Abstract.–Nearshore and shelf fish communities were studied in three areas of lower Cook Inlet, Alaska: the Barren Islands (oceanic and well-mixed waters), Kachemak Bay (mixed oceanic waters with significant freshwater runoff), and Chisik Island (estuarine waters). Fish were sampled with beach seines (n=413 sets) and midwater trawls (n=39 sets). We found that lower Cook Inlet supported a diverse nearshore fish community of at least 52 species. Fifty of these species were caught in Kachemak Bay, 24 at Chisik Island, and 12 at the Barren Islands. Pacific sand lance dominated Barren Islands and Kachemak Bay nearshore habitats, comprising 99% and 71% of total individuals, respectively. The nearshore Chisik Island fish community was not dominated by any one species; instead it exhibited higher diversity. These spatial differences appeared linked to local oceanographic regimes and sediment influx. Analysis of historical data revealed that the nearshore Kachemak Bay fish community changed significantly between 1976 and 1996, showing increased diversity and abundance in several taxa, notably gadids, salmonids, pleuronectids, and sculpins. Decadal differences appeared to be related to large-scale climate changes in the North Pacific. Catches of most taxa peaked in May–August, and were low during other months of the year. Several species were present for only part of the summer. Species composition of seine catches differed significantly between consecutive high and low tides, but not between consecutive sets or years. Midwater trawls took 26 species, 14 of which were present in Kachemak Bay, 19 near Chisik Island, and 7 at the Barren Islands. Community structures in shelf and nearshore waters were similar: diversity was high and abundance low at Chisik Island, whereas a few abundant species dominated at both Kachemak Bay and the Barren Islands. In addition, the low fish abundance near Chisik Island appeared to be related to declining seabird numbers at this colony.

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Temporal and geographic variation in fish communities of lower Cook Inlet, Alaska

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Dramatic changes 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 20 years (Piatt and Anderson, 1996; Anderson et al.[1]). Coincident with cyclical fluctuations in seawater temperatures, abundance of several key forage species, including capelin (*Mallotus villosus*), pricklebacks (mostly *Lumpenella longirostris*), and Pacific sandfish (*Trichodon trichodon*) declined precipitously in the late 1970s. Meanwhile populations of large predatory fish, including walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and several pleuronectids increased dramatically. Correspondingly, seabird diets shifted from mostly capelin in the 1970s to mostly Pacific sand lance (*Ammodytes hexapterus*) and juvenile pollock by the late 1980s (Piatt and Anderson, 1996). Furthermore, a variety of seabirds and marine mammals exhibited signs of food stress during the 1980s and early 1990s (Piatt and Anderson, 1996). Inferences about changes in Gulf of Alaska fish communities have been based on a limited number of site-specific long-term studies (e.g. Anderson et al.[1]); however, evidence is mounting that suggests these changes were wide-spread throughout the region (Francis et al., 1998).

The importance of inshore marine habitats as nursery areas for juveniles of many marine fish species has been well reported (Poxton et al., 1983; Orsi and Landingham, 1985; Bennett, 1989; Blaber et al., 1995; Dalley and Anderson, 1997). Studies in other parts of the world

[1] Anderson, P. J., S.A. Payne, and B. A. Johnson. 1994. Multi-species dynamics and changes in community structure in Pavlof Bay, Alaska 1972–1992. Natl. Mar. Fish. Serv., NOAA, Kodiak, Alaska. Unpubl. manuscript, 26 p.

have also described seasonal variation in shallow water fish assemblages (e.g. Horn, 1980; Allen, 1982; Nash and Gibson, 1982; Nash, 1988; Bennett, 1989). Little is known, however, about annual, seasonal, and daily variation in fish abundance in Alaska. Understanding the responses of fish populations at this scale are critical for examining finer-scale processes such as trophic interactions. Responses at these time scales also put interdecadal changes into perspective, and it is changes at the decadal scale that are rapidly becoming the focus of fishery oceanographers (Francis et al., 1998).

Our primary objectives were to assess variability in abundance, diversity, and distribution of nearshore fishes in three oceanographically distinct locations within lower Cook Inlet and to compare these data with information collected by Blackburn et al. (1980) 20 years ago. Until our study, Blackburn et al.'s 1976 surveys provided the only comprehensive description of nearshore fish communities in the region. Concurrent sampling of offshore species with midwater trawls also allowed us to make comparisons between shelf and nearshore fish communities.

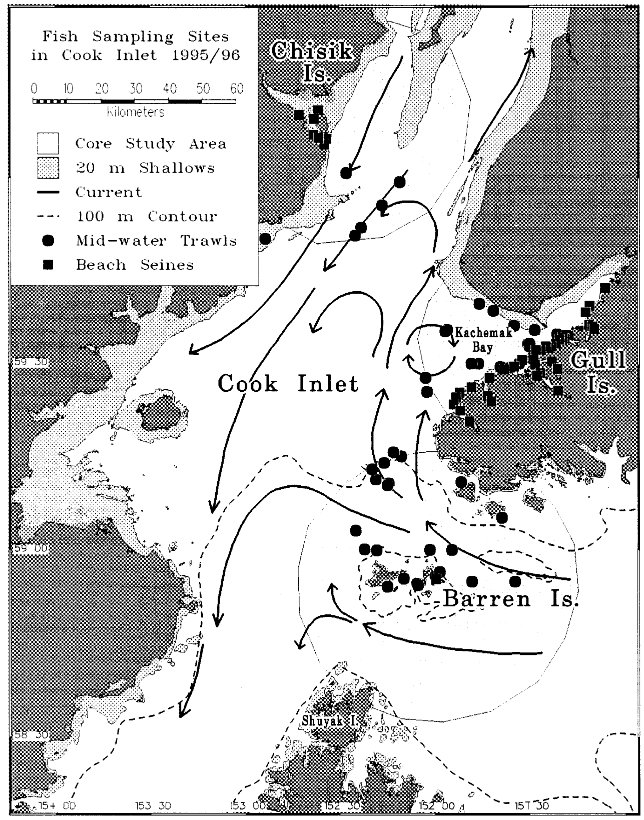

Figure 1

Map of lower Cook Inlet showing the three study areas, prevailing currents, bathymetry, and both beach seine and midwater trawl locations.

Methods

Study sites

Lower Cook Inlet (Fig. 1), in south-central Alaska, is the largest embayment in the northern Gulf of Alaska. The area supports several important seabird colonies and numerous marine mammals, as well as important commercial and recreational fisheries for salmon (*Oncorhynchus* spp.) and Pacific halibut (*Hippoglossus stenolepis*). We studied three lower Cook Inlet areas that primarily support colonies of fish-eating common murres (*Uria aalge*) and black-legged kittiwakes (*Rissa tridactyla*): Gull Island, in Kachemak Bay; Chisik Island, on the western side of Cook Inlet; and the Barren Islands, near the entrance to Cook Inlet. Investigations of nearshore fish communities were initiated around these colonies to provide information that can be used to improve understanding of how forage fish abundance and distribution may influence seabird diets and productivity in these areas.

Kachemak Bay (Fig. 1) lies along the southeastern shore of Cook Inlet. The bay is 38 km wide at its entrance and 62 km long. The upper 6 km consists of mud flats that are exposed during low tide. Depths are relatively shallow, ranging from about 35 to 90 m, with some deeper areas (100 to 165 m) present off Gull Island along the south-central side of the bay. Water entering the bay originates from the Gulf of Alaska and is largely oceanic (Fig. 1; Burbank, 1977).

