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Eelgrass Habitat and Faunal Assemblages in the City and Borough of Juneau, Alaska

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P. M. Harris, A. D. Neff, S. W. Johnson, and J. F. Thedinga

U.S. DEPARTMENT OF COMMERCE
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Clockwise from left: Sampling eelgrass (*Zostera marina*) at Auke Nu Cove in the City and Borough of Juneau, Alaska; exposed eelgrass; and submerged eelgrass with a sampling quadrat.

ABSTRACT

Eelgrass (*Zostera marina*) is an ecologically important nearshore habitat and is susceptible to degradation and loss due to coastal development and natural environmental changes. The distribution, areal extent, health, and faunal use of eelgrass habitat within the City and Borough of Juneau (CBJ), Alaska are unknown. We sampled eelgrass and faunal assemblages at 15 locations in the CBJ from 2004 to 2007 to establish a baseline of information to track long-term and large-scale biotic changes. Eelgrass was present on approximately 3% of the estimated 235 km of shoreline surveyed and occupied a total of 20.4 ha. Repeated sampling over 4 years found that most eelgrass beds were stable in size. Eelgrass characteristics (i.e., above-ground stem density, biomass) varied among years and locations and were generally lower than in other Pacific Northwest eelgrass beds.

Diverse species were found in the eelgrass beds, underscoring the importance of eelgrass as fishery habitat. A total of 18,134 fish, representing 42 species, were captured with a beach seine. The five most abundant species in decreasing order of abundance were chum salmon (*Oncorhynchus keta*), tubesnout (*Aulorhynchus flavidus*), crescent gunnel (*Pholis laeta*), threespine stickleback (*Gasterosteus aculeatus*), and Pacific herring (*Clupea pallasii*). Juvenile fish dominated our catches, indicating that eelgrass may be important nursery habitat in the CBJ for some species. The most ubiquitous invertebrate species epiphytic on eelgrass was the variegated chink snail (*Lacuna variegata*), whereas the most common invertebrates captured with a seine were juvenile shrimp (Crangonidae and Pandalidae), hermit crabs (*Pagurus* spp.), and juvenile Dungeness crabs (*Cancer magister*). We identified five locations representing a wide range of geographic locations and potential development for long-term monitoring. Limited distribution of eelgrass in the CBJ and its importance for many commercially important species warrant the monitoring and protection of this valuable habitat.

CONTENTS

INTRODUCTION

Eelgrass (*Zostera marina*) is the most widely distributed seagrass along the North American Pacific coast (Wyllie-Echeverria and Ackerman 2003), but it is susceptible to anthropogenic and natural environmental changes both in nearshore waters and on adjacent uplands. The low-gradient sheltered beaches, typical of eelgrass habitat, are often sought for development. Coastal modifications such as dredging, filling, or construction of overwater structures (e.g., ferry terminals, docks, residential floats) can eliminate or displace eelgrass (Wyllie-Echeverria and Ackerman 2003). Increased nutrient loads from agricultural runoff and sewer outfalls, sedimentation, and pervasive propeller or anchor scour have also been correlated with reductions in eelgrass bed area, density, depth limits, and biomass (Orth et al. 2006). In Alaska, filling, dredging, and deposition of logging and fish processing waste threaten eelgrass habitat (National Marine Fisheries 2005); eelgrass loss from such activities, however, is poorly documented.

Eelgrass beds in the nearshore waters of the City and Borough of Juneau (CBJ) are not widely distributed and are particularly vulnerable to development because construction on the predominantly steep terrain is often more difficult and expensive than on wetland habitat. Public harbors, private and commercial docks, and mariculture continue to be permitted in or near eelgrass beds. Since this study began in 2004, a fish processing plant began operation and a 60,000-68,000 liter oil spill occurred within a few meters of an eelgrass bed. Most recently, a new commercial loading facility has been permitted in the eelgrass bed at Auke Nu Cove.

Eelgrass supports high abundance and diversity of marine fish and invertebrates (Constanza et al.1997, Murphy et al. 2000, Johnson et al. 2003, Johnson and Thedinga 2005, Johnson et al. 2005), and may be an essential habitat for some species. In Alaska, eelgrass is used as a spawning substrate by Pacific herring (*Clupea pallasii*) (Blankenbeckler and Larson 1982) and provides rearing habitat in spring and summer for many sport and commercial fish species (Johnson and Thedinga 2005). Eelgrass also provides other important ecological functions–oxygen production, nutrient recycling, erosion control, and contaminant filtration (Spalding et al. 2003).

To date, there has not been an inventory of eelgrass beds in the CBJ. Anecdotally, it is known that some beds have changed over time, but changes near development sites have not been documented nor compared to beds not subject to developmental pressure. Environmental assessments of proposed development projects (USCOE 1984, USCOE 1985, ADOT 1996) identified some eelgrass beds in the CBJ, but lack of geo-referenced mapping decreased the usefulness of these studies as baseline information for monitoring potential changes in eelgrass habitat. In addition, most eelgrass beds in the CBJ have never been sampled for fish or invertebrates; exceptions are beds at Echo and Bridget coves (Harris et al. 2005).

Our study was undertaken to provide a baseline of information on the distribution, size, health, and faunal use of eelgrass within the CBJ for long-term assessment of biotic change. To establish the baseline and develop a measure of annual variability, we sampled eelgrass communities at 15 locations over a 4-year period for physical and biological characteristics (e.g., water temperature, stem density, faunal assemblages). Periodic re-sampling of some of these locations will allow resource managers to monitor large-scale and long-term changes in eelgrass communities and guide future development and protection of this valuable habitat.

STUDY AREA

The CBJ encompasses 841,228 hectares (ha) (8,412 km^2) of northern southeastern Alaska (Fig. 1). Our study focused on eelgrass sites that were accessible from the road system since future development will probably concentrate around this transportation corridor. The shoreline near Juneau is characterized by a mosaic of habitat types including protected bays, exposed rocky shorelines, deep inlets, numerous islands, and glacial fiords. Approximately 235 km of shoreline was surveyed for eelgrass; this represents about 30% of the entire shoreline in the CBJ (Fig. 1). Within the survey area, eelgrass was identified at 15 locations (Fig. 1); at many of these locations, there was more than one eelgrass bed. Most eelgrass and faunal assemblages were sampled in summer 2004 to 2007 (Table 1).

MATERIALS AND METHODS

Eelgrass Mapping and Description

All 15 eelgrass beds were mapped at least once from 2004 to 2007 (Table 1). At extreme low tide, a person with a backpack Trimble TSC1® Asset Surveyor GPS (global positioning system) walked the exposed perimeter of the eelgrass bed following the edge of the bed as closely as possible. On foot, eelgrass could be mapped in water up to about 1 m deep. Deeper portions of beds were mapped from a small boat by motoring slowly around the bed perimeter while keeping the GPS antenna over the visible edge. The GPS collected real-time, differentially corrected positions once each second while we circumnavigated the eelgrass beds. Accuracy of positions was ±0.5 m. Eelgrass maps (Figs. 2-16) are presented at a scale of 1:4,000, with the exceptions of Echo Cove (Fig. 2, 1:11,000) and Fish Creek (Fig. 15, 1:7,000). For those beds mapped more than once, the eelgrass shown on the map and the eelgrass area calculated is a compilation of all mapping.

Beach slope and tide height were determined using a laser level. A permanent transect perpendicular to the waterline was established at seven locations (Appendix 1) from the lower edge of the exposed bed to the upper edge and divided into 0.5 m blocks by tidal elevation. For example, if a bed extended from -1.0 m to +1.5 m tidal elevation relative to mean lower low water (MLLW = 0 m), five tidal blocks were delineated (block 1, -1.0 m to -0.5 m; block 2, -0.5 m to 0.0 m; block 3, 0.0 m to +0.5 m; block 4, +0.5 m to +1.0 m; and block 5, +1.0 m to +1.5 m). Some beds extended below tidal block 1, and only a few beds extended into tidal block 5. Substrate was visually examined and classified on site.

Eelgrass characteristics (percent cover, canopy height, stem density, biomass) were measured along each permanent transect following the methods of Duarte and Kirkman (2001) and Short et al. (2004). A 0.5 m × 0.5 m quadrat was placed (using a random numbers table) five times in each tidal block. Percent cover was the percentage of the quadrat covered by eelgrass shoots to the nearest 5% when beds were exposed. Percent-cover reference photos were used to standardize estimates, and two observers often conferred to determine an estimate. Canopy height was the height in millimeters (mm) of 80% of the eelgrass shoots in a quadrat (i.e., the tallest 20% were not included in this measurement). Above-ground stem density was determined by counting stems in a subquadrat (0.25 m × 0.25 m) placed inside the upper left corner of the 0.5 m × 0.5 m quadrat. To estimate above-ground biomass, all eelgrass shoots at the substrate surface in half of the subquadrat were clipped and collected. In the laboratory, each eelgrass shoot was rinsed and scraped of sediment and epiphytic flora and fauna. The separated shoots and epiphytes were then dried at 60° C to a constant weight and were weighed to the nearest 0.01 g. Epiphytic and benthic fauna in each 0.5 m × 0.5 m quadrat were identified to major taxonomic groups. At an additional four locations (Bridget Cove north, Auke Village, Indian Cove, and Waydelich Creek, Fig. 1), only percent cover, slope, and substrate were determined. Percent cover was estimated by placing a 0.5 m × 0.5 m quadrat every five paces along a temporary transect at right angles to the shoreline.

Faunal Sampling

Fish and invertebrates were sampled with a beach seine at 9 of the 15 locations (Fig. 1). Locations were selected because they had relatively large areas of eelgrass with sufficient gradient and were free from obstructions. Two locations (Echo Cove and Auke Nu Cove) had more than one seine site (Figs. 2, 11). Locations of seine sites were recorded with GPS (Table 1). At most seine sites, fauna were sampled with a variable-mesh 37-m long net that tapered from 5 m wide at the center to 1 m wide at the ends. Outer panels were each 10 m of 32-mm stretch mesh, intermediate panels were each 4 m of 6-mm square mesh, and the bunt was 9 m of 3.2-mm square mesh. We set the seine as a round haul by holding one end of the seine on the beach, backing around in a skiff with the other end along the beach about 18 m from the start, and pulling the seine onto shore. The seine had a lead line and a float line so that the bottom contacted the substrate and the top floated. In 2006, we began using a 37-m long, non-tapering (1.2 m wide), non-variable mesh (3.2-mm) net at four locations with low beach gradients (< 3.5%) (Tee Harbor, Auke Nu Cove, Bay Creek, and Peterson Creek; Fig. 1). This narrower net was more practical for the low gradients at these locations. We set the narrower seine as a modified round haul by having two people, each holding opposite ends of the seine, disembark either side of the bow of the skiff in about 1.0 m of water and then walk towards the beach pulling the seine onto shore about 18 m apart. All sampling occurred in daylight and within 2 hours of low tide (range +1.0 m to -1.5 m below MLLW).

Captured fish were identified to species and enumerated. Fork length or total length (TL) (the appropriate measurement for a given species) was measured to the nearest millimeter for up to 50 individuals of each fish species. Fish were anesthetized in a mixture of 1 part carbonated water to 2 parts seawater for identification and measurement. Smaller individuals (< 50 mm TL) of some families of fish (e.g., Cottidae, Gadidae, Hexagrammidae) that could not be easily identified to species in the field, were grouped and recorded as juvenile sculpin, juvenile cod, or juvenile greenling. Invertebrates collected in the seine were identified to major taxonomic groups and enumerated. Fauna were released at site of capture after they had been measured and counted.

Water Temperature and Salinity

Surface water temperature and salinity were measured at seine sites with a thermometer and hand-held refractometer at about 20 cm depth. In addition, TidbiT[1] thermographs recorded

[1] Onset Computer Corporation, PO Box 3450, Pocasset, Massachusetts.

water temperature once every 2 hours at Echo Cove, Bridget Cove north, Auke Nu Cove, and Peterson Creek (Fig. 1; Table 1). Two thermographs (one for backup) were placed in each of these locations at approximately -3.0 m depth relative to MLLW. Thermographs were attached to the mid-section of a 1-m polypropylene line; a 10 kg anchor was on one end of the line and a small float on the other end. Data were averaged for both thermographs at each location. Thermographs were deployed in summer 2004, retrieved and replaced in summer 2005, and retrieved again in summer 2006 or spring 2007.

DATA ANALYSIS

Statistical analyses for eelgrass characteristics were limited to five locations and three tidal blocks (1-3 combined) where all parameters (e.g., percent cover, canopy height) were measured for three consecutive years (2004-2006). The five locations were Echo Cove (transect 1), Bridget Cove central, Auke Nu Cove, Bay Creek, and Peterson Creek (Fig. 1). Nonparametric methods were used because data for most eelgrass parameters did not meet the assumptions of normality or homogeneity of variances even with transformation. Kruskal-Wallis ANOVA on ranks was used to test for differences in each of the eelgrass characteristics among locations and years (SigmaStat 1997). For analyses, location and year were grouped (e.g., Auke Nu Cove 2004, Bay Creek 2005; 5 locations × 3 years = 15 groups) and examined for overall differences among groups. If a significant difference was found among the 15 site-year groups, Dunn's multiple comparison procedure (SigmaStat 1997) was used to isolate a group or groups that differed from each other. Significance was accepted at $P \leq 0.05$. Overall patterns in eelgrass characteristics at the five locations were also examined individually (all three years combined) and by year (all locations combined).

For each fish species captured, total catch, mean catch, and percent frequency of occurrence (FO) were determined. Mean catch is the total catch of a species divided by the total number of seine hauls (all sampling periods, $n = 33$), whereas percent FO represents the number of seine hauls in which a species was captured divided by the total number of seine hauls multiplied by 100. At locations where multiple sets were made, a mean catch per haul for all species was also calculated. Species richness (total number of fish species captured) was also calculated for each eelgrass seine site. Individuals identified only to family (e.g., unidentified juvenile sculpin) were counted in the total catch but were only considered as a separate species for species richness calculations if no other species from the same family was captured.

RESULTS

Eelgrass Mapping and Description

Eelgrass was limited both in distribution and bed area within the CBJ. It was present on only approximately 3% of the estimated 235 linear km of shoreline surveyed. Eelgrass was generally found on sheltered to semi-sheltered, low-gradient, sand or silt beaches. Area of eelgrass beds ranged from 0.01 ha (Camping Cove; Fig. 3) to 5.8 ha (Bridget Cove south; Fig. 6), with a median area of 1.4 ha and a total area (all locations) of 20.4 ha. Area of beds that were mapped more than once during the 4 years of this study remained generally consistent from year to year with the exception of a bed at Bridget Cove central near a clam mariculture site (Fig. 5); a portion of this bed increased from 0.15 ha in 2004 and 2005 to 0.26 ha in 2007. Beach slopes ranged from 1% (Peterson Creek; Fig. 16) to 12% (Echo Cove; Fig 2), with a median slope of 3.4%.

Eelgrass depth distribution was also limited and ranged from -2.8 m to +2.0 m relative to MLLW (Figs. 2-16). Only the eelgrass bed at Camping Cove (Fig. 3) was entirely subtidal. Upper tidal height limits were highly variable, ranging from -0.4 m at Echo Cove (Fig. 2) to +2.0 m at Bridget Cove south (Fig. 6). Variability appeared to relate to substrate, slope, and drainage. Beaches supported eelgrass at higher elevations in drainage channels or tide pools or on substrates that were not well-drained because of mussel beds, topography, or fine sediments. Eelgrass beds tended to be relatively narrow on steeper shores and more expansive where gradients were shallower at the head of bays or coves.

Percent cover, canopy height, stem density, and biomass differed significantly ($P < 0.001$) among locations and years. Some of the significant differences identified in pairwise comparisons were the following: for percent cover, Bay Creek 2004 versus Peterson Creek 2004, 2005, and 2006; for canopy height, Echo Cove 2004 versus Peterson Creek 2004, 2005, and 2006; for stem density, Bay Creek 2004 versus Echo Cove 2005 and 2006; and for biomass, Auke Nu Cove 2004 versus Peterson Creek 2004 and 2005. A matrix of all pairwise comparisons and their significance is given in Appendix 2.

