# Nearshore fish in beach habitats associated with the Kenai Lowlands

Final report to the Kenai Peninsula Fish Habitat Partnership
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# Project summary

The marine nearshore provides critical habitat for fish communities, including species that occupy this habitat for rearing, migrating and forage purposes. The Kenai Peninsula Fish Habitat Partnership (KPFHP) identified the value of nearshore habitats and the threats that are posed to them in their 2014 Strategic Marine Conservation Action Plan; however, basic community information is lacking for low gradient, beach sediment habitats (KPFHP, 2014). This information is necessary for decision-making regarding potential shoreline developments, oil spill response procedures, or other activities. The Kachemak Bay National Estuarine Research Reserve (KBNERR) conducted studies to better understand fish communities within beach habitats of the Kenai Lowlands area of eastern Cook Inlet (see Figure 1), and to develop opportunities for future engagement with stakeholders of the area to build stewardship of fish habitat. Over the course of this project, the KBNERR established three representative beach habitat sites in the Kenai Lowlands area for these purposes. We report fish community assemblage and local water quality. During the project, we were also able to support a National Ocean and Atmospheric Administration Hollings Scholar (R. Veldman, co-author) who conducted an analysis of sediment grain sizes and forage fish egg abundances. This report includes a summary of how the nearshore habitat work has led to strengthened community relationships for the purposes of research and stewardship engagement. This project builds upon research previously supported by the KPFHP examining nearshore fish communities at river mouth estuaries found around Kachemak Bay. The work thus far has filled crucial data gaps that, left unfilled, would undermine efforts to address threats to fish habitats or engage in further research on this topic.

# Background

Nearshore habitats are regarded as critical nursery and feeding grounds for larval and juvenile fishes (Simenstad et al., 1982; Bennett, 1989; Blaber et al., 1995). Several different habitat types (e.g., river mouths, beach sediments, rocky substrate, kelp beds, seagrass beds) provide these functions in the KPFHP area. These habitats can enhance juvenile recruitment to adult populations, many of which are valued for cultural or economic reasons (Beck et al., 2001; Dahlgren et al., 2006). Support for forage fish populations is another major benefit provided by these habitats (Springer and Speckman, 1997). Forage fishes can include multiple life stages of the same species, such as with juvenile and adult Pacific herring (*Clupea pallasii*) and Pacific sand lance (*Ammodytes personatus*). The KPFHP has identified threats that nearshore habitats face, namely beach alterations and shoreline development; however, any possible deterrents to these threats are currently being undermined by the lack of information on fish community structure throughout the KPFHP area.

Until recently, the data available on nearshore fish assemblages in the KPFHP area has been sparse. Prior studies have assessed fish community structure within Kachemak Bay (Blackburn

1980; Robards et al., 1999a; Abookire et al., 2000); however, these prior studies likely contain outdated information since these communities are affected by interannual variability (Robards et al., 1999a). With support from the KPFHP, KBNERR recently began investigating the fish communities of nearshore river mouth habitats (Walker et al., 2020; Guo et al., *in review*). Additionally, the University of Alaska is in the final stages of a five-year study (EPSCoR Fire & Ice, Coastal Margins) that samples nearshore estuarine habitats of Kachemak Bay using a study design focused on differential glacial discharge. Still, there is a large data gap for fish communities in beach habitats adjacent and downstream of river mouth sites.

Intertidal beaches also serve as a spawning habitat for a certain forage fishes, including Pacific sand lance and surf smelt (*Hypomesus pretiosus).* Prior studies report different seasonal timing of spawning activity. Around the Kodiak area, Pacific sand lance spawn between February and March (Rogers et al., 1979). A study from the Port Moller estuary reports a longer spawning period between mid-January and late April (McGurk and Warburton, 1992). In Cook Inlet, Pacific sand lance were observed spawning during August to October (Blackburn & Anderson 1997). Specifically, in Kachemak Bay, Pacific sand lance were suggested to spawn annually within a one-to-three-week period during October (Robards et al., 1999b). Thus, we expected Pacific sand lance in the Kenai Lowlands area to spawn in the fall. In Puget Sound, surf smelt spawn year-round (Quinn et al., 2012), while some populations in Burrard Inlet, British Columbia exhibit a summer spawning season (DFO, 2002). We found no records of surf smelt spawning season in Alaska.

The KBNERR has developed a robust body of work demonstrating the importance of terrestrially derived nutrients as drivers of upstream watershed productivity in the Kenai Lowlands area (King et al., 2012; Hoem Neher et al., 2013; Walker and Pierce, 2016; Walker and Pierce, 2017), and there is growing evidence that nearshore areas associated with these rivers may also benefit from the downstream export of nutrients (Walker and King, 2017; Walker and King 2018). Additionally, Alaska Department of Fish and Game (ADFG) clam biologists have documented populations of Eastern Cook Inlet razor clams with differential growth rates depending on beach habitat (ADFG, *pers. comm.*). Razor clams from beaches associated with glacial river outflows have much lower growth rates than those found in nearshore areas associated with groundwater-wetland dominated watersheds (ADFG, 2017). The goal of this project was to complement the ongoing body of work in the Kenai Lowlands area by developing baseline physical and biological datasets. Specifically, we aimed to establish sites and collect fish community data paired with habitat information to better inform future research. In addition, we aimed to quantify grain sizes across the same sites thereby identifying potential spawning habitat usage by forage fishes.

# Methods

## Study area and timeline

The project was conducted in the Kenai Lowlands area of Eastern Cook Inlet, Alaska (Figure 1). Beach habitat sites were established at Anchor Point, Plumb Bluff (local name), and Ninilchik. These sites were chosen for a few reasons, including that they all had relatively easy access and represented well the geographical and physical range of beach habitat in the Kenai Lowlands. Furthermore, each site had qualities that allowed for opportunities for engagement with local community members and research partners. Anchor Point is the southernmost site that also overlaps with a KBNERR long-term monitoring station, and has been used in prior beach seine studies conducted by KBNERR. Ninilchik is the northernmost site that shares access with the popular Ninilchik harbor and river launch. Plumb Bluff is located approximately midway between Anchor Point and Ninilchik, whose access was granted to KBNERR by the local community members, including families and charter business owners. These sites were visited on a monthly schedule from May to November 2021 for data collection of fish community, water quality, and sediment analysis (see Table 1).