Chisik Island, on the western side of Cook Inlet (Fig. 1), is located in the mouth of Tuxedni Bay, which receives freshwater from glacier-fed rivers. Water passing outside the island is also estuarine, because it receives significant glacier-fed freshwater input from large rivers at the head of Cook Inlet before circulating down the western side of the inlet (Burbank, 1977; Feely and Massoth, 1982). Nearshore habitats around Chisik Island contain few sandy substrates and consist primarily of glacial silt and mud flats interspersed with rocky substrates that are exposed at low tides.

The Barren Islands, near the entrance to Cook Inlet (Fig. 1), are situated in a transition zone between deep Gulf of Alaska waters and the shallow Cook Inlet estuary. The Alaska Coastal Current enters Cook Inlet north of the Barren Islands, leading to intense upwelling of cold, nutrient-rich waters onto the shallow southeastern Cook Inlet shelf (Burbank, 1977). Because of the upwelling and strong tidal action (second highest tidal range in North America), waters in this area are turbulent and well mixed.

Field collections

We used beach seines to sample nearshore fish communities. These nets effectively and nonselectively sample shallow, inshore waters with sandy or smooth bottoms (Cailliet et al., 1986). In Kachemak Bay, samples were obtained during 16 June–26 July 1995 and 8 February–10 December 1996. Weather and sea conditions prevented sampling in January and November 1996. Sampling at Chisik Island and the Barren Islands occurred during 3 July–17 August, and 26 June–8 September 1996, respectively.

Our variable-mesh nets were 44 m long. The middle 15.3-m-long, 4-m-deep section was made of 3-mm knotless nylon stretch mesh (sm), and the wings tapered to a depth of 2.3 m were constructed of 13-mm knotted sm nylon. Thirty meters of rope were attached to the ends for deployment. Blackburn et al. (1980) used similar-size seines to sample Kachemak Bay in 1976. Nets were set parallel to shore about 25 m from the beach as described by Cailliet et al. (1986). Samples were collected about every two weeks in Kachemak Bay during May–September, and once a month throughout the winter. Samples from Chisik Island and the Barren Islands were collected every two weeks for the duration of their field seasons.

We sampled 38 Kachemak Bay sites that were seined by Blackburn et al. (1980) in 1976. At these sites, we made 60 and 245 sets during May–September of 1995 and 1996, respectively. In comparison, Blackburn et al. made 131 sets during May–September 1976. Raw data from the 1976 study were obtained from J. Blackburn, Alaska Department of Fish and Game (ADF&G), Kodiak, Alaska.

Sets were made at eight sites on the west side of Chisik Island. Twenty-three of these sets were made at high tide and seven at low tide (low tide sets were limited by deep mud in the subtidal zone). At the Barren Islands, 40 sets (18 at high tide and 22 at low tide) were made in Amatuli Cove.

Beach seining was conducted within one-hour windows on either side of high and low tides. To assess tidal influence on catch rates, seven sites in Kachemak Bay were seined regularly on consecutive high and low tides during periods of maximum tidal oscillation (about every 15 days). A single set usually provides good representation of species richness and dominant species rank (Allen et al., 1992). However, to assess variability of beach seine catches, two consecutive sets were made adjacent to each other at the seven sites intensively studied at each tidal stage. As a result, these sites were sampled four times on each day that seining occurred. Fish were sorted and counted by species. Owing to the key trophic role of sand lance in the Gulf of Alaska (Blackburn and Anderson, 1997), these fish were also separated into adult (age groups ≥1) and juvenile (age group 0) categories on the basis of otolith interpretations.

Midwater trawls were used to sample offshore shelf environments by using the ADF&G 22-m stern trawler RV *Pandalus* in July 1996. Forage fish were located with a Biosonics DT4000 digital echosounder (120 kHz), and significant targets were fished by using a modified herring trawl with a 50-m^2 opening. Mesh sizes diminished stepwise from about 5 cm in the wings to 1 cm at the codend. The codend was lined with 3-mm mesh and contained a collecting bucket. Trawls were monitored with a Furuno netsounding system. Tow duration ranged from 20 to 60 minutes depending on fish concentrations. Midwater trawls were not directly comparable to beach seines; trawls selectively sampled the pelagic zone, whereas beach seines unselectively sampled both pelagic and demersal zones.

Analyses

We calculated four indices to assess broad differences between sites and sampling periods. The Shannon-Wiener index (H') indicates diversity; it increases as both the species number (richness) and equitability of species abundance (evenness) increase (Pielou, 1977). To measure species “richness” in diversity, we used Margalef’s index (D; Margalef, 1968), and to assess equitability of species abundance, we calculated Pielou’s evenness function (J'; Pielou, 1977). Similarity between species lists from different sampling periods was tested by using Jaccard’s similarity coefficient for presence and absence data (Boesch, 1977). All diversity calculations were based on numbers of individuals and were made with natural logs ($\log_e$). Species assemblages were compared statistically with the Mann-Whitney rank sum test.

Results

Interdecadal comparison of beach seine catches in Kachemak Bay: 1976 versus 1995–96

Beach seines were an efficient method of catching nearshore fish. Of the 305 sets made in Kachemak Bay during May–September in 1995 and 1996, only four failed to yield fish. A total of 155,991 fish comprising 50 species were caught in these seines (Table 1). Of these species, 35 were primarily represented by juvenile stages. All species found during winter were also present during summer. Sand lance were most numerous; they represented 71% of total individuals.

Table 1

Frequency of occurrence and catch-per-unit-of-effort (CPUE) by species caught in beach seines during 1976 (May 21–September 29) and 1995/96 (May 16–September 27).