Some site differences in eelgrass characteristics were associated with substrate type, energy exposure, or tidal elevation. For example, mean percent cover was 27% at Peterson Creek versus 80% at Bay Creek (Fig. 17); Peterson Creek is a sandy, moderately exposed beach compared to Bay Creek where the substrate is finer and the beach more protected. Similarly, mean canopy height ranged from 244 mm at Peterson Creek to 702 mm at Echo Cove (Fig. 17). At Echo Cove, eelgrass distribution was limited to the lowest tidal block, where grass blades in all beds tended to be longer than blades at shallower depths; the mean canopy height at Echo Cove, therefore, was relatively long compared to beds with distribution over a greater tidal range. Eelgrass distribution at Peterson Creek was higher in the intertidal; hence, mean canopy height was shorter. A more detailed description of all eelgrass characteristics by location, transect, year, and tidal block is provided in Appendix 1.

By year (all five locations combined), overall mean percent cover, density, and biomass were highest in 2004, lowest in 2005, and intermediate in 2006 (Fig. 18). For example, mean percent cover was 68% in 2004, 53% in 2005, and 59% in 2006. Overall mean canopy heights, however, were similar (about 428 mm) in all 3 years (Fig. 18). Individual beds did not always follow the above patterns. For example, at Bridget Cove central, stem density increased each year from 419 stems/m^2 in 2004 to 480 stems/m^2 in 2006.

Fauna

A total of 18,134 fish representing at least 42 species were captured in 33 seine hauls (all sampling periods; Table 2). Among locations, mean catch per seine haul ranged from 73 fish ($n = 3$) at Peterson Creek to 1,195 fish ($n = 3$) at Bridget Cove south (Table 2). Catches were strongly influenced by month of sampling. For example, at Bridget Cove (north, central and south), 5,722 juvenile chum salmon (*Oncorhynchus keta*) were captured in June 2004, 142 in July 2005, and zero in August 2006. Similarly, at Echo Cove, 468 chum salmon were captured in June 2004, 50 fish in July 2005, and zero fish in August 2006.

Based on total catch, the five most abundant species accounted for 86% of the overall catch. The five most abundant species in decreasing order of abundance were chum salmon (35% of total catch), tubesnout (*Aulorhynchus flavidus*, 25%), crescent gunnel (*Pholis laeta*, 13%), threespine stickleback (*Gasterosteus aculeatus*, 7%), and Pacific herring (*Clupea pallasii*, 6%). Some species were captured infrequently but often in large numbers (e.g., chum salmon–6,400 fish in 33% of all seine hauls), whereas other species were captured frequently but usually in small numbers (e.g., Pacific staghorn sculpin–260 fish in 79% of all seine hauls) (Table 2). Other species important in sport or commercial fisheries that were caught in small numbers (< 4% of total catch) were walleye pollock (*Theragra chalcogramma*), coho salmon (*O. kisutch*), Pacific cod (*Gadus macrocephalus*), pink salmon (*O. nerka*), Dolly Varden (*Salvelinus malma*), cutthroat trout (*O. clarkia*), Chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), and sockeye salmon (*O. nerka*). Forage fish species caught in small numbers (< 0.1% of total catch) were surf smelt (*Hypomesus pretiosus*), Pacific sand lance (*Ammodytes hexapterus*), Pacific sandfish (*Trichodon trichodon*), and capelin (*Mallotus villosus*).

Species richness ranged from 7 at Peterson Creek to 31 at Bridget Cove central (Table 2). The most ubiquitous species, crescent gunnel, Pacific staghorn sculpin, threespine stickleback, and frog sculpins (*Myoxocephalus stelleri*) were captured at all seine sites (Table 2). Other widely distributed species were tubesnout and starry flounder (*Platichthys stellatus*); these species were captured at 11 of the 12 sites.

Most of the commercially important and forage fish species captured were juveniles (FishBase 2008). For example, mean length ranged from 35 mm for Pacific herring to 89 mm for Pacific cod (Table 3). All chum and pink salmon captured were young-of-the-year; mean fork length was less than 69 mm. Some of the largest species captured were starry flounder (219 mm mean total length) and whitespotted greenling (*Hexagrammos stelleri*; 196 mm mean fork length).

At least 25 invertebrate species were either observed epiphytic on eelgrass along transects, or captured with a beach seine (Table 4). The number of invertebrate species ranged from 6 at Echo Cove to 13 at Auke Nu Cove. The most ubiquitous epiphytes on eelgrass, variegated chink snail (*Lacuna varigata*) and juvenile Pacific blue mussel (*Mytilus trossulus*), were observed at seven locations. Other common epiphytic animals were barnacles (*Balanus glandula* and *Semibalanus balanoides*), bryozoans (Membraniporidae), and juvenile limpets (Lottiidae). Dry weights of epiphytic fauna and flora ranged from 2.0 g/m^2 (Bay Creek, tidal block 5) to 35.6 g/m^2 (Bridget Cove central, tidal block 1). Adult *Mytilus* were common as well but were attached to the substrate rather than eelgrass blades. False white sea cucumber *(Eupentacta pseudoquinquesemita*), mottled sea star (*Evasterias troschellii*), and amphipods (*Gammarus* spp.) were often observed. The most numerous invertebrates captured with the beach seine were juvenile shrimp (Pandalidae and Crangonidae, n >1,000) and hermit crabs (*Pagurus* spp., n = 160) (Table 4). Sixty-two juvenile Dungeness crabs (*Cancer magister*) were captured with a beach seine; most (92%) were captured at Bridget Cove.

Water Temperature and Salinity

At the four thermograph sites, annual mean seawater temperatures ranged from 7.9° to 8.5° C (SE = 0.85 to 1.21). Monthly mean seawater temperature profiles were similar at the four thermograph sites (Fig. 19), ranging from 3° C in February to 15° C in July. Salinity ranged from

2 to 28 practical salinity scale (PSS) during the summer months (June, July, and August), with a mean of 25 PSS in June, 15 PSS in July, and 10 PSS in August. Surface salinities became more dilute with seasonal fresh water input and increased stratification of the water column.

DISCUSSION

Eelgrass Distribution and Description

Eelgrass is very limited in the City and Borough of Juneau. Eelgrass was found at 15 locations accessible from the road system, roughly 3% of the linear shoreline surveyed. The total area of eelgrass was only 20.4 ha, and individual bed size was small. At five locations sampled repeatedly over 4 years, the area of most eelgrass beds was stable. Eelgrass characteristics (i.e., percent cover, stem density, and biomass), however, tended to vary among years and sites. Eelgrass is distributed throughout southeastern Alaska (Johnson et al. 2003, 2005) but is often absent or sparse in bays and inlets on or near the mainland probably due to turbid effluent from glacial rivers (McRoy 1968). Because eelgrass is so limited near the mainland, it may serve as an essential refuge habitat, especially for juvenile fish.

Eelgrass depth distribution was shallower, and stem density and biomass were generally lower in the CBJ than in other Pacific Northwest beds. The lower tidal limit of eelgrass in this study was about -2.3 m below MLLW, whereas Phillips (1984) reported a maximum depth limit of -30 m and an optimal tidal range for vegetative growth of 0.0 m to -6.6 m. Mean density values we observed (142-510 stems/m^2) are below or at the lower end of observations at Izembek Lagoon, Alaska, the largest seagrass bed along the Pacific coast of North America (740 stems/m^2; Phillips et al. 1983) and at several locations in southeastern Alaska (336-1,544 stems/m^2; Johnson and Thedinga 2005). Biomass values that we observed (35-69 g/m^2) are also below ranges observed at Izembek Lagoon (186-1,840 g/m^2; Phillips et al. 1983), but similar to ranges in southeastern Alaska (36-71 g/m^2; Johnson and Thedinga 2005). Limited distribution of eelgrass in the optimum tidal range as well as glacial turbidity at some locations in our study may have contributed to the overall lower density and biomass observations. In addition, mean seawater temperatures in our study were only in the optimum growing range for eelgrass (10° C to 20° C; Phillips 1984) from June through September.

Fauna

A diverse assemblage of fish species utilized the CBJ eelgrass beds, underscoring the importance of eelgrass beds as important fishery habitat. Of the 42 species that we identified, twenty-nine are included in a fishery management plan (FMP) for the Gulf of Alaska, Bering Sea, and Aleutian Islands (North Pacific Fishery Management Council 2006; Table 2) and 32 were captured in other eelgrass studies throughout southeastern Alaska (Murphy et al. 2000, Johnson et al. 2003, Harris et al. 2005, Johnson and Thedinga 2005). Some species that are common in eelgrass habitat in other areas of southeastern Alaska, however, were notably absent (e.g., rockfish, *Sebastes* spp.; shiner perch, *Cymatogaster aggregata*) or present in low numbers (e.g., bay pipefish, *Syngnathus leptorhynchus*) in the CBJ. Juvenile rockfish are common inhabitants of eelgrass habitat on or near the outer coast of southeastern Alaska but are nearly absent in more protected inside waters near Juneau (Johnson et al. 2005). Differences in water temperature, salinity, and turbidity between inside and outside waters of southeastern Alaska likely influence the different distribution patterns of species.

Seasonality and aggregating behavior of some species (e.g., Pacific herring) can also influence distribution patterns. For example, at Bridget Cove, abundance of herring varied between the three Bridget Cove seine sites on the same day of sampling in June 2005; 437 fish were captured at the central location and 2 or fewer fish at the north and south locations. While differences in individual eelgrass beds could explain this variability in catch, it is more likely a result of the aggregating behavior of herring (Carlson 1980). Further, we did not capture any herring in Bridget Cove in 2004. Johnson and Thedinga (2005) also reported "hit or miss" catches of several species in eelgrass. Similarly, seasonal use patterns were evident for some species. At Bridget Cove, 5,722 chum salmon fry were captured in June 2004, 142 in July 2005, and zero in August 2006. From mid-April to mid-June, chum salmon fry are abundant in nearshore waters of Alaska (Celewycz et al. 1994) and then move offshore to deeper waters by mid-summer.

The dominance of relatively few species at any eelgrass location in the CBJ is similar to many other nearshore studies. Three species accounted for greater than 68% of the total catch in southeastern Alaska (Johnson and Thedinga 2005), and five or fewer species accounted for greater than 98% of the individuals captured in central and southern California (Allen and Horn 1975, Allen 1982). Two of the most ubiquitous species in our study, crescent gunnel and Pacific staghorn sculpin, were captured at every eelgrass location reported in Johnson et al. (2005).

Juvenile fish dominated our catches, indicating that eelgrass may be important nursery habitat in the CBJ for some species. Worldwide, the importance of seagrasses as nursery areas has been well documented (Thayer et al. 1978, Macdonald and Chang 1993, Laur and Haldorson 1996). We cannot assess the nursery value of eelgrass, however, because we did not sample adjacent habitat types, and we sampled only in late spring and summer. We do know from this study and others in southeastern Alaska (Murphy et al. 2000, Johnson et al. 2003, Harris et al. 2005, Johnson and Thedinga 2005), however, that juveniles of many commercially important and forage fish species utilize eelgrass habitat. Historically, Pacific herring utilized the near shore for spawning and rearing in the CBJ; herring use of these areas has declined since the 1970s, however, likely from habitat alteration and degradation, especially in Auke Bay (Williams et al. 2004).

The invertebrate community we observed in eelgrass (e.g., mussels, barnacles, shrimps, snails, and crabs) is similar to that reported by other studies in the Pacific Northwest (Phillips 1984). For commercially important species such as Dungeness crabs, eelgrass provides valuable nursery habitat for juveniles (Thayer and Phillips 1977, McMillan et al. 1995). The abundance and diversity of invertebrates in eelgrass provides a food source for many predators and contributes to the overall productivity of eelgrass.

Water Temperature and Salinity

Annual seawater surface temperatures and pattern of minimum and maximum temperatures at our thermograph sites were similar to ranges reported for Auke Bay (Wing et al. 2006) and for other locations in northern southeastern Alaska (Johnson et al. 2003, Johnson and Thedinga 2005). In all studies, mean monthly water temperatures were usually lowest in February or March and highest in July or August. Salinities in our study were sometimes lower than those reported by Johnson et al. (2003) and Johnson and Thedinga (2005) because all CBJ sites were on the mainland and more influenced by freshwater input and seasonal water stratification.

Monitoring

The baseline information provided by this study establishes monitoring sites to track changes in eelgrass communities in the CBJ. The best monitoring locations would be those that we sampled most consistently for both eelgrass characteristics and faunal assemblages (Echo Cove, Bridget Cove central, Auke Nu Cove, Bay Creek, and Peterson Creek). These five locations are widely distributed geographically and represent a gradient of development. Auke Nu Cove and Bay Creek continue to be developed as recreational and commercial harbors; future recreational developments may impact the Echo Cove and Peterson Creek beds. Bridget Cove central is a mariculture site, but as a CBJ natural area park, it is least likely to experience commercial or residential development and could serve as a control site to monitor impacts in the other beds.

Eelgrass community response to environmental change may vary both temporally and spatially. Immediate changes could be expected in a local bed from physical damage resulting from filling, dredging, or vessel grounding. An immediate response could be reduction in bed area. Shading by overwater structures (e.g., docks) may have a more delayed impact such as reduced percent cover or stem density. Regional, long-term changes could be expected from isostatic rebound or increases in sea water temperatures, sea level, or glacial runoff. Possible indicators of regional change include the consistent increase or decrease of a specific eelgrass characteristic (e.g., bed size, depth distribution) at several monitored locations. A change in bed size would likely have to be large to indicate change, however, because of occasional large annual fluctuations in bed area (Johnson and Thedinga 2005). For faunal assemblages, shifts in the composition of the most abundant species or the appearance of a new species may also indicate environmental change.

A reasonable approach for monitoring would be to resample our five eelgrass locations every 5 years to track changes in bed area, stem density, and faunal assemblages–characteristics shown to be responsive to environmental change (Hauxwell et al. 2003, Jenkins et al. 1993). If a location undergoes major development, however, more frequent monitoring would be necessary to document immediate impacts and suggest possible mitigation. Periodic monitoring would allow a comparison of eelgrass characteristics and faunal assemblages in each location relative to overall trends, to a control site (Bridget Cove central), or to other areas monitored in northern southeastern Alaska (Johnson and Thedinga 2005). To reduce temporal variability, monitoring should occur at the same time of year; the last low tide series in July would be preferable since we have the most baseline data for this period. In addition, eelgrass bed area and growth are at their annual maxima in July and faunal assemblages are no longer inundated by hatchery salmon.

In the City and Borough of Juneau coastal areas, continuing development threatens to reduce eelgrass bed size and productivity. Further harbor development, a second Gastineau Channel crossing, expansion of transportation corridors, and increased shoreline development are possible in the next decade. The limited distribution of eelgrass and its vulnerability to shoreline development warrant the periodic monitoring, and protection of this important coastal habitat.

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Table 1.-- Locations of transects, thermographs, and seine sites sampled in eelgrass (*Zostera marina*) beds in the City and Borough of Juneau, Alaska, 2004 to 2007. Eelgrass characteristics (e.g., stem density) were measured along transects, thermographs measured daily water temperature, and a beach seine was used to sample faunal assemblages. Also shown are dates that eelgrass beds were mapped with global positioning system technology. Latitude and longitude are in decimal degrees. Eelgrass locations shown in Figure 1; individual sampling sites in Figures 2-16.