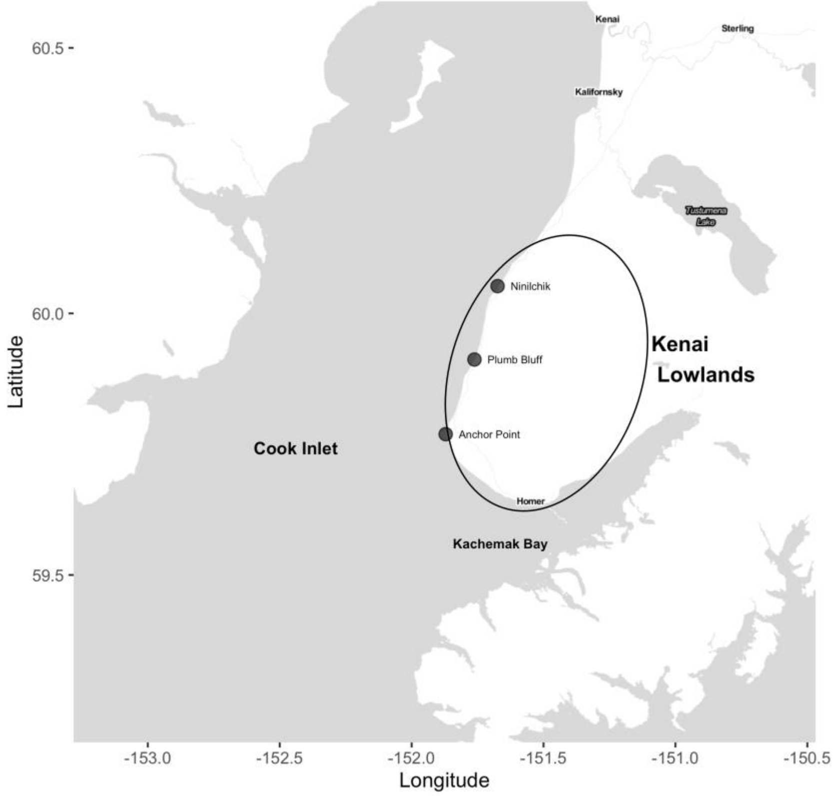

Figure 1. Map of study area (Kenai Lowlands, circled) and research sites (Anchor Point, Plumb Bluff, Ninilchik), located in East Cook Inlet on the southern portion of the Kenai Peninsula.

# Measurement of fish community and water quality

Fish community assemblage was measured with abundance and size metrics. Fish were collected monthly by beach seine from May to September 2021 (Table 1). Sampling occurred within two hours of the low slack tide, reducing effects related to the tidal stage. At least three replicates (seining sets) were conducted per site visit. All individuals caught (including macroinvertebrates) were identified to the lowest taxonomic level possible (usually species), counted, sized (30 individuals per species), and released live. Total catch was summarized for fish community assemblage (i.e., species abundance, life stage, and size range). Local water quality was measured concurrently with each beach seine at the apex point of setting the net. Surface measurements were collected for temperature (°C), salinity, dissolved oxygen (mg/L), and turbidity (FNU) using a multi-parameter water quality sonde (YSI, EXO1 Water Quality Sonde) at one-meter depth or half the distance to the sea floor. Probing instruments were calibrated monthly using manufacturer software (YSI, KOREXO v1.59).

# Grain size and fish egg abundance

Data on forage fish spawning habitats in the nearshore beaches of Kenai Lowlands area is relatively sparse. Thus, prior knowledge was drawn from other regions of Alaska and the Pacific Northwest. Prior Studies documenting Pacific sand lance habitat in other regions of Alaska and the Pacific Northwest indicate that spawning occurs in both 0.25-0.5 mm and 1-7 mm sand (WWF-CAMR, 2020); however, it is unclear whether the unreported usage of 0.5-1 mm grain sizes is a real or pseudo absence. Surf smelt prefer spawning habitat with a similar grain size range between 1-7mm (WWF-CAMR, 2020). Both Pacific sand lance and surf smelt prefer minimal silt; although, we are unaware of any reports quantifying a minimum silt amount (WWF-CAMR, 2020).

Intertidal sediment samples were collected monthly from May to November 2021 from three transects at each of the beach habitat sites (Figure 2A-C). Five samples were collected along each transect, spanning two beach gradients: a high-gradient upper intertidal zone and a low-gradient lower intertidal zone (Figure 2D). A single sediment sample consisted of a bulk amount of approximately 1.77 L. A subsample of 100 - 200 g was separated from each bulk sample collected in June and processed for grain size classifications (Wentworth 1922). The first two transects from each site were sieved through 4 mm, 2 mm, 0.5 mm, and 0.075 mm sieves, while the third transect was sieved through 4 mm, 2 mm, 0.5 mm, and 0.106 mm. This change in the methodology protocol was due to a change in equipment available. This was accounted for during analysis using the statistical program GRADISTAT (Blott and Pye, 2001). The percentage of smaller grain sizes (<0.075 mm and <0.106 mm) was determined by subtracting the total weights in each sieve from the initial dried bulk density weight. While this method is at risk of a high percentage of error due to factors such as mud particles adhering to larger particles or sticking to the sieves, because of the consistency of this analysis, it still allows for comparison of smaller particle percentages across samples. The percentage of gravel, percentage of sand, percentage of mud, and mean grain size per sample was determined by the GRADISTAT statistics program (Blott and Pye, 2001). Mean grain size was calculated using three different statistical methods, method of moments (arithmetic), method of moments (geometric), and Folk and Ward (Blott and Pye, 2001).

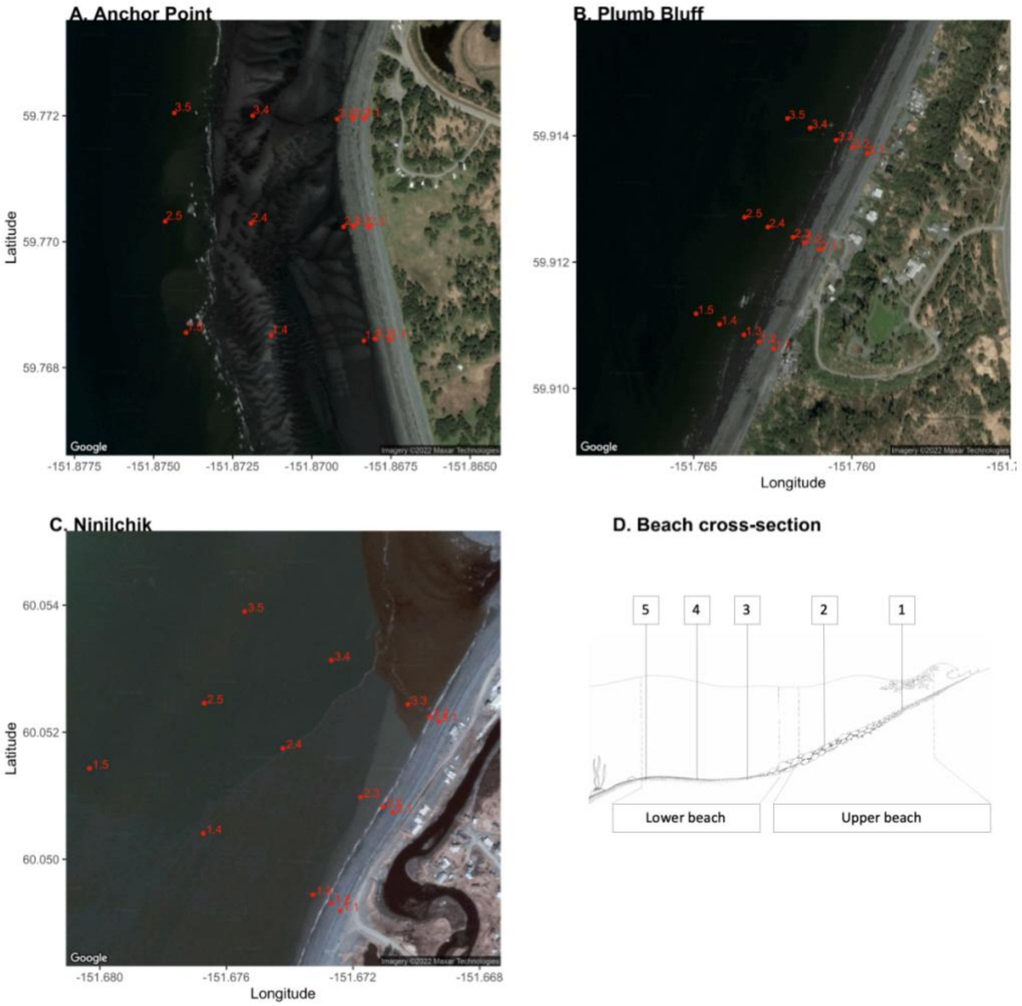

Figure 2. Sediment collection transects and locations at each site: (A) Anchor Point, (B) Plumb Bluff, and (C) Ninilchik. Sampling locations within each transect were spread amongst the upper and lower sections of the (D) beach elevation gradient. All sampling points are indicated in red with labels representing transect and location (e.g., 3.2 = second location along the third transect). Beach cross-section illustration by Conrad Field.

