

Fish Use and Size of Eelgrass Meadows in Southeastern Alaska: A Baseline For Long-term Assessment of Biotic Change

Abstract

Eelgrass meadows at six sites in southeastern Alaska were sampled for fish assemblages and mapped to establish a baseline of information for long-term assessment of biotic change. All sites were sampled in spring 2001, 2002, and 2003; four of the sites were also sampled in winter 2003. A total of 44 seine hauls from all sampling periods yielded 58,902 fish comprising 45 species. Fish abundance in spring differed significantly among sites but not among years. The most abundant commercially important or forage fish species captured were chum salmon, Pacific herring, pink salmon, coho salmon, and Pacific sand lance; mean size of each of these species was ≤ 100 mm FL. For those sites sampled seasonally in 2003, fish were significantly more abundant in spring than in winter. At each site, three different species accounted for most ($\geq 69\%$) of the total catch. Size of eelgrass meadows varied annually; maximum percent change in area ranged from -13% to $+27\%$. Eelgrass density ranged from 336 shoots/m² to 1,544 shoots/m², and dry biomass ranged from 36 g/m² to 71 g/m². Periodic re-sampling of the eelgrass sites established in this study will allow resource managers to track long-term and large-scale changes in fish communities and habitat that may result from shoreline development or global climate change.

Introduction

Eelgrass (*Zostera marina*) is an important near-shore habitat present in many bays, inlets, and lagoons along the Pacific coast of North America, including Alaska (McRoy 1968, Phillips 1984, Wyllie-Echeverria and Ackerman 2003). Eelgrass provides food resources, cover, and nursery habitat for many marine species important in sport and commercial fisheries (Phillips 1984, Macdonald and Chang 1993, Lazzari and Tupper 2002). Other beneficial functions of eelgrass include oxygen production, erosion control, and contaminant filtration (Spalding et al. 2003).

In Alaska, eelgrass is an important rearing habitat for many fish species in spring and summer; fish use of eelgrass in fall and winter, however, is largely unknown. In a spring survey, juvenile pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) were some of the most abundant species captured in eelgrass near Craig, Alaska (Murphy et al. 2000). In a 3-year summer survey throughout southeastern Alaska, Johnson et al. (2003) found 49 species of fish in eelgrass, including many commercially important species. In Prince William Sound, Alaska, summer SCUBA surveys identified Pacific cod (*Gadus macrocephalus*) as the dominant species in eelgrass (Laur and

Haldorson 1996, Dean et al. 2000). In addition to providing rearing habitat in Alaska, eelgrass is also used as a spawning substrate in spring by Pacific herring (*Clupea pallasii*) (Blankenbeckler and Larson 1982).

Because eelgrass grows in shallow nearshore waters, it is vulnerable to human disturbance from urban growth, dredge and fill operations, and nutrient and sediment loading (Short and Wyllie-Echeverria 1996). Seagrass beds are declining worldwide at an alarming rate—estimated losses of seagrass habitat were 2,900 km² between the mid-1980s and the mid-1990s, with actual losses certainly much higher (Short and Wyllie-Echeverria 1996, Spalding et al. 2003). In Alaska, the extent and magnitude of eelgrass loss is unknown, as is the total acreage of eelgrass throughout the state. Additionally, human-induced global climate change may affect eelgrass distribution and abundance, and shift the distribution of some fish species that use eelgrass toward the poles as water temperatures warm and sea levels rise (Short and Neckles 1999, IPCC 2001). Global temperature is predicted to rise 1.4° to 5.8°C, and sea level may rise 80 cm or more by the year 2100; some of the effects of global climate change may be more pronounced in high northern latitudes (Schneider 1993, IPCC 2001).

The objective of our study was to establish a baseline of information on fish use and size of

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several eelgrass meadows in southeastern Alaska to allow for long-term assessment of biotic change. To establish a baseline and develop a measure of annual variability, we sampled eelgrass meadows over a 3-yr period at six sites in spring (all years) and winter (one year) for species composition, distribution, relative abundance, and size of fishes, and also measured the area of each meadow using global positioning system (GPS) technology. For fish, we focus on only the most abundant species captured at each site and those species included in a fisheries management plan (FMP) for Alaska (North Pacific Fishery Management Council 2005). Periodic re-sampling of the monitoring sites established in this study will allow resource managers to track changes in fish communities and habitat that may result from shoreline development or global climate change.

Methods

Study Area

Six eelgrass sites in southeastern Alaska were sampled for fish assemblages and mapped: Funter Bay and Chaik Bay on Admiralty Island; Crab Bay on Chichagof Island; and Nakwasina, Sandy Cove, and Pirates Cove on Baranof Island (Figure 1). Sites were sampled in June 2001 and 2002, and in late May or early June 2003. Additionally, four of the sites (Funter Bay, Crab Bay, Nakwasina, and Sandy Cove) were sampled in late January or early February 2003. May and June sampling are hereafter referred to as spring, and January and February sampling as winter. All sites were sampled during daylight (0500–1200 h) in spring and during darkness (1700–1900 h) in winter; there were no suitable low tides for sampling during daylight hours in winter. Sites were chosen to represent a geographical gradient from inside to outside waters and because they could all be sampled during 1 wk of minus tides. One large eelgrass meadow was sampled at each of these sites: Funter Bay, Crab Bay, Nakwasina, and Sandy Cove. Two small but separate eelgrass meadows in the same vicinity were sampled at Chaik Bay, and only one small eelgrass meadow was sampled at Pirates Cove.

Most eelgrass meadows were bounded by small creeks or stream deltas where eelgrass was sparse or absent; these areas served as boundaries for determining size and extent of each meadow. All sites were located inside partly enclosed or

protected bays with freshwater influence from relatively small creeks or streams except at Chaik Bay, where a large salmon-producing stream was in the immediate vicinity of both small eelgrass meadows. Based on visual observations, most sites were characterized by low gradient beaches and substrates predominately comprising various combinations of mud, sand, gravel, or shell. Relative to mean lower low water (MLLW), eelgrass occupied areas of the lower intertidal and subtidal zones from +1 m to -6 m.

Sampling

Fish were sampled with a 37-m long variable-mesh beach seine 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. Two beach seine hauls were made at each site, and hauls were at least 50 m apart. At Chaik Bay, one seine haul was made in each meadow. We sampled within 2 hr of low tide (range +1.0 to -1.5 m below MLLW).