Location			Sampling date			
sample site	Latitude (N)	Longitude (W)	2004	2005	2006	2007
Echo Cove						
mapped			7/1	7/20		8/28
transect 1	58.6686	134.9121	7/1	7/21	8/9	
transect 2	58.6605	134.9112		7/20	8/8	
thermograph 1	58.6605	134.9106	6/3[a]	4/12[b]	5/30[b]	
thermograph 2	58.6680	134.9200	6/2[a]	nr	nr	
seine 1	58.6719	134.9148	6/2	7/6	8/9	
seine 2	58.6693	134.9127	6/2	7/6	8/9	
seine 3	58.6686	134.9121	6/2	7/6	8/9	
Camping Cove	58.6476	134.9658				
mapped			7/2			
Bridget Cove north						
mapped			7/5	7/23		
transect 3	58.6400	134.9556	8/4	7/23		
thermograph 3	58.6405	134.9552	6/1[a]	4/12[b]	5/30[b]	
thermograph 4	58.6418	134.9575	6/3[a]	4/12[b]	5/30[b]	
seine 4	58.6400	134.9556	6/3	7/7	8/10	
Bridget Cove central						
mapped			7/3	7/22		8/29
transect 4	58.6300	134.9480	7/5	7/22	8/10	
seine 5	58.6300	134.9480	6/4	7/7	8/10	
Bridget Cove south						
mapped			7/2	7/23		
transect 5	58.6300	134.9449		7/23	8/11	
seine 6	58.6300	134.9449	6/4	7/7	8/10	

Table 1.-- Continued.

Location sample site	Latitude (N)	Longitude (W)	Sampling date 2004	2005	2006	2007
Sunshine Cove	58.6084	134.9326				
mapped			9/1			
Tee Harbor						
mapped				6/26		
transect 6	58.4309	134.7648		6/26	7/27	
seine 7	58.4309	134.7648		7/18	7/27	
Auke Village						
mapped			8/3	6/8		
transect 7	58.3757	134.7256	8/3	6/8		
Indian Cove						
mapped			7/30	6/6		
transect 8	58.3774	134.7009	7/30	6/6		
Auke Nu Cove						
mapped			8/1	6/22		8/14
transect 9	58.3811	134.6924	8/1	6/22	7/25	
thermograph 5	58.3800	134.6911	6/29[a]	6/27[b]	nr	
thermograph 6	58.3792	134.6898	6/29[a]	6/27[b]	nr	4/18 [b]
seine 8	58.3808	134.6917		6/24	8/24	7/31
seine 9	58.3780	134.6919			8/23	7/31
Waydelich Creek						
mapped			8/2			
transect 10	58.3819	134.6603	8/3			
seine 10	58.3819	134.6603		6/23	8/24	
Bay Creek						
mapped			6/17	6/21		8/13
transect 11	58.3857	134.6490	8/2	7/24		
seine 11	58.3853	134.6517		6/27	7/24	8/2
Mendenhall Peninsula	58.3603	134.6462				
mapped						3/22
Fish Creek	58.3315	134.6080				
mapped				7/25		5/3

Table 1.-- Continued.

Location			Sampling date			
sample site	Latitude (N)	Longitude (W)	2004	2005	2006	2007
Peterson Creek						
mapped			7/6	7/19		
transect 12	58.3018	134.6813	7/6	7/19		
thermograph 7	58.3035	134.6840	7/6[a]	10/3[b]	8/29[c]	
thermograph 8	58.3015	134.6853	7/6[a]	10/3[b]	nr	
seine 12	58.3018	134.6813		6/28	7/26	

[a] date deployed
[b] date retrieved, downloaded, and redeployed
[c] date retrieved
nr = not retrieved

Table 2.-- Fish catch by species at 12 seine sites (Figs. 2-16) in eelgrass (*Zostera marina*) in the City and Borough of Juneau, Alaska, 2004 to 2007. Mean catch = total catch of each species divided by the total number of beach seine hauls (n = 33). Percent frequency of occurrence (FO) = number of seine hauls in which a species was captured divided by the total number of seine hauls multiplied by 100. Species are listed in decreasing order of abundance based on total catch. Asterisk denotes species included in a Fishery Management Plan. A blank indicates no fish were caught. Scientific names are shown in Table 3.

	Eelgrass seine sites												Total	Mean	
Common name	1	2	3	4	5	6	7	8	9	10	11	12	catch	catch	FO
Chum salmon*	1	177	340	2,270	474	3,120				18			6,400	193.9	33.3
Tubesnout	12	8	5	85	468	98	1,283	625	505	1,271	99		4,459	135.1	78.8
Crescent gunnel*	469	61	125	512	258	129	96	164	47	57	302	76	2,296	69.6	97.0
Threespine stickleback	33	18	24	8	18	4	203	130	183	22	529	65	1,237	37.5	78.8
Pacific herring	12		2	2	438		73	1	10	607			1,145	34.7	30.3
Walleye pollock*	12	1	4	148	475	14			1				655	19.8	27.3
Coho salmon*	75	74	25	105	49	98		4	1	5			436	13.2	54.5
Tubenose poacher	8	1	4	109	69	15	37	21	7	8			279	8.5	51.5
Pacific staghorn sculpin*	6	2	2	22	22	1	30	53	11	20	37	54	260	7.9	78.8
Pacific cod*				104	53	11			1				169	5.1	15.2
Pink salmon*		54	23		42					1			120	3.6	15.2
Snake prickleback*	7	19	20	10	3		1	5	1	45	3		114	3.5	48.5
Frog sculpin*	5	1	3	1	18	2	5	22	8	3	3	7	78	2.4	54.5
Dolly Varden		1	4		4	53						1	63	1.9	18.2
Starry flounder*		1	1	1	6	2	1	16	1	14	5	6	54	1.6	54.5
Rock sole*	2		2	25	13			1	1	7			51	1.5	30.3
Silverspotted sculpin*	1			3	2	6	8	22	2	1	1		46	1.4	42.4
Juvenile greenling	5	7	2	12	15	1		1		3			46	1.4	24.2

Table 2. -- Continued.

Common name	Eelgrass seine sites 1	2	3	4	5	6	7	8	9	10	11	12	Total catch	Mean catch	FO
Juvenile sculpin	5	1	1		3	2	12			5		10	39	1.2	30.3
Bay pipefish	1			7	16	1	1	1					27	0.8	24.2
Northern sculpin	2	5	3	4	2	5		1		3			25	0.8	27.3
Padded sculpin						7		2	14				23	0.7	9.1
Surf smelt*					23								23	0.7	3.0
Buffalo sculpin*					9			2	4				15	0.5	12.1
Whitespotted greenling	4			6	1	2							13	0.4	21.2
Great sculpin*	1	1	2		1	5							10	0.3	15.2
Cutthroat trout	1	1	1		1	3							7	0.2	15.2
Tidepool sculpin*				4	1	1	1						7	0.2	12.1
Pacific sand lance*					3	2		1					6	0.2	9.1
Yellowfin sole*										5	1		6	0.2	6.1
English sole*				1	2								3	0.1	6.1
Arctic shanny*			1						1				2	0.1	6.1
Chinook salmon*										2			2	0.1	3.0
Pacific sandfish*					2								2	0.1	3.0
Pacific spiny lumpsucker					1				1				2	0.1	6.1
Steelhead trout			1									1	2	0.1	6.1
Juvenile flatfish					1		1						2	0.1	6.1
Alaska plaice*		1											1	0.0	3.0
Capelin*			1										1	0.0	3.0
Crested sculpin*						1							1	0.0	3.0
Manacled sculpin*									1				1	0.0	3.0
Penpoint gunnel*					1								1	0.0	3.0

Table 2. -- Continued.

Common name	Eelgrass seine sites												Total catch	Mean catch	FO
	1	2	3	4	5	6	7	8	9	10	11	12			
Red Irish lord*					1								1	0.0	3.0
Sockeye salmon*						1							1	0.0	3.0
Juvenile cod	1												1	0.0	3.0
Juvenile gunnel*											1		1	0.0	3.0
Juvenile snailfish											1		1	0.0	3.0
Total catch	663	434	596	3,439	2,495	3,584	1,752	1,072	800	2,097	982	220	18,134		
Number of hauls	3	3	3	3	3	3	2	3	2	2	3	3	33		
Species richness	18	18	22	20	31	23	13	18	19	18	10	7	42		
Mean catch per haul	221	145	199	1,146	832	1,195	876	357	400	1,049	327	73	550		

Table 3.-- Length (fork length or total length) of fish species captured with a beach seine at 12 eelgrass (*Zostera marina*) sites (see Table 1 and Figure 1) in the City and Borough of Juneau, Alaska, 2004 to 2007. Species are listed in decreasing order of abundance based on total catch.

		Length (mm)		
Common name	Scientific name	n	Avg.	SE
Chum salmon	*Oncorhynchus keta*	255	68.2	7.7
Tubesnout	*Aulorhynchus flavidus*	387	66.0	33.4
Crescent gunnel	*Pholis laeta*	130	120.5	61.8
Threespine stickleback	*Gasterosteus aculeatus*	473	29.1	14.1
Pacific herring	*Clupea pallasii*	147	34.7	3.3
Walleye pollock	*Theragra chalcogramma*	97	63.9	11.8
Coho salmon	*Oncorhynchus kisutch*	183	85.9	21.0
Tubenose poacher	*Pallasina barbata*	129	65.7	20.2
Pacific staghorn sculpin	*Leptocottus armatus*	199	166.9	63.7
Pacific cod	*Gadus macrocephalus*	92	89.1	11.6
Pink salmon	*Oncorhynchus gorbuscha*	48	60.4	6.7
Snake prickleback	*Lumpenus sagitta*	72	138.4	81.7
Frog sculpin	*Myoxocephalus stelleri*	72	122.7	79.0
Dolly Varden	*Salvelinus malma*	10	159.7	23.8
Starry flounder	*Platichthys stellatus*	54	219.3	130.0
Rock sole	*Lepidopsetta* spp.	26	80.3	26.5
Silverspotted sculpin	*Blepsias cirrhosus*	21	65.9	10.3
Juvenile greenling	Hexagrammidae	10	69.8	11.2
Juvenile sculpin	Cottidae	26	34.2	12.1
Bay pipefish	*Syngnathus leptorhynchus*	26	178.4	25.9
Northern sculpin	*Icelinus borealis*	12	92.5	22.5
Padded sculpin	*Artedius fenestralis*	23	81.2	24.4
Surf smelt	*Hypomesus pretiosus*	23	116.7	10.4
Buffalo sculpin	*Enophrys bison*	13	73.5	55.2
Whitespotted greenling	*Hexagrammos stelleri*	12	195.6	66.7
Great sculpin	*Myoxocephalus polyacanthocephalus*	1	172.0	
Cutthroat trout	*Oncorhynchus clarkii*	4	189.0	46.7
Tidepool sculpin	*Oligocottus maculosus*	7	62.1	8.1

Table 3.-- Continued.

Common name	Scientific name	Length (mm)		
		n	Avg.	SE
Pacific sand lance	*Ammodytes hexapterus*	6	65.8	14.3
Yellowfin sole	*Limanda aspera*	6	141.2	32.5
English sole	*Parophrys vetulus*	3	137.7	23.6
Arctic shanny	*Stichaeus punctatus*	1	50.0	
Chinook salmon	*Oncorhynchus tshawytscha*	2	150.5	4.9
Pacific sandfish	*Trichodon trichodon*	2	89.0	2.8
Pacific spiny lumpsucker	*Eumicrotremus orbis*	2	13.0	4.2
Steelhead trout	*Oncorhynchus mykiss*	2	195.0	33.9
Juvenile flatfish	Pleuronectidae	2	29.0	21.2
Alaska plaice	*Pleuronectes quadrituberculatus*	1	269.0	
Capelin	*Mallotus villosus*	1	57.0	
Crested sculpin	*Blepsias bilobus*	1	190.0	
Manacled sculpin	*Synchirus gilli*	1	42.0	
Penpoint gunnel	*Apodichthys flavidus*	1	52.0	
Red Irish lord	*Hemilepidotus hemilepidotus*	1	125.0	

Table 4.-- Invertebrates observed or captured at 11 eelgrass (*Zostera marina*) locations (see Table 1) in the City and Borough of Juneau, Alaska, 2004 to 2007. Observations were recorded along eelgrass transects and from beach seine hauls. Epiphytic animals were identified from subquadrat eelgrass clippings collected for above-ground biomass determination.

Common name	Scientific name
Variegated chink snail	*Lacuna variegata*
Pacific blue mussel	*Mytilus trossulus*
Acorn barnacle	*Balanus glandula*
Northern rock barnacle	*Semibalanus balanoides*
Amphipods	*Gammarus* spp.
Bryozoans	Membraniporeae
Limpets	Lottidae
Rockweed isopod	*Idotea wosnesenskii*
Polychaete	*Eteone* spp.
Pile worm	*Nereis vexillosa*
False white sea cucumber	*Eupentacta pseudoquinquesemita*
Mottled sea star	*Evasterias troschelii*
Spot shrimp	*Pandalus platyceras*
Dock shrimp	*Pandalus danae*
Opossum mysid	*Neomysis mercedes*
Alaskan crangon	*Crangon alaskensis*
Long-clawed crangon	*Crangon franciscorum angustimana*
Hermit crab	*Pagurus* spp.
Dungeness crab	*Cancer magister*
Tuskworm	*Pectinaria granulata*
Featherduster worm	*Schizobranchia insignis*
Burrowing green anemone	*Anthopleura artemisia*
Six-arm seastar	*Leptasterias epichlora*
Littleneck clam	*Protothaca staminea*
Heart cockle	*Clinocardium nuttalii*
Jellyfish	Hydrozoa
Green sea urchin	*Strongylocentrotus droebachiensis*
Broken back shrimp	Hippolytidae

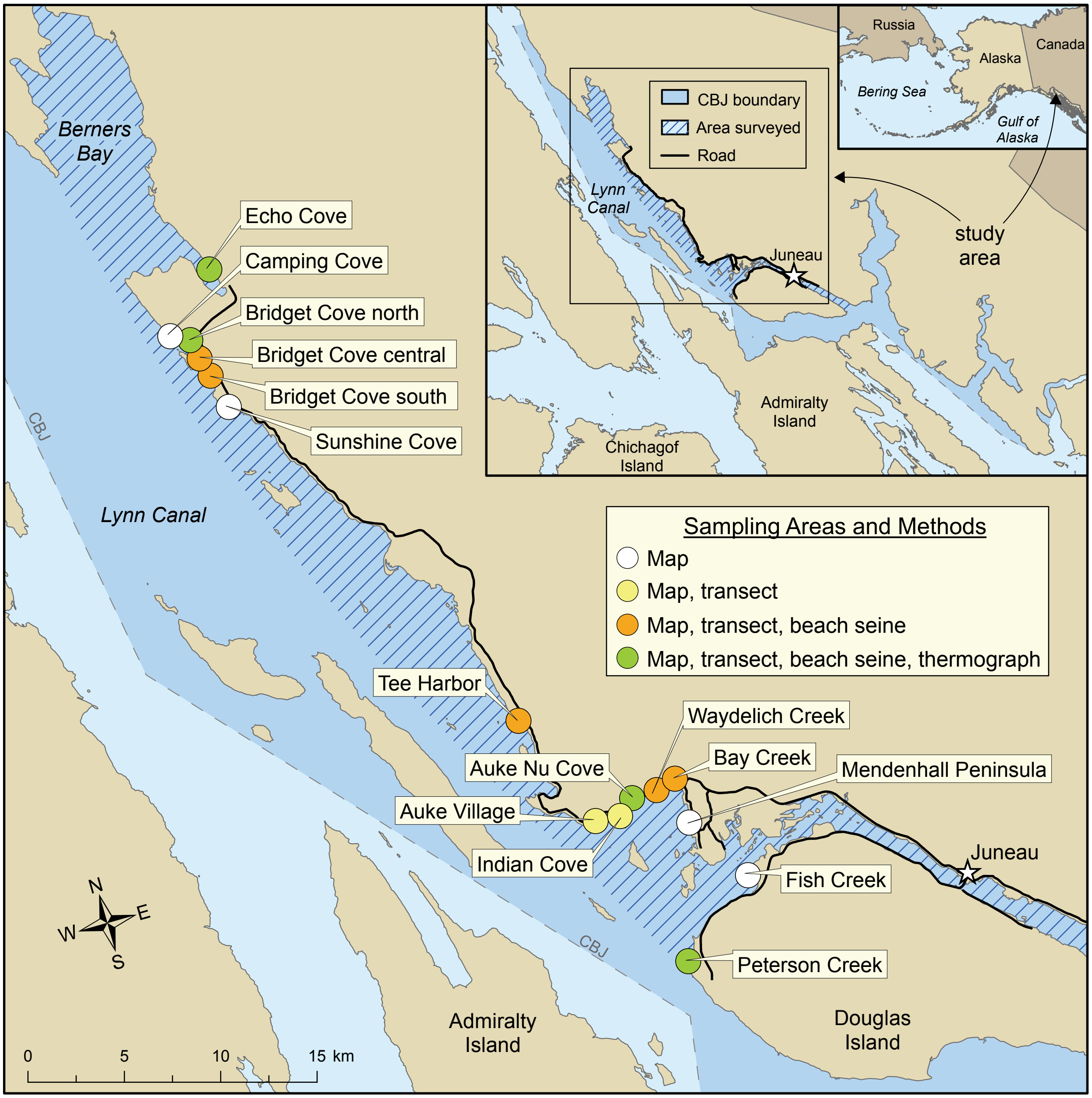

Figure 1.-- Eelgrass (*Zostera marina*) locations sampled within the City and Borough of Juneau (CBJ), Alaska. At each location, all eelgrass beds were mapped with global positioning system technology, and some beds were sampled on transects for eelgrass characteristics (e.g., percent cover) and by beach seine for faunal assemblages. Daily water temperatures were recorded at some locations with thermographs. All sampling was from 2004 to 2007. Individual locations are shown in Figures 2-15.

