Distribution and Abundance of Small Schooling Fish in Nearshore Areas of Glacier Bay, Alaska during June, 1999

Preliminary Summary
by
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July 1999

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Abstract

We sampled the nearshore fish of Glacier Bay during June 1999 using a beach seine. We visited 59 different beaches and sampled at both high and low tide, except when unsuitable substrate was present at one of the tidal states. We collected a total of 5,245 fish comprising at least 24 species from a total of 91sets. Of these species, 17 were represented primarily by juvenile stages. Our results indicated a clear gradation of abundance from Icy Strait to the upper areas of Glacier Bay. Lower and central areas were dominated by salmonids, whereas much greater diversity existed in the upper areas. Several key forage fish exist in the nearshore regions of Glacier Bay including schooling (e.g., *herring Clupea pallasi*, capelin *Mallotus villosus*, walleye pollock *Theragra chalcogramma*, sand lance *Ammodytes hexapterus*) and benthic species (e.g., crescent gunnel *Pholis laeta* and Pacific snake prickleback *Lumpenus sagitta*).

Introduction

The distribution and health of marine predator populations depends on the abundance and distribution of their prey species. Declines in seabird and marine mammal populations in the Gulf of Alaska have been linked to shifts in abundance and composition of forage fish stocks over the past 45 years (Anderson and Piatt, 1999). Glacier Bay hosts a variety of abundant marine predators during summer including significant populations of humpback whales (*Megaptera novaeangliae*) and *Brachyramphus* murrelets. The distribution and abundance of forage species in Glacier Bay may well affect the status of predators, but little is known about temporal and spatial patterns of forage species in the Bay (Wing and Krieger, 1983; Krieger and Wing, 1984; Krieger and Wing, 1986). Glacier Bay also provides the unique opportunity to study post-glacial succession in the marine environment. Research has usually focused on vegetative colonization in Glacier Bay (e.g., Lawrence et al., 1967) and more recently the colonization of postglacial freshwater streams (e.g., Milner, 1987; Sidle and Milner, 1989). Colonization of new freshwater streams, particularly by anadromous species presumably influences the nearshore marine community. Additionally, newly exposed marine areas will also provide unique opportunities for opportunistic marine species that are able to live in highly turbid waters.

Inshore marine areas in the Gulf of Alaska provide important habitat for several resident forage fish species such as sand lance *Ammodytes hexapterus* and snake prickleback *Lumpenus sagitta* (Robards *et al.*, 2000). Inshore habitat also represents an important nursery area for juveniles of many marine fish species (Poxton *et al.*, 1983; Orsi and Landingham, 1985; Bennett, 1989; Blaber *et al.*, 1995; Dalley and Anderson, 1997), several of which are also important forage fish in their juvenile stages (e.g., walleye pollock *Theragra chalcogramma* and herring).

This study was established to provide some baseline data on the nearshore distribution of different forage fish species within Glacier Bay and to identify critical forage fish habitat. For example, several key Alaskan forage fishes (capelin [*Mallotus villosus]*, herring, and sand lance may spawn intertidally. These areas are critical to the survival of these species, but are vulnerable to shoreline disturbance or pollution.

Methods

Study Area

Glacier Bay is a recently deglaciated Y-shaped fiord in southeast Alaska, and is about 100 km long and 20 km wide. The Fairweather range dominates the head of the bay, with numerous peaks over 3,000 m culminating in Mt. Fairweather at 4600 m. Numerous glaciers (some tidewater) discharge ice and water into the upper arms. Glacier Bay is connected to the Gulf of Alaska via Icy Strait. The whole area lies within the 3.3 million-acre Glacier Bay National Park and Preserve. Glacier Bay is an important wildlife area , providing habitat and feeding opportunities for numerous marine mammals, seabirds, and commercially exploited fish species.

Fishing Protocol

We used beach seines to sample nearshore fish communities between 10 June and 23 June 1999. This fishing method effectively and non-selectively samples shallow, inshore waters with sandy or smooth bottoms (Cailliet *et al.*, 1986). Our variable-mesh net was 37 m long. The wings were tapered from 2.4 m in the middle to 0.5 m at the wing using 28 mm knotless nylon stretch mesh. The seine was equipped with a 6 mm stretch mesh bag located in the middle of the seine. Thirty meters of rope were attached to the ends for deployment. The net was set parallel to shore about 15 m from the beach as described by Cailliet *et al.* (1986).

We sampled 59 sites in Glacier Bay and Icy Strait (Figure 1, Appendix 1). We attempted to seine each site at both high and low tide. However, several sites could not be seined at high tide due to large rocks, or at low tide due to large rocks or mussel beds. Beach seining was conducted within two-hour windows on either side of high and low tides. A single set was made as this usually provides good representation of species richness and dominant species rank (Allen *et al.*, 1992; Robards *et al.*, 2000). Fish were sorted by species, counted, and subsampled individuals were weighed and measured.

Analyses

We arbitrarily divided Glacier Bay into three regions for comparison. The lower-bay is defined as south of a line between Rush Point and the northwestern tip of Young Island (i.e., Sitakaday Narrows); the middle bay lies between there and a line between Muir Point and the northern entrance to Geike Inlet; and the upper bay lies from there to the head of the western and eastern arms of Glacier Bay (Figure 1).

Results and Discussion

Beach seines were effective at catching nearshore fish. From the 91 sets made in Glacier Bay during our investigation, a total of 5,245 fish comprising at least 24 species (juvenile greenling and snailfish only identified to genus) were caught (Table 1, Appendix 2). Of these species, 17 were represented primarily by juvenile stages. Juvenile salmonids dominated the nearshore fish community in both the lower and middle regions of Glacier Bay, comprising 69% and 61% of the fish caught, respectively. In contrast, the upper bay showed greater diversity of catch with no single species dominating these nearshore areas (Figure 2).