Captured fish were identified to species and counted. The number of fish in large catches was estimated gravimetrically. To achieve this, a presumably random sub-sample of approximately 500 fish was removed from the total catch and the remainder of fish were collectively weighed to the nearest 0.1 kg. Fish in the sub-sample were weighed to the nearest gram and counted by species. A mean weight of fish determined from the sub-sample was used to estimate the number of fish in the total catch. The proportion of each species in the sub-sample was also used to determine the species composition of the total catch. Fork length (FL) was measured to the nearest millimeter for up to 50 individuals of the selected species, primarily commercially important and forage fish species (e.g., chum salmon, Pacific herring). Fish were anesthetized in a mixture of 1 part carbonated water to 2 parts seawater for identification and measurement; occasionally a more dilute mixture was used (1:7) for some sensitive species (e.g., Pacific cod). Smaller individuals (< 40

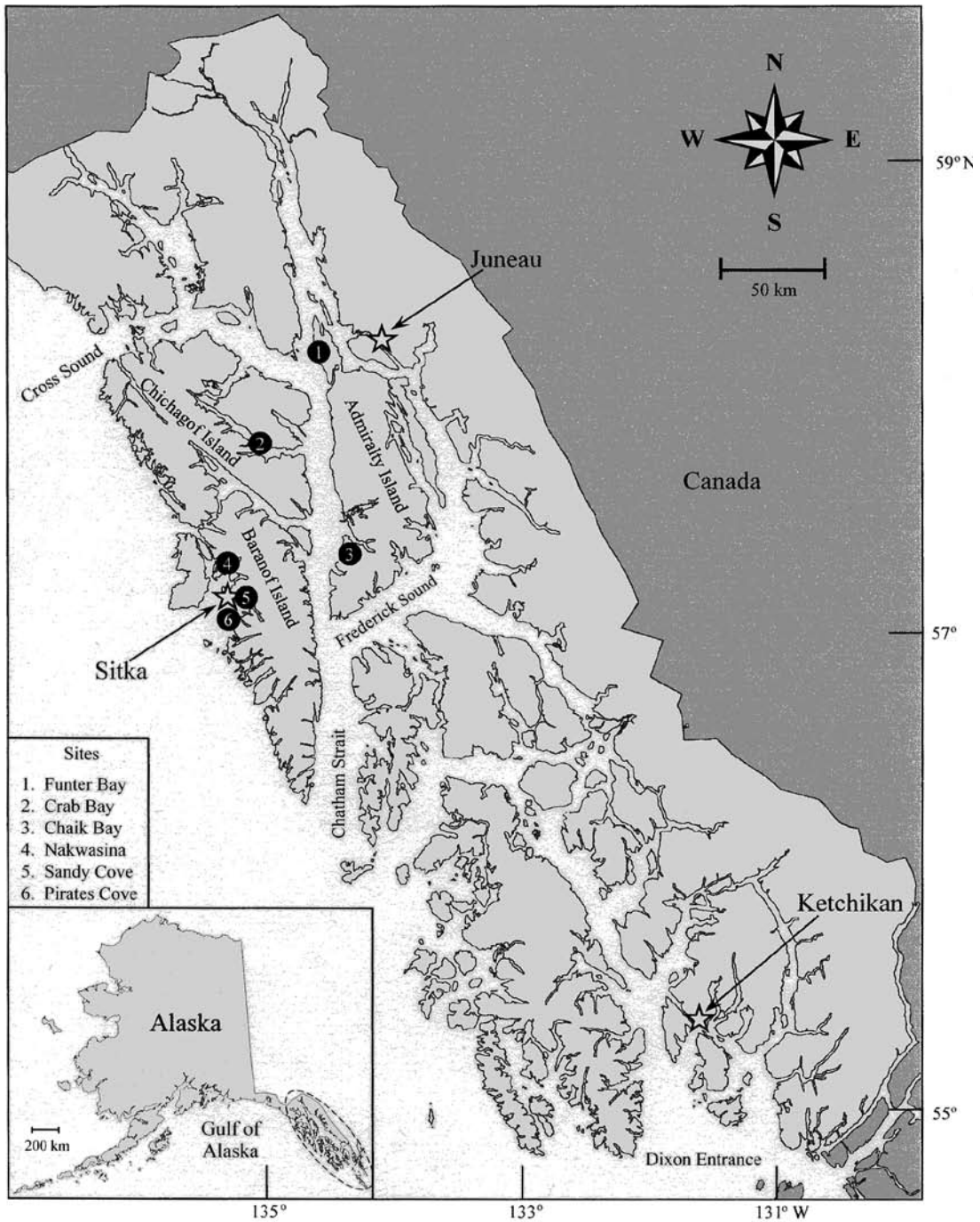


Figure 1. Locations of eelgrass (*Zostera marina*) sites sampled for fish assemblages and mapped by GPS in southeastern Alaska.

mm FL) of some families of fish (e.g., Cottidae, Scorpaenidae) that could not be easily identified to species in the field were grouped and recorded as juvenile cottids or juvenile rockfish.

Eelgrass meadows were mapped by walking and boating the perimeter of the meadow with a backpack Trimble^{®2} TSC1 Asset Surveyor GPS (McKenzie et al. 2001). Two white PVC pipes were driven into the substrate at opposing ends of each meadow as reference points for present and future surveys. At low tide, starting at one reference point, a person with a GPS walked the exposed perimeter of the eelgrass meadow. Upon reaching the water's edge, the individual would get in a small boat and motor around the subtidal perimeter of the meadow keeping the GPS antenna over the visible edge. During most sampling periods, clear water and calm winds allowed for good viewing of the subtidal eelgrass boundary from the boat. Most meadows were mapped at least twice in spring of all years; we considered all passes with the GPS to be equal in accuracy. The GPS collected real-time differentially corrected positions once each second while circumnavigating the eelgrass meadows. Accuracy of positions collected was usually ± 0.5 m.

At each site, we also measured above-ground eelgrass shoot density and biomass during spring of each year. A transect was laid parallel to shore approximately 0.5 m below MLLW, and three 313-cm² quadrats were placed about 5 m apart on the transect. Eelgrass shoots within each quadrat were cut at the substrate surface and rinsed to remove sediments and detritus. Loose epiphytic algae was removed manually. We counted all eelgrass shoots in each sample and placed them in plastic bags. In the laboratory, samples were dried at 60°C to a constant weight and were weighed to the nearest 0.1 g. Placement of the transect to collect eelgrass samples allowed only a relative measure of shoot density and biomass at each site; means for collecting subtidal eelgrass samples (e.g., SCUBA divers) were not available to characterize the entire meadow.

At each site, water temperature was recorded once every 2 hr with TidbiT^{®3} thermographs. Two thermographs (one for backup) were placed in the

vicinity of each site at about 3-m depth relative to MLLW. Thermographs were attached to the mid-section of a 1-m long piece of stainless steel cable or polypropylene line; attached on one end of the cable or line was a 10-kg anchor and on the other end a small float. Locations of thermographs were recorded with a GPS when deploying them from a boat. Thermographs were deployed in June 2001 and retrieved by SCUBA divers in June 2002. New thermographs were deployed again in the same locations in June 2002 and were retrieved by SCUBA in June 2003. Salinity was measured at approximately 20-cm depth with a hand-held refractometer at each seine site each sampling period.