Bulk sediment samples (n = 270) were kept cold until they were able to be processed in the lab. Samples were sieved through 2 mm and 0.5 mm sieves, isolating the fraction of the sample that would contain forage fish eggs. They were then processed in a hydro-cyclone device to condense and concentrate the lighter material from the heavier sediment. This vortex functions by creating a pressure gradient that moves the less-dense material, containing eggs, through the cone and into the sieve (Dionne, 2015). The lighter material was preserved in Stockard's solution. The isolated less-dense material was then examined under 30x magnification, observing fish egg presence, abundance and identifiable taxa. Identification was based upon morphological descriptions and diagrams (Moulton and Pentilla, 2006).

# Results

## Overview

Site visits were made on an approximately monthly basis (Table 1). Data collection for fish community and water quality were made on separate visits than those for sediment grabs for fish egg abundance and grain size fraction. Fish community and water quality measurements were conducted from May to September for all sites, except for the May sample from Plumb Bluff. Sediment grabs were conducted from May to November from all sites; however, samples were unevenly distributed during early and late seasons due to weather and protocol tuning. Sediment samples from June were used for grain size fraction analysis. Monthly site visits allowed our team to observe seasonal changes in data collected, as well as provide opportunities for happenstance interactions with local stakeholders. This was particularly useful in engaging with the local community at Plumb Bluff as this was a new community engagement opportunity for KBNERR. Additionally, monthly visits to Anchor Point and Ninilchik allowed KBNERR to opportunistically engage with the ADFG Sportfish team members while they conducted management activities in these areas (e.g., share personnel and materials, crosswalk initiatives).

Table 1. Summary of samples collected per site, analysis type, and date during the 2021 field season. Sediment samples used for grain size analyses were collected in June, indicated by [*].

| Site | Analysis type | Month-Day | #Samples |
|---|---|---|---|
| Anchor Point | Fish community & water quality | 05-25 | 3 |
| | | 06-10 | 3 |
| | | 07-15 | 3 |
| | | 08-12 | 4 |
| | | 09-09 | 3 |
| | Fish egg abundance & grain size | 05-26 | 6 |
| | | 05-29 | 6 |
| | | *06-25 | *15 |
| | | 07-25 | 15 |
| | | 08-23 | 15 |
| | | 09-21 | 15 |
| | | 11-05 | 15 |
| Ninilchik | Fish community & water quality | 05-28 | 3 |
| | | 06-09 | 3 |
| | | 07-14 | 3 |
| | | 08-11 | 3 |
| | | 09-08 | 3 |
| | Fish egg abundance & grain size | 05-28 | 12 |
| | | *06-24 | *15 |

|  |  |  |  |
|---|---|---|---|
|  |  | 07-24 | 15 |
|  |  | 08-24 | 15 |
|  |  | 09-21 | 15 |
|  |  | 11-04 | 14 |
| Plumb Bluff | Fish community & water quality | 06-11 | 3 |
|  |  | 07-13 | 3 |
|  |  | 08-09 | 3 |
|  |  | 09-07 | 3 |
|  | Fish egg abundance & grain size | 05-27 | 30 |
|  |  | *06-26 | *15 |
|  |  | 07-23 | 15 |
|  |  | 08-25 | 15 |
|  |  | 09-20 | 15 |
|  |  | 11-04 | 14 |

## Fish collections

A total of 8,420 individuals were collected during beach seine surveys, comprising 40 fish taxa and seven macroinvertebrate taxa (Table 2). A subset of the total (n = 3,898) was also sized by length or width depending on the taxa. Fishes encountered included taxa from the flatfishes, sculpins, salmonids, gadids, greenlings, poachers, gunnels, and smelts among others. The most abundant fish was the surf smelt, followed by young-of-the-year (YOY) Pacific herring, and the sand sole (*Psettichthys melanostictus*). Other common fishes included the sturgeon poacher (*Podothecus accipenserinus*), Pacific tom cod (*Microgadus proximus*), staghorn sculpin (*Leptocottus armatus*), Pacific sand lance, and starry flounder (*Platichthys stellatus*). The macroinvertebrates encountered were predominantly crab (*Brachyura*) or shrimp (*Caridea*). Gammarids (*Gammaridae*) were also common and abundant but were not quantified. By far the most abundant macroinvertebrate was the sand shrimp (*Crangonidae*), and the most abundant crab was the dungeness (*Metacarcinus cancer*).

Mean fish sizes were relatively small for most taxa measured (<200 mm, Table 2). The lower range of most taxa was very small (<50 mm) as most individuals collected appeared to be in the juvenile life stage. However, individuals of most taxa were indistinguishable between juvenile and adult life stages, except for adult pink salmon (*Oncorhynchus gorbuscha*) and juveniles of Pacific halibut (*Hippoglossus stenolepis*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and chinook salmon (*O. tshawytscha*). The largest individuals sized (>200 mm) were from taxa including the starry flounder, sand sole, staghorn sculpin, adult pink salmon, and Dolly Varden trout (*Salvelinus malma*); although, these were usually collected along with numerous smaller individuals of the same taxa. The young of the year (YOY) individuals that were encountered include Pacific herring, surf smelt, Pacific sand lance, capelin (*Mallotus villosus*), walleye pollock (*Gadus chalcogrammus*), saffron cod (*Eleginus gracilis*), and starry flounder. Except for starry flounder, these species are all considered important forage fishes in marine food web (Springer and Speckman, 1997).

Table 2. Fish and macroinvertebrate collection information for all individuals caught. Taxonomies represent lowest identification possible. Life stages were classified into young-of-the-year (YOY), juvenile (J), or adult (A), but most taxa were indistinguishable between juvenile and adult (J/A). Sizes (mm) were measured using different method types depending on the taxa as total length (TL), fork length (FL), rostrum-tail length (RT), or carapace-width (CW).