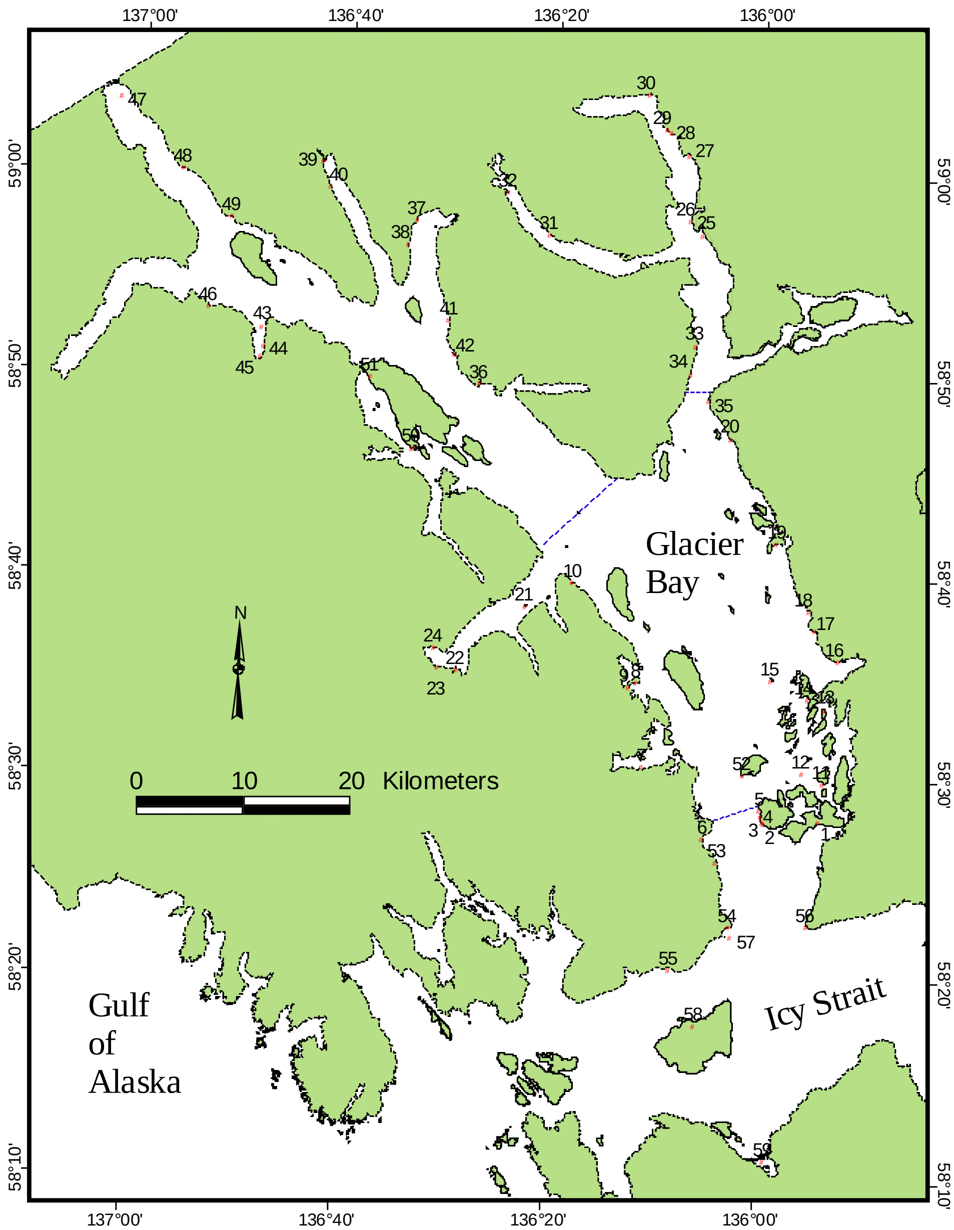


Figure 1. Location of beach seine sample sites used during June 1999. Dotted lines demarcate the lower, middle, and upper bay

Table 1. Summary catch statistics for fish caught by beach seine in three regions of Glacier Bay during June, 1999.									
		Lower (22 sets, 2005 fish)		Middle (34 sets, 2354 fish)		Upper (35 sets, 886 fish)		Overall (91 sets, 5245 fish)	
Common Name	ScientificName	CPUE	% Occurrence	CPUE	% Occurrence	CPUE	% Occurrence	CPUE	% Occurrence
Pink Salmon	*Oncorhynchus gorbuscha*	60.68	41	6.29	26	0.43	11	17.19	24
Red Salmon	*Oncorhynchus nerka*	0.18	14	35.06	12	0.00	0	13.19	8
Pacific Sand Lance	*Ammodytes hexapterus*	0.05	5	19.35	41	5.17	34	9.23	30
Juvenile Sculpins	*Myoxocephalus Spp.*	11.64	50	3.47	21	10.11	40	8.00	35
Dolly Varden	*Salvelinus malma*	10.96	41	0.32	12	0.40	11	2.92	24
King Salmon	*Oncorhynchus tshawytscha*	3.55	9	1.97	15	0.00	0	1.59	8
Pacific Snake Prickleback	*Lumpenus sagitta*	0.09	5	0.03	3	4.06	43	1.59	19
Walleye Pollock	*Theragra chalcogramma*	0.05	5	0.18	9	2.66	51	1.10	24
Rock Sole	*Pleuronectes bilineatus*	0.91	23	0.44	15	0.77	17	0.68	18
Capelin	*Mallotus villosus*	0.00	0	0.18	6	1.40	20	0.60	10
English Sole	*Pleuronectes vetulus*	2.14	27	0.00	0	0.00	0	0.52	7
Pacific Herring	*Clupea pallasi*	0.00	0	1.15	18	0.00	0	0.43	7
Great Sculpin	*Myoxocephalus polyacanthocephalus*	0.23	18	0.29	21	0.09	9	0.20	15
Starry Flounder	*Platichthys stellatus*	0.09	9	0.06	6	0.09	9	0.08	8
Greenling Spp.	*Hexagrammos Spp.*	0.14	14	0.06	6	0.00	0	0.05	5
Cutthroat Trout	*Salmo clarki*	0.18	5	0.00	0	0.00	0	0.04	1
Crescent Gunnel	*Pholis laeta*	0.05	5	0.06	6	0.03	3	0.04	4
Threespine Stickleback	*Gasterosteus aculeatus*	0.00	0	0.12	9	0.00	0	0.04	3
Snailfish Spp.	*Careproctus Spp.*	0.09	5	0.00	0	0.06	6	0.04	3
Northern Sculpin	*Icelinus borealis*	0.00	0	0.06	6	0.03	3	0.03	3
Pacific Staghorn Sculpin	*Leptocottus armatus*	0.09	9	0.00	0	0.00	0	0.02	2
Buffalo Sculpin	*Enophrys bison*	0.05	5	0.00	0	0.00	0	0.01	1
Silverspotted Sculpin	*Blepsias cirrhosus*	0.00	0	0.03	3	0.00	0	0.01	1
Tadpole Sculpin	*Psychrolutes paradoxus*	0.00	0	0.00	0	0.03	3	0.01	1