Statistical Analyses

Differences in fish abundance among sites and years in spring were analyzed by two-way ANOVA followed by Tukey pairwise multiple comparisons. Seine hauls were considered sampling units with the sites. Thus, the analysis was a two-factor, completely crossed experimental design, with sites and years as fixed factors and two replicates within cells. Catch data was log-transformed prior to analysis. The assumption of equal variances was not met after data transformation; however, with the robustness of ANOVA, only fixed factors in the model, and equal sample sizes (Minitab 2000), we felt our results could be interpreted reliably. To examine for seasonal differences in abundance, we limited our analysis to the spring and summer of the same year (2003) that sampling occurred—a paired t-test was used on the cell means computed over the fixed sites. Catch data was again log-transformed prior to analysis. A coefficient of variation (CV) to examine the relative variability in total catch (both seine hauls combined) in spring at each site was calculated. Data collected from eelgrass quadrats at each site were combined (all years) and Kruskal-Wallis and Dunn multiple comparisons were used to determine if differences in eelgrass shoot density and biomass existed among sites. Significance for all tests was accepted at $P \leq 0.05$.

Results

Fish Assemblages

A total of 58,902 fish representing 45 species were captured in 44 seine hauls (all sampling periods; Table 1). Total catch for each year was dominated

²Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

³Onset Computer Corporation, Pocasset, Massachusetts.

TABLE 1. Total catch and frequency of occurrence of fish in eelgrass (*Zostera marina*) at six sites in southeastern Alaska from 2001–2003. Sampling was between late May and mid-June in all years (spring); winter sampling was in January and early February of 2003. Number of seine hauls was 12 each spring and 8 in winter. Species are listed in decreasing order of abundance based on total catch in all years. An asterisk indicates that a species is included in a fishery management plan in Alaska.

Common name	Scientific name	Total Catch			Winter 2003	Frequency of occurrence (%) n = 44
		2001	2002	2003		
Chum salmon*	<i>Oncorhynchus keta</i>	6,275	8,323	23,451	5	70
Shiner perch	<i>Cymatogaster aggregata</i>	530	4,175	875	12	45
Threespine stickleback	<i>Gasterosteus aculeatus</i>	513	1,907	303	18	25
Pacific herring	<i>Clupea pallasii</i>	0	1,234	787	0	11
Pink salmon*	<i>Oncorhynchus gorbuscha</i>	127	31	1,253	0	52
Crescent gunnel*	<i>Pholis laeta</i>	270	463	445	10	91
Coho salmon*	<i>Oncorhynchus kisutch</i>	348	51	776	0	52
Pacific sand lance*	<i>Ammodytes hexapterus</i>	1	1,095	1	0	11
Snake prickletback*	<i>Lumpenus sagitta</i>	411	348	230	7	52
Juvenile cottids	Cottidae	155	454	122	47	55
Bay pipefish	<i>Syngnathus leptorhynchus</i>	141	121	187	105	61
Surf smelt*	<i>Hypomesus pretiosus</i>	0	498	0	9	7
Pacific cod*	<i>Gadus macrocephalus</i>	8	493	0	0	14
Silverspotted sculpin	<i>Blepsias cirrhus</i>	84	96	156	2	70
Northern sculpin	<i>Icelinus borealis</i>	107	80	71	44	86
Juvenile gadids*	Gadidae	9	3	265	0	34
Juvenile greenling	<i>Hexagrammos</i> spp.	72	120	74	3	75
Tube-nose poacher	<i>Pallasina barbata</i> aix	24	182	30	2	39
Copper rockfish*	<i>Sebastes caurinus</i>	4	45	83	0	25
Tube snout	<i>Aulorhynchus flavidus</i>	3	12	4	92	36
Juvenile rockfish*	<i>Sebastes</i> spp.	91	0	1	5	16
Walleye pollock*	<i>Theragra chalcogramma</i>	12	0	0	75	9
Pacific staghorn sculpin	<i>Leptocottus armatus</i>	10	29	41	3	52
Great sculpin*	<i>Myoxocephalus polyacanthocephalus</i>	35	17	15	13	59
Rock sole*	<i>Lepidopsetta</i> spp.	28	13	2	3	23
Yellowfin sole*	<i>Limanda aspera</i>	0	26	2	0	11
Buffalo sculpin	<i>Enophrys bison</i>	2	23	1	0	16
Dolly Varden	<i>Salvelinus malma</i>	12	1	8	1	14
Quillback rockfish*	<i>Sebastes maliger</i>	14	0	7	0	11
Red Irish lord*	<i>Hemilepidotus hemilepidotus</i>	5	3	6	5	27
Masked greenling	<i>Hexagrammos octogrammus</i>	1	1	15	0	18
Whitespotted greenling	<i>Hexagrammos stelleri</i>	2	4	2	8	20
Juvenile flatfish	<i>Pleuronectidae</i>	0	0	12	1	9
Rock greenling	<i>Hexagrammos lagocephalus</i>	2	11	0	0	11
Kelp greenling	<i>Hexagrammos decagrammus</i>	1	0	3	5	11
Arctic shanny*	<i>Stichaeus punctatus</i>	9	0	0	0	2
Black rockfish	<i>Sebastes melanops</i>	0	2	4	1	9
Sturgeon poacher	<i>Podothecus accipenserinus</i>	3	0	2	0	9
Penpoint gunnel*	<i>Apodichthys flavidus</i>	1	0	1	1	7
Steelhead trout	<i>Oncorhynchus mykiss</i>	3	0	0	0	2
Starry flounder*	<i>Platichthys stellatus</i>	1	0	0	1	5
Tidepool snailfish	<i>Liparis florum</i>	0	2	0	0	5
C-O sole	<i>Pleuronichthys coenosus</i>	0	0	1	1	5
Pacific sanddab	<i>Citharichthys sordidus</i>	0	0	0	2	2
Cabezon	<i>Scorpaenichthys marmoratus</i>	0	0	2	0	2
Showy snailfish	<i>Liparis pulchellus</i>	0	0	0	1	2
Unid. snailfish	<i>Liparidae</i>	0	0	0	1	2
Sailfin sculpin	<i>Nautichthys oculo fasciatus</i>	0	0	1	0	2
Cutthroat trout	<i>Oncorhynchus clarkii</i>	0	0	1	0	2
Painted greenling	<i>Oxylebius pictus</i>	0	0	1	0	2
Speckled sanddab	<i>Citharichthys stigmæus</i>	0	0	1	0	2
Total catch		9,314	19,863	29,242	483	

by a few species that were sometimes captured in large numbers. For example, more than 20,000 chum salmon fry were captured in one seine haul at Chaik Bay in late spring 2003. The most abundant commercially important or forage fish species captured were chum salmon, Pacific herring, pink salmon, coho salmon (*O. kisutch*), and Pacific sand lance (*Ammodytes hexapterus*) (Table 1). Other species captured in more than incidental numbers and important in sport or commercial fisheries in Alaska were Pacific cod, walleye pollock (*Theragra chalcogramma*), rockfish (*Sebastes* spp.), and Dolly Varden (*Salvelinus malma*). The three most abundant non-commercial species captured were shiner perch (*Cymatogaster aggregata*), three-spine stickleback (*Gasterosteus aculeatus*), and crescent gunnel (*Pholis laeta*) (Table 1). The two most frequently occurring species were crescent gunnel and northern sculpin (*Icelinus borealis*); these species were captured in 91% and 86% of all seine hauls (Table 1).