| **Scientific name** | **Common name** | **Life stage** | **Counts** | **Sizes** | | |
|---|---|---|---|---|---|---|
| | | | Total (#Sized) | Mean | Range | Type |
| Fishes | | | | | | |
| *Ammodytes personatus* | Pacific Sand Lance | YOY | 185 (103) | 56 | (39-78) | TL |
| | | J/A | 166 (61) | 69 | (43-109) | TL |
| *Atradius fenestralis* | Padded Sculpin | J/A | 31 (31) | 113 | (75-170) | TL |
| *Artedius harringtoni* | Scalyhead Sculpin | J/A | 13 (13) | 94 | (62-136) | TL |
| *Blepsias cirrhosus* | Silver Spotted Sculpin | J/A | 144 (101) | 76 | (37-162) | TL |
| *Clinocottus acuticeps* | Sharpnose Sculpin | J/A | 1 (1) | 45 | -- | TL |
| *Clupea pallasii* | Pacific Herring | YOY | 971 (146) | 36 | (22-60) | FL |
| | | J/A | 28 (28) | 103 | (93-141) | FL |
| *Cottidae* | Unidentified Sculpin | J/A | 12 (10) | 22 | (12-29) | TL |
| *Eleginus gracilis* | Saffron Cod | YOY | 3 (3) | 67 | (53-74) | FL |
| | | J/A | 4 (4) | 68 | (64-71) | FL |
| *Enophrys bison* | Buffalo Sculpin | J/A | 17 (17) | 35 | (7-135) | TL |
| *Gadus chalcogrammus* | Walleye Pollock | YOY | 5 (5) | 49 | (43-61) | FL |
| *Gadus macrocephalus* | Pacific Cod | J/A | 16 (16) | 97 | (78-112) | FL |
| *Gymnocanthus galeatus* | Armorhead Sculpin | J/A | 3 (2) | 90 | (74-105) | TL |
| *Hexagrammos decagrammus* | Kelp Greenling | J/A | 4 (4) | 58 | (47-63) | FL |
| *Hexagrammos octogrammus* | Masked Greenling | J/A | 1 (1) | 65 | -- | FL |
| *Hexagrammos stelleri* | White Spotted Greenling | J/A | 80 (80) | 103 | (20-262) | FL |
| *Hippoglossus stenolepis* | Pacific Halibut | J | 139 (137) | 89 | (32-197) | TL |
| *Hypomesus pretiosus* | Surf Smelt | YOY | 130 (85) | 43 | (28-59) | FL |
| | | J/A | 1320 (233) | 93 | (54-205) | FL |
| *Lepidopsetta spp.* | Rock Sole | J/A | 157 (118) | 92 | (26-175) | TL |
| *Leptocottus armatus* | Staghorn Sculpin | J/A | 314 (310) | 226 | (20-352) | FL |
| *Liparis spp.* | Snailfish | J/A | 100 (90) | 38 | (13-90) | TL |
| *Lumpenus sagitta* | Snake Prickleback | J/A | 67 (67) | 171 | (83-323) | TL |
| *Mallotus villosus* | Capelin | YOY | 15 (15) | 41 | (25-47) | FL |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Microgadus proximus* | Pacific Tom Cod | J/A | 348 (269) | 182 | (70-286) | FL |
| *Myoxocephalus polyacanthocephalus* | Great Sculpin | J/A | 12 (12) | 58 | (21-105) | TL |
| *Myoxocephalus scorpius* | Shorthorn Sculpin | J/A | 2 (2) | 134 | (80-188) | TL |
| *Oligocottus maculosus* | Tidepool Sculpin | J/A | 10 (10) | 48 | (33-73) | TL |
| *Oncorhynchus gorbuscha* | Pink Salmon | A | 2 (2) | 310 | (170-451) | FL |
| *Oncorhynchus kisutch* | Coho Salmon | J | 3 (3) | 96 | (95-97) | FL |
| *Oncorhynchus nerka* | Sockeye Salmon | J | 1 (1) | 48 | -- | FL |
| *Oncorhynchus tshawytscha* | Chinook Salmon | J | 15 (15) | 109 | (104-120) | FL |
| *Pallasina barbata* | Tubenose Poacher | J/A | 103 (97) | 65 | (26-153) | TL |
| *Parophrys vetulus* | English Sole | J/A | 193 (167) | 97 | (36-142) | TL |
| *Pholis laeta* | Crescent Gunnel | J/A | 9 (9) | 135 | (34-170) | TL |
| *Platichthys stellatus* | Starry Flounder | YOY | 18 (18) | 31 | (19-40) | TL |
| | | J/A | 278 (227) | 227 | (50-619) | TL |
| *Pleuronectes quadrituberculatus* | Alaska Plaice | J/A | 1 (1) | 56 | -- | TL |
| *Pleuronectidae* | Unidentified Flatfish | J/A | 12 (6) | 26 | (11-43) | TL |
| *Podothecus accipenserinus* | Sturgeon Poacher | J/A | 475 (266) | 53 | (20-193) | TL |
| *Psettichthys melanostictus* | Sand Sole | J/A | 712 (597) | 114 | (24-510) | TL |
| *Pungitius pungitus* | Nine Spine Stickleback | J/A | 1 (1) | 47 | -- | TL |
| *Salvelinus malma* | Dolly Varden | J/A | 29 (29) | 190 | (119-340) | FL |
| *Spirinchus thaleichthys* | Longfin Smelt | J/A | 27 (27) | 112 | (88-132) | FL |
| *Trichodon trichodon* | Sandfish | J/A | 26 (25) | 148 | (63-197) | FL |
| Macroinvertebrates | | | | | | |
| *Brachyura* | Unidentified Crab | J/A | 7 (0) | -- | -- | -- |
| *Caridea* | Unidentified Shrimp | J/A | 12 (3) | 47 | (45-50) | RT |
| *Crangonidae* | Sand Shrimp | J/A | 2150 (391) | 53 | (10-103) | RT |
| *Hapalogaster mertensii* | Hairy Crab | J/A | 1 (1) | 52 | -- | CW |
| *Metacarcinus magister* | Dungeness Crab | J/A | 26 (26) | 79 | (22-163) | CW |
| *Oregonia gracilis* | Graceful Decorator Crab | J/A | 8 (3) | 22 | (5-44) | CW |
| *Paguridae* | Hermit Crab | J/A | 4 (0) | -- | -- | -- |
| *Pandalus spp.* | Pandalus Shrimp | J/A | 2 (2) | 36 | (28-44) | RT |
| *Pugettia gracilis* | Graceful Kelp Crab | J/A | 7 (7) | 19 | (12-24) | CW |

## Water quality

Each water quality parameter measured exhibited temporal and/or site variability to an extent (Figure 3). Across all sites, water temperature increased from May through August, then decreased slightly in September (Figure 3A). By contrast, oxygen saturation decreased from May to August before increasing slightly in September (Figure 3B). Overall, salinity decreased from May to September (Figure 3C). Turbidity did not appear to exhibit temporal patterns (Figure 3D).

Sites exhibited noticeable differences in water quality when compared amongst each other (Figure 3). Water temperature and turbidity at Ninilchik was higher than Anchor Point and Plumb Bluff from May to July. Ninilchik oxygen saturation and salinity was lower than the other sites from May to August. Ninilchik also exhibited high variability in turbidity from June measurements and in salinity from August measurements. Another interesting site difference was that Plumb Bluff measurements were lower in temperature and higher in salinity compared to the other two sites. In general, however, the mean and variance for all measurements among the three sites became more similar by September.