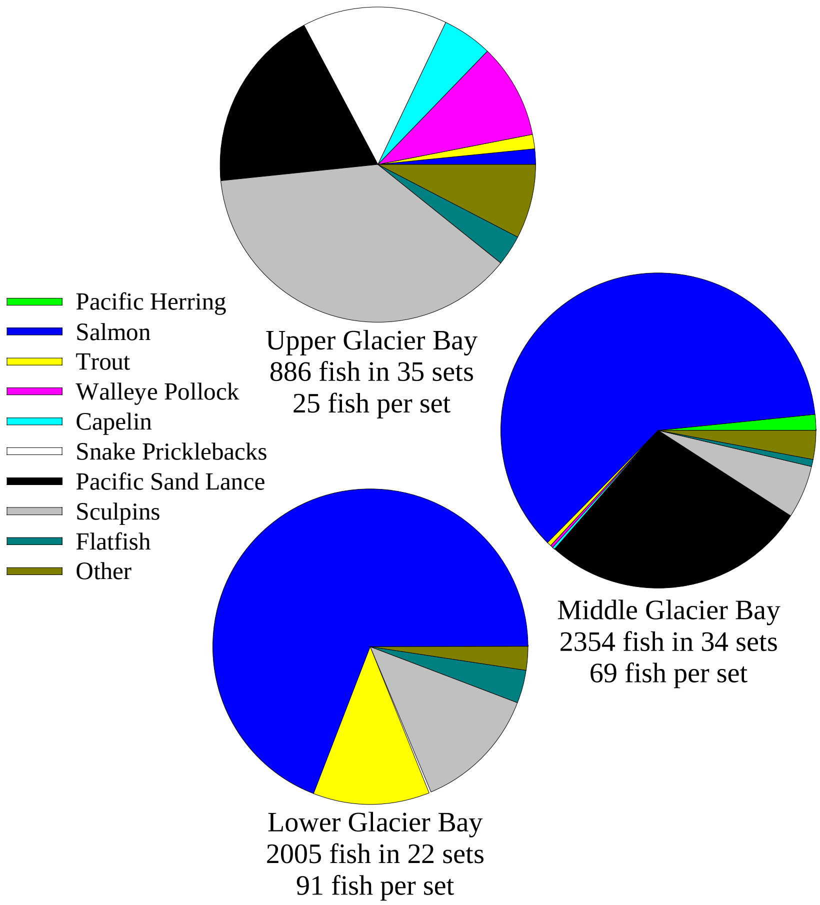


Figure 2. Proportional Catch-Per-Unit-Effort in Glacier Bay Beach Seines

The diversity of species in Glacier Bay (24 species) appeared somewhat depauperate compared to other subarctic areas of Alaska. Isakson *et al.* (1971) caught 40 species in the nearshore waters of Amchitka Island, Robards et al., (2000) found 50 species in Lower cook Inlet, and Orsi and Landingham (1985) found 42 species at another southeast Alaskan site (Auke Bay). However, our short sampling period may have missed species that are only seasonally present at other times. Number of sets made appeared adequate based on Figure 3 with 88 percent of species caught at the first 25 beaches. However, it is clear that several more species may have been found with a greater sampling effort.

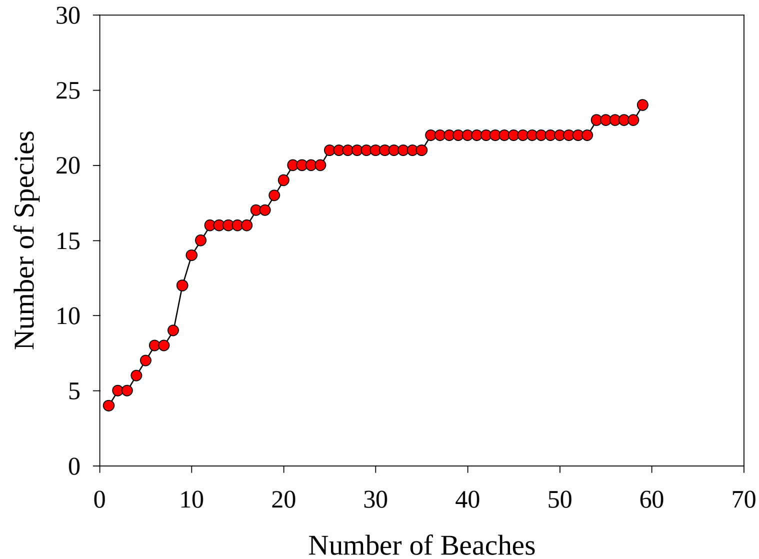


Figure 3. Number of Species Caught Versus Effort.

The five dominant species in each of the lower-, middle-, and upper- regions of the bay accounted for 98, 96, and 92 percent of the fish caught, respectively. In estuarine, inshore, and bay habitats in the northeastern Pacific, it is typical for five or fewer species to account for more than 75% of the individuals in local fish communities, even though the total number of species comprising these communities may be much larger (e.g., Allen and Horn, 1975; Hancock, 1975; Horn, 1980; Allen, 1982; Gordon and Leavings, 1984; Orsi and Landingham, 1985). As might be expected from these patterns of relative abundance, these fish were predominantly juveniles (Gibson *et al.*,1996) and typically low in the trophic web (Allen, 1982). The general size of fish caught in the nearshore reflected this, as most were less than 200 mm in length (Figure 4).

Of the 59 beaches visited, we were able to make 49 sets at high tide and 42 sets at low tide (Appendix 1). At these sites we caught 24 species, of which 21 were caught at each tide. Rarer species accounted for the small difference in species assemblage between tidal states. However, although species assemblages were similar, catch was dramatically different between tides, with 25 fish caught per set at high tide compared to 96 per set at low tide. We used a natural break method of classification to portray high and low tide catches. This method identifies breakpoints between classes using Jenk's optimization technique to minimize the sum of variance within each class (i.e., the different sized points reflect natural breaks within the data; Figures 4 and 5). Larger low tide catches were clearly apparent in the Lower Bay compared to the upper bay (particularly the eastern arm) except for Reid Inlet (beaches 43-45) which appeared unusually productive (Figure 3). Smaller catches at high tide prevented a clear pattern being observed at this tidal stage (Figure 4).