Fish abundance in spring differed significantly among sites ($F = 8.436$, $df = 5$, $P < 0.001$) but not

among years. Pairwise comparisons revealed that catch per seine haul was significantly greater ($P \leq 0.015$) at Chaik Bay than at all other sites—no other pairwise comparisons were significantly different. Total catch at each site (both seine hauls combined) in spring ranged from a low of 205 fish at Pirates Cove in 2001 to a high of 25,492 fish at Chaik Bay in 2003 (Figure 2). Variability in total catch among sites was evidenced by a wide range in coefficients of variation (CV); CV for total catch in spring (all years) ranged from 11% at Funter Bay to 107% at Pirates Cove (Figure 2). In spring, total catch of fish among all sites was always greatest in Chaik Bay and was lowest in Funter Bay in 2 of 3 years (Figure 2).

For those sites sampled seasonally in 2003, fish were significantly ($P = 0.009$) more abundant in spring than in winter. Mean catch per seine haul was 408 fish (SE = 106; $n = 8$ hauls) in spring compared to only 60 fish (SE = 16; $n = 8$ hauls) in winter. Total catch by site (both seine hauls combined) in winter ranged from only 25 fish at Funter Bay to 220 fish at Sandy Cove (Figure 2).

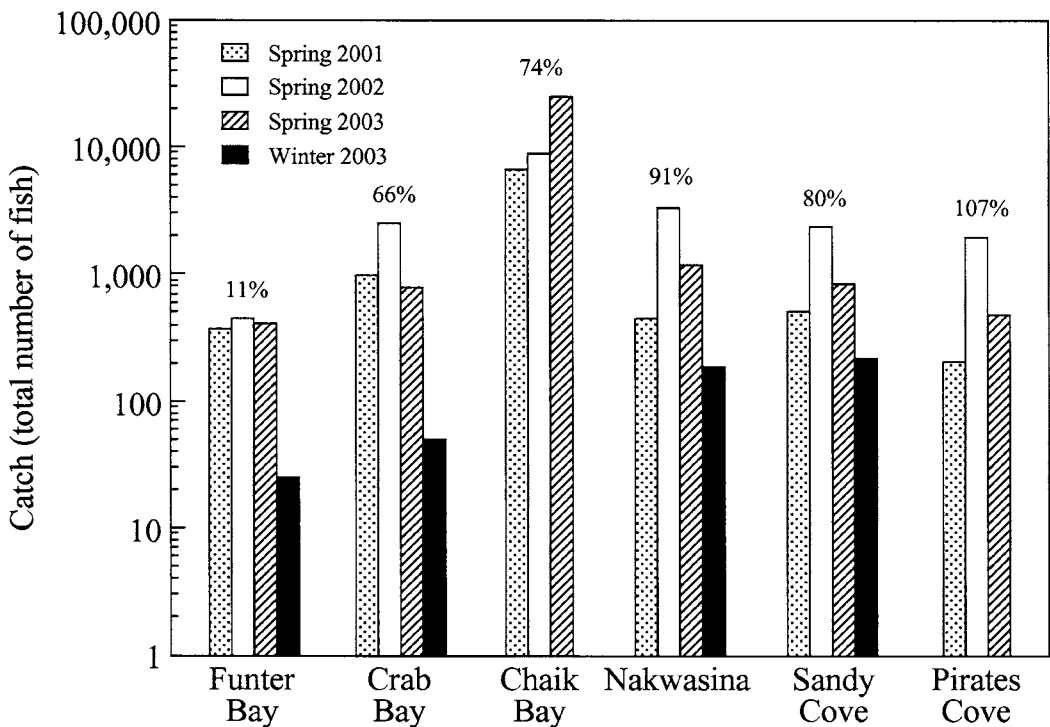


Figure 2. Total catch of all fish species by site and season in six eelgrass (*Zostera marina*) meadows in southeastern Alaska. Total catch represents the sum of all fish captured in two beach seine hauls at each site. The percentage shown above bars is the coefficient of variation and represents the variability in total catch over all springs.

In winter, most commercially important or forage fish species were absent (e.g., coho salmon, Pacific sand lance) or were captured in low numbers (e.g., chum salmon, rockfish) (Table 1). Walleye pollock was the only commercially important species captured in higher numbers in winter than in spring (Table 1), and most (86%) were captured at Nakwasina.

Species richness was also greater in spring than in winter. Median number of species captured in spring (all years) was 15, whereas the median number of species captured in winter was 13. Of those sites sampled in spring and in winter, number of species captured in spring (all years) ranged from 11 to 23, whereas number of species captured in winter ranged from 8 to 14.

At each site, three different species accounted for most ($\geq 69\%$) of the total catch, although

principal species varied among sites (Figure 3). The most abundant species captured by site for all sampling periods were crescent gunnel (Funter Bay), threespine stickleback (Crab Bay), chum salmon (Chaik Bay), shiner perch (Nakwasina and Sandy Cove), and Pacific sand lance (Pirates Cove). Depending on the site, other species that were one of the three most abundant were Pacific cod, pink salmon, coho salmon, Pacific herring, bay pipefish (*Syngnathus leptorhynchus*), silverspotted sculpin (*Blepsias cirrhosus*), surf smelt (*Hypomesus pretiosus*), and juvenile cottids (Figure 3). Most species in the top three for abundance at each site were captured every spring but catches varied greatly. For example, catch of shiner perch at Sandy Cove was 214 fish in 2001 (42% of total catch), 2,080 fish in 2002 (88% of total catch), and 449 fish in 2003 (53% of total catch).