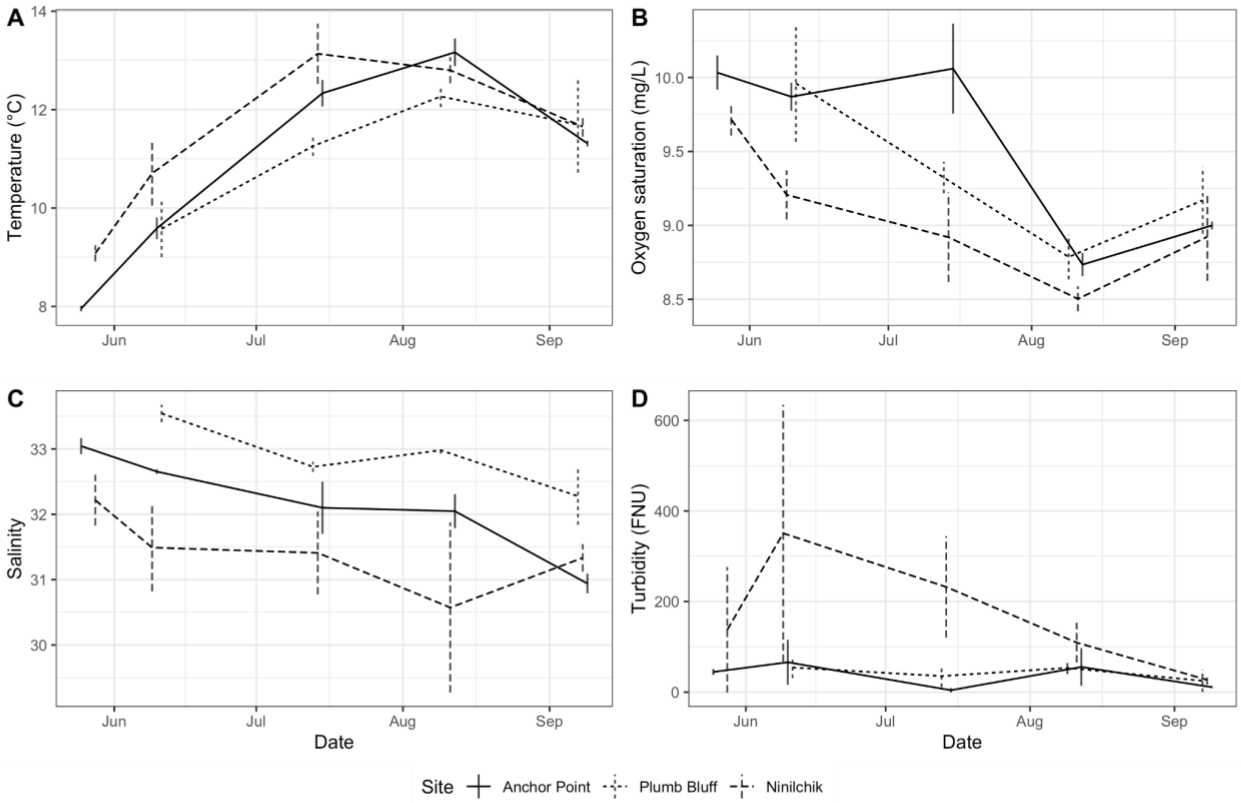

Figure 3. Monthly mean water quality measurements by site for (A) temperature, (B) oxygen saturation, (C) salinity, and (D) turbidity. Vertical bars indicate the standard deviation from the mean, and different line types represent each site.

Site differences in water quality can potentially be explained by the relative distance to river outflows and overall spatial context. The Ninilchik beach site is located close (<0.5 km) to a river outflow (Ninilchik River). Comparatively, the Anchor Point and Plumb Bluff sites are much further from major river outflows: approximately 3.5 km from the Anchor River and 2.5 km from Stariski Creek, respectively. Furthermore, Plumb Bluff had a much shorter beach width (distance between uppermost and lowermost beach locations) compared to the relatively vast beach width at Ninilchik (see Figure 2). Thus, the Plumb Bluff beach site appeared to have more oceanic influences (i.e., higher salinity and lower temperature) compared to the relatively shallow and warm Ninilchik beach site (Figure 3A, 3C).

## Sediment grain size

Intertidal sediment samples from the upper intertidal zone were predominantly gravel and sand, while the lower intertidal zone had minimal percentages of gravel consisting almost entirely of sand (Table 3; Figure 2D). Percent mud was relatively low at all sites and transect locations (Figure 4), except for anomalous samples from Ninilchik transect location 3 (Table 3) There was an observed bimodality in the grain size distribution among all sites, where the upper zone was predominantly sand-gravel and the lower zone was primarily sand (Table 3; Figure 4).

Table 3. Mean and standard deviation percent grain fraction by site and transect location (n = 3, see also Table 1 and Figure 2D). Grain fractions include size classes of gravel (2 to 64 mm), sand (0.063 to 2 mm), and mud (<0.063 mm; includes both silt and clay) (Udden, 1914; Wentworth, 1922).

| | | Anchor Point | | Plumb Bluff | | Ninilchik | |
|---|---|---|---|---|---|---|---|
| Location | Class | Mean% | Sd | Mean% | Sd | Mean% | Sd |
| 1 | Gravel | 51.40 | 5.16 | 58.70 | 4.44 | 46.10 | 16.88 |
| | Sand | 47.93 | 5.07 | 40.37 | 4.36 | 52.73 | 16.35 |
| | Mud | 0.67 | 0.17 | 0.93 | 0.09 | 1.17 | 0.54 |
| 2 | Gravel | 75.40 | 3.48 | 66.07 | 10.01 | 42.43 | 2.98 |
| | Sand | 24.07 | 3.45 | 33.03 | 9.99 | 56.57 | 3.09 |
| | Mud | 0.57 | 0.07 | 0.93 | 0.09 | 1.00 | 0.12 |
| 3 | Gravel | 5.67 | 4.43 | 5.70 | 3.00 | 0.23 | 0.23 |
| | Sand | 92.07 | 4.44 | 92.83 | 2.90 | 70.97 | 20.47 |
| | Mud | 2.23 | 0.62 | 1.47 | 0.12 | 28.80 | 20.62 |
| 4 | Gravel | 1.10 | 0.61 | 0.43 | 0.12 | 0.13 | 0.13 |
| | Sand | 97.40 | 0.15 | 97.33 | 0.28 | 96.57 | 0.84 |
| | Mud | 1.50 | 0.74 | 2.23 | 0.38 | 3.33 | 0.88 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Gravel | 0.00 | 0.00 | 1.93 | 1.59 | 0.07 | 0.03 |
| | Sand | 98.23 | 0.44 | 94.27 | 2.15 | 92.83 | 4.88 |
| | Mud | 1.73 | 0.45 | 3.83 | 0.73 | 7.13 | 4.89 |