Echo Cove

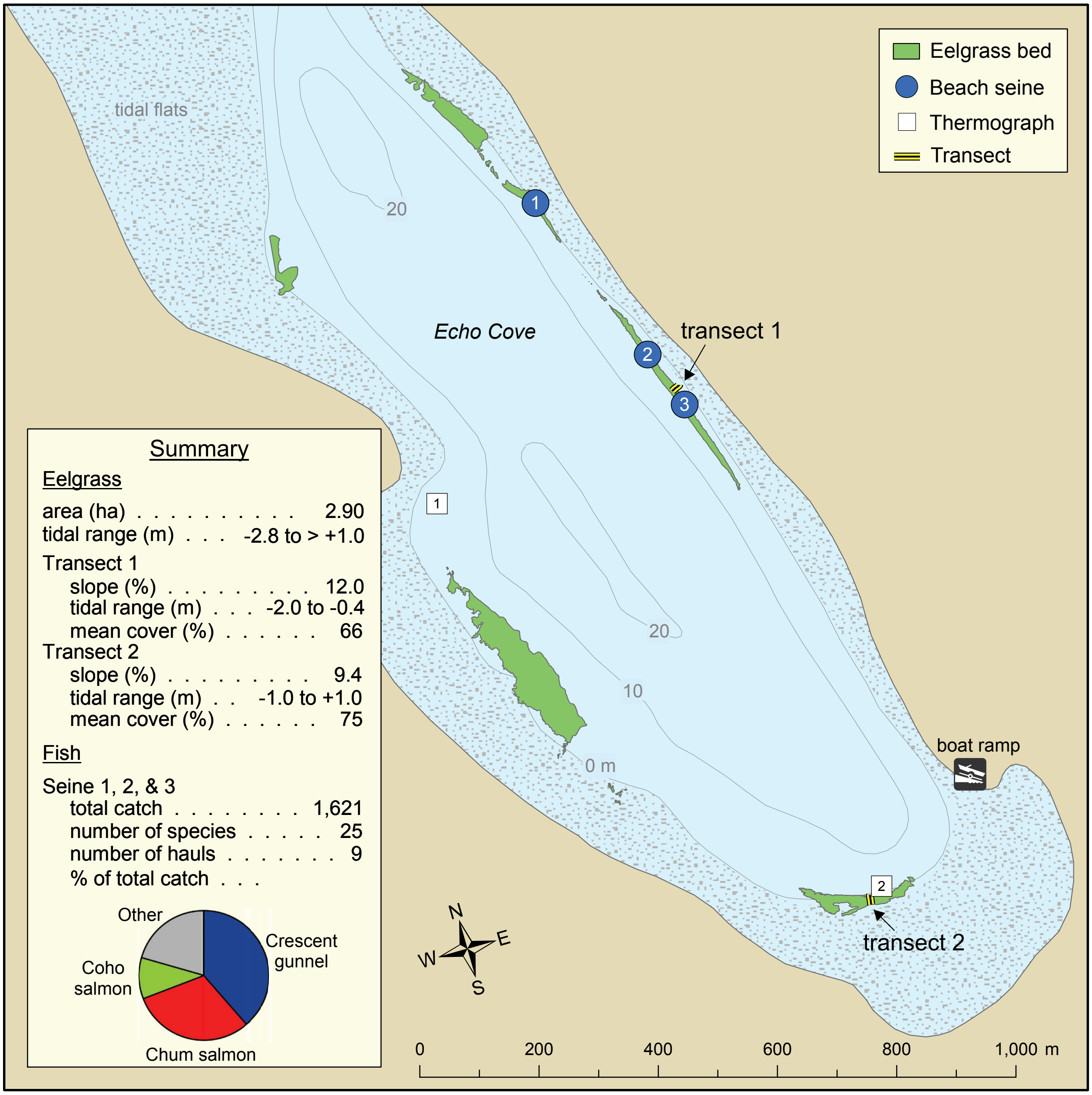

Figure 2.-- Eelgrass (*Zostera marina*) beds sampled at Echo Cove, Juneau, Alaska, in summer 2004 to 2007. Eelgrass was mapped with global positioning system technology. Shown are eelgrass transects, fish sampling sites (beach seine), and water temperature monitoring sites (thermograph). See Figure 1 for location within the City and Borough of Juneau.

Camping Cove

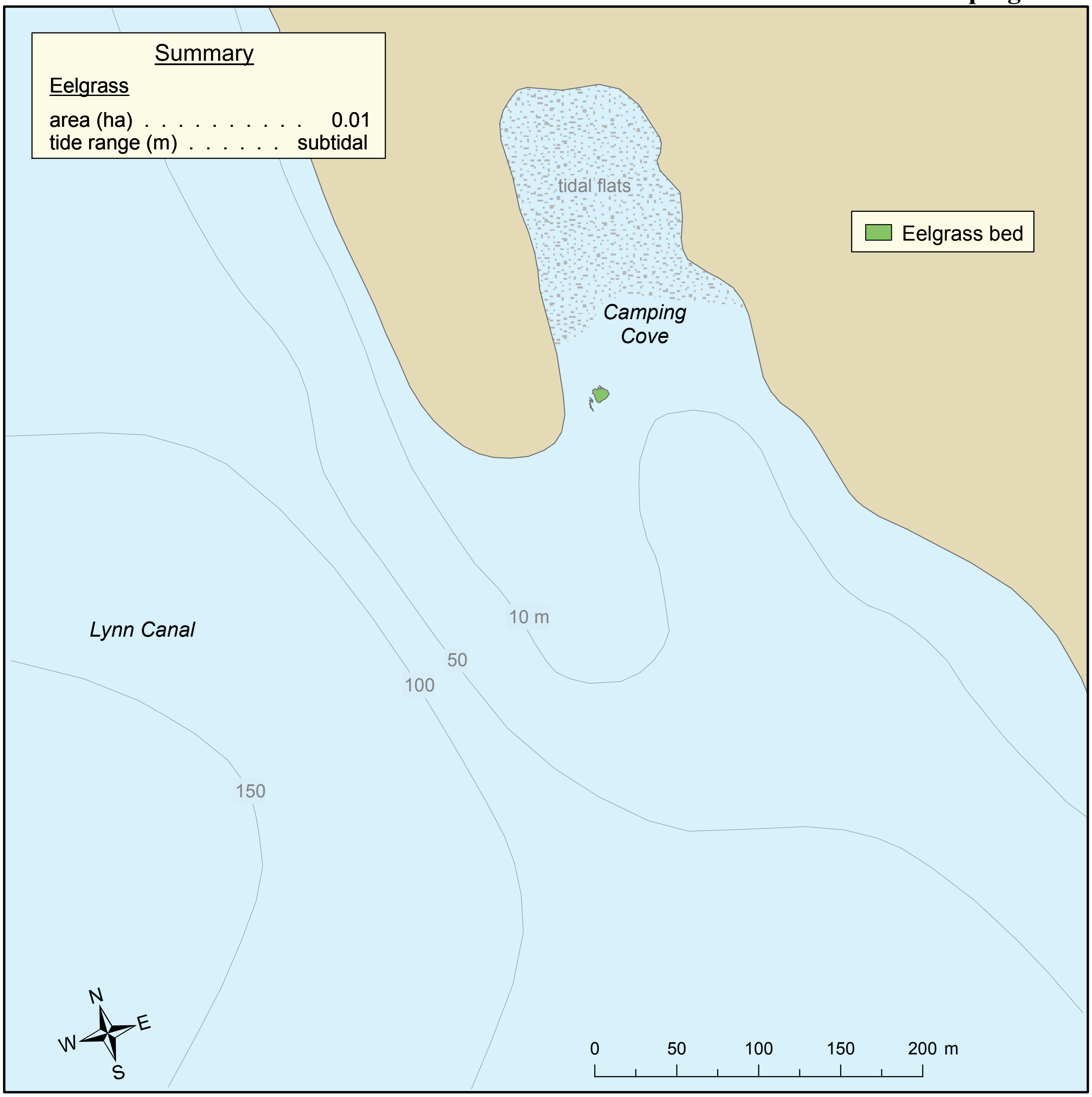

Figure 3.-- Eelgrass (*Zostera marina*) bed sampled at Camping Cove, Juneau, Alaska, in summer 2004. Eelgrass was mapped with global positioning system technology. See Figure 1 for location within the City and Borough of Juneau.

Bridget Cove north

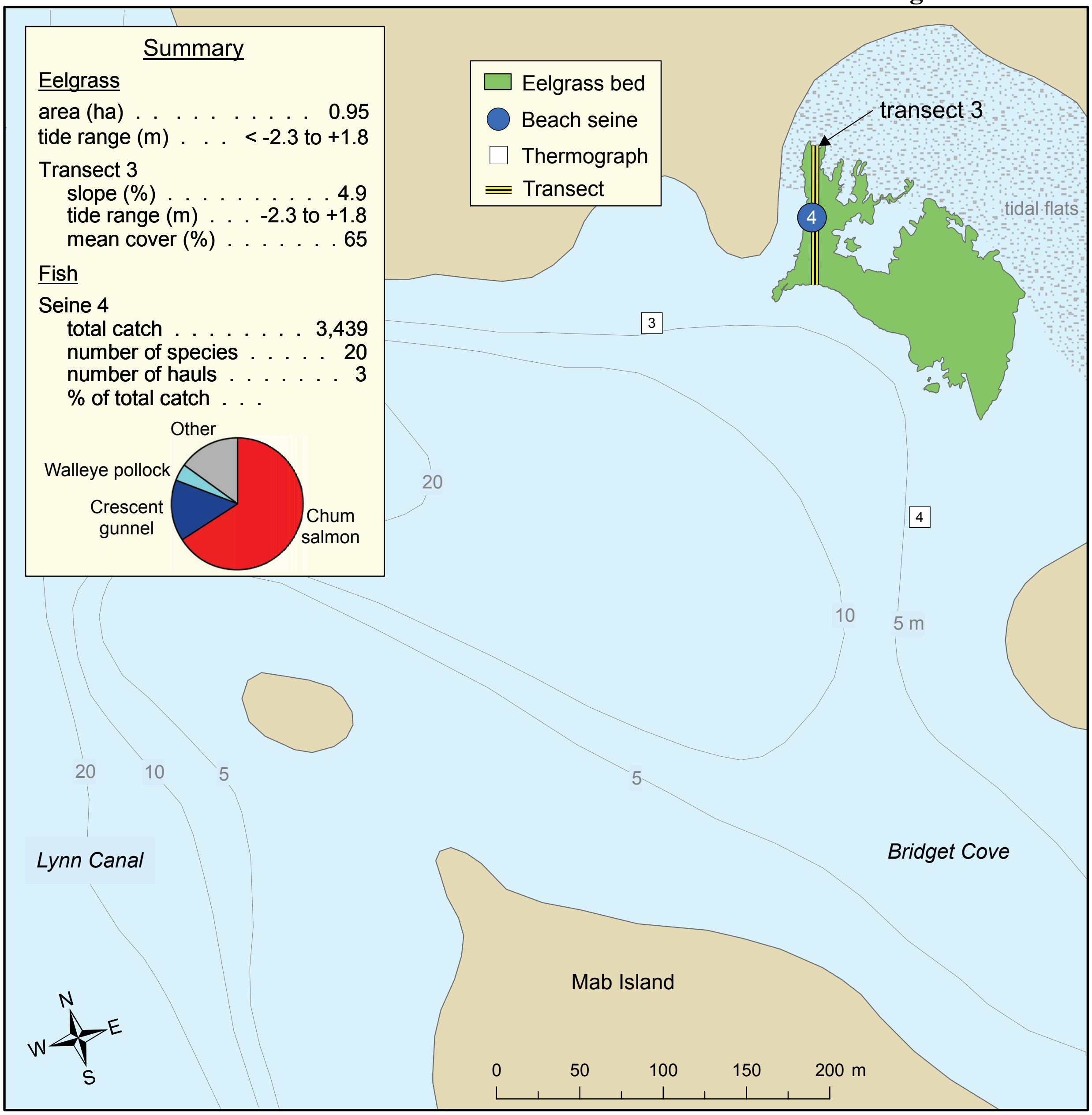

Figure 4.-- Eelgrass (*Zostera marina*) bed sampled at the north end of Bridget Cove, Juneau, Alaska, in summer 2004 to 2006. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect, fish sampling site (beach seine), and water temperature monitoring sites (thermographs). See Figure 1 for location within the City and Borough of Juneau.

Bridget Cove central

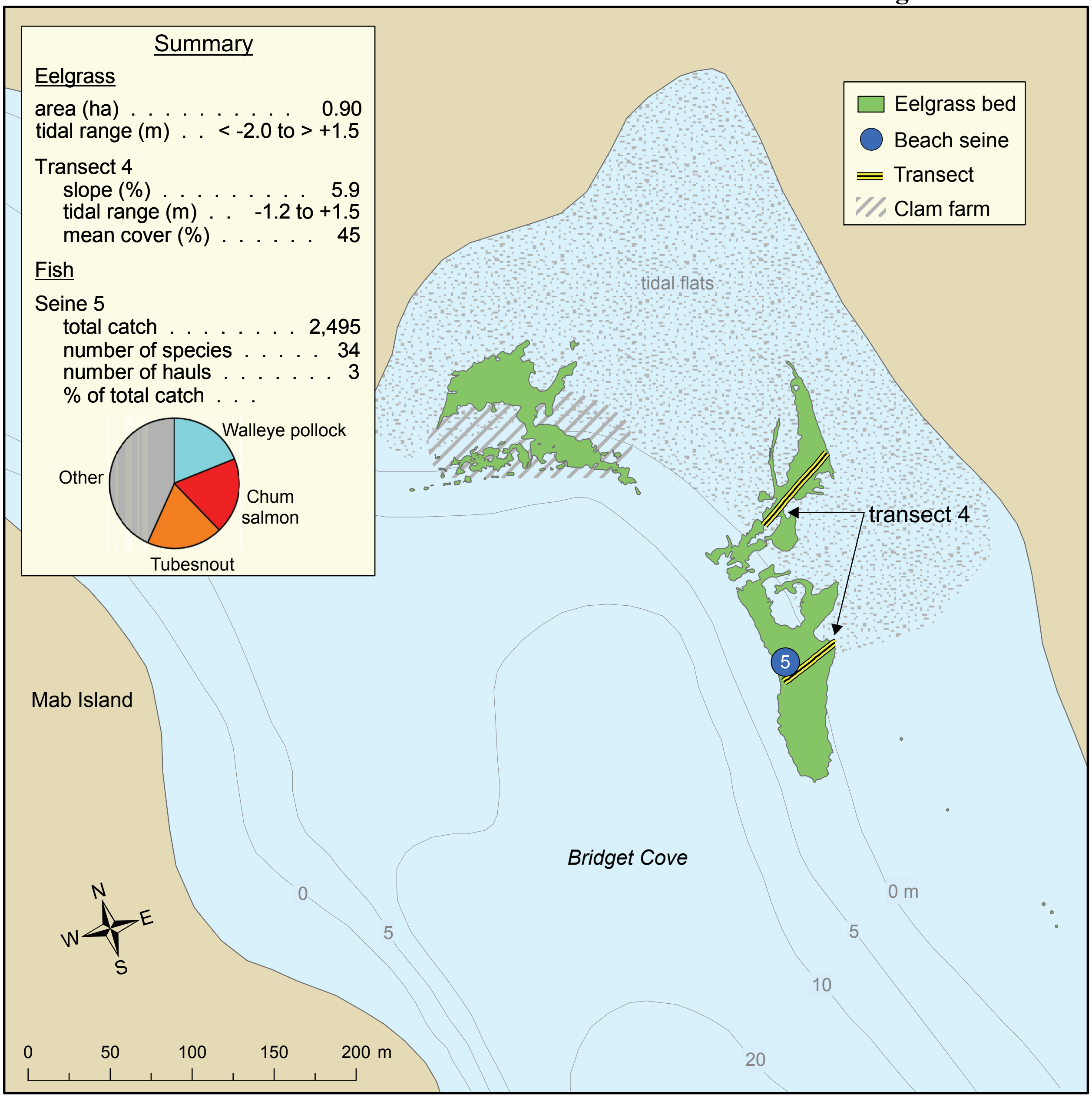

Figure 5.-- Eelgrass (*Zostera marina*) beds sampled at the central area of Bridget Cove, Juneau, Alaska, in summer 2004 to 2007. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect, fish sampling site (beach seine), and private clam farm. See Figure 1 for location within the City and Borough of Juneau.

