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Suitability of Dry Bay, Southeastern Alaska, as Rearing Habitat for Juvenile Salmon

by
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U.S. DEPARTMENT OF COMMERCE
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Suitability of Dry Bay, Southeastern Alaska, as Rearing Habitat for Juvenile Salmon

bY
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ABSTRACT

Dry Bay is located at the terminus of the Alsek River, a large glacial river originating in Canada and flowing to the Gulf of Alaska. The Alsek River was historically a major producer of chinook salmon *(Oncorhynchus tshawytscha)* in southeastern Alaska, but the stock is currently depressed even after decades of rebuilding efforts. We studied physical characteristics and juvenile salmon utilization of Dry Bay to determine whether rearing conditions in Dry Bay may limit production.

Dry Bay provided poor rearing habitat for juvenile salmon. The water was mostly cold (<5°C) and turbid throughout summer. Little salt water intruded into Dry Bay from the Gulf of Alaska; at high tide it is a shallow, 80-km^2 freshwater lagoon, and at low tide the impounded water flows out at 80-180 cm/s. Strong currents and sand substrate result in habitat instability and absence of large organic debris. The few juvenile salmon captured were in low-current refuges near the mouth. Neither zooplankton nor benthic prey were abundant in Dry Bay. The diets of juvenile chinook, coho *(0. kisutch),* and sockeye salmon (0. nerka) were similar, presumably because all three species occupied the same low-current refuges.

Dry Bay has undergone substantial geomorphological changes since the early 1900s due to heavy glacial silt deposition and the rising of the land mass following glacial recession. These changes may have reduced suitable rearing habitat and increased predator pressure on juvenile salmon.

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INTRODUCTION

The Alsek River is one of the major producers of chinook salmon *(Oncorhynchus tshawytscha)* in southeastern Alaska (Holland et al. 1983). Because the Alsek is a transboundary river system originating in Canada, management of its anadromous salmon stocks is an international concern (Pacific Salmon Commission 1993). Since 1901, a commercial gill-net fishery for chinook salmon has been conducted on the Alsek River, mostly within Dry Bay (Moser 1902, Gmelch 1982). Harvest of chinook salmon has varied greatly, with a peak of 22,882 fish in 1920 and a low of 46 fish in 1984 (Fig. 1; Kissner 1982, Transboundary Technical Committee 1996). The U.S. commercial catch of 805 chinook salmon in 1994 equaled the 1964-93 historic average catch, but was only 11% of the 1908-60 average annual harvest (Kissner 1982, Pacific Salmon Commission 1995). Canada does not fish commercially in the Alsek drainage, but does conduct Aboriginal and sport fisheries that harvested an average of 575 chinook salmon from 1976 to 1994, 85% as many chinook as were harvested in the U.S. commercial fishery during that period (Transboundary Technical Committee 1996).