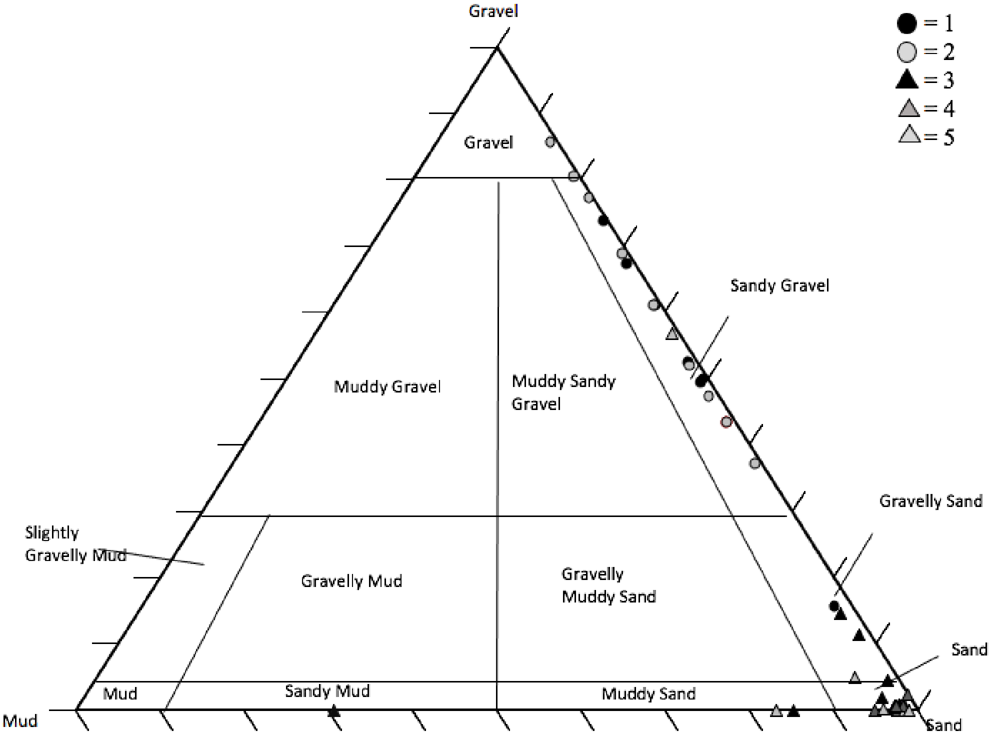

Figure 4. Ternary diagram with gravel, sand, and mud (silt + clay) distribution for all samples (n = 45) from all sites. Grain size calculated with GRADISTAT statistical program (Blott and Pye, 2001), and diagram produced with Tri-Plot Software (Graham and Midgley, 2000). Circles represent the upper intertidal zone (locations 1 and 2) and triangles represent the lower intertidal zone (locations 3-5; see also Figure 2D).

The mean grain size of the upper intertidal zone was higher than the lower intertidal zone (Figure 5). The method of moments analysis (arithmetic) provided grain size results almost twice as large as that of its counterparts. When taking into account standard error, all three analysis types show that the upper intertidal zone is a potential spawning habitat for Pacific sand lance, as it falls within the 1-7mm preference (WWF-CAMR, 2020). According to the method of moments (geometric) analysis, the third and fourth sampling locations within the lower intertidal zone are also potential spawning grounds for Pacific sand lance. The method of moments (arithmetic) gives an approximation for the mean grain size of site three that fits within the preference parameters for Pacific sand lance; however, the Folk and Ward analysis approximates the mean grain size to be below 0.25 mm for all sites within the lower intertidal zone.

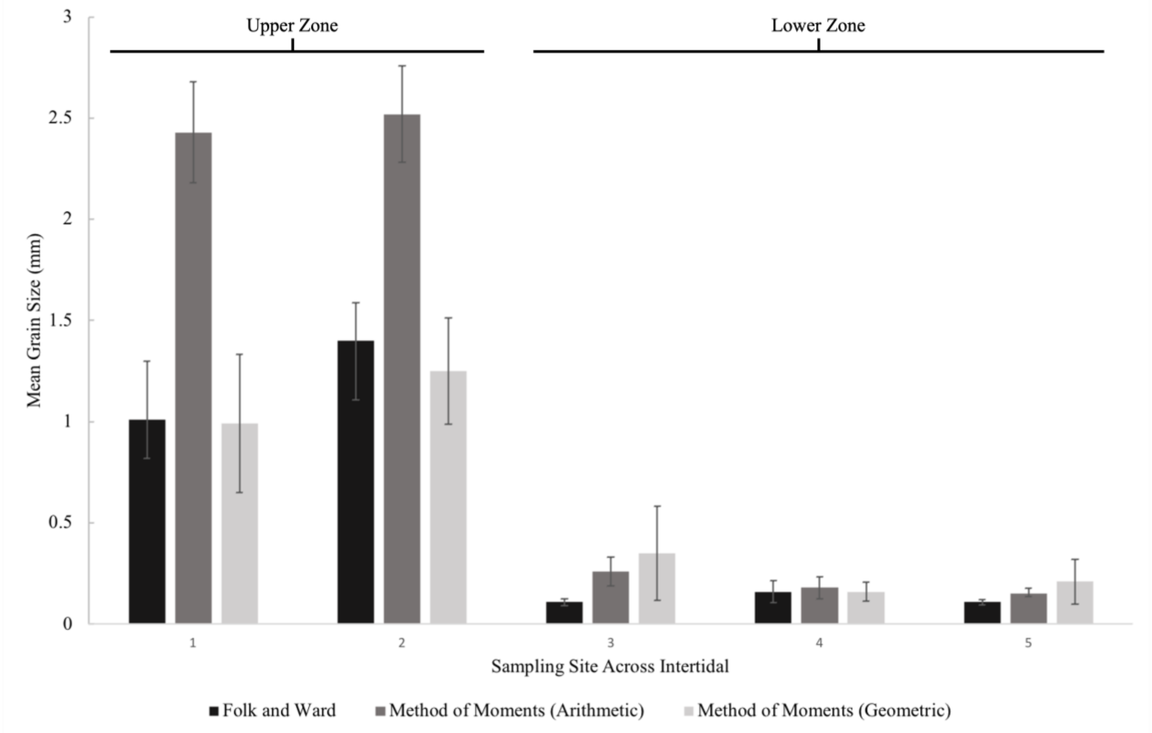

Figure 5. Mean grain size by transect location (n = 45, see also Table 1 and Figure 2D) using three different calculation methods. Statistical analysis done by GRADISTAT program (Blott and Pye, 2001).

## Fish egg abundances

A total of 85 eggs were observed from 16 samples. Of these, 73 were identified as Pacific sand lance (Figure 6), eight as surf smelt, and four were unidentified. The unidentified eggs were likely either rock sole (*Lepidopsetta spp.*) or Pacific herring; however, taxonomy was not confirmed. Pacific sand lance eggs were found in both the upper and lower intertidal zones, with the highest abundance in the lower zone in May (Figure 7). We expected to find the highest abundance of eggs in the fall; however, only seven eggs were observed in September and none in November. The eggs observed in September and August were all carapaces (Figure 6B), indicating that the eggs had either ruptured or hatched. The lack of Pacific sand lance eggs observed in the fall months could be due to limited effort resulting from our sampling design.