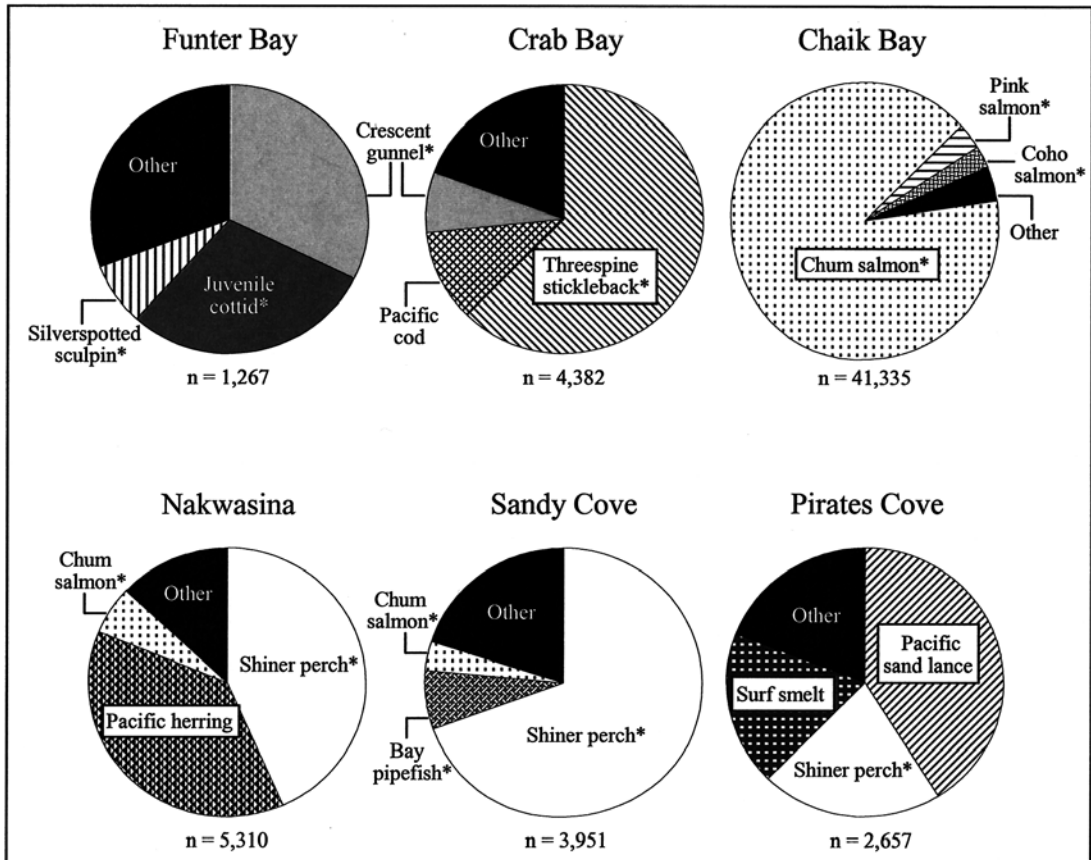


Figure 3. The three most abundant fish species captured in six eelgrass (*Zostera marina*) meadows in southeastern Alaska. Total catch for all sampling periods (n) is shown below each chart. An asterisk indicates that the species was captured every spring.

Most of the commercially important and forage fish species captured were juveniles. Mean FL of fish ranged from 46 mm for Pacific cod to 100 mm for Pacific herring (Table 2). All chum salmon, pink salmon, and Pacific cod were young-of-the-year. Some of the larger (> 130 mm FL) Pacific sand lance captured were adults.

TABLE 2. Size (fork length, FL) of select commercially important or forage fish species captured with a beach seine in eelgrass (*Zostera marina*) at six sites in southeastern Alaska from 2001–2003.

Species	Mean FL (mm)	FL range (mm)	n
Chum salmon	58	37–92	660
Coho salmon	91	33–136	254
Pink salmon	53	38–75	160
Pacific cod	46	21–67	53
Walleye pollock	87	33–142	65
Pacific herring	100	87–140	116
Pacific sand lance	84	49–168	71
<i>Sebastes</i> spp.	85	35–195	238

Eelgrass Characteristics and Abiotic Factors

Size of eelgrass meadows differed among sites and varied among years (Table 3). The smallest

meadow sampled was Chaik Bay with a mean area of 434 m² in 2002, whereas the largest meadow sampled was Funter Bay with a mean area of 79,027 m² in 2001 (Table 3). Sites where meadow size consistently declined in all years were Funter Bay and Sandy Cove. The largest percent change in meadow area was from 2002 to 2003; a 13.3% decline at Funter Bay and a 26.9% increase at Nakwasina (Table 3). At most sites, the narrow range in area measurements within years demonstrated good repeatability in our eelgrass boundary measurements (Table 3). Eelgrass meadows differed in their physical configuration; for example, eelgrass meadows at Crab Bay and Nakwasina were confined to long and narrow fringing bands that closely paralleled the shoreline, whereas eelgrass meadows at Funter Bay and Sandy Cove were located in flats and covered much of one corner of their respective sites (Figures 4 and 5).

Eelgrass shoot density differed significantly among sites ($H = 28.037$, $df = 5$, $P \leq 0.001$), whereas eelgrass biomass was similar among sites. In pairwise comparisons, shoot density was significantly greater ($P < 0.05$) at Nakwasina than at Funter Bay, Crab Bay, Chaik Bay, and Pirates

TABLE 3. Range, mean, and percent change in area (m²) of eelgrass meadows (*Zostera marina*) measured using global positioning system (GPS) technology at six sites in southeastern Alaska each spring from 2001 to 2003. Sample size in parentheses next to ranges. Two small meadows were measured at Chaik Bay. Percent change is the difference in mean area between adjacent years. ND = not determined.

Site	2001	2002	2003
Funter Bay	76,687–81,367 (2)	71,205–73,686 (2)	62,220–63,428 (2)
mean	79,027	72,446	62,824
% change		-8.3	-13.3
Crab Bay	15,420–17,098 (2)	17,645–18,065 (3)	17,055–17,675 (2)
mean	16,259	17,785	17,365
% change		+9.4	-2.4
Chaik Bay (A)	1,025 (1)	902–950 (3)	981–983 (2)
mean	1,025	932	982
% change		-9.1	+5.4
Chaik Bay (B)	not measured	426–449 (3)	not measured
mean		434	
% change		ND	
Nakwasina	5,102–5,350 (3)	4,508–4,644 (3)	5,712–5,895 (3)
mean	5,196	4,557	5,783
% change		-12.3	+26.9
Sandy Cove	6,963–7,054 (2)	6,725–6,836 (3)	6,374–6,612 (2)
mean	7,009	6,789	6,493
% change		-3.1	-4.4
Pirates Cove	1,650–1,923 (6)	1,970–2,107 (2)	1,946–2,057 (3)
mean	1,815	2,039	2,002
% change		+12.3	-1.8