Status	Common name	Scientific name	1976[1] (131 Sets) % Occurence	1976[1] (131 Sets) CPUE	1995–96 (305 Sets) % Occurrence	1995–96 (305 Sets) CPUE	Change in % Occurrence[2]	Change in CPUE[3]
Abundant								
>50% of sets in at least one of the time periods	Dolly varden	*Salvelinus malma*	51.1	6.03	46.6	5.36	=	=
	Pacific sand lance	*Ammodytes hexapterus*	40.5	248.02	50.8	363.28	=	=
	Great sculpin	*Myoxocephalus polyacanthocephalus*	32.8	0.92	56.7	1.59	=	=
Common								
10–50% of sets in at least one of the time periods	Pink salmon	*Oncorhynchus gorbuscha*	24.4	6.14	39.0	28.16	=	=
	Rock sole	*Pleuronectes bilineatus*	15.3	0.33	30.2	1.24	=	=
	Pacific herring	*Clupea pallasi*	14.5	35.62	17.4	64.94	=	=
	Pacific cod	*Gadus macrocephalus*	0.8	0.01	27.2	14.49	+++	+++
	Whitespotted greenling	*Hexagrammos stelleri*	10.7	0.25	17.0	0.68	=	=
	Tubenose poacher	*Pallasina barbata*	5.3	0.07	15.7	0.42	+	=
	Threespine stickleback	*Gasterosteus aculeatus*	13.0	0.27	6.2	0.14	--	=
	Chinook salmon	*Oncorhynchus tshawytscha*	12.2	2.20	5.6	0.25	--	=
	Surf smelt	*Hypomesus pretiosus*	11.5	1.36	4.9	0.16	--	=
	Silverspotted sculpin	*Blepsias cirrhosus*	0.8	0.01	13.8	0.51	+++	+
Occasional 1–10% of sets in at least one of the time periods	Snake prickleback	*Lumpenus sagitta*	6.9	0.41	5.6	0.58	=	=
	Chum salmon	*Oncorhynchus keta*	3.1	0.06	7.5	2.58	++	++
	Saffron cod	*Eleginus gracilis*	1.5	0.02	8.9	1.71	+++	+
	Pacific staghorn sculpin	*Leptocottus armatus*	6.1	0.09	3.3	0.04	=	=
	Sockeye salmon	*Oncorhynchus nerka*	0.8	0.01	8.5	2.54	+++	++
	Pacific tomcod	*Microgadus proximus*	0.0	<0.01	9.2	2.16	+++	+++
	Crescent gunnel	*Pholis laeta*	2.3	0.04	4.9	0.19	+	=
	Starry flounder	*Platichthys stellatus*	3.8	0.05	2.6	0.15	=	=
	Pacific sandfish	*Trichodon trichodon*	0.0	<0.01	6.2	0.15	+++	+++
	Kelp greenling	*Hexagrammos decagrammus*	0.0	<0.01	4.6	0.15	?[4]	?[4]
	Buffalo sculpin	*Enophrys bison*	0.8	0.02	3.6	0.08	+++	=
	Slender eelblenny	*Lumpenus fabricii*	0.0	<0.01	4.3	0.88	+++	+++
	Masked greenling	*Hexagrammos octogrammus*	3.8	0.15	0.3	0.01	---	--
	Rock greenling	*Hexagrammos lagocephalus*	0.0	<0.01	3.6	0.15	?[4]	?[4]
	Lobefin snailfish	*Liparis greeni*	0.0	<0.01	3.3	<0.01	+++	+++
	Lingcod	*Ophiodon elongatus*	1.5	0.02	1.3	0.02	=	=
	Butter sole	*Pleuronectes isolepis*	1.5	0.02	1.3	0.01	=	=
	Walleye pollock	*Theragra chalcogramma*	0.0	0.00	2.6	4.62	+++	+++
	Coho salmon	*Oncorhynchus kisutch*	1.5	0.50	0.7	0.01	--	--
	Warty sculpin	*Myoxocephalus verrucosus*	0.0	0.00	2.0	0.04	+++	+++
	Sablefish	*Anoplopoma fimbria*	0.0	0.00	1.6	0.17	+++	+++
	Longsnout prickleback	*Lumpenella longirostris*	1.5	0.06	0.0	0.00	---	---
	Daubed shanny	*Lumpenus maculatus*	0.0	<0.01	1.3	0.02	+++	+++

continued

Pacific herring (*Clupea pallasi*), pink salmon (*Oncorhynchus gorbuscha*), walleye pollock, and Pacific cod accounted for 22% of the remaining individuals. Great sculpin (*Myoxocephalus polyacanthocephalus*), sand lance, and Dolly Varden (*Salvelinus malma*) were the most frequently caught species during 1995–1996, each occurring in over 40% of the samples.

Table 1 (continued)

Status	Common name	Scientific name	1976[1] (131 Sets) % Occurence	1976[1] (131 Sets) CPUE	1995/96 (305 Sets) % Occurrence	1995/96 (305 Sets) CPUE	Change in % Occurrence[2]	Change in CPUE[3]
Rare								
<1% of sets in both time periods	Flathead sole	*Hippoglossoides elassodon*	0.0	<0.01	1.3	0.02	+++	+++
	Northern rockfish	*Sebastes polyspinis*	0.8	<0.01	0.7	0.01	[5]	[5]
	Sawback poacher	*Sarritor frenatus*	0.8	<0.01	0.3	<0.01	[5]	[5]
	Soft sculpin	*Psychrolutes sigalutes*	0.0	<0.01	1.0	0.02	[5]	[5]
	Petrale sole	*Eopsetta jordani*	0.0	<0.01	1.0	0.04	[5]	[5]
	Prowfish	*Zaprora silenus*	0.0	<0.01	0.7	0.01	[5]	[5]
	Padded sculpin	*Artedius fenestralis*	0.0	<0.01	0.7	0.01	[5]	[5]
	Pacific halibut	*Hippoglossus stenolepis*	0.0	<0.01	0.7	0.01	[5]	[5]
	English sole	*Pleuronectes vetulus*	0.0	<0.01	0.7	0.01	[5]	[5]
	Capelin	*Mallotus villosus*	0.0	<0.01	0.3	<0.01	[5]	[5]
	Arctic shanny	*Stichaeus punctatus*	0.0	<0.01	0.3	<0.01	[5]	[5]
	Yellow Irish lord	*Hemilepidotus jordani*	0.0	<0.01	0.3	<0.01	[5]	[5]
	Ribbed sculpin	*Triglops pingeli*	0.0	<0.01	0.3	<0.01	[5]	[5]
	Smooth alligatorfish	*Anoplagonus inermis*	0.0	<0.01	0.3	<0.01	[5]	[5]
	Smooth lumpsucker	*Aptocyclus ventricosus*	0.0	<0.01	0.3	<0.01	[5]	[5]

[1] 1976 data also includes: 28% sets with unidentified sculpins and 25% sets with unidentified greenlings. Data from J. Blackburn (Alaska Dept. Fish and Game, Kodiak).

[2] Change in frequency of occurrence between 1976 and 1995–96 defined by = (<100% change in frequency), + or – (100–200% change), ++ or -- (200–300% change), or +++ or --- (>300 % change).

[3] Change in CPUE between 1976 and 1995/96 defined by = (values within an order of magnitude), + or – (values changed by one order of magnitude), ++ or -- (values changed by two orders of magnitude), and +++ or --- (values changed by at least three orders of magnitude).

[4] Unidentified greenlings in 1976 were a mix of rock and kelp greenlings.

[5] CPUE and frequency of occurrence were too small to infer change.

In 1976, a total of 39,927 fish comprising at least 28 species were collected from 131 seine sets (greenling, Hexagrammidae, and sculpins, Cottidae, were not always identified to species; Blackburn et al., 1980; Table 1). To compare these data statistically with 1995–96 information, sculpin and greenling were combined into two general categories. By number, sand lance (81%) and herring (12%) accounted for more than 93 % of the 1976 catch. Four of the five species that dominated 1976 catches also dominated the 1995–96 catches (sand lance, herring, Dolly Varden, and pink salmon), and sand lance and herring were the two most abundant fish caught during both study periods. In 1976, only four (0.01%) fish were gadids (3 saffron cod, *Eleginus gracilis*; and 1 Pacific cod). By 1995–96, gadids (Pacific cod; saffron cod; Pacific tomcod, *Microgadus proximus*; and walleye pollock) were more numerous on the basis of catch-per-unit-of-effort (CPUE, defined as catch-per-individual-seine) by 1–3 orders of magnitude and had increased in frequency of occurrence by more than 300% (Table 1). Furthermore, Pacific cod was a dominant species in the 1995–96 catches. Similar increases in CPUE or frequency of occurrence were apparent for sockeye and chum salmon (*O. nerka*, *O. keta*), three sculpin species (silverspotted sculpin, *Blepsias cirrhosus*; buffalo sculpin, *Enophrys bison*; warty sculpin, *Myoxocephalus verrucosus*), Pacific sandfish, two prickleback species (slender eelblenny, *Lumpenus fabricii*; daubed shanny, *L. maculatus*), lobefin snailfish (*Liparis greeni*), sablefish (*Anoplopoma fimbria*), and a flatfish species (*Hippoglossoides elassodon*). Marked declines only occurred in catches of masked greenling (*Hexagrammos octogrammus*), coho salmon (*O. kisutch*), and longsnout prickleback (*Lumpenella longirostris*). Differences between 1976 and 1995–96 catches were significant on the basis of change in CPUE (Mann-Whitney rank sum test; t=1339.5, P=0.007), percent composition (t=1373.0, P=0.018), and frequency of capture (t=1398.0, P=0.033).