Bridget Cove south

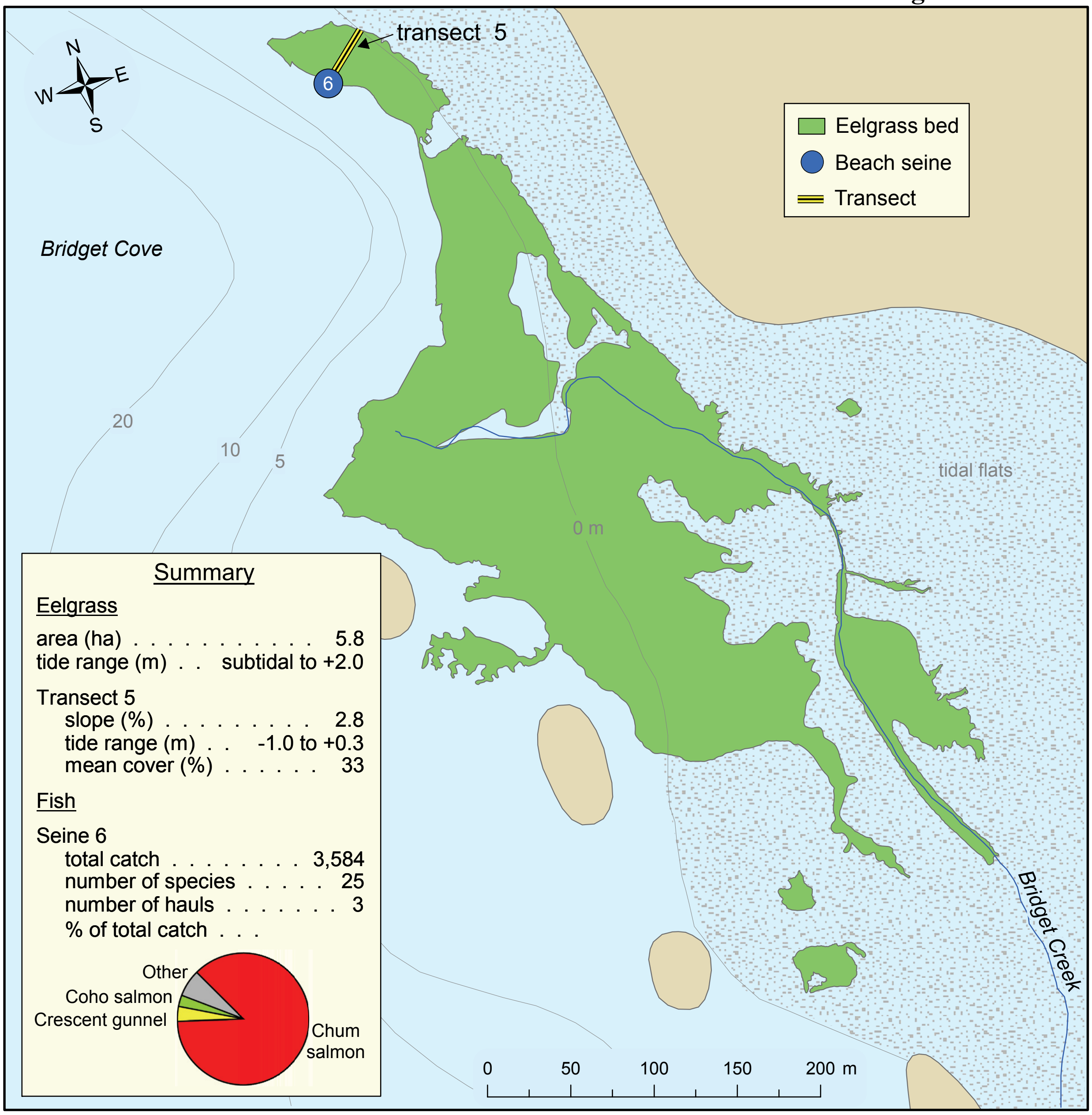

Figure 6.-- Eelgrass (*Zostera marina*) beds sampled at the south end of Bridget Cove, Juneau, Alaska, in summer 2004 to 2006. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect and fish sampling site (beach seine). See Figure 1 for location within the City and Borough of Juneau.

Sunshine Cove

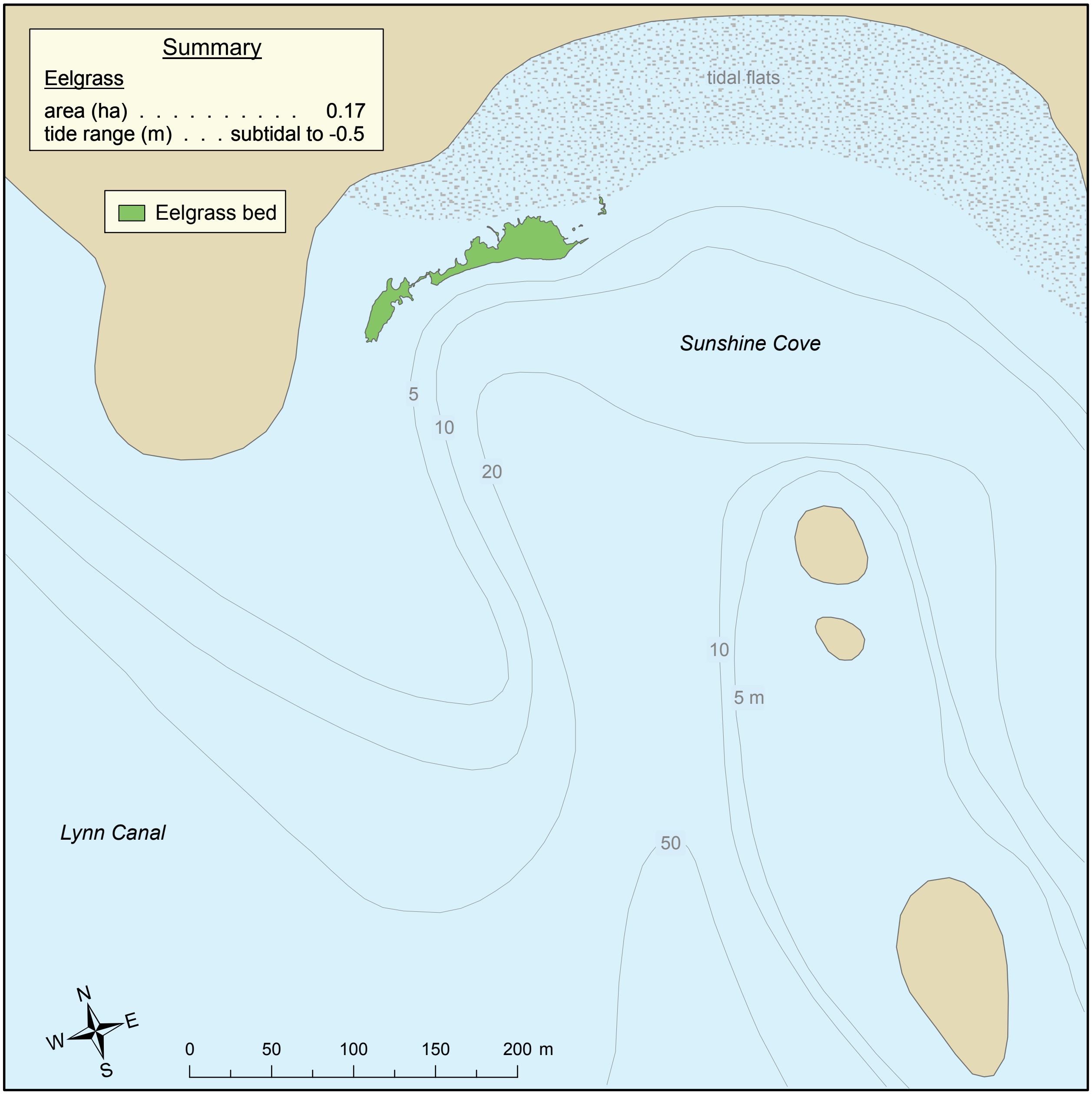

Figure 7.-- Eelgrass (*Zostera marina*) bed sampled at Sunshine Cove, Juneau, Alaska, in summer 2004. Eelgrass was mapped with global positioning system technology. See Figure 1 for location within the City and Borough of Juneau.

Tee Harbor

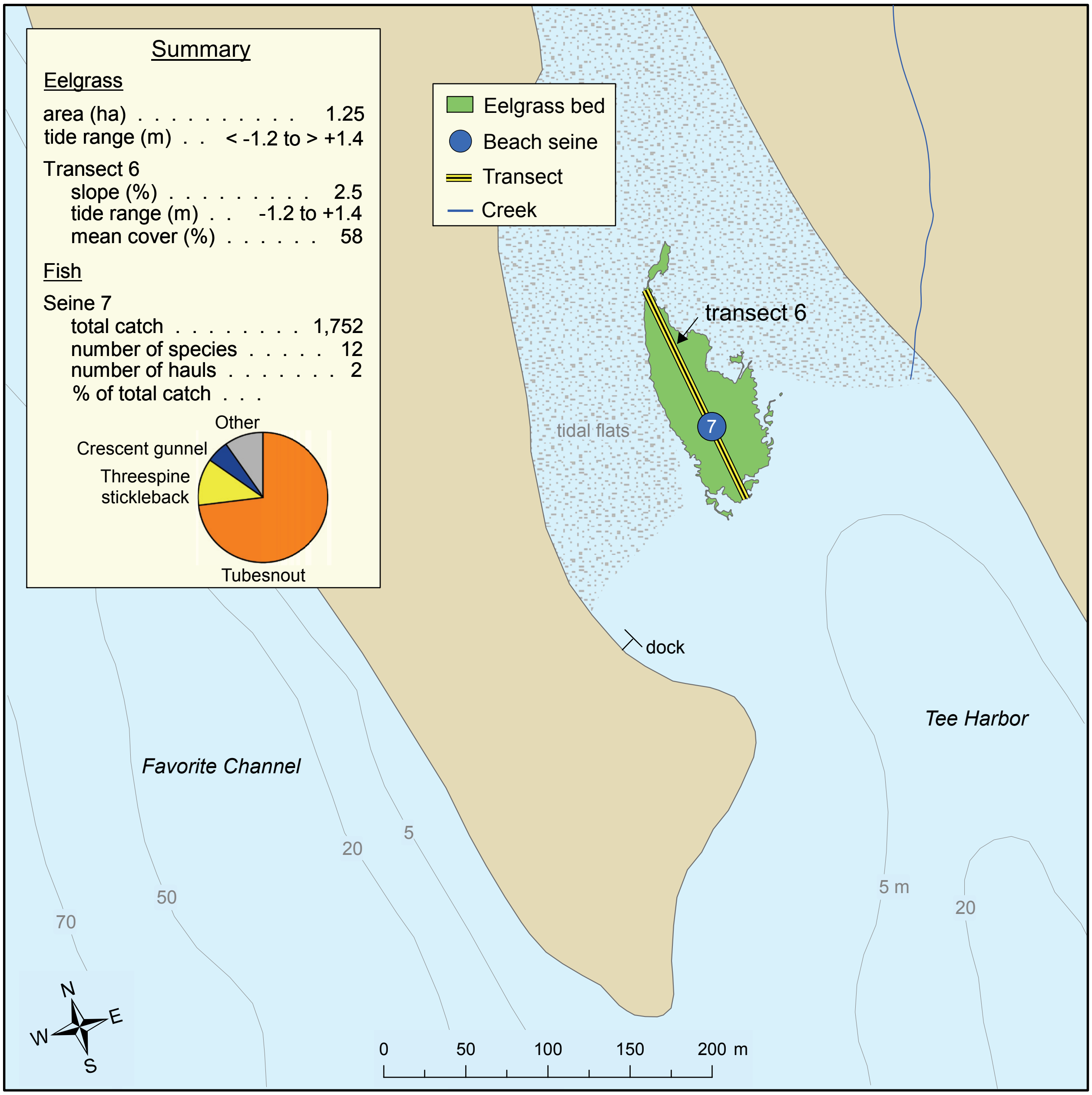

Figure 8.-- Eelgrass (*Zostera marina*) bed sampled at Tee Harbor, Juneau, Alaska, in summer 2005 and 2006. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect and fish sampling site (beach seine). See Figure 1 for location within the City and Borough of Juneau.

Auke Village

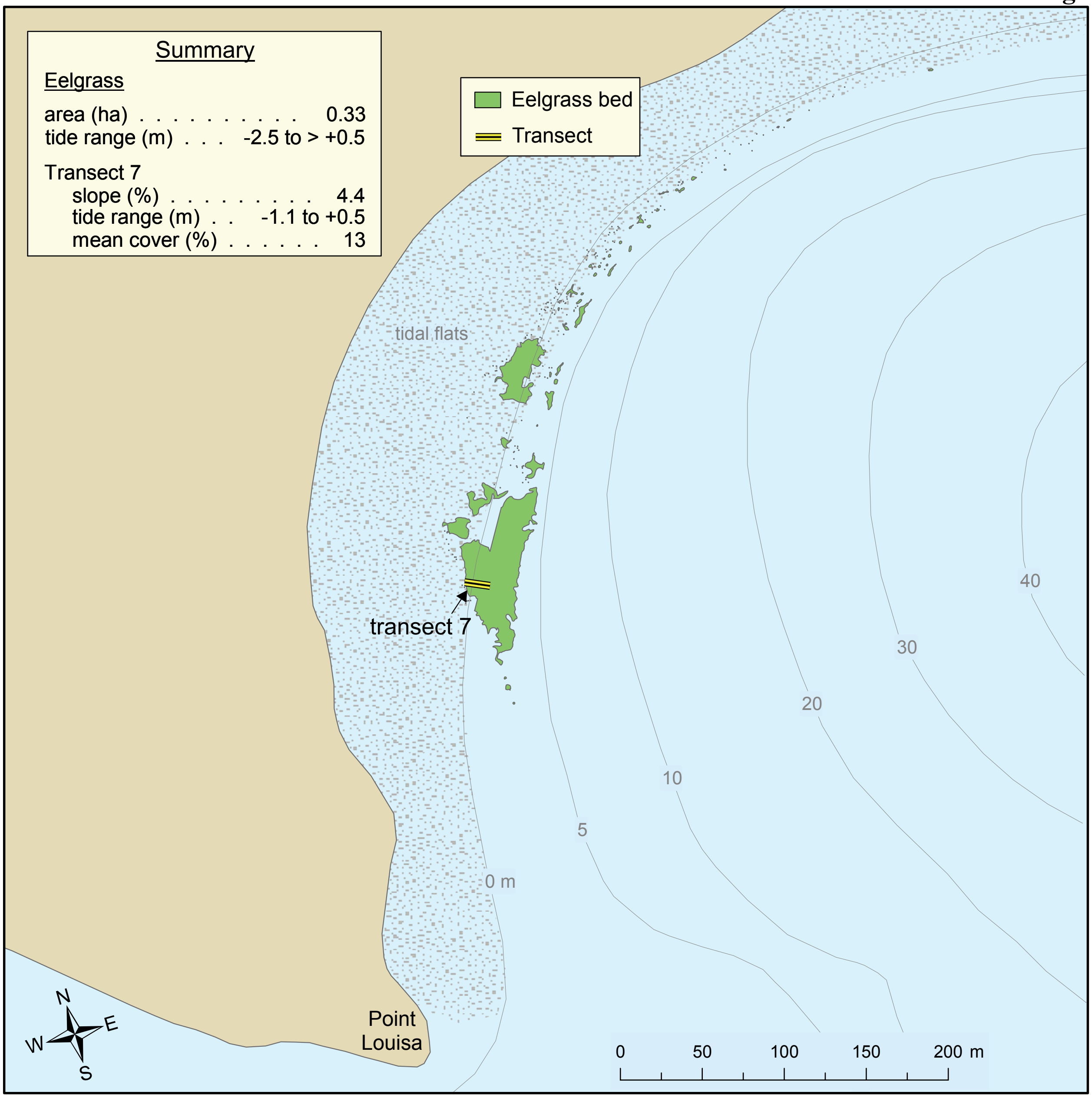

Figure 9.-- Eelgrass (*Zostera marina*) beds sampled at Auke Village, Juneau, Alaska, in summer 2004 and 2005. Eelgrass was mapped with global positioning system technology. Shown is an eelgrass transect. See Figure 1 for location within the City and Borough of Juneau.