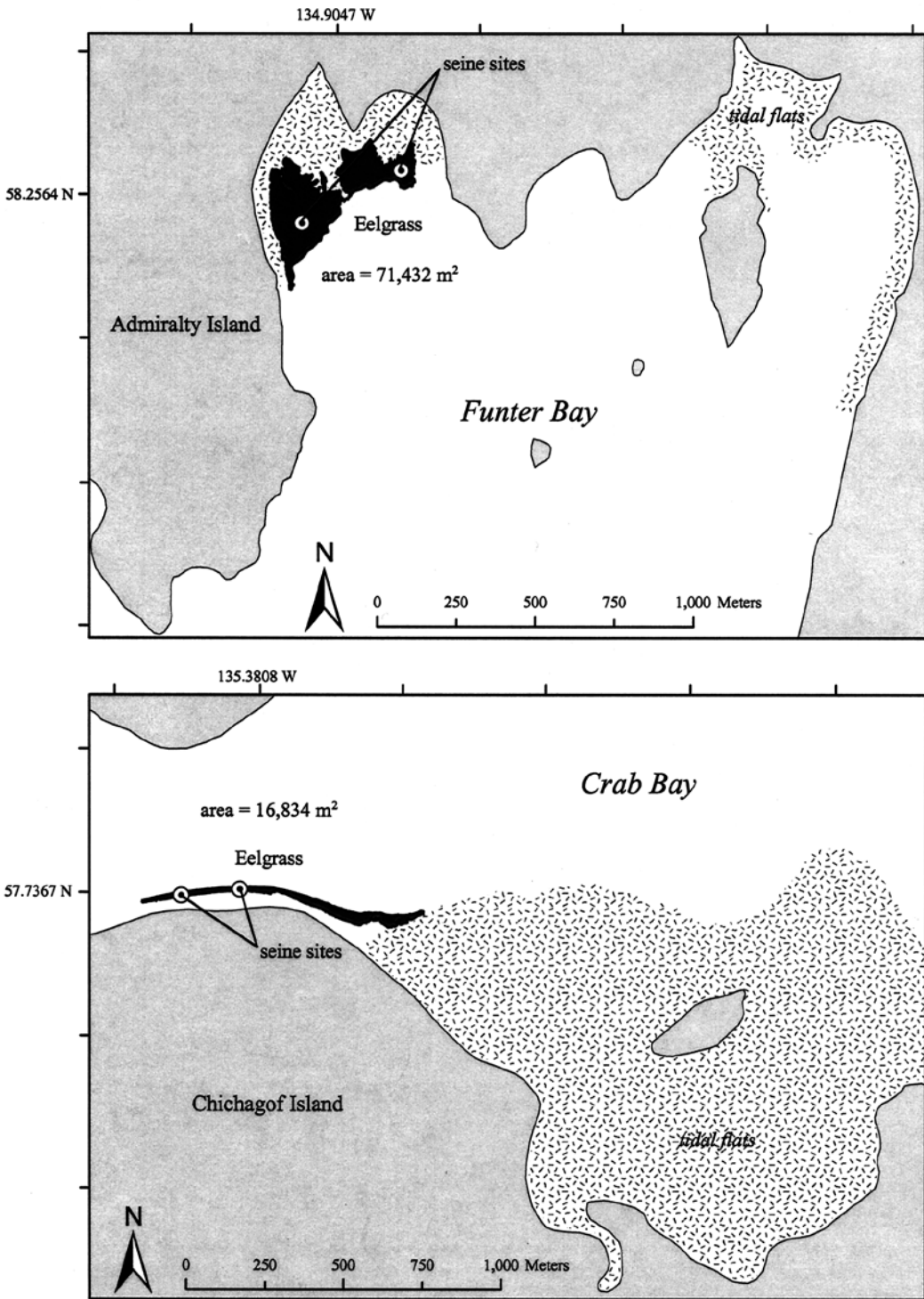


Figure 4. Map of eelgrass (*Zostera marina*) meadows sampled for fish assemblages at Funter Bay and Crab Bay in south-eastern Alaska. Both sites were sampled in late spring 2001, 2002, and 2003 and in winter 2003.

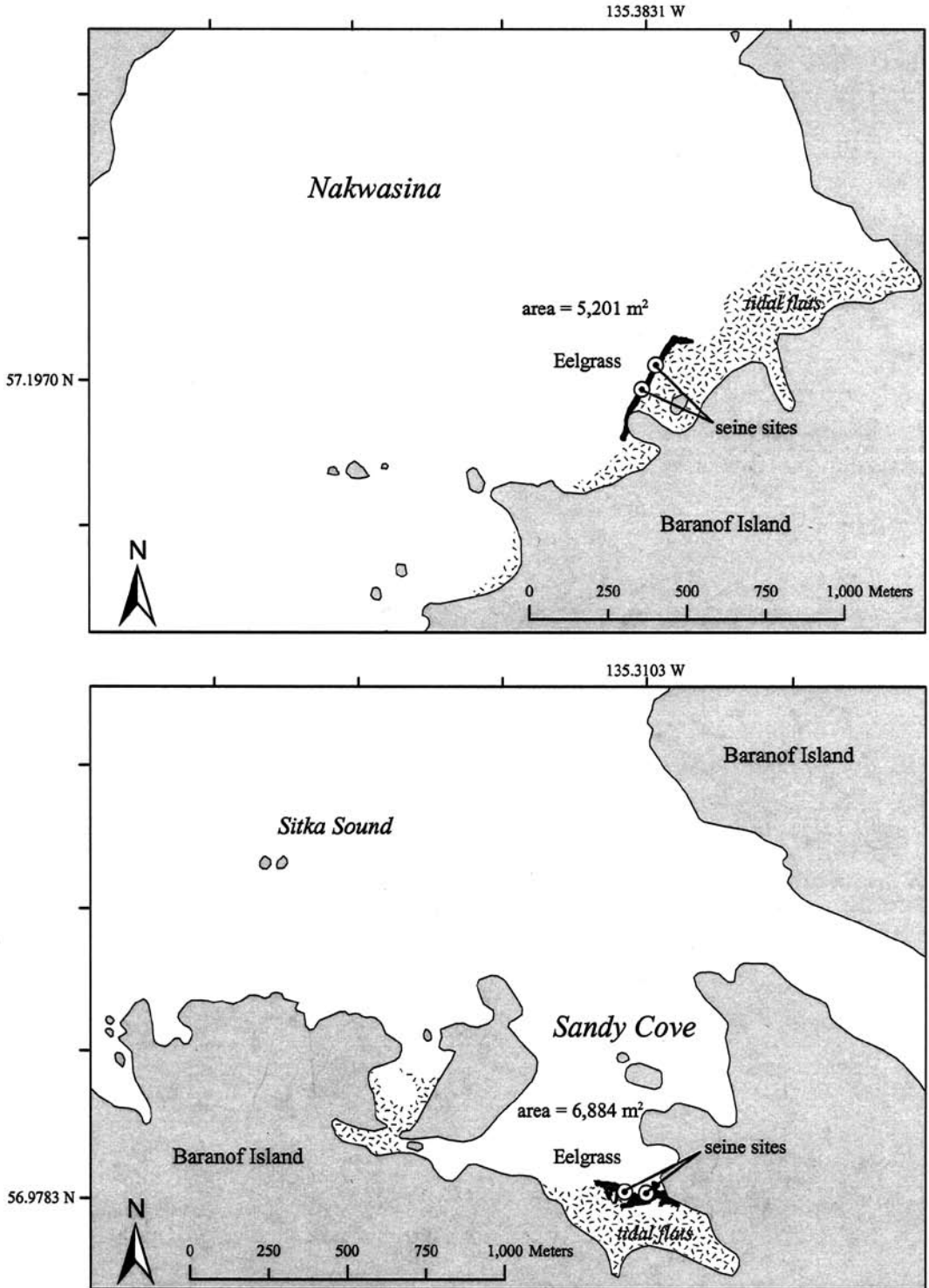


Figure 5. Map of eelgrass (*Zostera marina*) meadows sampled for fish assemblages at Nakwasina and Sandy Cove in southeastern Alaska.