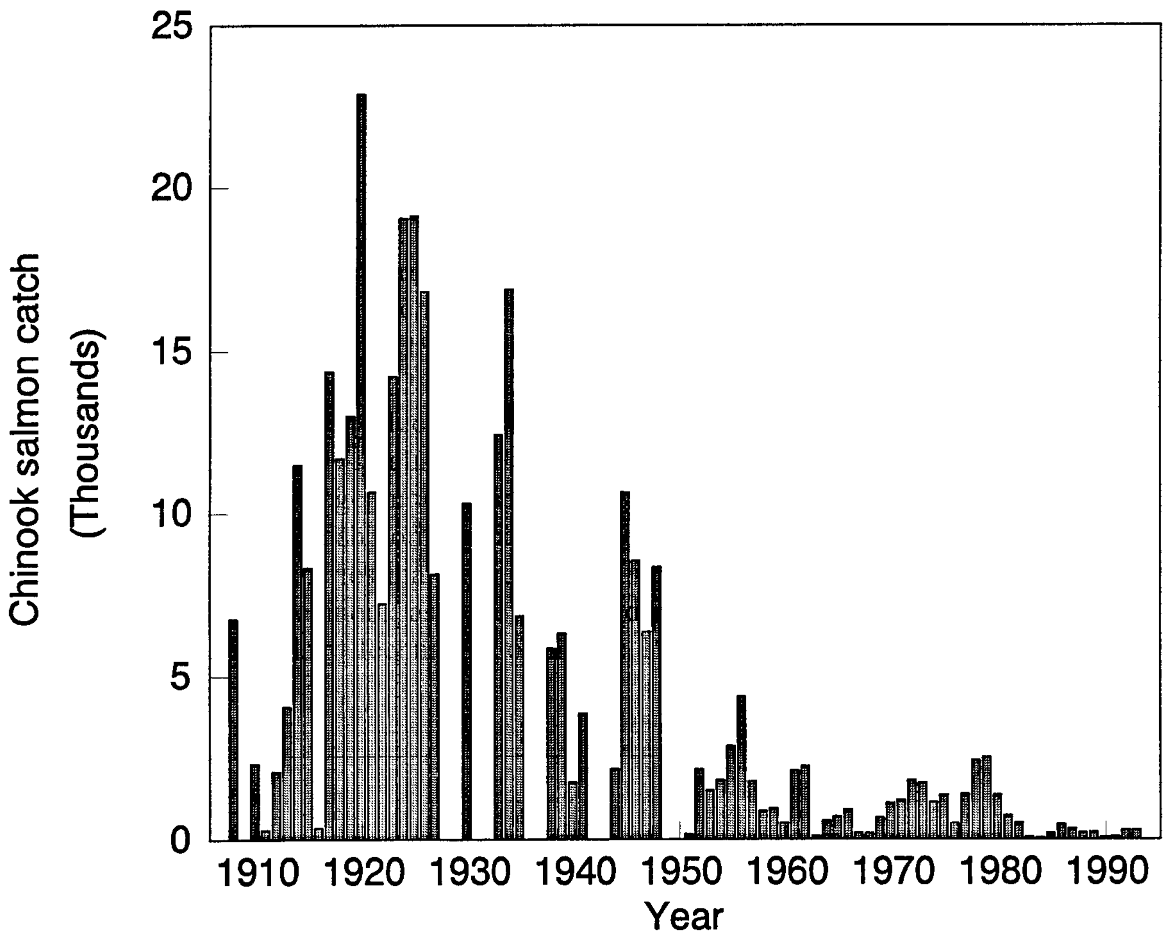

Figure l.--Historic gill-net catch of chinook salmon in the U.S. commercial fishery in Dry Bay, Alaska. No catch data are available for the years 1909, 1928, 1929, 193 1, 1932, 1936, 1937, 1942, 1943, 1949, and 1950.

Since the early 196Os, the Alaska Department of Fish and Game (ADF&G) has restricted the Dry Bay commercial fishery to rebuild the wild chinook salmon stocks (Kissner 1982, Anonymous 1985). The directed fishery has been closed since 1962, and chinook salmon have been harvested only incidentally since then (Transboundary Technical Committee 1996). However, as of 1994, escapement goals were still not being met, and the Alsek River chinook salmon population was still considered to be depressed and not rebuilding (Pacific Salmon Commission 1995). The 1990-94 mean escapement was 51% of the escapement goal (Pacific Salmon Commission 1995).

Little is known of the ocean distribution or exploitation of Alsek River chinook salmon. Therefore, in 1985, we initiated a project to mark juvenile chinook salmon with coded-wire tags (CWTs) to determine their migration patterns and fishery contribution. Based on the freshwater growth pattern on the scales of Alsek River adult chinook salmon (Kissner and Hubartt 1986) and scarcity of possible rearing areas upstream of Dry Bay, we thought that juveniles might mill and feed in Dry Bay before entering the open ocean. The lower Taku River, a similar, large, glacial, transboundary river in southeastern Alaska, provides important summer rearing habitat for an estimated 1 million juvenile chinook, coho (0. kisutch), and sockeye (0. nerka) salmon (Murphy et al. 1989). However, we captured few juvenile salmon in Dry Bay in 1985. In 1986, the study was repeated to determine whether the low abundance of juvenile salmon in 1985 was anomalous or whether rearing conditions in Dry Bay may limit production not only of chinook salmon but also of coho and sockeye salmon. Specific objectives in 1986 were to 1) determine some physical characteristics of Dry Bay, 2) document the presence of juvenile salmonids throughout the summer, 3) document availability of both epibenthic and zooplankton prey to juvenile salmonids, and 4) examine the diets of juvenile salmonids.