Changes in fish abundance were accompanied by changes in community diversity (Table 2). The Shannon-Wiener index (H') was greater in 1995–96 than in 1976, reflecting the large increase in gadid species during the 1990s (accounting for two thirds of the difference in H'). Species richness (D) was also higher in 1995–96, compared with 1976. This difference resulted from the fact that four species represented 92% of the total 1995–96 catch. In contrast, only two species accounted for 93% of the 1976 catch.

Table 2

Catch-per-unit-of-effort (CPUE) and species diversity indices from nearshore and shelf areas of Kachemak Bay (1976 and 1995–96), Chisik Island, and the Barren Islands. Diversity indices: H' = species diversity; J' = species evenness function; D = species richness (see "Methods" section).

		CPUE		H'		J'		D	
Location	Year	Nearshore	Shelf	Nearshore	Shelf	Nearshore	Shelf	Nearshore	Shelf
Kachemak Bay	1976	305	—	0.74	—	0.23	—	2.27	—
Kachemak Bay	1995–96	511	345	1.05	1.07	0.29	0.40	3.26	1.51
Chisik Island	1996	33	92	2.13	1.89	0.67	0.64	3.34	2.85
Barren Islands	1996	4506	821	0.06	0.31	0.03	0.16	0.91	0.63

Table 3

Comparison of 1995 and 1996 Kachemak Bay beach seine catches for species that occurred in more than 10% of sets.

	1995			1996		
Species	Frequency of capture	Percent of total catch	CPUE	Frequency of capture	Percent of total catch	CPUE
Pacific sand lance	75.0	66.6	310.2	67.2	60.0	250.1
Dolly varden	68.3	1.8	8.5	55.7	1.8	7.5
Great sculpin	68.3	0.7	3.2	49.2	0.2	1.0
Pink salmon	51.7	3.0	14.0	52.5	13.8	57.4
Rock sole	33.3	0.2	1.0	36.9	0.4	1.5
Pacific cod	41.7	7.4	34.4	18.9	0.5	2.2
Pacific herring	30.0	16.1	75.1	11.5	16.5	68.8
Whitespotted greenling	20.0	0.2	0.9	21.3	0.1	0.5
Tubenose poacher	31.7	0.3	1.3	11.5	>0.1	0.2
Silverspotted sculpin	20.0	0.2	0.8	17.2	0.1	0.5

The low equitability (J') in both time periods reflected dominance by a few species (e.g. sand lance, herring) in catches.

Jaccard's similarity coefficient indicated only moderate (59%) similarity in the presence-absence of species between 1995–96 and 1976. This may have resulted from a combination of 1) a dramatic increase in abundance of some species in 1995–96 (e.g. tomcod, sandfish); and 2) increased fishing effort in 1995–96, which may have increased catches of less common species (e.g. prowfish, *Zaprora silenus*; capelin) that might have also been detected in 1976, if fishing effort had been greater.

Interannual comparison of beach seine catches in Kachemak Bay: 1995 versus 1996

As evidenced by catches of common species in Kachemak Bay (Table 3), there was little obvious difference in catches between consecutive years. During June and July of 1995, 27,944 fish belonging to 42 species were caught in 60 beach seine sets (CPUE=466). During the same period in 1996, 50,859 fish representing 37 species were found in 122 sets (CPUE=417). Forty-four species were identified over the course of the two year study, of which 30 were caught in both years. Species diversity (H') was similar in 1995 and 1996 (1.21 and 1.22, respectively), as were species richness (D; 3.61 and 3.43, respectively) and equitability (J'; 0.34 in both years).

Jaccard's similarity coefficient indicated a 68% similarity between the species assemblages caught in 1995 and 1996. Species not represented in one year or the other were generally uncommon species that were found in only a few seine sets. Differences in percent composition of 1995 and 1996 species assemblages were not significant (Mann-Whitney rank sum test).

Seasonal variation in the nearshore fish community of Kachemak Bay

To examine seasonal variation in nearshore fish abundance, we used only data collected in 1996 (130,325 fish, 46 species, 283 beach seine sets in February–December). Most species were present in greatest numbers during summer months, apparently moving inshore as water temperatures increased above 4°C in May (Fig. 2), and moving offshore as temperatures declined in October (Fig. 3). Almost no fish were caught or observed during the winter months (December–March; Fig. 3); however, CPUE increased markedly for all species in June and declined dramatically in mid-July. This pattern was also reported by Blackburn et al. (1980; Fig. 4). This change largely resulted from changes in nearshore sand lance abundance but was compounded by movements of pink salmon and Pacific cod. Large catches of juvenile pink salmon increased the CPUE in June as they migrated along shorelines (Orsi and Landingham, 1985), but salmon CPUE declined rapidly in July as fish moved offshore (Fig. 3; Blackburn et al., 1980). Catches of gadids (particularly Pacific cod and pollock) increased markedly in late summer (Fig. 3) and contributed to the large August increase in CPUE. However, most of the August–September increase in CPUE was due to recruitment of first-year sand lance (Fig. 3), which dominated late summer seine catches after adults moved out of nearshore environments in late July (Blackburn et al., 1980). In October, adult sand lance returned to inshore waters to spawn (Dick and Warner, 1982; Robards, 1999). CPUE began declining rapidly in October, in conjunction with a decline in diversity from 34 species in August to only 3 by December.

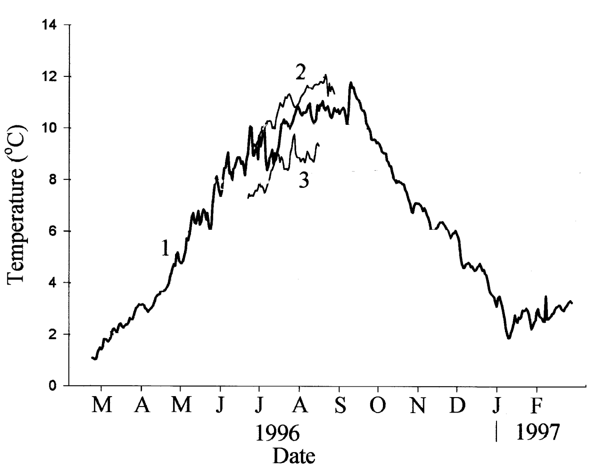

Figure 2

Seasonal variation in 1996 subsurface temperatures (5 m below low tide [0 m]) at Kachemak Bay (1), Chisik Island (2), and the Barren Islands (3).