Indian Cove

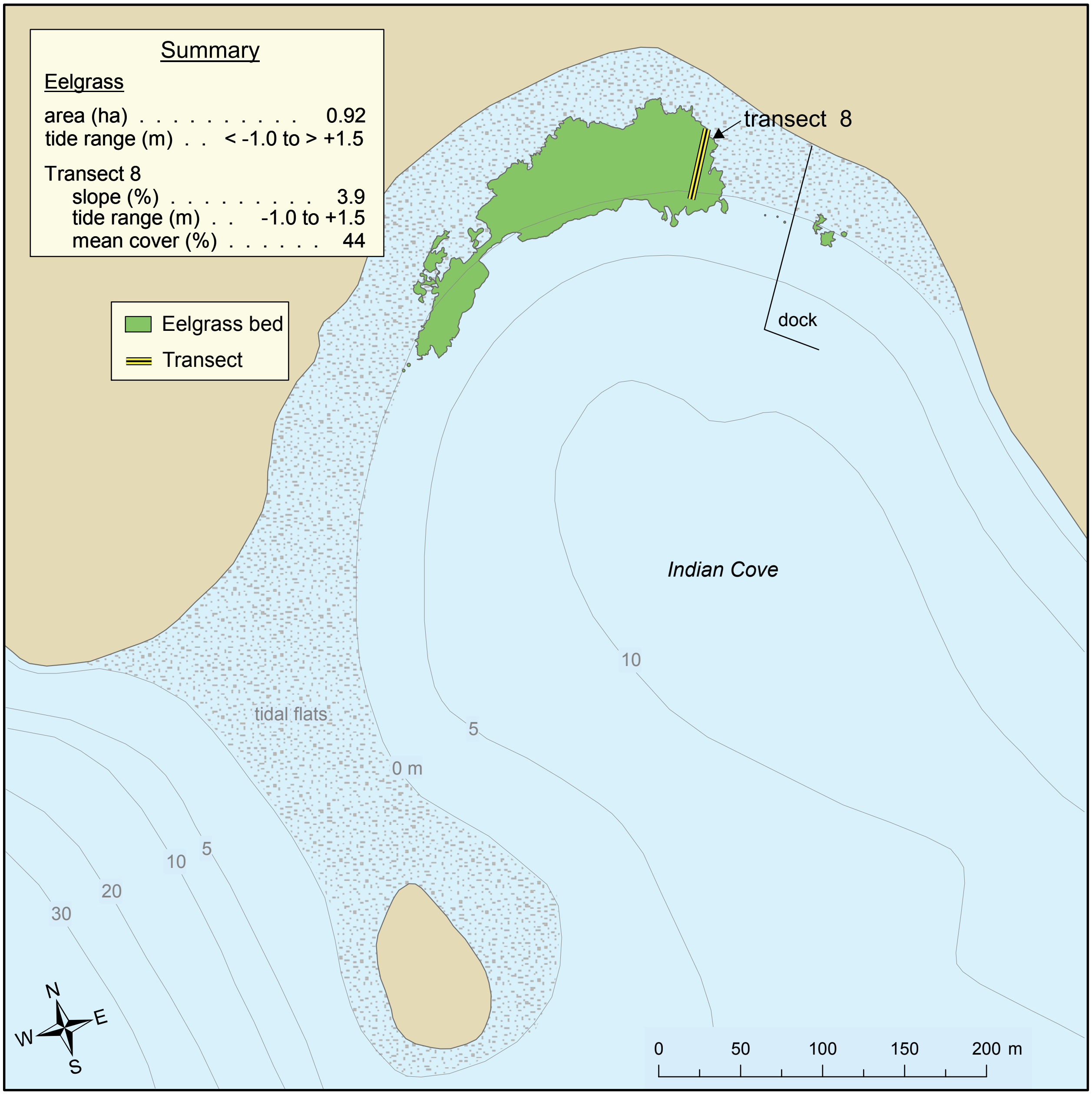

Figure 10.-- Eelgrass (*Zostera marina*) bed sampled at Indian Cove, Juneau, Alaska, in summer 2004 and 2005. Eelgrass was mapped with global positioning system technology. Shown is an eelgrass transect. See Figure 1 for location within the City and Borough of Juneau.

Auke Nu Cove

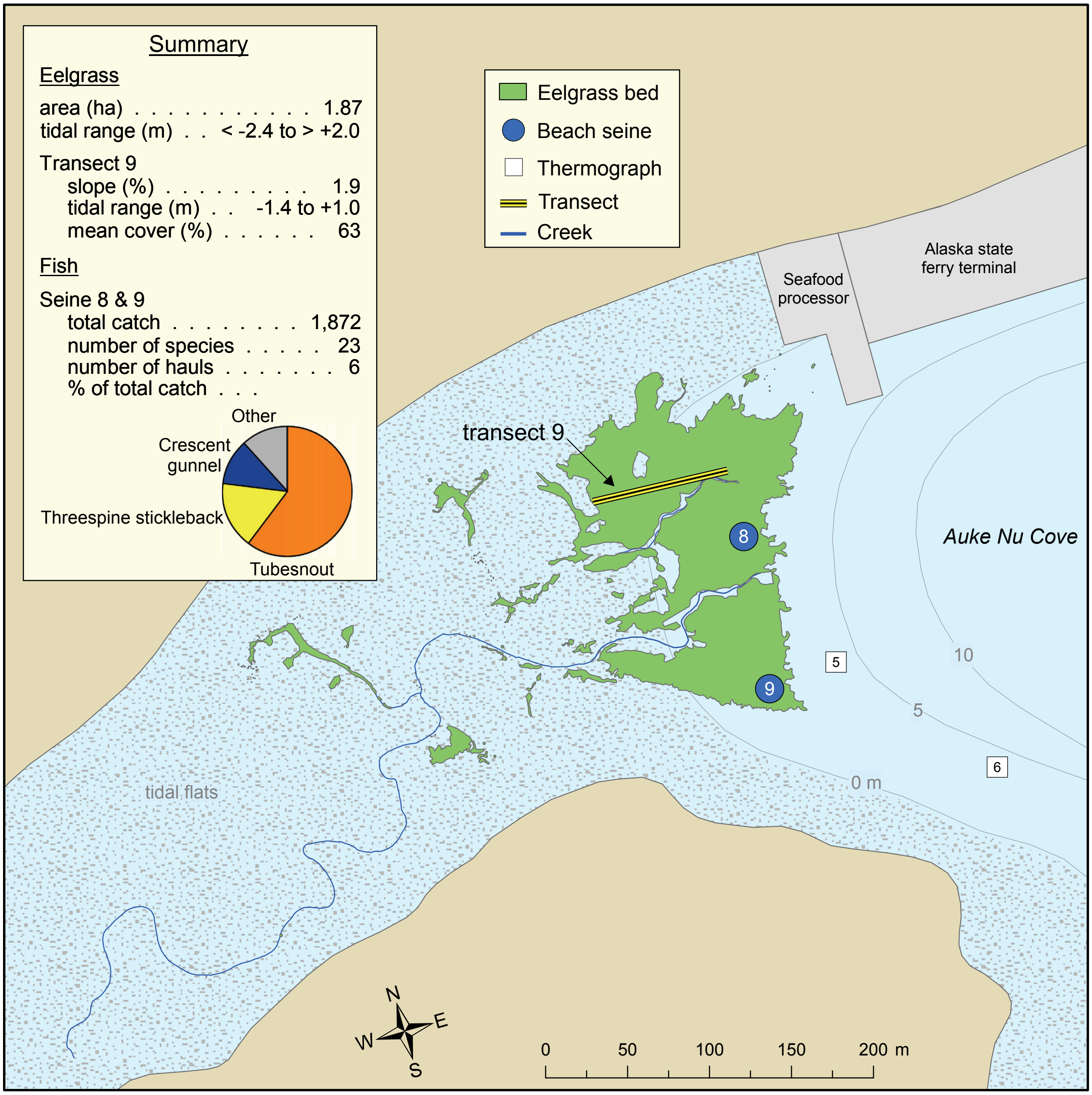

Figure 11.-- Eelgrass (*Zostera marina*) beds sampled at Auke Nu Cove, Juneau, Alaska, in summer 2004 to 2007. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect, fish sampling sites (beach seine), and water temperature monitoring sites (thermographs). See Figure 1 for location within the City and Borough of Juneau.

Waydelich Creek

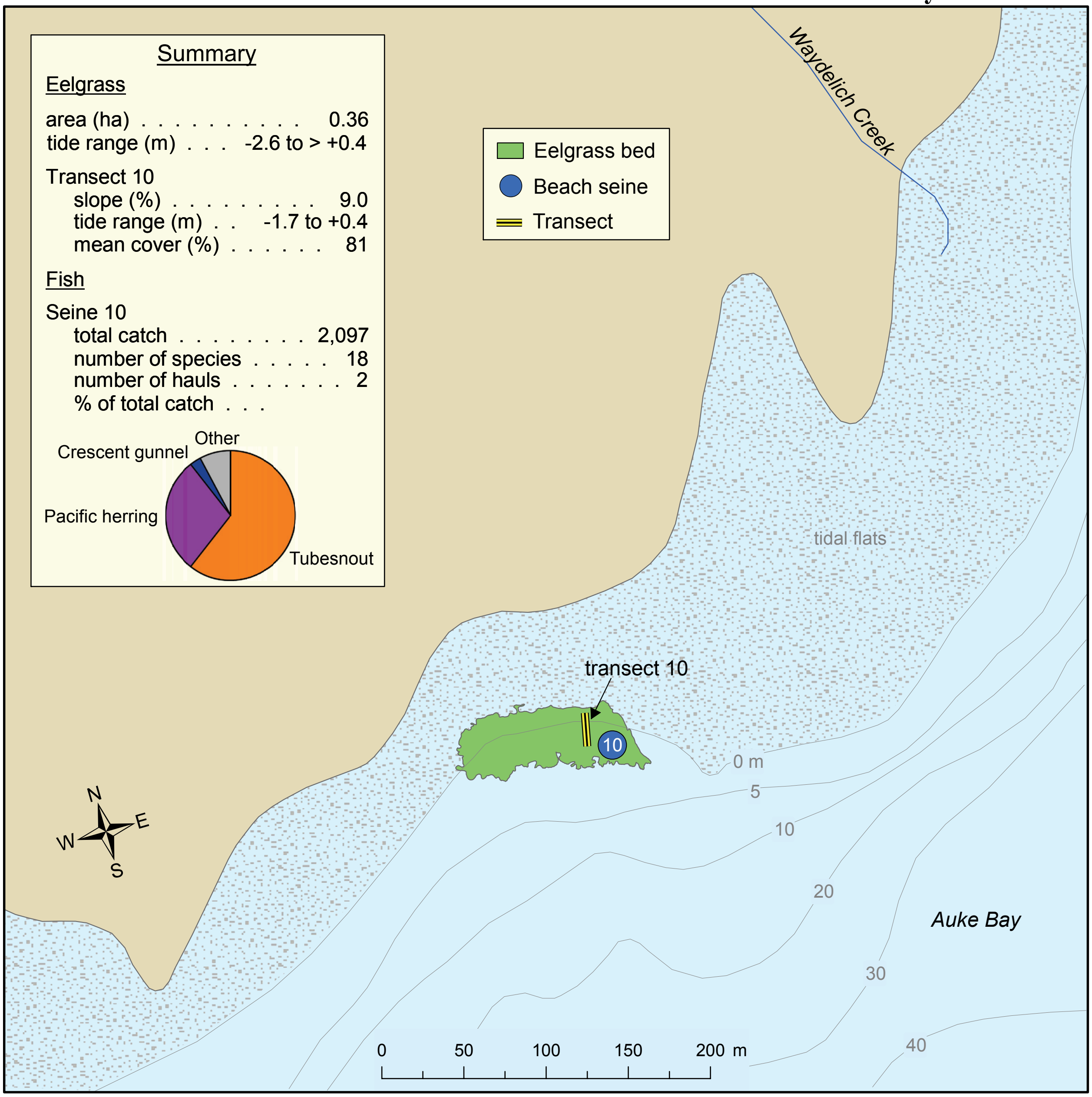

Figure 12.-- Eelgrass (*Zostera marina*) bed sampled near Waydelich Creek, Juneau, Alaska, in summer 2004 to 2006. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect and fish sampling site (beach seine). See Figure 1 for location within the City and Borough of Juneau.

