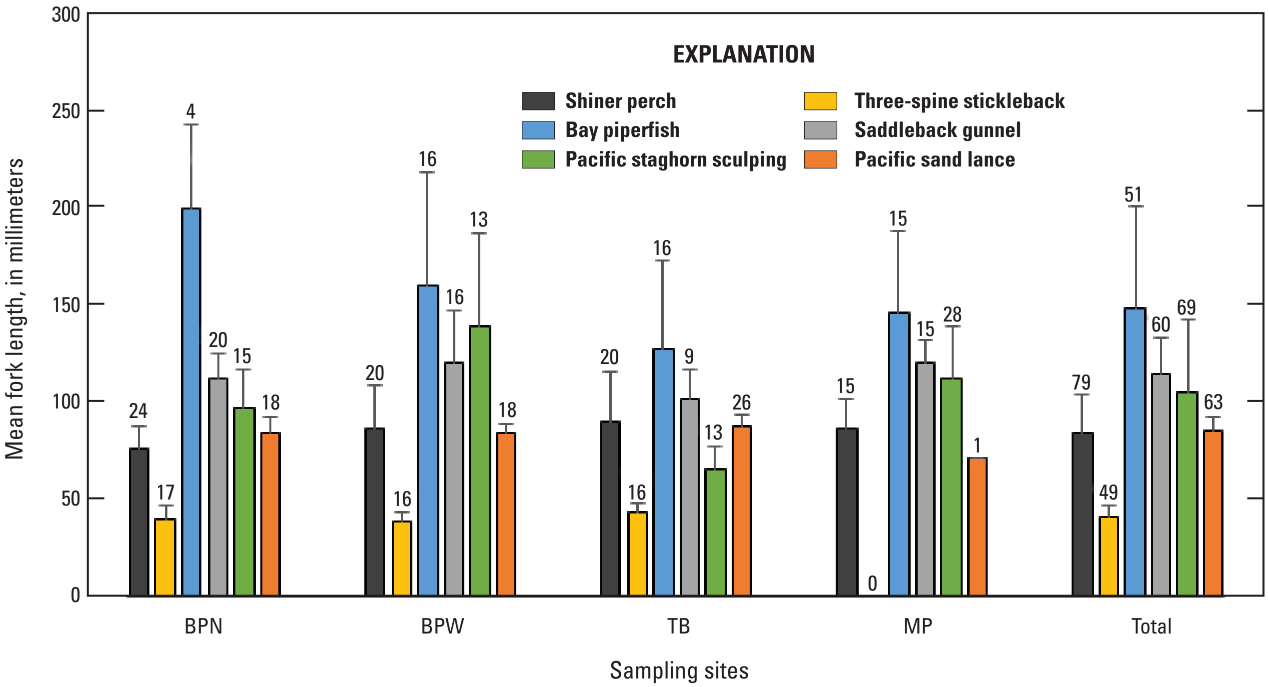

Figure 4. Mean fork length of the six most common fish species sampled at four sites in Bellingham Bay, Washington. The numbers above the error bars indicate sample size, and the error bars themselves represent the standard deviation. The total category shows mean fork length per species from all sampling locations combined. Scientific names of species: shiner perch, *Cymatogaster aggregata*; three-spine stickleback, *Gasterosteus aculeatus*; bay pipefish, *Syngnathus leptorhynchus*; saddleback gunnel, *Pholis ornata*; Pacific staghorn sculpin, *Leptocottus armatus*; Pacific sand lance, *Ammodytes personatus*. BPN, Boulevard Park North; BPW, Boulevard Park West; TB, Taylor Bridge; MP, Marine Park.

Fish Assemblages in Eelgrass Beds

The surveys conducted in four eelgrass beds in Bellingham Bay were of limited spatial and temporal scope and likely underestimated the species richness and abundance present at these sites. Beach seining occurred for only 3 days in September 2019, and each eelgrass bed was sampled for only 37 m of its shoreline extent (the length of the beach seine). As part of the site characterization efforts in Bellingham Bay, the CHIPS team started mapping the extent of these eelgrass beds, but the data analysis is not yet complete. From field observations during surveys, however, it became clear that each of the four beds has substantially more shoreline extent than was sampled. The limited temporal sampling period for this study likely caused some species to be missed that might typically be present at other times. Many fish use eelgrass at specific times in their life histories for rearing their young, migration, or spawning. Fish communities and abundance can vary seasonally because many species are not permanent residents (Phillips, 1984). For example, although we did not catch any juvenile Pacific salmon, it is unlikely that they are not present in the eelgrass beds in Bellingham Bay at some point during the year (McCormick, 2018). Our survey findings were also likely influenced by time of day and water depth (Thedinga and others, 2011; McCormick, 2018). Additional effects on the fish species captured include ocean currents, eelgrass-patch size, proximity to other environments (that is, non-eelgrass areas), and edge effects (Cowen and Sponaugle, 2009; McCormick, 2018).