We also observed strong seasonal trends in use of nearshore habitats by other species. Dolly Varden moved into nearshore waters in April, where they remained throughout July. After July they followed salmon into natal freshwater systems to overwinter (Isakson et al., 1971, Orsi and Landingham, 1985). Juvenile rock sole (*Pleuronectes bilineatus*) and great sculpins were consistently the most abundant fish found in nearshore habitats during February–March. Flatfish (Pleuronectidae) were caught at low rates throughout spring and summer but were not present after October (Fig. 3). Numbers of juvenile great sculpins increased rapidly in spring owing to an influx of small juveniles (<20 mm). Catches of these juveniles fell markedly by late June, and small but regular numbers of second-year individuals were caught during summer. Only one capelin was caught in Kachemak Bay (26 July 1995) prior to October 1996, when 1586 first-year fish were captured in three seine sets. Several large capelin schools were also observed at the same time. Capelin were also captured in three of eight seine sets in December. Although herring were present throughout the summer (Fig. 3), almost all of them (99%) were captured in five June and four August sets at one area (Halibut Cove) historically known for its aggregations of herring (Rounsefell, 1930).

Species abundance, diversity (H'), and richness (D) in the nearshore Kachemak Bay fish community increased steadily from April to June, peaked in July, and declined rapidly in September. Although sand lance dominated the community in summer, more than 30 species of fish were present during June–August. Species evenness (J') declined throughout summer, when sand lance dominated nearshore habitats, but increased again in fall as numbers of species and individuals declined.

Variability among consecutive beach seine sets and tidal states in Kachemak Bay

To assess variability in catches among sets and tidal states within Kachemak Bay, we made two sets immediately adjacent to each other at each site during consecutive high and low tides (i.e. 4 sets per site, 17 samples, 68 sets). CPUE declined markedly between first and second sets at both high (42% decline) and low (50% decline) tides, although numbers of species caught remained similar (Table 4). Jaccard's similarity coefficient for species composition indicated a high degree of similarity between the two adjacent high (75%) and low (74%) tide sets. However, species diversity, richness, and evenness all increased on the second set, at both tidal states, because of a decrease in dominant species (Table 4). Because species composition of seine catches did not differ significantly between consecutive sets at high and low tidal states (Mann-Whitney rank sum test), it appears that one set is adequate for assessing species richness and dominance, as suggested by Allen et al. (1992)

Twenty-eight species were represented in high tide sets and the overall CPUE was 425, in contrast to 38 species and a CPUE of only 191 at low tide. This difference probably resulted from a scarcity of pricklebacks (Stichaeidae), gunnels (Pholidae), and sculpins at high tide. The species difference in catches in part accounted for the moderate coefficient of similarity (Jaccard's) between tidal states (58% and 61% on sets 1 and 2, respectively). Catch composition differed significantly between high and low tides (Mann-Whitney rank sum test; T=2645, P=0.02). Several schooling species (e.g. pink salmon, adult sand lance) and one demersal species (great sculpin) showed little disparity in overall CPUE or frequency of occurrence between tidal states (Table 5). These species (or age classes) appeared to remain close to the shore throughout the tidal cycle. Other species (e.g. Dolly Varden, juvenile sand lance) apparently moved from deeper waters into the intertidal zone at high tide, as shown by the greater frequency of capture and CPUE. Although Pacific cod, saffron cod, whitespotted greenling (*Hexagrammos stelleri*), silverspotted sculpin, juvenile great sculpin, and rock sole were caught at both tide levels, these species appeared to remain preferentially in the subtidal zone during high tide (Table 5). Overall, species diversity, richness, and evenness were greatest at low tides (Table 4).

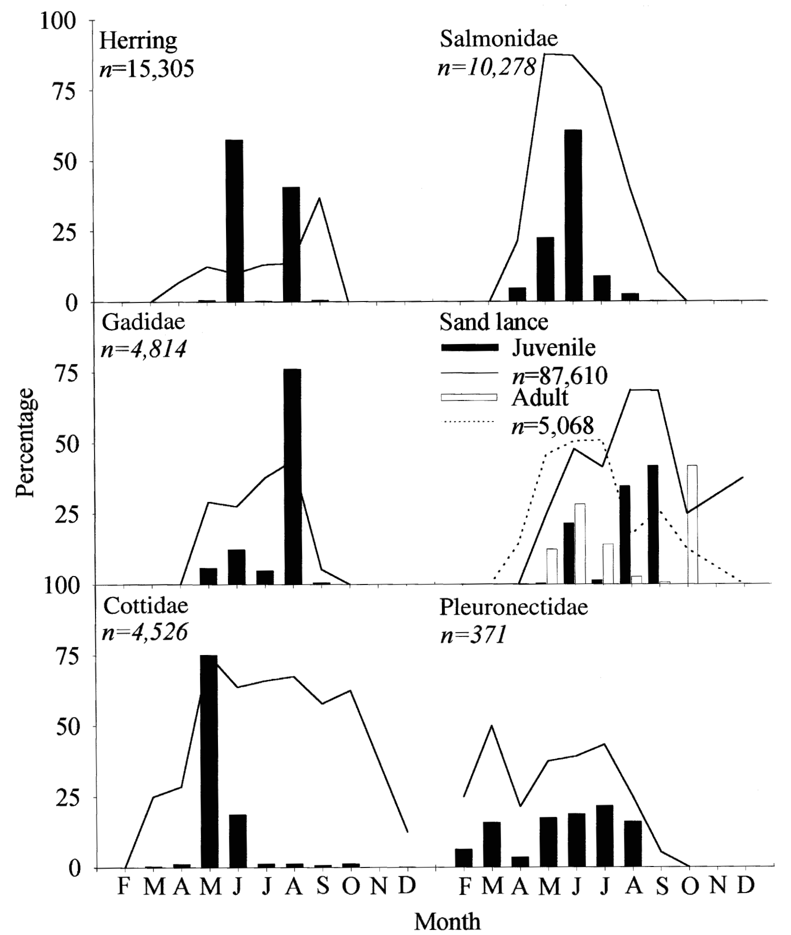

Figure 3

Seasonal variation in CPUE (bars) and frequency of occurrence (lines) of selected fish species caught by beach seines in Kachemak Bay.

Geographic comparison of beach seine catches from Kachemak Bay, Chisik Island, and the Barren Islands

A total of 988 fish representing 24 species were caught in 30 beach seine sets in the warmer (Fig. 2) nearshore waters around Chisik Island during summer 1996 (Table 6). Dolly Varden was the most common species; it was present in 63% of the sets and represented 30% of total catch by numbers. In contrast to Kachemak Bay and the Barren Islands, sand lance were found in only 33% of sets and accounted for only 24% of the catch by number. Snake pricklebacks (*Lumpenus sagitta*; 12%) and Pacific cod (8%) were the next most abundant species. Sculpins and flatfishes were also commonly caught in the sets.

A total of 180,232 fish representing at least 12 species (including 482 unidentified sculpins, 1 unidentified flatfish, and 1 unidentified greenling) were caught in 40 seine sets in the somewhat cooler (Fig. 2) nearshore waters at the Barren Islands during summer 1996 (Table 6). Barren Islands catches were dominated by sand lance (predominantly juveniles; Table 6). This species was found in 90% of the sets and represented over 99% of the total catch. Other species commonly found in the sets included Pacific cod (>50%), sculpins (>40%), and butter sole (*Pleuronectes isolepis*; 18%).