Methods

Study Area

The Alsek River is a large (over 300 km long) glacial system that originates in the Yukon Territory and flows through British Columbia and Alaska before entering the Gulf of Alaska. The mean discharge from June through August 1992 was 2,300 m^3/s, surpassed in southeastern Alaska only by the Stikine River (Kemnitz et al. 1993). Ten kilometers from the ocean, the river divides into numerous braided channels and side sloughs that fan out over a large tideflat delta called Dry Bay (Fig. 2). Sand is the predominant substrate in Dry Bay. The most stable habitat suitable for juvenile salmon rearing that was accessible at different tide stages and had low water velocity, to allow fish sampling, was near the mouth of Dry Bay. Thus, most sampling was conducted in three areas near the mouth of Dry Bay (Fig. 2): the West Arm, the Main Channel, and the East Channel. Other areas farther upriver were also sampled occasionally to try to locate concentrations of juvenile salmon. However, much of Dry Bay above the mouth was inaccessible to sampling because the large tidal fluctuations, coupled with very turbid water and the highly braided channels of the large tideflat delta, could have stranded the crew for hours.

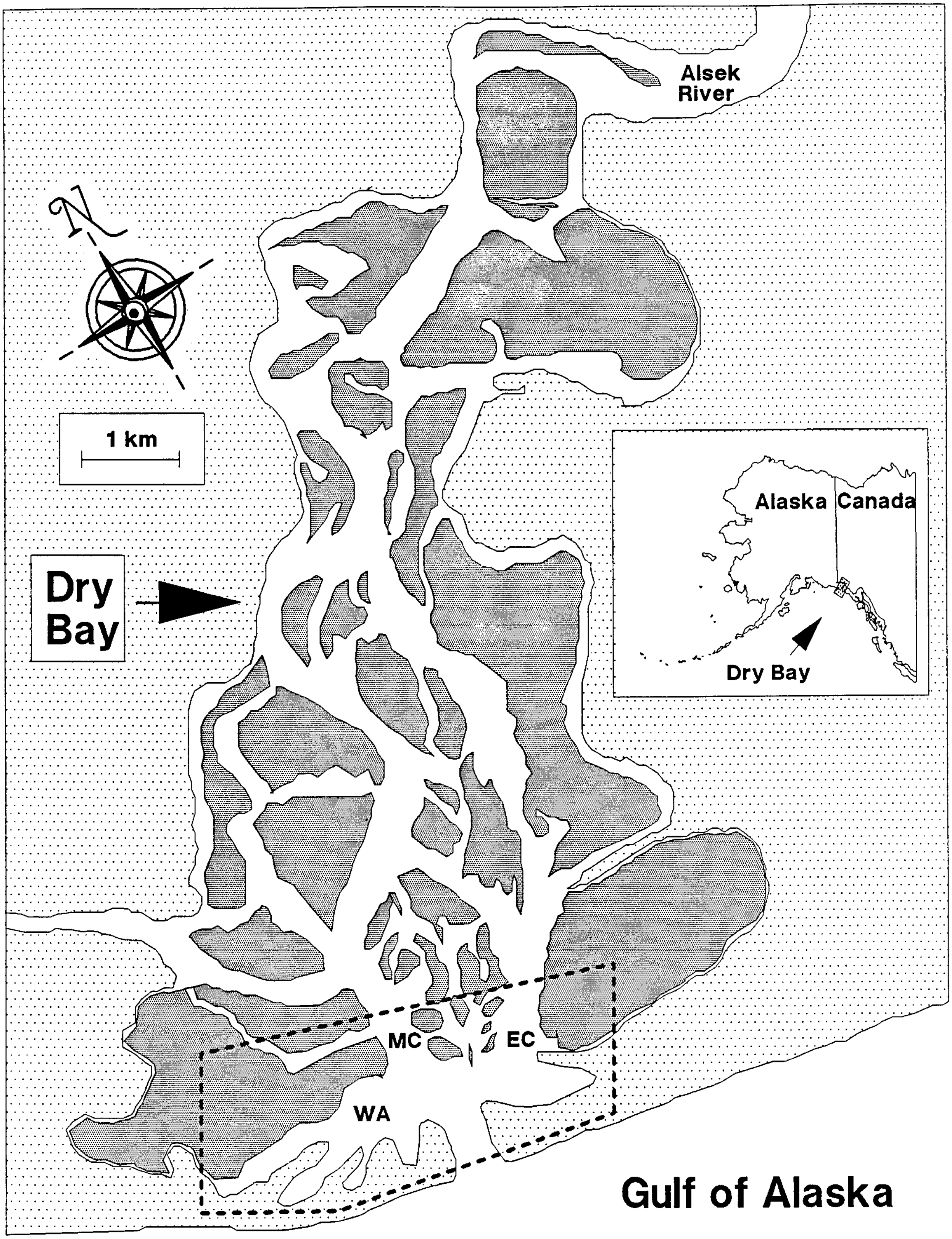

Figure 2.--Dry Bay, Alaska, at low tide. At high tide, dark-shaded areas (sand bars) were flooded with water. WA (West Arm), MC (Main Channel), and EC (East Channel) are shown. Fish, zooplankton, and benthic invertebrates were mostly sampled within the area enclosed by the dotted lines.

Time Period

In 1985, as part of a cooperative agreement between the National Marine Fisheries Service (NMFS) and ADF&G, fish were sampled in Dry Bay for 42 sampling days from 20 May to 30 July. In 1986, Dry Bay was sampled 22 days during three periods: 7-16 June, 9-18 July, and 29 August-7 September.

Physical Features

Physical features of Dry Bay were measured in 1986. Surface water temperature was recorded at 0.3 m depth with a bucket thermometer, and water turbidity was measured with a 0.25 m diameter Secchi disc whenever a seine haul was made. Depth profiles of temperature, salinity, and turbidity were measured at high tide at the zooplankton tow stations on 11 June, 15 June, 10 July, 17 July, and 4 September 1986 and at stations throughout Dry Bay on 5 September 1986. High water velocity precluded measuring depth profiles of temperature, salinity, and turbidity at any tide stage other than high tide. Water velocity was measured at stations throughout Dry Bay at various tide stages with a Marsh-McBirney, Inc. model 201 electromagnetic flow meter. Water temperature at depths greater than 0.3 m and salinity measurements were recorded with a Beckman RS5-3 salinometer.