The relative distances of the eelgrass beds from the urban center influenced total catch amounts and indexes of biodiversity. The four eelgrass sites are best summarized by defining two groups: a close group (the two sites closest to the urban center) and a far group, which compromises two sites farthest from the urban center. The catch characteristics at the two close sites, BPN and BPW, were similar to each other, but different from those at TB and MP, the two far sites. Total catch and species richness were highest at the close sites, but diversity and evenness were highest at the two far sites. The combined catch numbers at BPN and BPW were more than double the combined catch at TB and MP. The total number of fish captured is not, by itself, a useful indicator of the health or condition of an eelgrass meadow or any other ecosystem. Species richness should also be considered because the interactions between species are important drivers of ecosystem health. Thirteen species were captured at each of the close sites and 11–12 species at the distant sites, so species richness was higher for the close group, but only by 1 or 2 species. Catches at the close sites were dominated by shiner perch (45–70 percent of the total catch); although shiner perch were also captured at the far sites, they were a smaller proportion of the total catch (29–39 percent). The distant group had higher values for the diversity index and evenness. A diversity index is a useful indicator because it provides more information about the composition of the fish community than simply species richness. The index accounts for both abundance and the relative evenness of the species present. For this study, shiner perch was a dominant species, so comparing the four sites based on the diversity index is powerful because it takes the dominance into account. The mean diversity index for the close group (1.25) was lower than the mean for the far group (1.61), indicating that eelgrass beds farther from the urban center have more diverse species assemblages.

The diversity-index values we observed are comparable to the results of similar evaluations in other eelgrass beds. A study by Johnson and others (2003) in eastern Alaska reported a mean Shannon diversity-index value of 1.52 (range: 0.04–2.32) based on beach seining during 2 years in eelgrass beds. Another eelgrass survey during the period of April through September near Craig, Alaska, evaluated Shannon diversity-index values that ranged from 0.25 to 2.00 and averaged 1.39 overall (Murphy and others, 2000). The average index for just the September surveys was 1.59 (Murphy and others, 2000), which is close to the mean value of 1.61 for TB and MP combined.

The final measure of biodiversity we examined was evenness. Mean evenness was 0.66 for the far group and 0.49 for the close group. Evenness is calculated as the ratio of the diversity index for a given site to the maximum diversity possible for that site if the capture of every species at that site were equally likely. An evenness value of 0.66 translates to 66 percent of the maximum diversity possible based on the species present. Species diversity and evenness are both typically high in stable, healthy ecosystems.

Our total catch of forage fish was low. Pacific sand lance represented about 3 percent of the total catch, and we captured more sand lance than either surf smelt or Pacific herring. Surf smelt or Pacific herring each were less than 1 percent of the total catch, and they were captured only at one or two sites, whereas Pacific sand lance were captured at all study sites. Forage fish are, by definition, tightly schooling species, and capturing a school or a partial school by using a beach seine can be difficult. It is not surprising, therefore, that our catches of these species were not high. Another possible explanation for low catches could be low relative abundance. The abundance of Pacific sand lance and surf smelt in Puget Sound is unknown, but there has been a documented decline in northern Puget Sound herring stocks (Landis and others, 2004; Puget Sound Partnership, 2012). The Puget Sound Partnership, a state agency leading the efforts to protect and restore Puget Sound, has identified the Pacific herring as an ecological indicator based on its sensitivity to contaminants and prominence in the food web (Puget Sound Partnership, 2012). A study by Landis and others (2004) reported declines in Pacific herring stocks during multiple decades just north of our study location in Bellingham Bay. These declines were reportedly caused by several stressors, such as habitat modification, urban development, overfishing, climate change, and toxin accumulation (Landis and others, 2004).

Beach-seine surveys at four eelgrass sites in Bellingham Bay captured higher numbers of non-commercial fish species than species that are targeted commercially. Approximately 253 fish species in 78 families are known to make use of the range of habitats in the Salish Sea (Pietsch and Orr, 2015). The Salish Sea includes the Strait of Georgia, adjacent to the Canadian province of British Columbia, the Strait of Juan de Fuca, and Puget Sound. Eelgrass meadows are common throughout the Salish Sea, especially in the northern region (Christiaen and others, 2016), and they can strongly influence localized marine biodiversity. Commercially valuable fish species that could be vulnerable to capture by a beach seine in this study area include Pacific salmonids, Pacific herring, and surf smelt. Our total catch of these commercial species represented less than 1 percent of the total catch. Fish of non-commercial value such as shiner perch, three-spine stickleback, bay pipefish, saddleback gunnel, Pacific staghorn sculpin, and Pacific sand lance were captured in relatively large numbers throughout our sampling locations. Other beach-seining studies have found shiner perch to be the most abundant species, followed by Pacific sand lance and Pacific herring (Brennan and others, 2004). As our study showed, abundant catch of non-commercial species has been observed in southeastern Alaska fish assemblages (Johnson and others, 2003).

Fish assemblages in eelgrass beds of northern Puget Sound are not well described in the literature to date. This study, as part of a larger site-characterization effort in Bellingham Bay by the CHIPS team, will be helpful in the development of future process-based investigations focused on the movements of sediments and contaminants and their influence on biota.

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