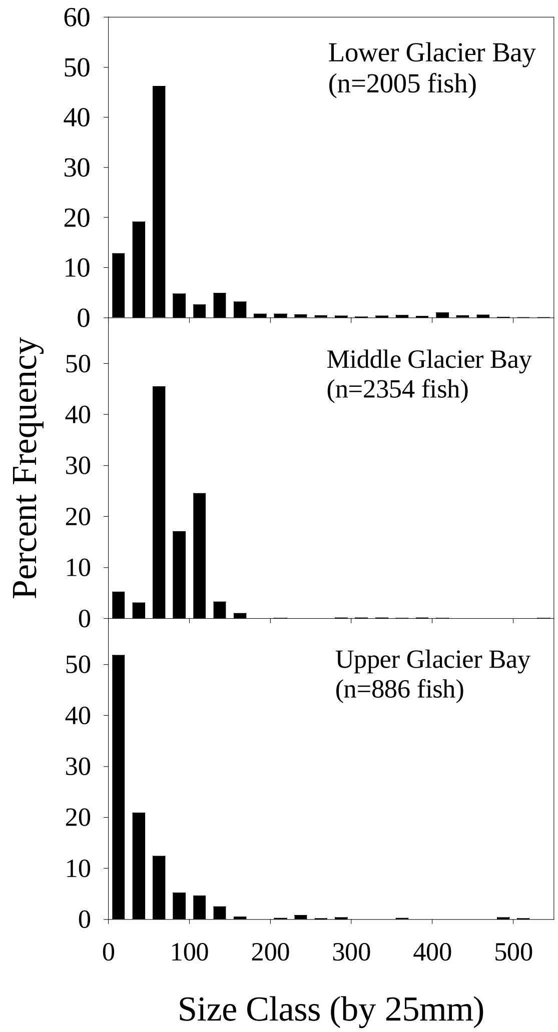


Figure 4. Size Frequency of Fish Caught in Glacier Bay Beach Seines

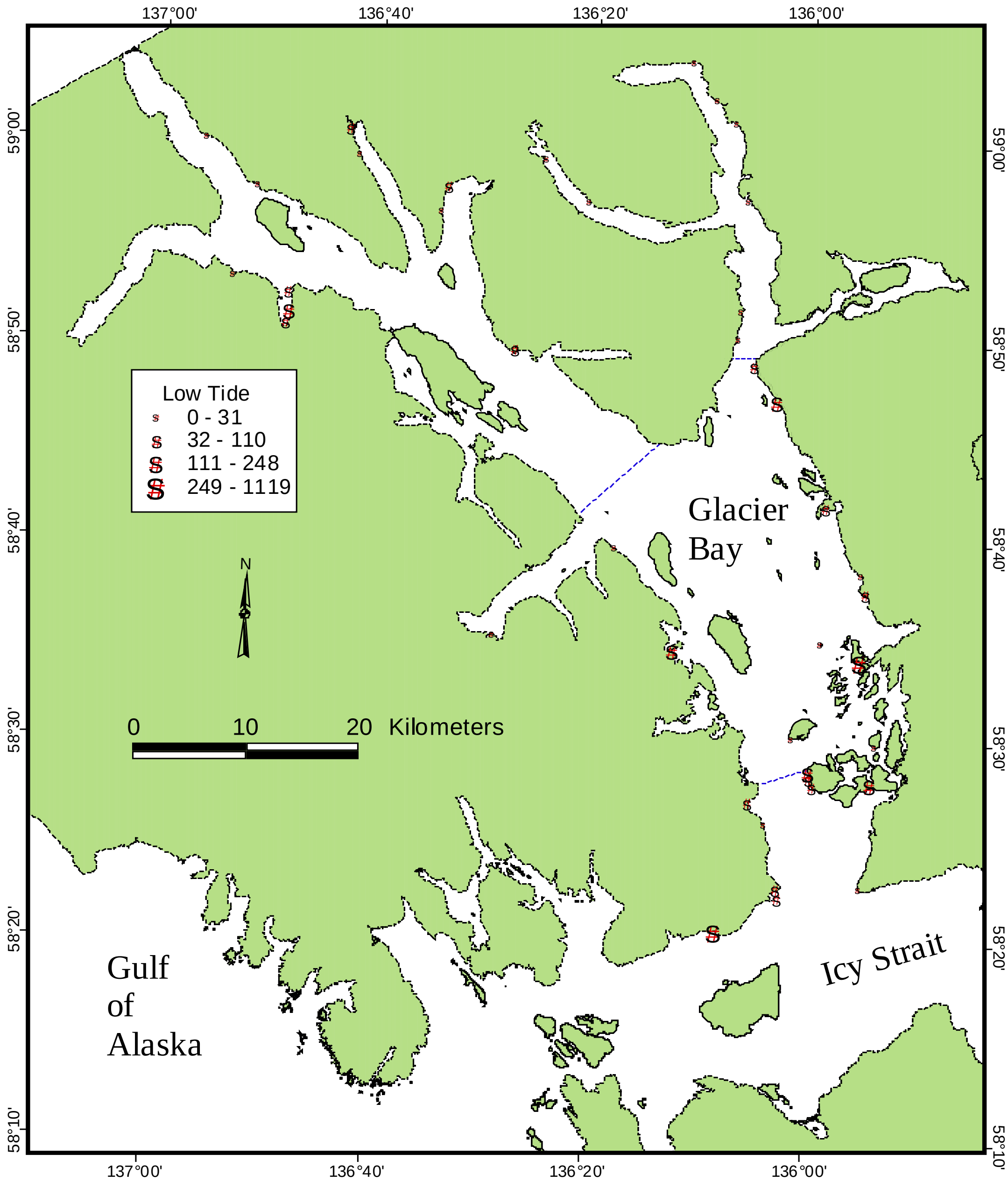


Figure 3. Low tide catches for June 1999 in Glacier Bay. Plot is scaled using natural breaks (see text)

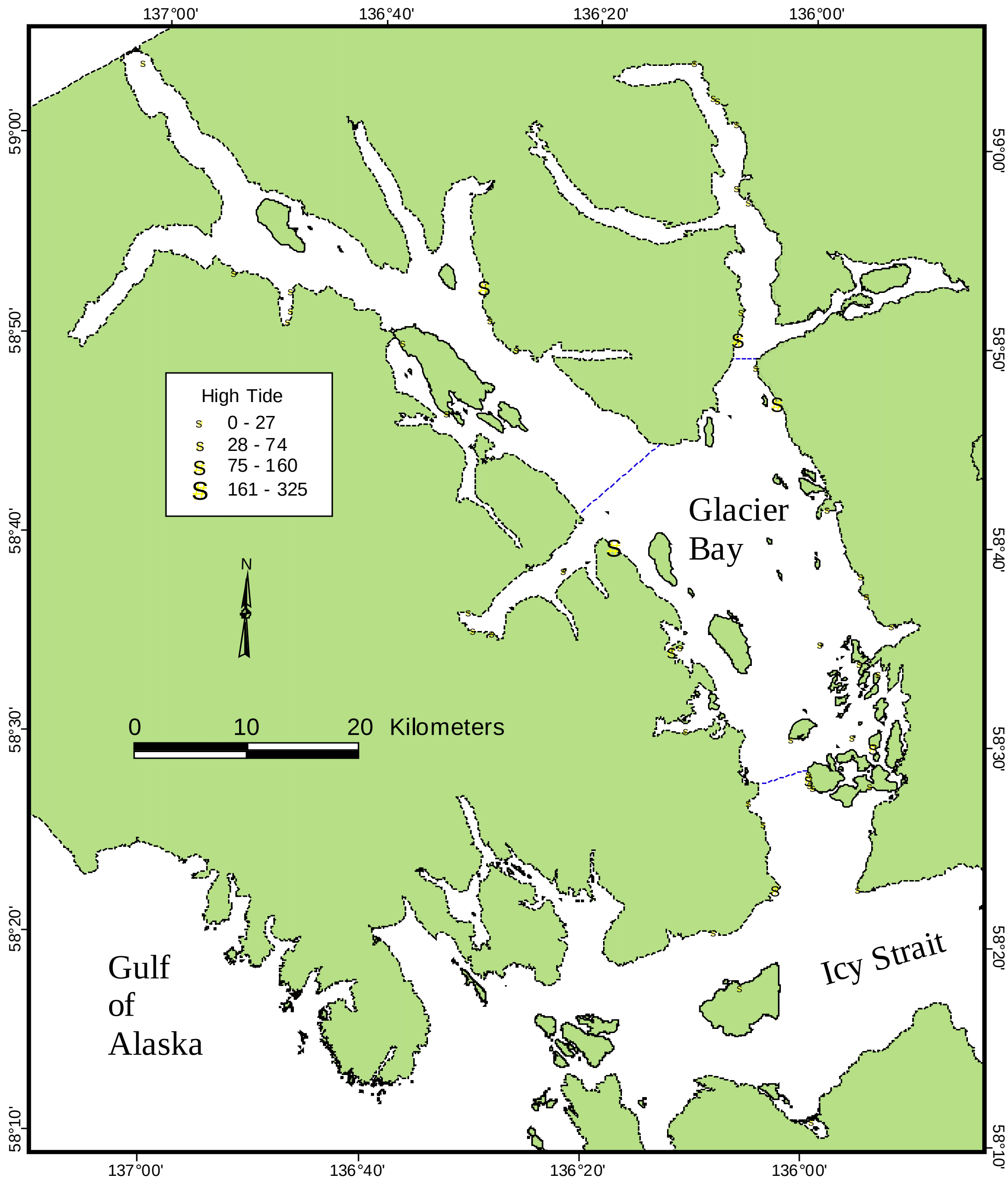
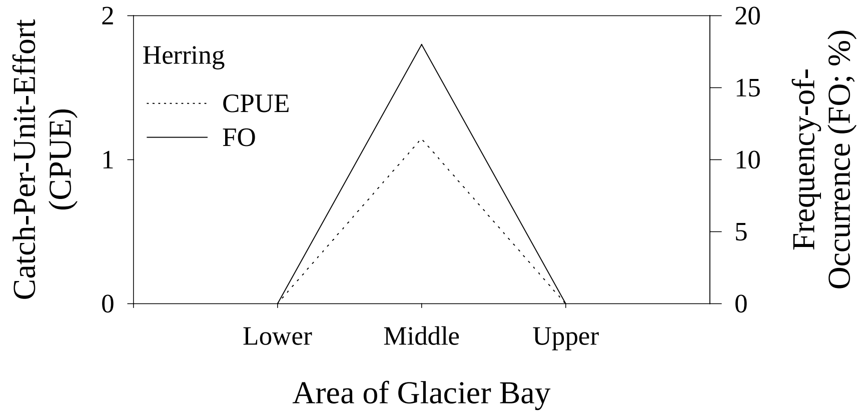