CPUE varied by about two orders of magnitude among the three areas. On the basis of this variable, we determined that Barren Islands waters were more productive than those of Kachemak Bay and Chisik Island (Table 2). However, Chisik Island and Kachemak Bay displayed greater species diversity and richness than the Barren Islands (Table 2; Fig. 5). Equity (J') was much greater at Chisik Island (Table 2), indicating that this community was not dominated by any one species. Jaccard's similarity coefficients were low when compared between areas. Species assemblages in Kachemak Bay and at Chisik Island were similar (42%), and both of these areas differed from the Barren Islands (<25% similarity).

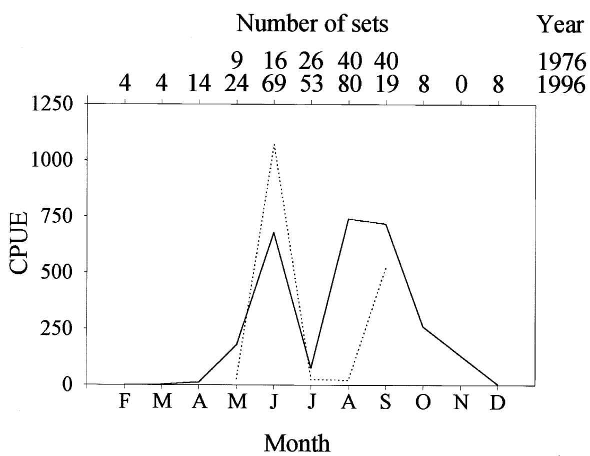

Figure 4

Seasonal variation of CPUE in beach seines during 1976 (······) and 1996 (——) in Kachemak Bay.

Comparison of nearshore and shelf communities in lower Cook Inlet

In 1996, midwater trawls were made during July at all three study sites (Fig. 1). Nine species were found

Table 4

Catch-per-unit-of-effort (CPUE) and species diversity indices for consecutive beach seine sets made at high and low tides in Kachemak Bay. Diversity indices: H' = species diversity; D = species richness; J' = species evenness function (see "Methods" section).

Tidal state	Set	CPUE	Species	H'	D	J'
High	1	539.35	24	0.85	2.34	0.27
High	2	310.97	25	1.42	2.59	0.44
High	Overall	425.16	28	1.09	2.63	0.33
Low	1	255.26	33	1.96	3.53	0.56
Low	2	127.71	33	2.29	3.82	0.65
Low	Overall	191.49	38	2.17	3.91	0.60

Table 5

Frequency of occurrence and catch-per-unit-of-effort (CPUE) of selected fish species (occurring in more than 10% of sets) caught on consecutive beach seine sets made at high and low tide in Kachemak Bay.

	High tide				Low tide			
	Set 1 (34 sets)		Set 2 (34 sets)		Set 1 (34 sets)		Set 2 (34 sets)	
Species	% Occurrence	CPUE	% Occurrence	CPUE	% Occurrence	CPUE	% Occurrence	CPUE
Pink salmon	47.1	77.6	38.2	44.5	44.1	41.68	38.2	24.24
Dolly varden	47.1	3.09	47.1	14.85	29.4	1.65	32.4	2.26
Pacific cod	8.8	3.24	11.8	6.32	29.4	22.82	26.5	18.85
Saffron cod	5.9	0.06	2.9	0.74	14.7	4.88	14.7	7.82
Juvenile sand lance	44.1	417.94	61.8	187.32	32.4	88.97	32.4	9.79
Adult sand lance	35.3	8.74	32.4	16.4	41.2	24.76	38.2	2.00
Whitespotted greenling	8.8	0.15	2.9	0.03	20.6	0.32	23.5	2.06
Silverspotted sculpin	0.0	0.00	5.9	0.12	26.5	2.06	29.4	0.59
Juvenile great sculpin	8.8	5.88	5.9	15.24	26.5	46.59	23.5	33.74
Adult great sculpin	41.2	0.94	52.9	1.53	58.82	1.91	44.12	0.85
Tubenose poacher	2.9	0.03	2.9	0.09	8.8	0.18	11.8	0.32
Rock sole	2.9	0.03	11.8	0.12	58.8	3.32	50.0	2.59

(Table 7) that were not present in any of the beach seine sets (Tables 1 and 6). Similar proportions of the most abundant taxa were evident in trawl and beach seine samples from Kachemak Bay (Fig. 5), and sand lance dominated both nearshore and offshore catches. Few midwater trawls were made at Chisik Island because acoustic sign signals rarely indicated that fish were present in the water column. There was moderate overlap in composition of seine and trawl catches at Chisik Island, and no single species dominated the samples (Fig. 5). In contrast, the shelf environment of the Barren Islands was clearly dominated by walleye pollock, and nearshore habitats were almost completely populated by sand lance.

CPUE (defined as catch-per-individual-trawl) for trawl sets varied by an order of magnitude among the three study areas, paralleling results from beach seine sets (Table 2). Geographic trends in community diversity indices from trawl catches were also similar to those calculated for nearshore beach seine sets (Table 2). Species diversity (H'), species richness (D), and equity (J') were highest at Chisik Island, somewhat lower in Kachemak Bay, and lowest at the Barren Islands (Fig. 5).

Table 6

Frequency of occurrence and catch-per-unit-of-effort (CPUE) by species for beach seine catches at Chisik Island (30 sets) and the Barren Islands (40 sets) in 1996.

	Chisik Island (988 fish)		Barren Islands (180,232 fish)	
Common name[1]	% Occurrence	CPUE	% Occurrence	CPUE
Pacific sand lance	33.3	7.77	90.0	4465.03
Pacific cod	16.7	2.47	52.5	12.58
Dolly varden	63.3	9.90	2.5	0.13
Great sculpin	50.0	1.07	0.0	0.00
Pink salmon	13.3	0.70	35.0	11.23
Starry flounder	46.7	1.70	0.0	0.00
Unidentified sculpins	0.0	0.00	42.5	12.05
Snake prickleback	33.3	3.97	0.0	0.00
Capelin	13.3	0.43	10.0	3.38
Threespine stickleback	23.3	0.33	0.0	0.00
Butter sole	0.0	0.00	17.5	0.33
Rock sole	16.7	2.07	0.0	0.00
Lingcod	0.0	0.00	15.0	0.33
Whitespotted greenling	13.3	0.73	0.0	0.00
Crescent gunnel	10.0	0.37	0.0	0.00
Kelp greenling	0.0	0.00	7.5	0.13
Pacific herring	6.7	0.60	0.0	0.00
Eulachon	6.7	0.10	0.0	0.00
Silverspotted sculpin	6.7	0.07	0.0	0.00
Padded sculpin	6.7	0.07	0.0	0.00
Pacific staghorn sculpin	6.7	0.07	0.0	0.00
Sawback poacher	6.7	0.17	0.0	0.00
Rock greenling	3.3	0.03	2.5	0.03
Surf smelt	0.0	0.00	5.0	0.55
Coho salmon	3.3	0.03	0.0	0.00
Sockeye salmon	3.3	0.03	0.0	0.00
Longfin smelt	3.3	0.17	0.0	0.00
Pacific tomcod	3.3	0.07	0.0	0.00
Pacific halibut	3.3	0.03	0.0	0.00
Walleye pollock	0.0	0.00	2.5	0.03

[1] Latin names included in Table 1 except eulachon (*Thaleichthys pacificus*) and longfin smelt (*Spirinchus thaleichthys*).