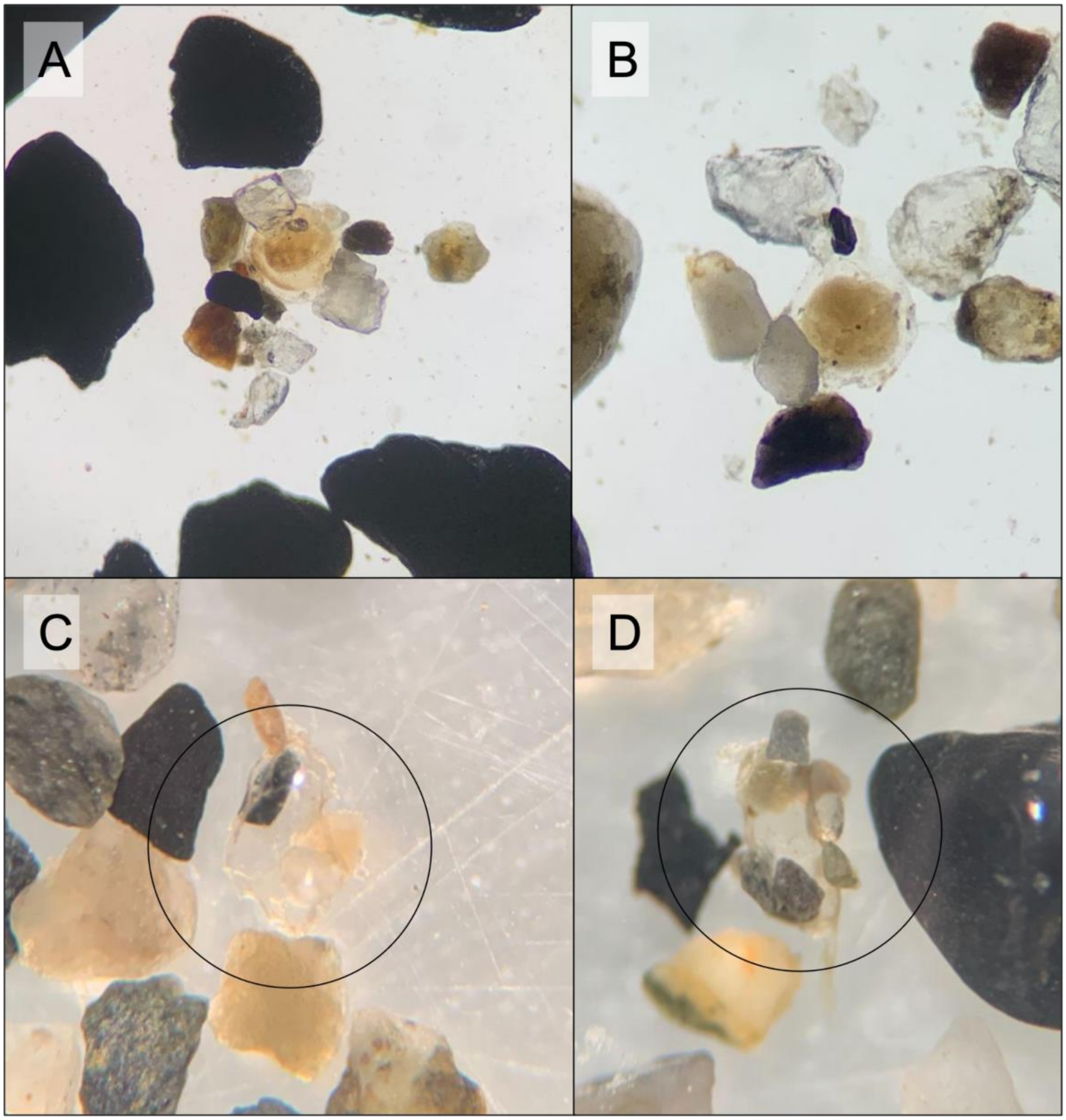

Figure 6. Images of Pacific sand lance eggs at 30x magnification. Unhatched eggs collected in May 2021 are shown from (A) Anchor Point and from (B) Ninilchik. Sometimes egg carapaces (black circles in C and D) were observed such as those from Anchor Point in September 2021. Note: Pacific sand lance eggs were attached to multiple grains of sand via connection points on the outer membrane. Photo credit: Renee Veldman.

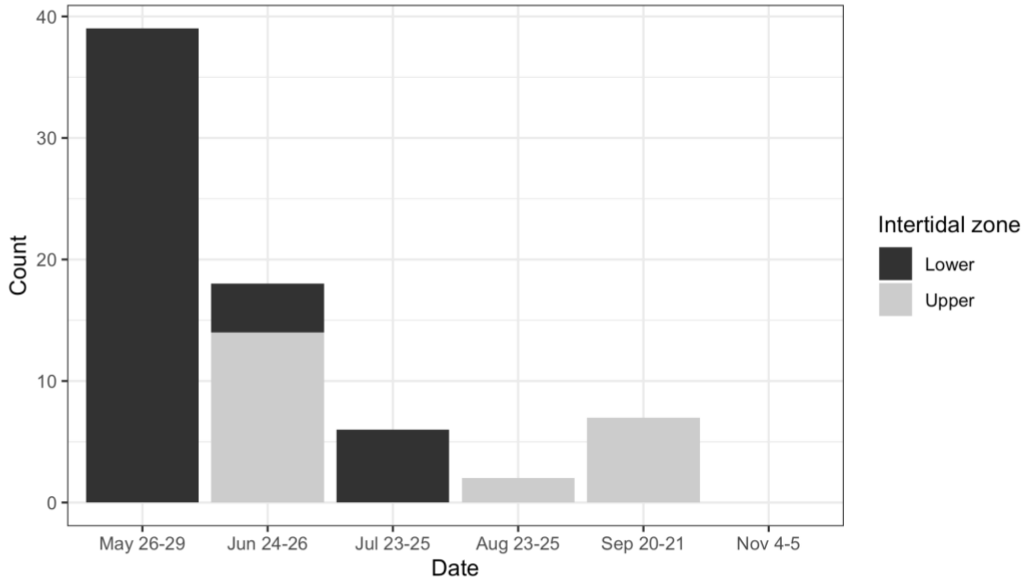

Figure 7. Abundance of Pacific sand lance eggs observed in monthly sediment grabs from all sites during May to November 2021 (n = 277). Bar shade represents the intertidal zone where eggs were collected (see also Figure 2D).

# Conclusions

The beach habitats of the Kenai Lowlands support a diverse community of fish and invertebrates. In particular, these habitats appear to be important for juvenile fishes as evidenced by the dominance of relatively small individuals (<200 mm) amongst most taxa. Furthermore, these beaches provide habitat for important species of interest including juvenile Pacific salmon and Pacific halibut, as well as YOY of numerous forage fishes. By far the most abundant taxa were sand shrimp (mean size = 53 mm) and juvenile/adult surf smelt (mean size = 93 mm), indicating that these habitats are likely to support substantial mid-trophic biomass. Habitat characteristics such as distance to nearest river outflow and overall beach gradient likely influenced the local water quality and habitat conditions at our sites. For example, Ninilchik appeared to consistently accrue more detached kelp (submerged beach wrack) compared to the other two sites due to its relatively low gradient and shallow waters. This in addition to its proximity to river outflow, which likely reduced oxygen saturation and salinity, increased water temperature, and at times created highly turbid conditions.

There was bimodality in the grain size distribution along the beach elevation gradient. The upper intertidal zone was composed of finer grain sizes (sandy gravel) than the lower intertidal zone (gravelly sand). Therefore, we expected Pacific sand lance and surf smelt eggs to be more abundant in the upper intertidal zone. However, Pacific sand lance eggs were found primarily in the lower zone. Differing distributions among sites and beach locations may be influenced by water movement by wind, wave, or tidal forces. This study suggests that Pacific sand lance in the East Cook Inlet may spawn in late spring rather than fall; although, a higher resolution study design would provide better insight on this issue.

Few surf smelt eggs were observed (n = 8), which was unexpected because of the high abundance of surf smelt collected in beach seine surveys. This low egg abundance does not indicate a lack of spawning habitat at these sites. Rather, it is more likely that our sampling design did not accurately capture surf smelt egg distribution. This inconsistency could also be due to interannual variability in the densities of spawning populations and/or eggs laid (Parks et al., 2013). Variability in egg density is related to sea surface temperatures (Kaltenberg et al., 2010). A multi-year, high resolution assessment accounting for such factors would illuminate the spatial and temporal patterns of surf smelt egg abundances in the study area.