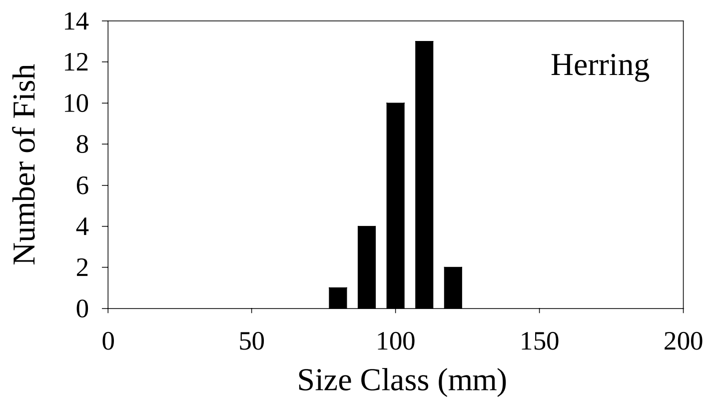
Figure 4. High tide catches for June 1999 in Glacier Bay. Plot is scaled using natural breaks (see text)

Species Accounts

Herring

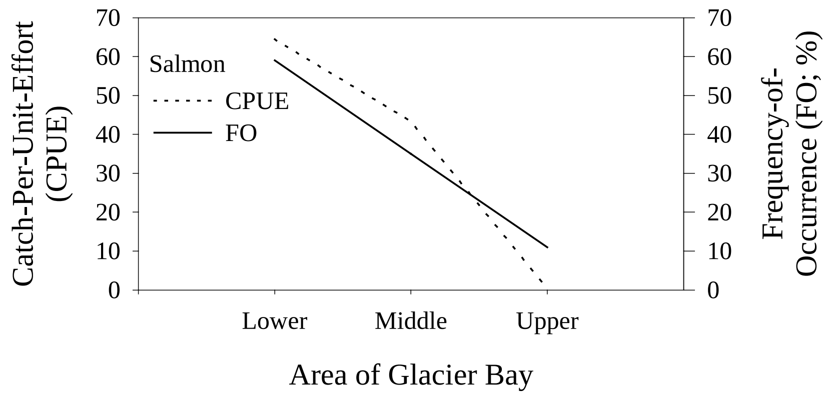
Although herring were only caught in small numbers within the middle region of Glacier Bay they were relatively common (18% of seines); and none were caught in the upper of lower regions. Our sampling may have underestimated this species because they tend to be patchily distributed in large aggregations. Sampling of this species may have been biased by the habitats selected for beach seines or because herring were less abundant in the nearshore at the time of our sampling. All herring caught were of similar size and probably all second-year fish.

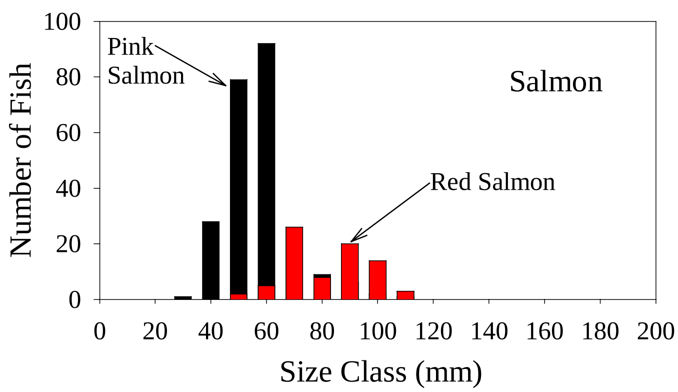




Salmon

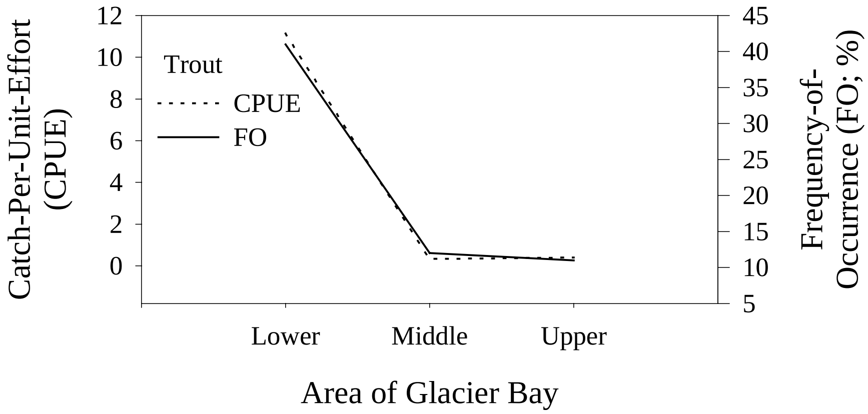
Salmon species (all juvenile) graduated from common and abundant in the lower region of the bay to infrequently caught individuals in the upper bay. Quality of streams for spawning of these anadromous fish is likely the most important factor influencing their distribution. Quality improves from the newly formed, highly turbid streams in the upper reaches of the bay to the more mature streams in the lower bay (Milner, 1987). Milner (1987) clearly showed a corresponding succession from low salmonid numbers in the upper bay to an abundance in the lower bay streams. Pink salmon were the only species of salmon caught in the upper bay in this study. Pink salmon (as well as Chum, *Oncorhynchus keta*) are two of the most suitable initial colonizers of newly formed stream systems as their fry migrate directly into the ocean, eliminating the need for suitable rearing habitat in the highly turbid waters. This was reflected in the small size of juvenile pink salmon compared to other salmonids in this study. Pink salmon have also been reported as one of the species most likely to stray from their home streams (Pritchard, 1939) enhancing their ability to colonize new areas. Our results do not establish if the juvenile salmonids that we caught originated in Glacier Bay or whether they were carried into the bay by currents.