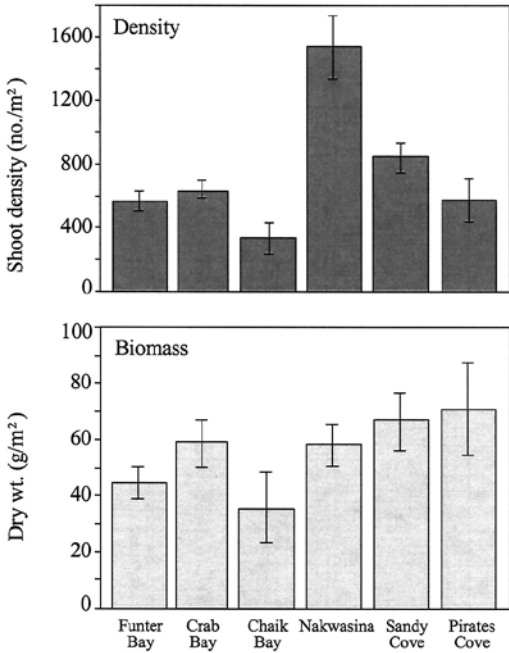


Figure 6. Mean (± 1 SE) eelgrass (*Zostera marina*) shoot density and biomass from sites sampled for fish assemblages in southeastern Alaska.

Cove, and was also significantly greater ($P < 0.05$) at Sandy Cove than at Chaik Bay. Mean density ranged from 336 shoots/m² at Chaik Bay to 1,544 shoots/m² at Nakwasina (Figure 6). Eelgrass biomass ranged from a mean of 35.5 g/m² at Chaik Bay to 71.4 g/m² at Pirates Cove (Figure 6).

Water temperatures followed a similar pattern among all sites and years (Figure 7), whereas salinity varied widely among sites. Mean monthly water temperatures were usually lowest in March and highest in August or September. Sandy Cove had the highest mean monthly water temperatures in 2001 and 2002, about 12.7°C both years. The lowest mean monthly water temperatures were 3.8°C at Crab Bay in 2001 and 4.7°C at Funter Bay in 2002. Inclusive of all sampling periods, mean salinity (PSS) was 29 at Funter Bay, 21 at Crab Bay, 5 at Chaik Bay, 23 at Nakwasina, 24 at Sandy Cove, and 32 at Pirates Cove.

Discussion

We have established a baseline of information on fish use and size of several eelgrass meadows in southeastern Alaska, and the seasonal importance of eelgrass as fish habitat. Eelgrass is used by

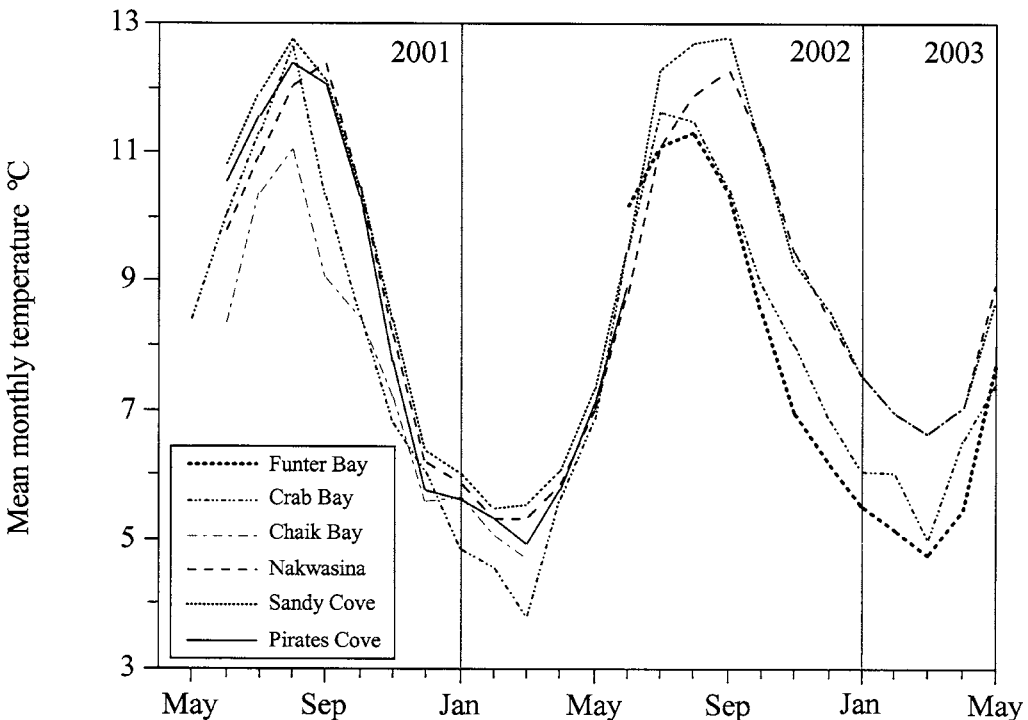


Figure 7. Mean monthly water temperature measured at six eelgrass (*Zostera marina*) meadows in southeastern Alaska.

a wide variety of fish species, including many important commercial and forage fish species. Of the 45 species that we captured, 18 are included in an FMP for Alaska either as target species or in the forage fish category (North Pacific Fishery Management Council 2005). The most abundant target species that we captured were chum salmon, pink salmon, coho salmon, and Pacific cod, whereas the most abundant forage fish species captured were Pacific herring, crescent gunnel, and Pacific sand lance. Although Pacific herring are an important commercial and forage fish species, they are managed by the state of Alaska and are not an FMP species. Similar fish assemblages in eelgrass have been observed in other areas of Alaska and the northeast Pacific Ocean (Phillips 1984, Macdonald and Chang 1993, Laur and Haldorson 1996, Murphy et al. 2000, Johnson et al. 2003).