Bay Creek

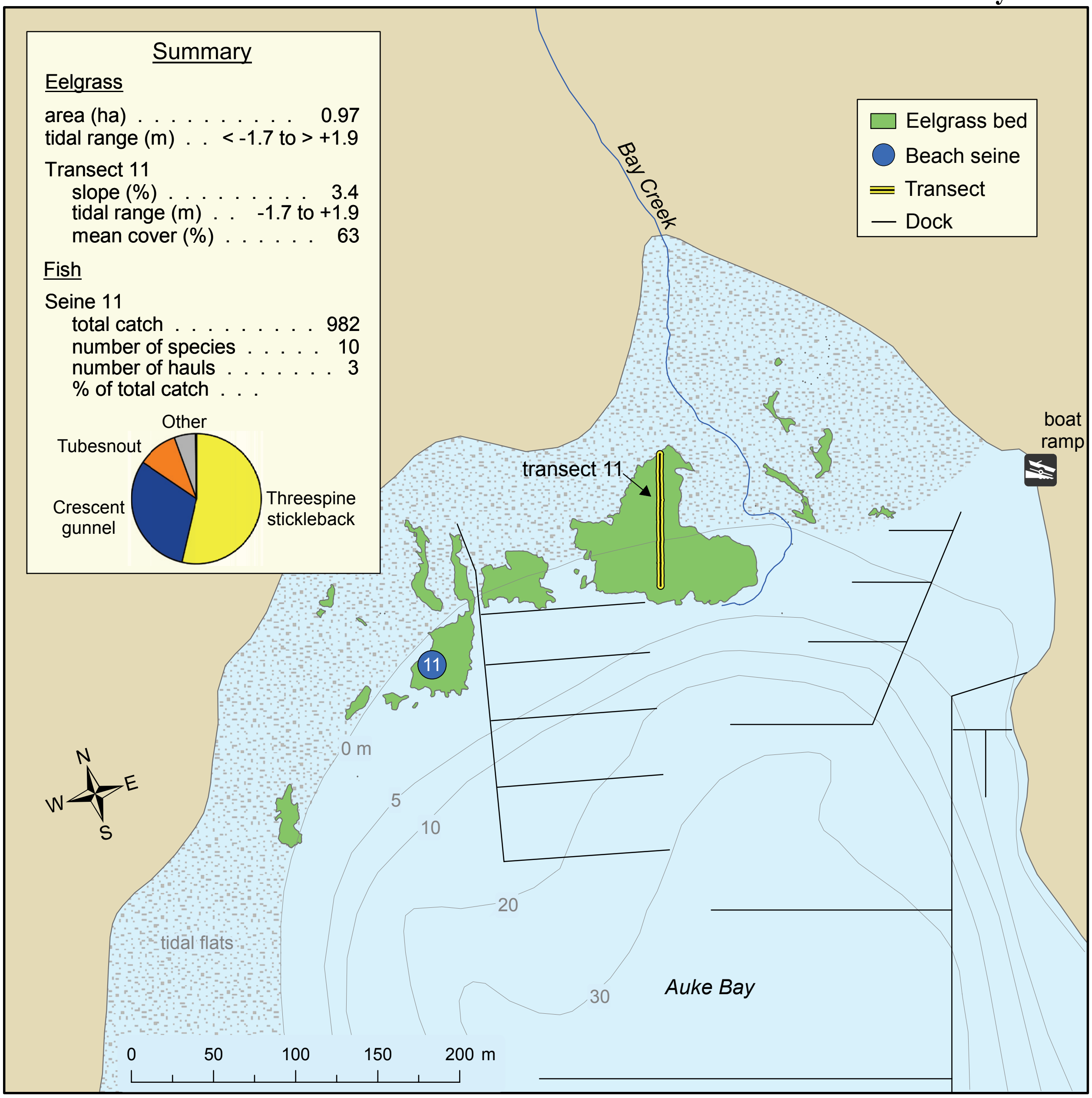

Figure 13.-- Eelgrass (*Zostera marina*) beds sampled near Bay Creek, Juneau, Alaska, in summer 2004 to 2007. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect, fish sampling site (beach seine), and private and public docks. See Figure 1 for location within the City and Borough of Juneau.

Mendenhall Peninsula

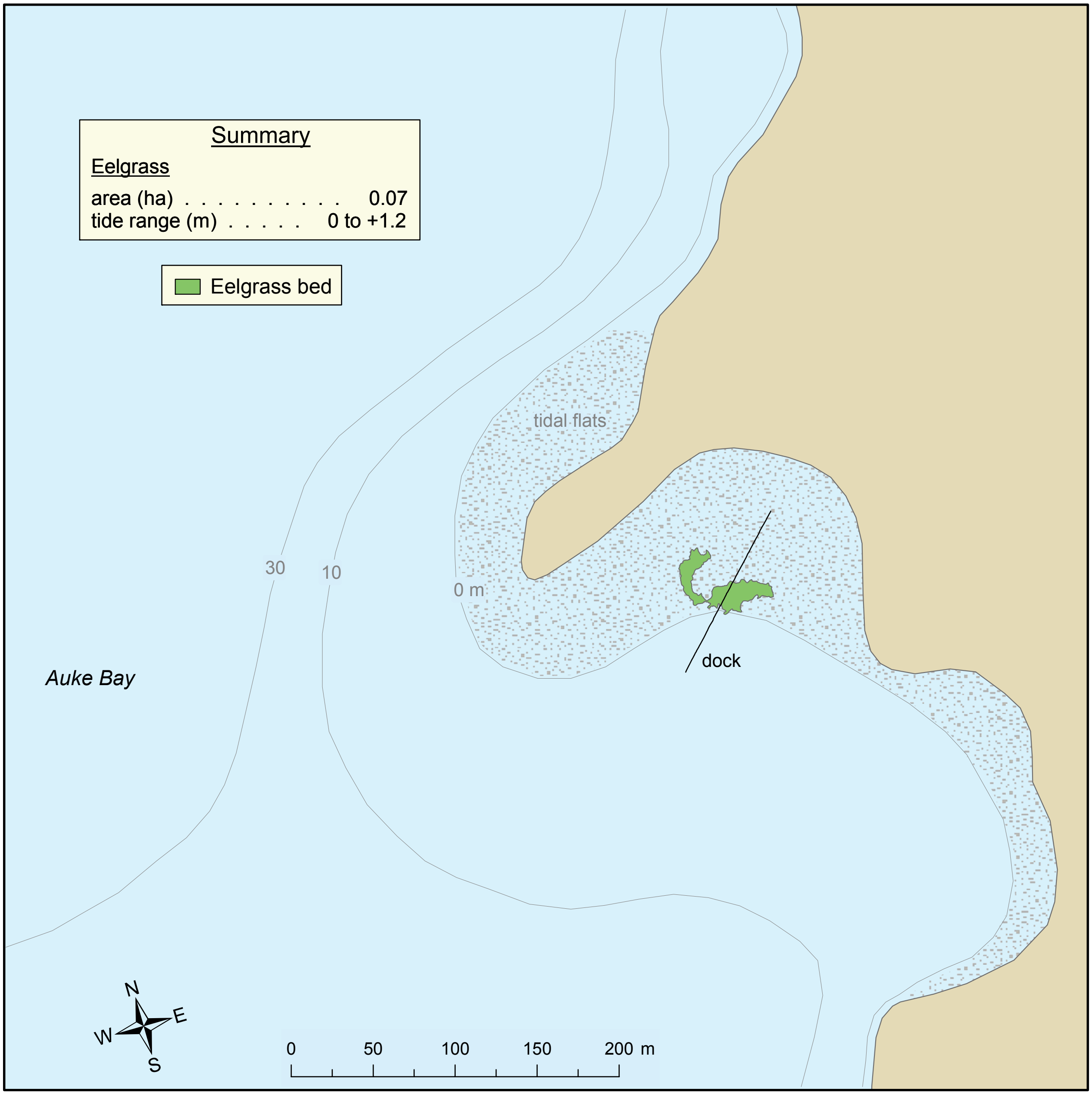

Figure 14.-- Eelgrass (*Zostera marina*) bed sampled on the Mendenhall Peninsula, Juneau, Alaska, in winter 2007. Eelgrass was mapped with global positioning system technology. See Figure 1 for location within the City and Borough of Juneau.

Fish Creek

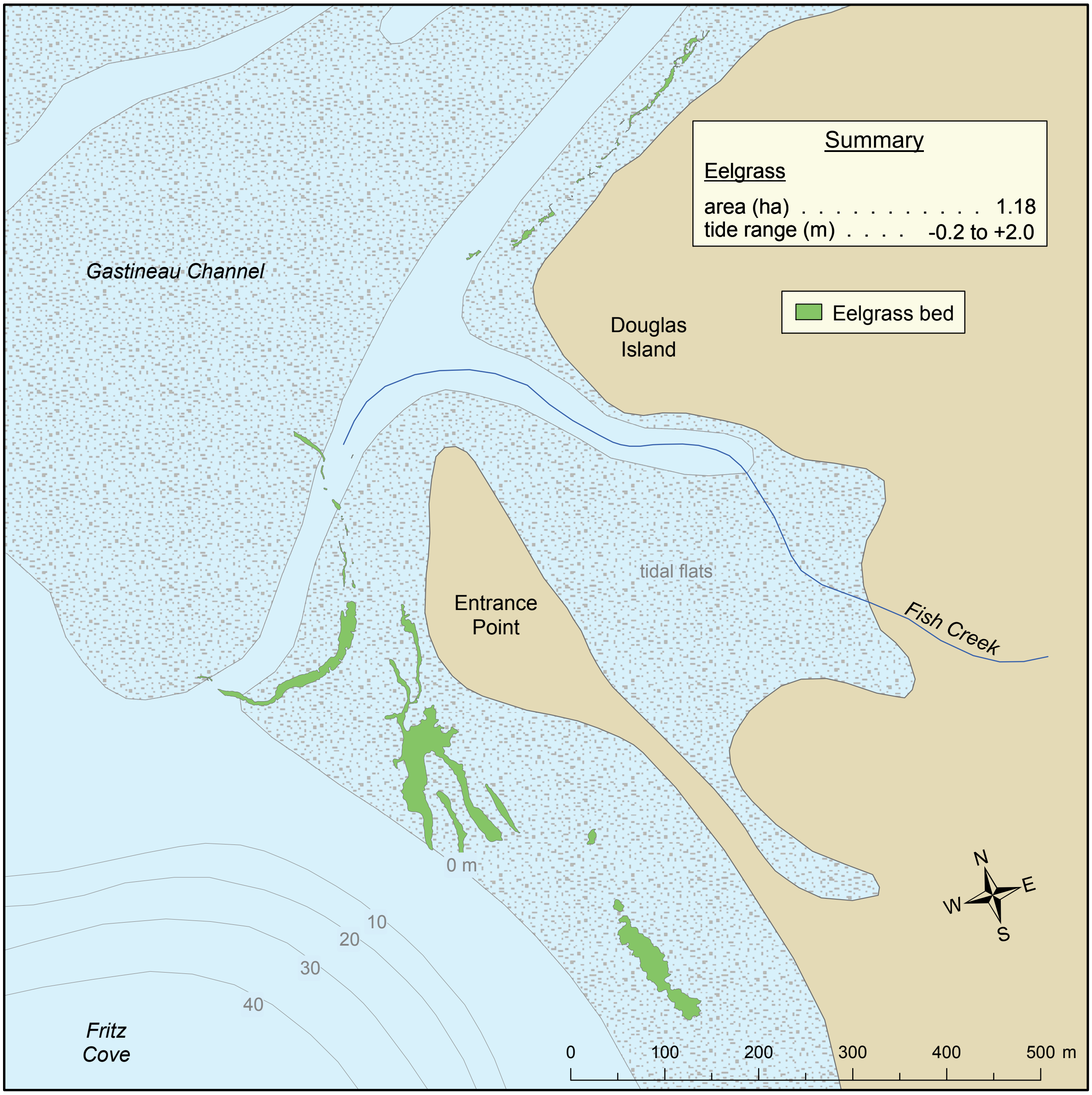

Figure 15.-- Eelgrass (*Zostera marina*) beds sampled near Fish Creek, Juneau, Alaska, in summer 2005 and spring 2007. Eelgrass was mapped with global positioning system technology. Small eelgrass patches (≤ 0.002 ha) were mapped, but are not visible at a 1:7,000 scale. These patches, however, are included in area calculations. See Figure 1 for location within the City and Borough of Juneau.

Peterson Creek

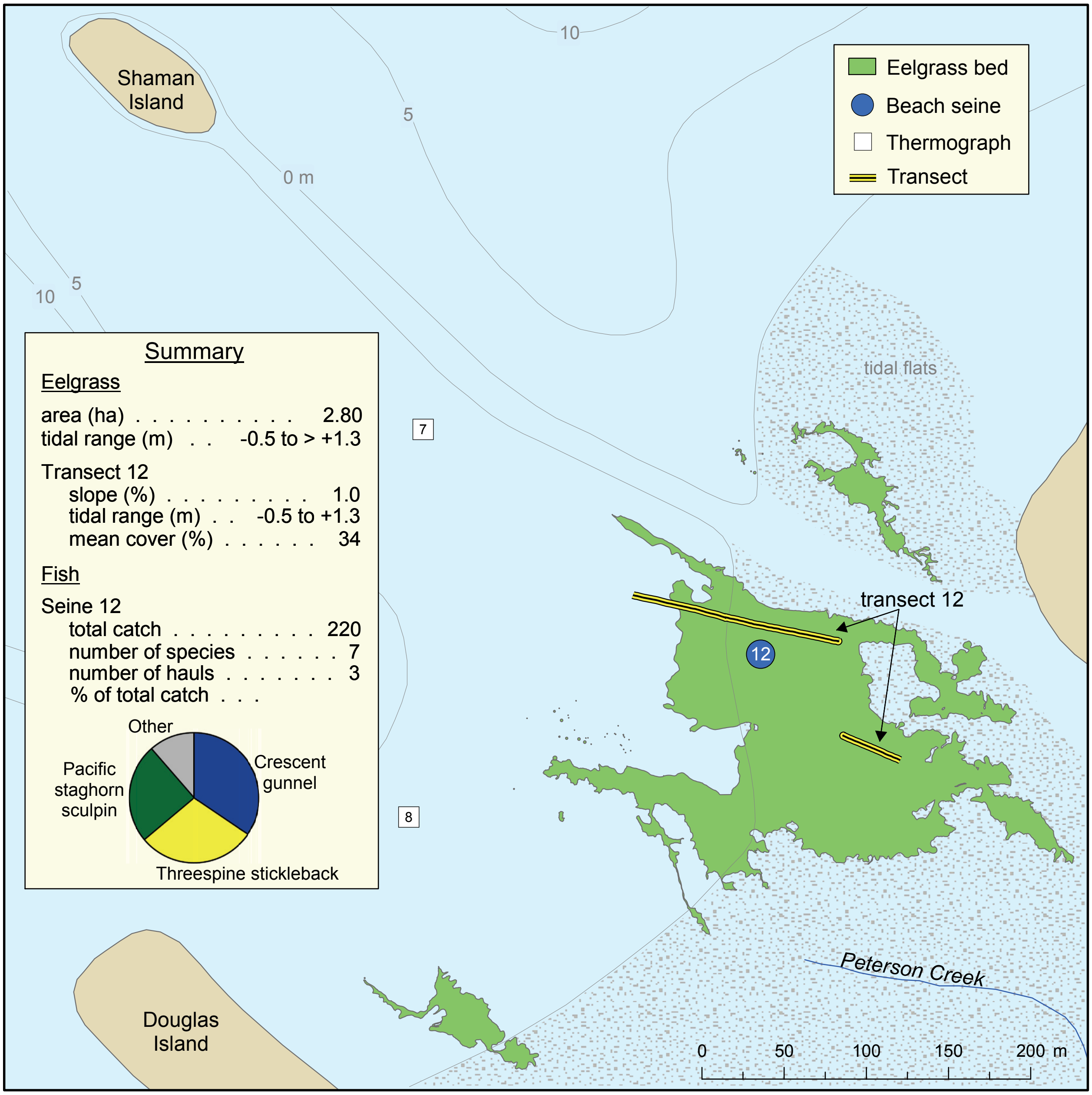

Figure 16.-- Eelgrass (*Zostera marina*) beds sampled near Peterson Creek, Juneau, Alaska, in summer 2004 to 2007. Eelgrass was mapped with global positioning system technology. Shown are an eelgrass transect, fish sampling site (beach seine), and water temperature monitoring sites (thermographs). See Figure 1 for location within the City and Borough of Juneau.