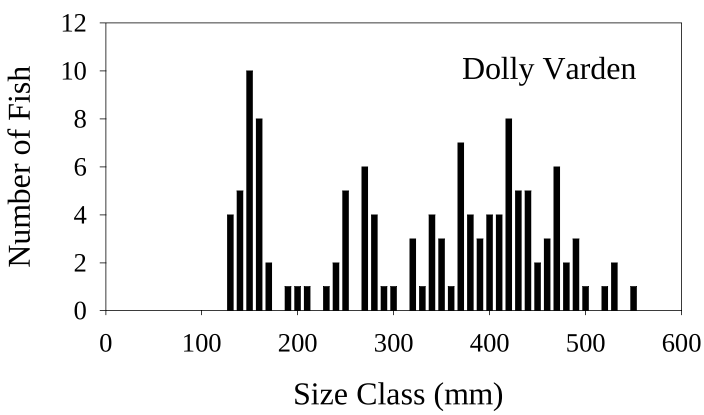




Trout

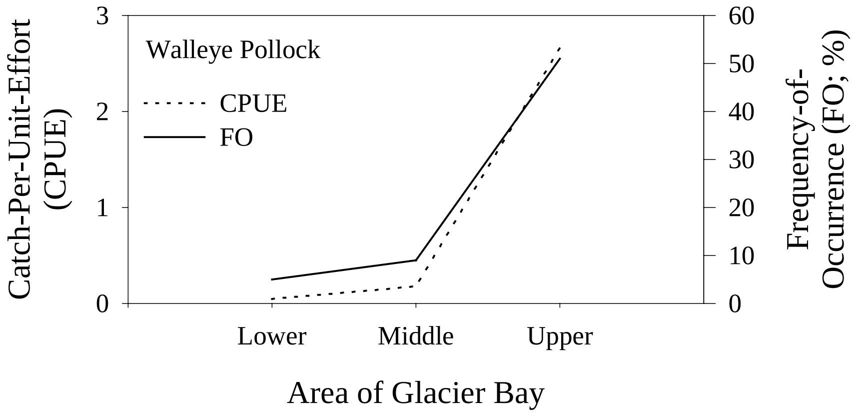
Trout were mainly represented by Dolly Varden (only 4 cutthroat trout were caught). This species clearly preferred the lower regions of Glacier Bay. Upper and middle bay catches were only one percent of those found in the lower bay. This species is a common predator in the nearshore area of Alaskan marine bays and is typically the first salmonid to colonize new stream habitats (Milner, 1994). No clear class structure was present from our samples, although at least three age-classes are suggested from the length/frequency histogram.

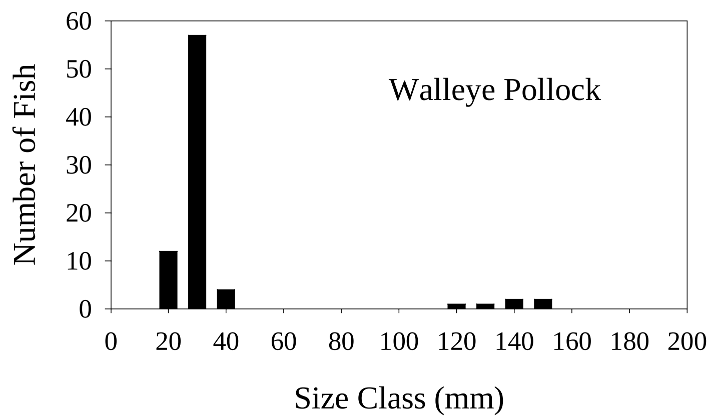




Walleye Pollock

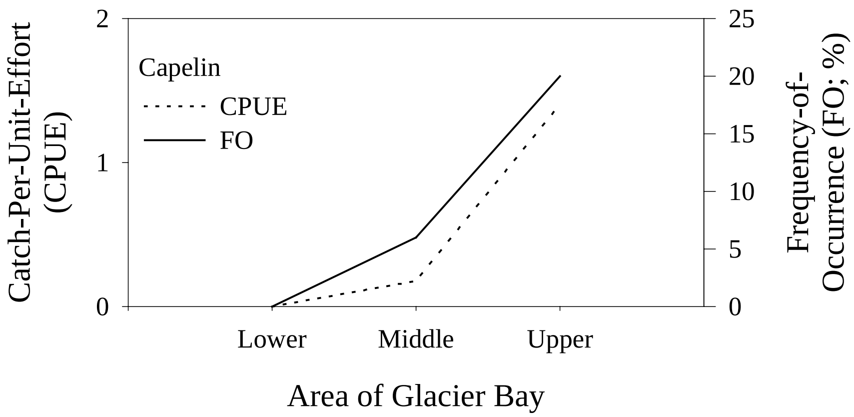
Walleye Pollock were one of the most frequently caught species in the upper part of Glacier Bay, but scarce in the lower- and middle-bays. These were mostly larval fish in their first year, although a few juvenile (probably second year) pollock were also found. This species does not appear to use nearshore habitats as nursery areas (Robards et al., 2000). Therefore, finding juvenile pollock in the glacially influenced arms of Glacier Bay raises the question as to whether spawning occurs in this area. Another typically oceanic fish, the myctophid was also found in this area in trawls (Abookire, *pers comm*) indicating this environment is unique in it's assemblage of fish.

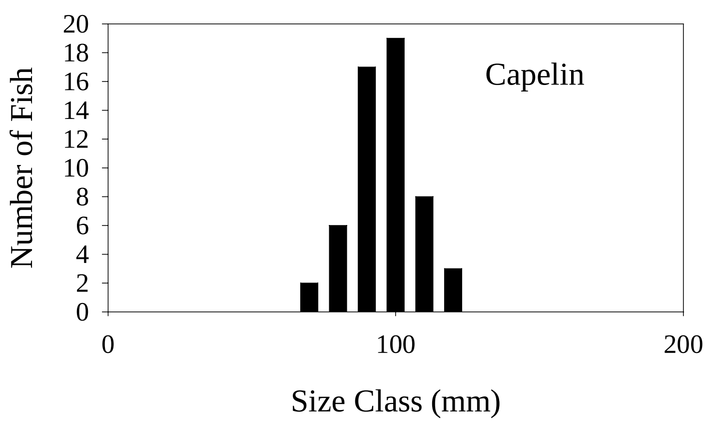




Capelin

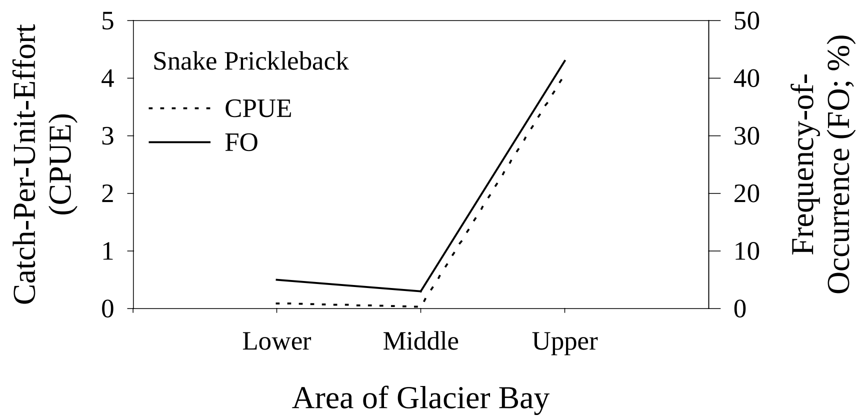
Capelin were predominantly found in the upper bay. Although found in low numbers, they were caught in 20 percent of sets in the upper region of Glacier Bay indicating that they are relatively common. All fish were a single size class and represented adult fish. Capelin were also observed being preyed on by arctic terms at the entrance to Bartlett Cove but were not caught in seines in that region.