Most commercially important and forage fish species that we captured were juveniles, indicating that eelgrass may be an important nursery habitat for some species. Worldwide, the importance of seagrasses as nursery areas has been well documented (Thayer et al. 1978, Pollard 1984, Lazzari and Tupper 2002, Spalding et al. 2003). We cannot assess the nursery value of eelgrass in this study because our focus was only on eelgrass and not on any adjacent habitat types, and most of our sampling was limited to June. We do know from this study and others in southeastern Alaska (Murphy et al. 2000, Johnson et al. 2003), however, that juveniles of many commercially important and forage fish species occupy eelgrass in spring and summer. Additional studies are needed on the contribution of all nearshore habitats to the production of adults to adequately define and identify valuable nursery habitats (Beck et al. 2003).

Variability in total catch among sites and years is largely due to the aggregating behavior and seasonality of many species. For example, at Chaik Bay, we captured more than 20,000 chum salmon fry in early June 2003 compared with about 6,000 chum in 2001 and 8,000 chum in 2002. This is likely because we sampled about 1 wk earlier in June 2003 than in 2001 and 2002, and we were closer to the peak downstream migration of chum salmon fry (April or May depending on stock; Salo 1991, Halupka et al. 2000). Similarly, the schooling behavior of Pacific sand lance (Robards et al. 1999) and Pacific herring (Carlson 1980) likely account for the sometimes “hit or miss”

catches of these species. The wide variability in catch of fish among years enforces the need for multi-year sampling or repeated sampling within a year to adequately assess fish use of eelgrass in future monitoring studies.

Sampling during darkness in winter versus daylight in summer probably had little effect on the low number of fish captured in winter. In several other nearshore studies, more species and fishes were collected at night than during the day (Horn 1980, Bayer 1981, Gibson et al. 1996, Methven and Bajdik 1994). Near the Brothers Islands and Benjamin Island in southeastern Alaska, a variety of nearshore habitats (e.g., eelgrass, kelp) were sampled during daylight in summer and late winter (March); total catch in winter was < 5% of the total catch in summer (Thedinga et al. 2003). Low abundance of fishes in eelgrass at night and during the day in winter is evidence that this shallow water habitat is not a suitable year-round habitat for most species in southeastern Alaska.

Our observations of greater fish abundance and species richness in late spring than in winter is similar to results from other nearshore studies (Allen and Horn 1975, Bayer 1981, Allen 1982, Macdonald and Chang 1993). High fish abundance in late spring is probably influenced by warm water temperatures that may offer increased food production and growth to juveniles. Turbulence with the onset of fall and winter storms, and seasonal declines in water temperature, eelgrass biomass, and food availability are likely cues for fish to migrate from shallow water habitats to alternate habitats (Orth and Heck 1980, Allen 1982, Love et al. 1991).

Use of eelgrass in spring and summer may encompass only a few days or weeks, or several months. Juvenile salmon use eelgrass at least temporarily as they migrate from their natal streams through estuaries to the open sea. Juvenile rockfish and flatfish may rear in eelgrass for several months before migrating to more protected areas in winter. In an earlier mark-recapture study at Sandy Cove, Byerly (2001) reported that juvenile copper rockfish (*Sebastes caurinus*) reared in eelgrass for up to 3 mo in summer. The seasonal movement of juvenile rockfish and flatfish from nearshore habitats in summer to offshore habitats in fall and winter has been described by others (Moulton 1977, Gibson 1997, Abookire and Norcross 1998). Juvenile rockfish likely move to nearby rocky

areas in winter to hide in cracks, crevices, and holes (Patten 1973, Matthews 1990).

The dominance of a few species in nearshore fish communities is characteristic of many bays and estuaries, including those we sampled. Relatively few species (≤ 5) made up the majority ($> 80\%$) of the individuals captured at sites in central and southern California and Chesapeake Bay, Virginia (Allen and Horn 1975, Horn 1980, Orth and Heck 1980, Allen 1982). Of particular interest, shiner perch were one of the most abundant species captured at two of our sites (Nakwasina and Sandy Cove) and was also one of the most abundant species captured in some California locations (Allen and Horn 1975, Horn 1980). Shiner perch, a common schooling fish found in shallow waters along the Pacific Coast, likely use eelgrass for spawning in spring and summer before migrating to deeper water in winter (Hart 1973). All shiner perch that we captured were at sites close to the outer coast of southeastern Alaska (Nakwasina, Sandy Cove, Pirates Cove) and most (99%) were captured in spring.

Eelgrass shoot density and biomass were similar to ranges observed at other locations in southeastern Alaska and along the Pacific Coast of the United States (Phillips 1984, Murphy et al. 2000, Johnson et al. 2003). Eelgrass in Chaik Bay had the lowest shoot density and biomass of any site, probably because of low salinities (4–7 PSS) from the large inflow of freshwater at this site. The highest eelgrass density we observed at Nakwasina ($\bar{x} = 1,544$ shoots/m²) is well below densities recorded at Izembek Lagoon, Alaska, the largest bed of seagrass along the Pacific Coast of North America ($\bar{x} = 4,381$ shoots/m²; Phillips et al. 1983). Differences in seasonal growth patterns among sites may partially explain why some sites (e.g., Nakwasina) had the highest shoot density but not the highest biomass.

Eelgrass meadows in southeastern Alaska appear to be dynamic with sometimes large annual fluctuations in area. Risser (2000) reported that the size and density of eelgrass beds may vary naturally by as much as 50% from one year to the next. Likely places for meadow size to change would be near deltas where high stream flow can deposit sediments or scour edges of the meadow, or intertidal areas of beds exposed to waves and storms. An examination of area maps among years for Nakwasina revealed that most

fluctuation in meadow size occurred in the delta. Annual fluctuations in meadow size limit our chances for detecting small changes in area. Thus, our data are probably best suited for following large-scale and long-term trends in abundance of eelgrass; meadows that consistently show a decline over several years would signal a cause for concern and that some type of management action is required.

Monitoring the eelgrass sites established in this study will allow resource managers to track trends in abundance of this valuable habitat type and associated changes in fish assemblages. Long-term and large-scale trends are probably a more important indicator of eelgrass health than yearly fluctuations. The best approach for monitoring may be to focus on the four largest meadows that we sampled—Funter Bay, Crab Bay, Nakwasina, and Sandy Cove—and sample them every year for several years. To identify changes in fish assemblages at each site, the focus should be on those species that were the most abundant and present in all years during the baseline study (e.g., shiner perch at Nakwasina and Sandy Cove) and not some of the “hit or miss” species that were captured in large numbers in only one year (e.g., Pacific cod at Crab Bay). A reasonable threshold could be established where consecutive years (≥ 3 yrs) of eelgrass decline or greatly reduced abundance of an indicator species (e.g., shiner perch) would indicate a change has occurred or is in progress. Attention must also be given to the appearance of new species not normally found in Alaska as fish distributions may shift with climate change. Because many commercially important fish species use eelgrass in Alaska, a complete understanding of this coastal resource and how it may be altered by human or natural disturbance is justified.

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