Table 7

Total numbers of fish by species caught in midwater trawls in shelf waters within about 40 km of Gull Island (Kachemak Bay), Chisik Island, and the Barren Islands in 1996.

Common name	Scientific name	Kachemak Bay 16 Sets	Chisik Island 6 Sets	Barren Islands 17 Sets
Walleye pollock	*Theragra chalcogramma*	456	123	12,912
Pacific sand lance	*Ammodytes hexapterus*	3857	132	195
Capelin	*Mallotus villosus*	441	141	840
Pink salmon	*Oncorhynchus gorbuscha*	413	44	0
Pacific cod	*Gadus macrocephalus*	317	4	1
Pacific sandfish	*Trichodon trichodon*	0	59	0
Chinook salmon	*Oncorhynchus tshawytscha*	0	19	0
Tadpole sculpin	*Psychrolutes paradoxus*	16	0	0
Snailfish	*Cyclopteridae*	1	4	0
Eulachon	*Thaleichthys pacificus*	0	10	0
Prowfish	*Zaprora silenus*	9	0	1
Rock sole	*Pleuronectes bilineatus*	2	1	6
Flatfish	*Pleuronectidae*	6	0	0
Armorhead sculpin	*Gymnocanthus galeatus*	0	5	0
Sculpin	*Myoxocephalus* spp.	2	0	1
Sculpin	*Gymnocanthus* spp.	2	0	0
Dover sole	*Microstomus pacificus*	0	2	0
Poacher	*Bathyagonus* spp.	2	0	0
Smooth alligatorfish	*Anoplagonus inermis*	0	2	0
Pacific herring	*Clupea pallasi*	0	1	0
Spinyhead sculpin	*Dasycottus setiger*	0	1	0
Northern sculpin	*Icelinus borealis*	0	1	0
Ribbed sculpin	*Triglops pingeli*	0	1	0
Arrowtooth flounder	*Atheresthes stomias*	0	1	0
Starry flounder	*Platichthys stellatus*	1	0	0
Pacific lamprey	*Lampetra tridentata*	0	1	0
Total fish		5525	552	13,956

Discussion

Nearshore fish communities

The overall composition of beach seine catches did not differ between 1995 and 1996, and community indices were also similar between years. This gives us confidence that changes in community composition observed between 1976 and 1995–96 reflected decadal-scale variability rather than just annual variability. The increase in beach seine CPUE between 1976 and 1995–96 may have also been real, but we have less confidence in this result because beach seines were deployed closer to shore in 1976 (10 m) than in 1995–96 (25 m), and this difference might have influenced catch rates. The most dramatic difference between decades was in catches of gadids (including pollock). Few were caught in the whole of lower Cook Inlet during 1976, when gadids represented only 0.2% of the total catch (85 individuals in 262 seines; Blackburn et al., 1980). The 1000-fold increase in gadids that we observed in the mid-1990s parallels a similar increase in abundance of gadids in offshore shrimp trawls in Cook Inlet (Bechtol, 1997) and the Gulf of Alaska (Piatt and Anderson, 1996; Anderson et al., 1997). Similarly, the increase in pleuronectids and salmonids that we observed in Kachemak Bay between 1976 and 1995–96 was paralleled in the Gulf of Alaska in shrimp trawls (Anderson et al., 1997) and commercial salmon catches (Francis and Hare, 1994), respectively.

Interdecadal changes in abundance of these fishes are probably related to large-scale climate changes in the North Pacific, but causal mechanisms are unclear (Francis et al., 1998). Water temperatures in the northern Gulf of Alaska changed from being

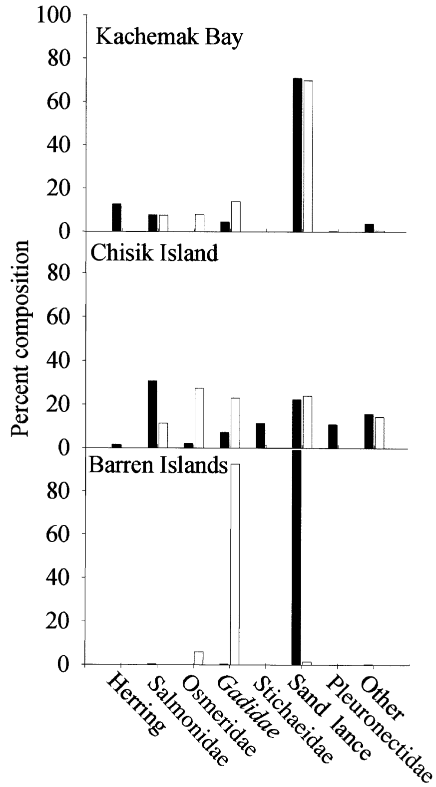

Figure 5

Species composition (% of total catch) in the nearshore (■) and shelf (□) areas of Kachemak Bay, Chisik Island, and the Barren Islands.

colder than average through the 1970s to warmer than average through the 1980s and 1990s (Royer, 1993). Temperature changes have been linked to El Niño Southern Oscillation (ENSO) events and shifts in the location and intensity of the Aleutian low-pressure cell (Niebauer, 1983). This climatic "regime shift'" caused a major reorganization of North Pacific biota (Francis et al., 1998). Phytoplankton and zooplankton abundance increased in the Gulf of Alaska, and this may have increased availability of food to larval stages of salmon and other groundfish, leading to enhanced recruitment (Francis et al., 1998). The timing of peak production of zooplankton biomass also changed, and this may have influenced recruitment in a suite of fish and invertebrates by altering the survival of larvae ("match-mismatch" hypothesis; Anderson and Piatt, in press). However, not all species appear to have been affected by changing climate. It is notable that the most abundant fish in Kachemak Bay, sand lance, exhibited no significant change in abundance or frequency of occurrence between 1976 and 1995–96. Sand lance have a unique life history. They spawn during the fall and larvae emerge in January or February, much earlier than the spring plankton blooms or larvae of many other Gulf of Alaska fish species. This strategy may be adaptive in situations where prey availability is unpredictable (Haldorson et al., 1993). Therefore, sand lance recruitment may have been little affected by changes in the timing or magnitude of zooplankton abundance during spring and early summer.

Capelin abundance declined sharply throughout the Gulf of Alaska after the late 1970s (Bechtol, 1997; Piatt and Anderson, 1996) but may have started to rebound in Cook Inlet waters during the early 1990s (Roseneau et al.[2]). Apart from catches in 10 beach seine sets (three sets in Kachemak Bay and at Chisik Island, and four at the Barren Islands), there is little evidence that capelin occur in nearshore areas of Cook Inlet. However, they were the third most common species caught in midwater trawls, and capelin were widely consumed by halibut and seabirds in Cook Inlet in 1995 and 1996 (Roseneau and Byrd, 1997; Roseneau et al.[3]). This species may occupy habitats offshore of the littoral zone, but largely inshore of where we made midwater trawls and may therefore be under-represented by this study.