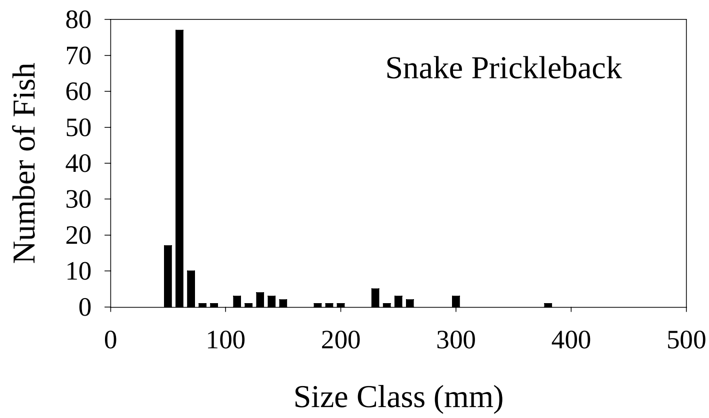




Snake Prickleback

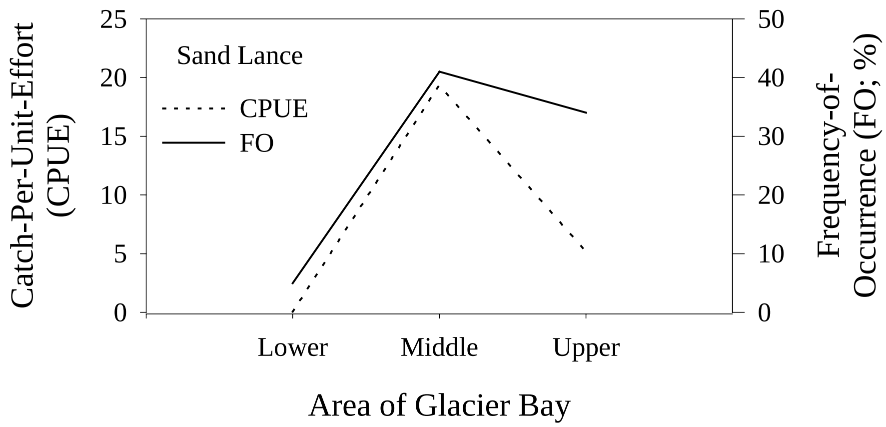
This species was widely distributed in the upper parts of Glacier Bay; few were caught in the lower and middle regions. Larval pricklebacks were caught most commonly except from in Reid Inlet (beaches 43-45) where large numbers of adults were caught within one-half mile of Reid Glacier. Results were similar to Chisik Island in Cook Inlet, which is also a glacial-silt dominated system. In this area, numerous snake pricklebacks were also found in otherwise depauperate silty areas. This species may be an important early colonizer of nearshore areas.

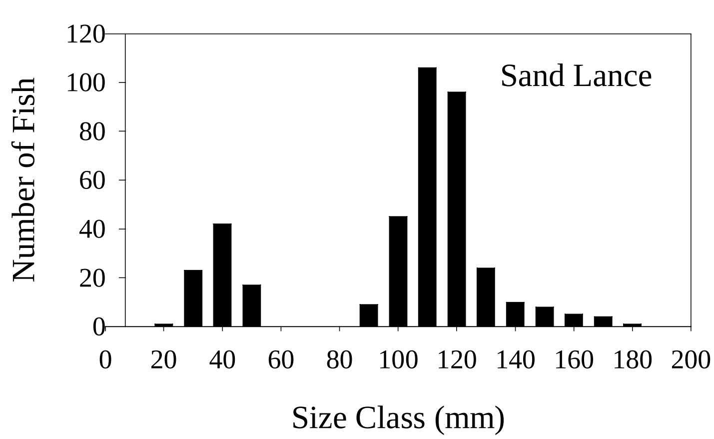




Sand Lance

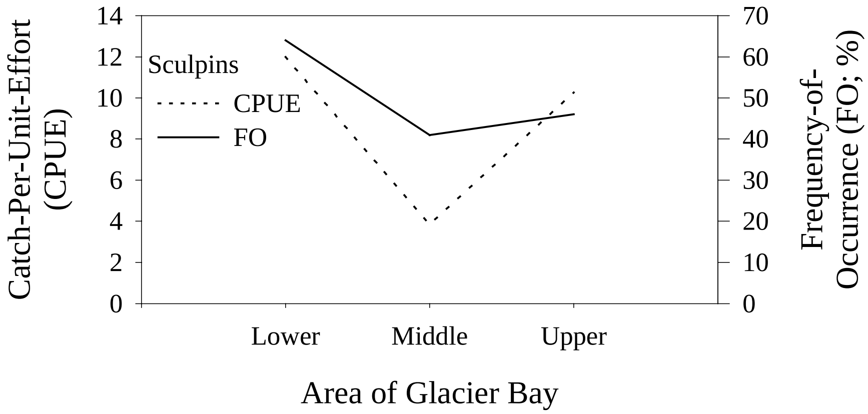
Sand lance were the second-most frequently caught taxa in this study (30% of sets; Table 1) and distributed mostly in the middle and upper reaches of Glacier Bay. This species is closely associated with clean sand substrates, in which they live for much of their lives. Areas of high water flow, such as the entrance to lagoons and outwash plains, generally provided the best substrates for sand lance. We caught sand lance at most beaches of this type within Glacier Bay. Much of the sandy substrate in Glacier Bay is covered in mussel beds rendering it unsuitable for sand lance. Although we were unable to sample several outwash areas by seine, we established by digging in intertidally exposed substrates that sizeable sand lance populations exist at the following areas: the flats at the southwestern head of Geike inlet; the outwash from Dirt Glacier where large flocks of pigeon guillemots, glaucous-winged gulls, black-legged kittiwakes, cormorants, scoters, porpoises, and seals were seen feeding – some of which were observed carrying sand lance; and at beaches 33 and 34 located opposite the entrance to Adams Inlet. Size distribution of sand lance clearly showed the newly recruiting young-of-the-year and adult sand lance. Without otolith analysis, number of age classes of adult sand lance could not be established.





Sculpins

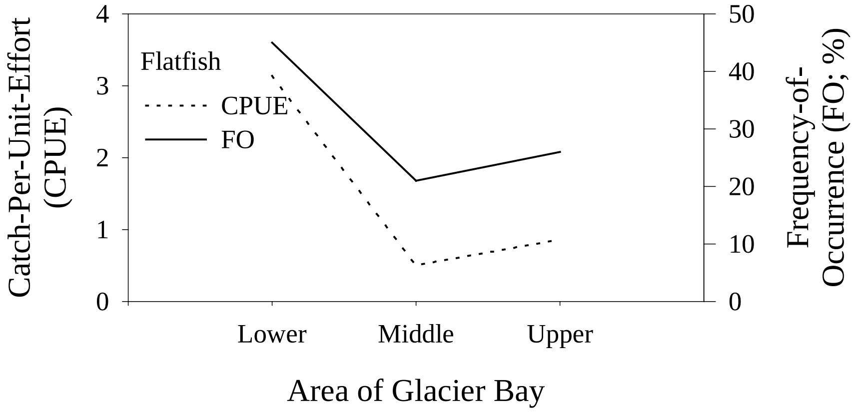
Sculpins (mostly juveniles) were the most commonly caught taxa in this study (35% of sets; Table 1). Small juveniles ranging from 15 to 25 mm dominated sculpin catches. Second year fish were caught regularly, but at the rate of only one or two per set. These fish were distributed throughout the bay, and unlike many of the other species sampled, did not display a distinct preference for any particular regions.