This study provided new information on nearshore fish assemblages, water quality, grain size, and intertidal egg abundances for nearshore sites along the Kenai Lowlands. Collectively, these sites introduced new avenues to engage with local communities and helped to strengthen KBNERR's ongoing efforts to better understand the Kenai Lowlands beach habitats. As a result of the findings of this project, we suggest the following next steps to further the research. Continuing to monitor fish community assemblage and habitat characteristics will help account for interannual variability. We suggest to additionally investigate drivers of observed mid-trophic production because of the high abundance of YOY and juvenile forage fishes (including sand shrimp). Furthermore, such information would be potentially useful to ADFG Sportfish biologists regarding their management of the local razor clam fishery. Lastly, we suggest future comparisons of findings with other sites along the Kenai Lowlands area. This would increase the analytical power of the research and strengthen the relevance of the science to the community of the Kenai Lowlands.

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# References

Abookire AA, Piatt JF, Robards MD (2000) Nearshore fish distributions in an Alaskan estuary in relation to stratification, temperature and salinity. Estuar Coast Shelf Sci 51:41-59. doi: 10.1006/ecss.1999.0615

Alaska Department of Fish and Game (2017) Cook Inlet razor clams. Online article available at http://www.adfg.alaska.gov/static-sf/region2/pdfpubs/clams.pdf. Department of Sport Fish, Southcentral Region: Anchorage, Alaska.

Beck MW, Heck KL, Able KW, et al. (2001) The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. Bioscience 51:633-641.

Bennett BA (1989) The fish community of a moderately exposed beach on the southwestern cape coast of South Africa and an assessment of this habitat as a nursery for juvenile fish. Estuar Coast Shelf Sci 28:293-305.

Blaber SJM, Brewer DT, Salini JP (1995) Fish communities and the nursery role of the shallow inshore waters of a tropical bay in the gulf of Carpentaria, Australia. Estuar Coast Shelf Sci 40(2):177-193. doi: 10.1016/S0272-7714(05)80004-6

Blackburn JE (1980) Pelagic and demersal fish assessment in the lower Cook Inlet estuary system. In: Environmental Assessment of the Alaskan Continental Shelf: Annual Reports of the Principal Investigators for the year ending March 1979. Vol. 4: Receptors - Fish, Littoral, Benthos. Alaska Department of Fish and Game, Kodiak, Alaska, 289-446.

Blackburn JE, Anderson, PJ (1997) Pacific sand lance (*Ammodytes hexapterus)* growth, seasonal availability, movements, catch variability, and food in the Kodiak-Cook Inlet area of Alaska. Proceedings, Symposium on the Role of Forage Fish in the Marine Ecosystem, 409-426.

Blott SJ, Pye K (2001) GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surface Processes and Landforms 26:1237-1248.

Dahlgren CP, Kellison GT, Adams AJ, et al. (2006) Marine nurseries and effective juvenile habitats: Concepts and applications. Mar Ecol Prog Ser 312:291-295. doi: 10.3354/meps312291

Department of Fisheries and Oceans (2002) Surf smelt. Stock status, Pacific region, Department of Fisheries and Oceans. Final report. Can Sci Advis Sec, B6-09.

Dionne P (2015) Vortex method for separation of forage fish eggs from beach sediment. Technical report. Washington Department of Fish and Wildlife, Olympia, Washington.

Graham DJ, Midgley NG (2000) Graphical representation of particle shape using triangular diagrams: an Excel spreadsheet method. Earth Surf Process Landf 25(13):1473-1477.

Hoem Neher TD, Rosenberger AE, Zimmerman CE, et al. (2013) Estuarine environments as rearing habitats for juvenile coho salmon in contrasting south-central Alaska watersheds. Trans Am Fish Soc 142:1481-1494. doi: 10.1080/00028487.2013.815660

Kaltenberg AM, Emmett RL, Benoit-Bird KJ (2010) Timing of forage fish seasonal appearance in the Columbia River plume and link to ocean conditions. Mar Eco Prog Ser 419:171-184. doi: 10.3354/meps08848

Kenai Peninsula Fish Habitat Partnership (2014) Marine Conservation Action Plan. Kenai Peninsula Fish Habitat Partnership, Soldotna, Alaska.

King RS, Walker CM, Whigham DF, et al. (2012) Catchment topography and wetland geomorphology drive macroinvertebrate community structure and juvenile salmonid distributions in southcentral Alaskan headwater streams. Freshw Sci 31(2):341–364. doi: 10.1899/11-109.1

McGurk MD, Warburton HD (1992) Pacific sand lance of the Port Moller estuary, southeastern Bering Sea: an estuarine-dependent early life history. Fish Ocean 1:306–320.

Moulton L, Pentilla D (2006) San Juan County forage fish assessment project: field manual for sampling forage fish spawn in intertidal shore regions First Edition. San Juan County Marine Resource Committee and Northwest Straits Commission, La Conner, Washington, 1-23.

Parks D, Shaffer A, Barry D. (2013). Nearshore drift-cell sediment processes and ecological function for forage fish: Implications for ecological restoration of impaired Pacific Northwest Marine Ecosystems. J Coast Res 289:984–997.

Quinn T, Krueger K, Pierce K, et al. (2012) Patterns of surf smelt, *hypomesus pretiosus,* intertidal spawning habitat use in Puget sound, Washington State. Estuar Coast 35(5):1214–1228.

Robards MD, Piatt JF, Kettle AB, et al. (1999a) Temporal and geographic variation in fish communities of lower Cook Inlet, Alaska. Fish Bull 97(4):962-977. doi: 10.1155/2015/765406

Robards MD, Piatt JF, Rose GA (1999b) Maturation, fecundity, and intertidal spawning of Pacific sand lance in the northern Gulf of Alaska. J Fish Bio 54(5):1050–1068.

Rogers DE, Rabin DJ, Rogers BJ, et al. (1979) Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Final report. University of Washington, Fisheries Research Institute, Seattle, Washington. FRI-UW-7925, 1-291.

Simenstad CA, Fresh KL, Salo EO (1982) The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. In: Estuarine Comparisons. Elsevier, Gleneden Beach, Oregon, 343-364.

Springer AM, Speckman SG (1997) A forage fish is what?: summary of the symposium. Alaska Sea Grant College Program, AK-SG-97-01. Proceedings, Forage Fishes in Marine Ecosystems 773-795.

Udden JA (1914) Mechanical composition of clastic sediments. Bull Geo Soc Amer 25:655-744.

Walker CM, Guo C, Argueta J (2020) Characterizing biological communities of nearshore habitats associated with river mouths. Final report. Kenai Peninsula Fish Habitat Partnership, Soldotna, Alaska.

Walker CM, Pierce BD (2016) Estuary habitat use by juvenile chinook and coho salmon in a Kenai Lowlands (Anchor) river. Final report. State Wildlife Grant, T-31-13, P-01.

Walker CM, Pierce BD (2017) Habitat models for juvenile salmon rearing in Cook Inlet estuaries. Final report. State Wildlife Grant, T-36-13, P-01.

Walker CM, King RS (2017) Downstream effects of headwater stream productivity on juvenile salmonids and stream macroinvertebrate communities in the Kenai Lowlands. Final Report. State Wildlife Grant, T-35-1, P-01.

Walker CM, King RS (2018) Headwater stream nutrient export and downstream community response. Final Report. State Wildlife Grant T-37-1, P-01.

World Wildlife Fund - Canada and Archipelago Marine Research (2020) Forage fish spawning surveys in British Columbia. Mount Arrowsmith Biosphere Region Research Institute, Vancouver Island, British Colombia.

Wentworth CK (1922) A scale of grade and class terms for clastic sediments. J Geo 30:377-392.