The diversity of species in Kachemak Bay is comparable to that of other subarctic areas of Alaska. Isakson et al. (1971) caught 40 species in the nearshore waters of Amchitka Island and Orsi and Landingham (1985) found 42 species in southeastern Alaska. About 20–30 species are typically present in nearshore habitats in the more temperate regions of Sweden (Thorman, 1986a), Norway (Nash, 1988), Scotland (Gibson et al., 1996), and California (Allen and Horn, 1975; Horn, 1980; Allen, 1982).

In Kachemak Bay, four species accounted for over 92% of the catch in 1995–96, and two species represented over 93% of the 1976 catch. One species (sand lance) made up more than 99% of Barren Islands catch, and even at Chisik Island, where species equity was high, only five species accounted for 79% of the total numbers. 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). In estua-

[2] Roseneau, D. R., A. B. Kettle, and G. V. Byrd. 1995 and 1996. Common murre restoration monitoring in the Barren Islands, Alaska. 1993 and 1994. Exxon Valdez Oil Spill Restoration Projects 93049 and 94039. Unpubl. final reports.

[3] Roseneau, D. G., A. B. Kettle, and G. V. Byrd. 1996 and 1997. Barren Islands seabird studies. *In* D. C. Duffy (compiler), APEX: Alaska Predator Ecosystem Experiment. Exxon Valdez Oil Spill Restoration Project. Alaska Natural Heritage Program, University of Alaska, Anchorage. Appendix J. Unpubl. annual reports.

rine, inshore, and bay habitats in the northeastern Pacific, it appears to be normal 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).

Although no significant differences were observed in species composition between consecutive beach seine sets at the same study sites, CPUE was markedly reduced for the second sets made at both high and low tides. This reduction in CPUE may have resulted from avoidance by schooling species to disturbance, or removal of most individuals during the first set. As Gibson et al. (1996) observed, we found marked differences in species composition between tidal states, and the number of species found at low tide was reduced by 26% in sets made at high tide. The fact that only species that typically migrate into the intertidal zone (e.g. pink salmon, sand lance, great sculpin) were caught at high tide may have accounted for this difference. Juvenile sand lance occurred in greater numbers and were caught at higher frequencies during high and flood tides, compared with low and ebb states as observed by Blackburn and Anderson (1997). These results suggested that juvenile sand lance may have moved laterally on each tide, by ascending from demersal habitats to pelagic zones at flood stages, and returning at ebb stages. Larval plaice (*Pleuronectes platessa*) of the North Sea exhibited this kind of behavior in coastal nursery areas (Rijnsdorp et al., 1985).

High-latitude fish assemblages, particularly those found in shallow water habitats, are subject to large seasonal variations in temperature and day length. These physical factors impart a strong natural seasonality to community structure (Nash, 1988) as observed in the nearshore waters of Kachemak Bay. 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, 1986b; Methven and Bajdik, 1994). However, the midsummer CPUE declines in Kachemak Bay were not accompanied by declines in species diversity, as observed by Thorman (1986b). Reduction in numbers of adult Atlantic sand lance (*Ammodytes marinus*) has also been noted in midsummer seabird diets (Monaghan et al., 1996). This change corresponds to the time when predation by chick-rearing seabirds is at maximum; adult sand lance may be responding to the increased presence of predators by avoiding nearshore and surface habitats, or they may be coincidentally estivating in preparation for spawning (Sekiguchi et al., 1976).

Geographic variability

The relative abundance and distribution of fish species in lower Cook Inlet appears to be largely determined by oceanography and sediment influx. Intense insular upwelling of nutrient-rich waters around the Barren Islands leads to high productivity along frontal zones that in turn results in high abundance of fish. Upwelled water entering Kachemak Bay is nutrient-rich and becomes locally stratified, resulting in the highest primary production recorded in lower Cook Inlet (Larrance et al., 1977). In Kachemak Bay, high habitat diversity and the plankton prey-base provide the marine environments needed to support an abundant, diverse fish community. As water circulates around Cook Inlet to Chisik Island (Fig. 1), sediment loads increase from freshwater glacial runoff (Feely and Massoth, 1982), leading to maximum primary production that is only about one-tenth of that found in Kachemak Bay (Larrance et al., 1977). The lower abundance of sand lance at Chisik Island probably results from a combination of low food availability and deposition of glacial silt and mud (Feely and Massoth, 1982) that blanket most of the local substrates. Sand lance are known to require clean, sandy nearshore substrates (e.g. Pinto et al., 1984), and they appear to favor these habitats; few were caught in the offshore, oceanic waters surrounding the Barren Islands. On the north side of the Alaska Peninsula, sand lance also dominated nearshore catches and were caught less frequently offshore (Houghton, 1987).

The storm-prone Barren Islands displayed lower species diversity than the other lower Cook Inlet areas. Species inhabiting this more exposed oceanic region may avoid shallow habitats and favor slightly deeper, less disturbed waters (Thorman, 1986a), leading to reduced nearshore diversity (Horn, 1980). Diversity of fish in the nearshore Kachemak Bay and Chisik Island environments was apparently related to increasing habitat diversity and reduced salinity, as seen elsewhere (Thorman, 1986b; Blaber et al., 1995).

The most notable difference observed between nearshore and offshore shelf environments in lower Cook Inlet was that shelf areas were dominated by walleye pollock. Pollock were found in 88% of midwater trawls, compared with only 3% in beach seine sets. This species does not appear to use nearshore habitats as nursery areas, as does a related species, the Pacific cod (Houghton, 1987). The presence of some pollock in nearshore areas of Kachemak Bay may be related in part to the presence of oceanic water within the bay. Pollock also frequent Amchitka Island nearshore environments, which are similarly bathed by mixed, oceanic waters (Isakson et al., 1971).

Unequivocal declines in seabird populations (predominantly murres and black-legged kittiwakes) at Chisik Island (Slater et al., 1994) may be related to declines of locally abundant forage fish, particularly sand lance. It is possible that historically larger numbers of capelin (Piatt and Anderson, 1996) or herring (or both) (Rounsefell, 1930; Reid, 1971) may have inhabited this region when stocks of pelagic seabirds were higher prior to the mid-1970s. Colder than average temperatures prior to the late 1970s would have favored both of these fish species (Ware, 1995; Frank et al., 1996).

Limitations of the study

Sampling nearshore habitats with beach seines was limited to sandy and cobble substrates. Strong currents or inshore swells over 0.5 m also prevented effective retrieval of nets. Therefore, fish inhabiting muddy or rocky substrates, mussel (*Mytilus edulis*) and kelp beds, or the surf zone are under-represented in our study. The surf zone is preferentially used by some species because of low numbers of predators and food-rich waters (Bennett, 1989).

Burrowing fish, such as sand lance, may also be under-represented in the beach seine data because of their ability to escape under the net (Dick and Warner, 1982; Gordon and Leavings, 1984; Allen et al., 1992; Robards, personal obs). However, sand lance were the most abundant fish caught in Kachemak Bay and the Barren Islands, indicating that beach seines were clearly effective for sampling this species.

Juvenile cod migrate from deep water habitats during the day to shallower, nearshore waters at night (Methven and Bajdik, 1994; Gibson et al., 1996). Therefore, cod and other gadids may be under-represented in our catches, which were made only during daylight hours. However, diel variability in gadid catches has been shown to be lower than variability associated with tide cycles (Gibson et al.,1996).

Acknowledgments

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