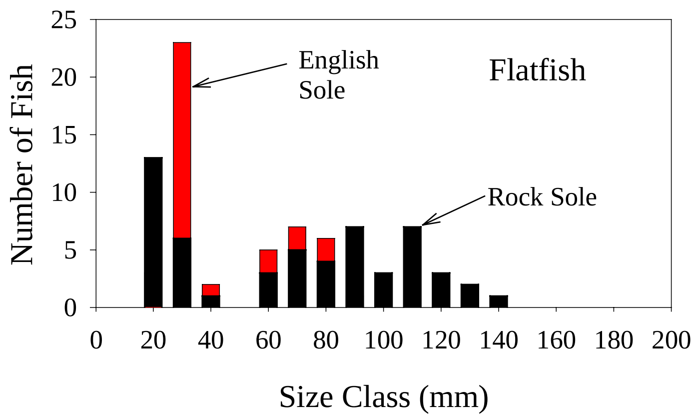


Flatfish

Flatfish were predominantly found in the lower-reaches of Glacier Bay. Rock Sole were the most commonly found species within the bay. However, in the lower reaches and particularly into Icy Strait we found larger numbers of English Sole.

At least two size classes of flatfish are evident from size-frequency histograms. Newly recruiting juveniles at about 30mm for both Rock and English Sole were found, as well as second year fish ranging from 60-140 mm.





Other species

Other fish species were caught infrequently (Appendix 2). We also caught large numbers of invertebrates at several sites. Numerous amphipods were found at the Glacial outflow from Carroll Glacier (Beach 32) and numerous euphausids were found close to the Grand Pacific (beach 47) and Reid (Beach 43) glaciers.

Recommendations

High-latitude fish assemblages, particularly those found in shallow water habitats, are subjected to large seasonal variations in temperature and day length. These physical factors impart a strong natural seasonality to community structure (Nash, 1988). Some fish species move from shallow water habitats to deeper waters in winter when thermal tolerances are exceeded (Allen and Horn, 1975; Allen, 1982; Bennett, 1989). Decreases in catch size between spring and fall peaks have also been observed by many investigators (e.g., Livingston, 1976; Horn, 1980; Allen, 1982; Thorman, 1986; Methven and Bajdik, 1994; Robards et al., 2000). These other studies highlight the need for seasonal sampling to establish a full picture of both the species assemblage within an area as well as how abundance changes through a season.

As mentioned earlier, our sampling of the nearshore is restricted to suitable substrates for beach seining. This study could be expanded to cover a wider range of habitats using fyke nets, small-mesh purse seines, small-mesh gill nets, and small fish traps.

Acknowledgements

This project was funded by the USGS NRPP program.

Special thanks to Jennifer Marie Anson and Jon Schroeder for volunteering their time to help with beach seining. Sincere appreciation to the crew of the ADF&G vessel *R/V* Pandalus and to Glacier Bay National Park staff for their hospitality and support. This research was part of the larger study on small schooling fish and vertebrate predators conducted by Alissa Abookire, Mayumi Arimitsu, Brenda Ballachey, Jim Bodkin, Janene Driscell, George Esslinger, Jennifer De Groot, Philip Hooge, Kim Kloecker, Kathy Kuletz, Dan Monson, Suzann Speckman, and Jim Taggart.

References

Allen, D. M., S. K. Service, and M. V. Ogburn-Matthews. 1992. Factors influencing the collection efficiency of estuarine fishes. *Transactions of the American Fisheries Society* **121**: 234-244.

Allen, L. 1982. Seasonal abundance, composition, and productivity of the littoral fish assemblage in upper Newport Bay, California. *Fishery Bulletin US* **80**: 769-790.

Allen, L. G. and M. H. Horn. 1975. Abundance, diversity, and seasonality of fishes in Colorado Lagoon, Alamitos Bay, California. *Estuarine, Coastal and Marine Science* **3**: 371-380.

Anderson, P. J. and J. F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. *Marine Ecology Progress Series. In Press*.

Cailliet, G. M., M. S. Love, and A. W. Ebeling. 1986. Fishes: A field and laboratory manual on their structure, identification, and natural history. Wadsworth Publishing Company, Belmont, California, 132-134.

Gordon, D. K. and C. D. Leavings. 1984. Seasonal changes of inshore fish populations on Sturgeon and Roberts Bank, Fraser River estuary, British Columbia. *Canadian Technical Report of Fisheries and Aquatic Science* **1240**: 1-12.

Hancock, M. J. 1975. A survey of the fish fauna in the shallow marine waters of clam lagoon, Adak, Alaska. Florida Atlantic University, M.S. Thesis, 49pp.

Horn, M. H. 1980. Diel and seasonal variation in abundance and diversity of shallow-water fish populations in Morro Bay, California. *Fishery Bulletin US* **78**: 759-770.

Isakson, J. S., C. A. Simenstad, and R. L. Burgner. 1971. Fish communities and food chains in the Amchitka area. *Bioscience* **21**: 666-670.

Krieger, K. J. and B. L. Wing. 1984. Hydroacoustic surveys and identification of humpback whale forage in Glacier Bay, Stephens Passage, and Frederick Sound, Southeastern Alaska, Summer 1983. U. S. Dep. Commer., NOAA Technical Memorandum. NMFS/NWC-66, 60p.

Krieger, K. J. and B. L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. U.S. Dep. commer., NOAA Technical Memorandum. NMFS/NWC-98, 62p.

Lawrence, D. B., R. C. Schonike, Q. Quispel, and G. Bond. 1967. The role of *Dryas drummondii* in vegetation development following ice recession at Glacier Bay, Alaska, with special reference to its nitrogen fixation by root nodules. *Journal of Ecology* **55**: 793-813.

Livingston, R. J. 1976. Diurnal and seasonal fluctuations or organisms in a north Florida estuary. *Estuarine Coastal and Marine Science* **4**: 373-400.

Milner, A. M. 1987. Colonization and ecological development of new streams in Glacier Bay National Park, Alaska. *Freshwater Biology* **18**: 53-70.

Milner, A. M. 1994. Colonization and succession of invertebrate communities in a new stream in Glacier Bay National Park, Alaska. *Freshwater Biology* **32**: 387-400.

Orsi, J. A. and J. H. Landingham. 1985. Numbers, species, and maturity stages of fish captured with beach seines during the spring 1981 and 1982 in some nearshore marine waters of southeastern Alaska. U.S. Dept. Comm., NOAA Tech. Mem. NMFS F/NWC-86, 34pp.

Pritchard, A. L. 1939. Homing tendancy and age at maturity of pink salmon (*Oncorhynchuys gorbuscha*) in British Columbia. *Journal of the fisheries research board of Canada* **4**: 233-251.

Robards, M. D., J. F. Piatt, A. B. Kettle, and A. A. Abookir. 2000. Temporal and Geographic Variation in Fish Communities of Lower Cook Inlet, Alaska. *Fishery Bulletin*., In Press

Sidle, R. C., and A. M. Milner. 1989. Stream development in Glacier Bay National Park, Alaska, USA. *Arctic and Alpine Research* **21**: 350-363.

Thorman, S. 1986. Seasonal colonization and effects of salinity and temperature on species richness and abundance of fish of some brackish and estuarine shallow waters in Sweden. *Holarctic Ecology* **9**, 126-132.

Wing, B. L. and K. Krieger. 1983. Humpback whale prey studies in southeastern Alaska, summer 1982. Unpubl. rep., 60p. Auke Bay Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 210155, Auke Bay, AK 99821.