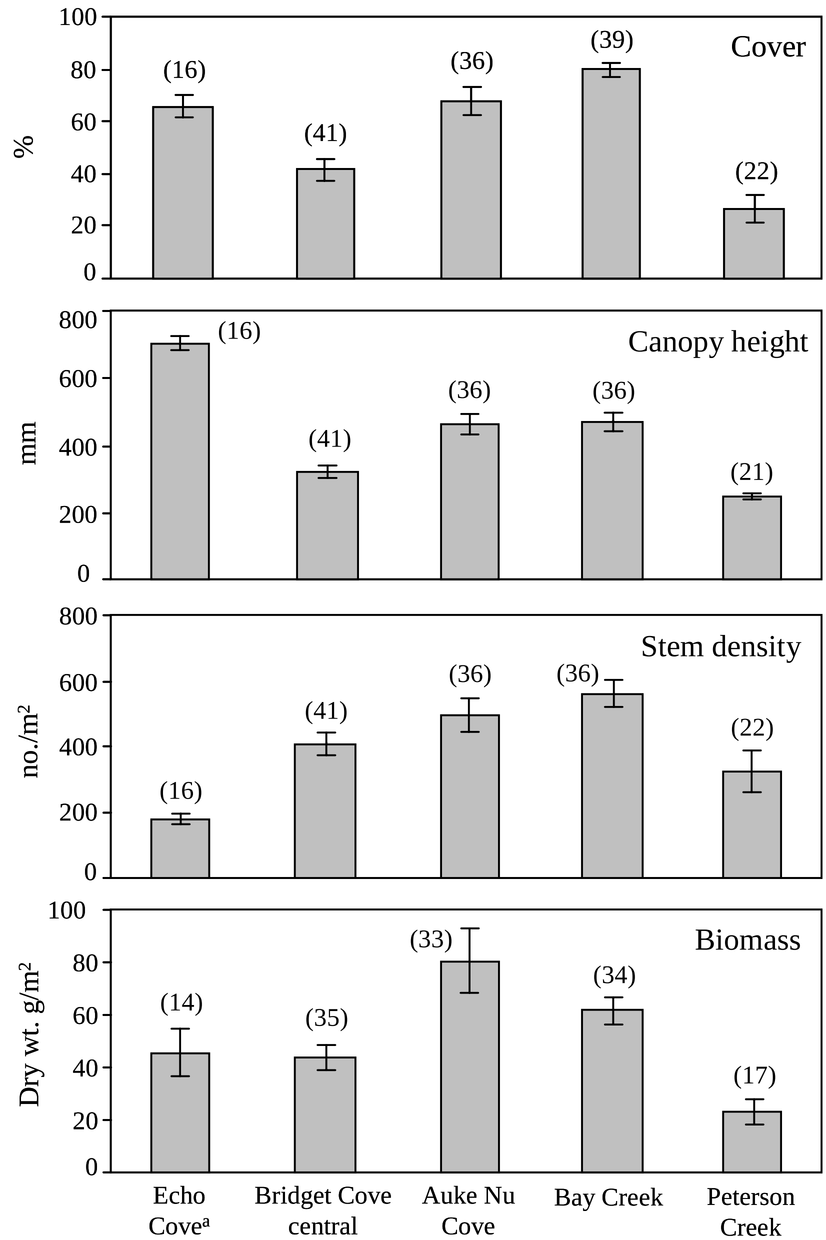

Figure 17.-- Eelgrass (*Zostera marina*) characteristics at five locations sampled in the City and Borough of Juneau, Alaska. Data are means (± SE) from three summers (2004 to 2006) and three tidal blocks (-1.0 m to -0.5 m, -0.5 m +0.0 m, and 0.0 m to 0.5 m) relative to mean lower low water. Stem density and biomass were above-ground measurements. Sample size in parentheses. (a = transect 1)

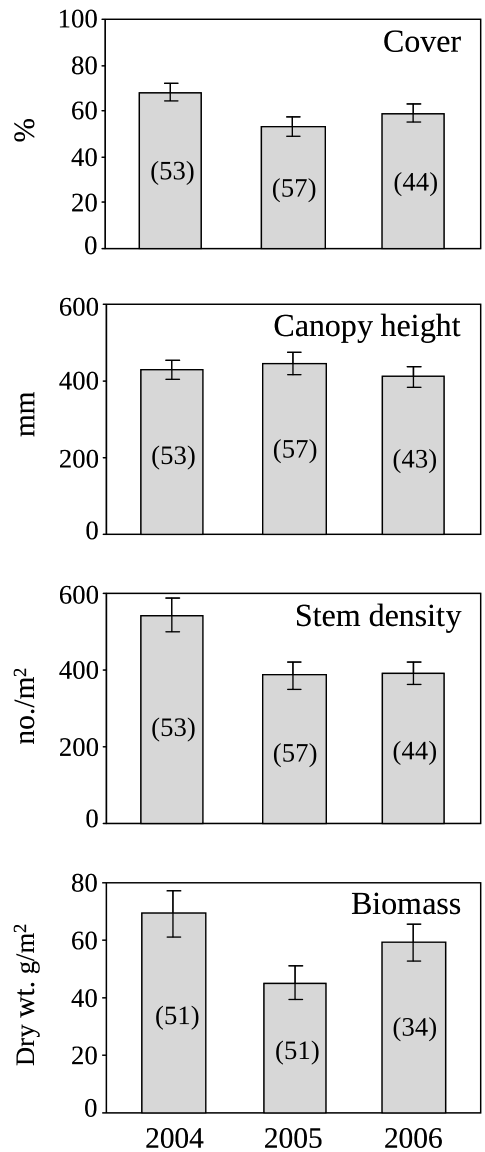

Figure 18.-- Eelgrass (*Zostera marina*) characteristics by year (2004 to 2006) in the City and Borough of Juneau, Alaska. Data are means (± SE) from five locations (Echo Cove - transect 1, Bridget Cove central, Auke Nu Cove, Bay Creek, and Peterson Creek) and three tidal blocks (-1.0 m to -0.5 m, -0.5 m +0.0 m, and 0.0 m to 0.5 m) relative to mean lower low water. Stem density and biomass were above-ground measurements. Sample size in parentheses.

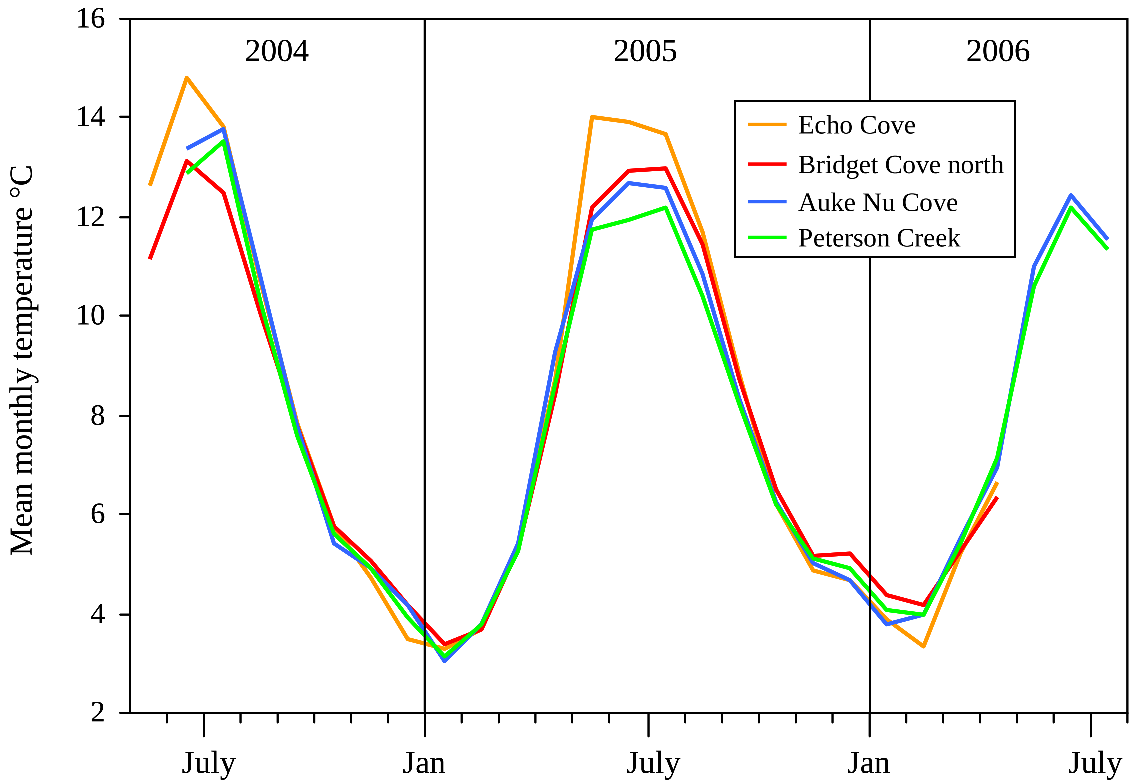

Figure 19.-- Mean monthly water temperatures recorded by thermographs at Echo Cove, north end of Bridget Cove, Auke Nu Cove, and Peterson Creek in the City and Borough of Juneau, Alaska, from June 2004 through August 2006. Locations of thermographs are shown in Table 1 and in Figures 1, 2, 4, 11, and 16.

Appendix 1.-- Eelgrass (*Zostera marina*) percent cover, canopy height (mm), above-ground stem density (number shoots/m^2), and above-ground biomass (grams/m^2) by transect, year, and tidal block at seven locations in the City and Borough of Juneau, Alaska. Eelgrass characteristics are means (± SE). Transects were sampled in July and August 2004, 2005, and 2006. Tidal blocks are relative to mean lower low water: 1 = -1.0 m to -0.5 m, 2 = -0.5 m to 0.0 m, 3 = 0.0 m to +0.5 m, 4 = +0.5 m to +1.0 m, 5 = +1.0 m to +1.5 m.

Location	Figure	Transect	Year	Block	Cover	SE	Canopy	SE	Density	SE	Biomass	SE
Echo Cove	2	1	2004	1	63	3	697	10	214.4	38.7	30.81	12.24
			2005	1	11	73	770	52	163.2	45.7	26.94	10.80
			2006	1	63	10	650	32	165.3	12.2	650.00	74.59
		2	2005	1	74	9	550	32	140.8	35.6	39.26	6.81
			2006	1	48	18	620	11	136.0	62.8	35.52	23.44
			2005	2	50	48	475	43	168.0	48.2	49.79	29.00
			2006	2	90	5	660	70	188.8	43.9	72.42	8.82
Bridget Cove central	5	4	2004	1	73	9	448	41	480.0	77.3	49.74	6.11
			2005	1	53	11	390	10	400.0	110.7	53.28	18.30
			2006	1	66	9	550	61	520.0	40.5	104.68	10.41
			2004	2	16	4	374	32	262.4	69.9	33.56	12.39
			2005	2	88	13	460	51	704.0	135.2	88.20	16.50
			2006	2	53	14	260	43	500.0	41.0	59.20	14.12
			2004	3	59	17	306	10	528.0	132.0	48.10	21.30
			2005	3	15	5	245	38	252.0	82.7	13.06	5.91
			2006	3	53	16	190	15	540.0	129.4	41.99	10.14

Appendix 1.-- Continued.

Location	Figure	Transect	Year	Block	Cover	SE	Canopy	SE	Density	SE	Biomass	SE
			2004	4	42	19	316	39	297.6	33.8	30.79	11.59
			2005	4	24	6	260	47	184.0	43.0	14.08	4.84
			2006	4	37	15	240	43	246.4	88.3	30.02	16.87
Bridget Cove south	6	5	2004	1	19	8	298	63	185.6	38.4	16.76	4.51
			2005	1	5	2	345	68	160.0	56.9	8.14	3.74
			2006	1	56	14	460	46	368.0	48.0	66.94	18.34
			2004	2	99	1	532	20	469.3	117.7	88.75	19.30
			2005	2	26	15	260	65	204.8	65.1	18.38	9.00
			2006	2	41	13	170	40	592.0	180.0	57.18	25.29
			2004	3	78	15	476	35	467.2	73.9	82.46	15.30
Tee Harbor	8	6	2006	2	77	8	470	25	528.0	54.3	56.83	4.39
			2006	3	60	10	420	32	448.0	67.3	36.83	12.70
			2006	4	15	4	300	32	264.0	47.3	20.60	2.46
			2006	5	18	11	190	24	148.0	49.0	4.70	0.25
			2004	4	7	3	254	38	88.0	11.0	10.91	4.89
Auke Nu Cove	11	9	2004	1	98	2	767	33	613.3	129.4	197.62	58.43
			2005	1	90	12	470	12	329.6	128.6	90.02	45.70
			2004	2	97	2	700	10	650.7	83.8	127.53	15.70
			2005	2	13	50	388	31	296.0	66.8	30.04	13.39

Appendix 1.-- Continued.

Location	Figure	Transect	Year	Block	Cover	SE	Canopy	SE	Density	SE	Biomass	SE
			2006	2	80	9	460	99	518.4	70.6	96.04	29.45
			2004	3	85	12	352	45	972.8	144.0	96.38	21.80
			2005	3	25	77	370	26	256.0	77.2	25.38	13.10
			2006	3	55	10	370	28	419.2	41.2	41.79	10.33
			2005	4	28	12	210	19	278.4	81.2	18.36	6.11
			2006	4	69	13	390	31	537.6	113.6	45.90	26.75
Bay Creek	13	11	2004	1	82	3	520	37	416.0	65.6	90.52	24.24
			2005	1	92	3	800	76	377.6	21.2	65.62	9.39
			2004	2	90	3	390	37	787.2	101.9	89.58	9.37
			2005	2	56	11	540	56	483.2	117.4	56.36	12.10
			2006	2	73	6	470	37	412.8	49.4	40.43	13.48
			2004	3	90	4	296	16	857.6	127.7	56.61	7.51
			2005	3	41	77	325	48	732.0	77.7	40.90	10.40
			2006	3	64	11	360	12	460.8	63.0	41.17	10.83
			2004	4	73	8	324	19	643.2	120.1	49.39	9.16
			2005	4	18	17	230	26	355.2	178.0	18.44	10.90
			2006	4	71	13	320	25	600.0	86.3	50.61	12.65
			2004	5	33	10	246	28	512.0	154.2	35.42	11.47
			2005	5	27	7	200	25	272.0	107.1	8.50	3.70

Appendix 1.-- Continued.

Location	Figure	Transect	Year	Block	Cover	SE	Canopy	SE	Density	SE	Biomass	SE
			2006	5	19	5	240	31	355.2	115.6	14.73	12.29
Peterson Creek	16	12	2004	2	33	12	260	29	464.0	186.8	34.02	8.55
			2005	2	22	16	260	24	259.2	153.1	11.43	2.64
			2004	3	43	19	213	26	360.0	125.4	18.56	11.03
			2005	3	25	12	256	19	608.0	189.7	18.92	7.33
			2006	3	12	2	220	17	156.0	21.0	35.27	19.44
			2004	4	30	9	268	13	612.0	86.3	36.54	13.41
			2005	4	31	8	243	8	556.0	225.1	19.19	8.57
			2006	4	75	15	330	37	780.8	138.3	145.92	58.29
			2006	5	39	17	260	59	316.8	192.2	56.65	37.10

Appendix 2.-- Pairwise multiple comparison of eelgrass (*Zostera marina*) characteristics (i.e., percent cover, canopy height, stem density, biomass) among five locations sampled in the City and Borough of Juneau, Alaska, from 2004 to 2006. Significant differences among location and year groups by eelgrass characteristic are identified by a specific letter (see below). For example, canopy height at Echo Cove (2004) differed significantly ($P < 0.05$) from Bridget Cove (2006) and Peterson Creek (2004, 2005, and 2006). A dash indicates no significant difference.

		Echo Cove[1]			Bridget Cove[2]			Auke Nu Cove			Bay Creek			Peterson Creek		
Location	Year	'04	'05	'06	'04	'05	'06	'04	'05	'06	'04	'05	'06	'04	'05	'06
Echo Cove[1]	'04	-	-	-	-	-	b	c	-	-	-	-	-	b	b	b
	'05	-	-	-	-	-	b	c	-	-	c	-	-	b	b	b
	'06	-	-	-	-	-	-	c	-	-	c	-	-	-	-	-
Bridget Cove[2]	'04	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
	'05	-	-	-	-	-	-	a	-	-	-	a	-	-	-	-
	'06	b	b	-	-	-	-	-	-	-	-	-	-	-	-	-
Auke Nu Cove	'04	c	c	c	a	a	-	-	a, c	-	-	-	-	a, d	a, d	a, c
	'05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	'06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bay Creek	'04	-	c	c	-	a	-	-	-	-	-	-	-	a	a, d	a, c
	'05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	'06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peterson Creek	'04	b	b	-	-	-	-	a, d	-	-	a	-	-	-	-	-
	'05	b	b	-	-	-	-	a, d	-	-	a, d	-	-	-	-	-
	'06	b	b	-	-	-	-	a, c	-	-	a, c	-	-	-	-	-

[1]Echo Cove – transect 1
[2]Bridget Cove central
a = percent cover
b = canopy height (mm)
c = above-ground stem density (no./m^2)
d = above-ground biomass (dry wt. g/m^2)

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