The univariate approach to analysis of variance (ANOVA) of a repeated-measures design (Frane 1980) was used to analyze 1986 water temperature data. Factors in the ANOVA were time period (3 levels) and site (3 levels). Water temperature (untransformed) was the dependent variable.

Fish Sampling

Fish were sampled with a beach seine and baited minnow traps. Only low-current refuges such as tidal channels and backwater sloughs could be sampled with the beach seine because of high water velocity in the main channel. Tidal channels are dead-end waterways that dewater through a narrow opening at low tide, whereas backwater sloughs are open-ended, exposed to the river at all tidal levels, and do not dewater at low tide. The baited minnow traps were fished in habitats that could not be sampled with the beach seine: habitats with space limitations, slightly higher water velocity, or more unstable substrate.

Two seining techniques were used to capture juvenile salmon in different habitats near the mouth of Dry Bay. The same seine (91 m long by 3 m deep, with 9.4 mm mesh) was used with both techniques. In tidal channels, the seine was set across the entrance of the channel at high tide. As the tide dropped and water flowed out of the enclosed channel, the fish concentrated in a small pool. After an average soak of 2.7 h, the seine was pulled, and the catch was processed. In backwater sloughs, the seine was set with a skiff in a semi-circle away from shore and pulled ashore immediately. Catch rates between different habitats could not be compared directly because of the different soak times. Although salmon smolts were sampled effectively with the beach seine, the catch of salmon fry was not representative of actual abundance because fry <30 mm fork length (FL) could escape through the mesh.

Fish were also captured in 1986 with minnow traps baited with salmon roe. Usually 3-6 traps were tied at 2-m intervals to a line anchored perpendicular to shore with the trap closest to shore in water just deep enough to be totally submerged throughout the soak. Traps rested on the bottom substrate and soaked an average of 5.5 h.

Fish captured with either technique were processed similarly. After the catch was placed in buckets, the fish were anaesthetized with MS-222, identified to species, and measured for fork length. Non-salmonids were then released, but most salmonids (except those caught in minnow traps) were preserved in 10% formalin solution for later stomach and scale analysis. In the laboratory, stomachs from the esophagus to the pyloris were dissected from each salmonid. Each stomach was weighed and graded for fullness, and the contents were preserved in a 75% isopropyl alcohol solution. Stomach contents were identified to the lowest taxon possible and enumerated by taxa. Scale samples collected from juvenile salmon were examined under a microscope to determine freshwater age.

Prey Availability

Prey availability was documented only in 1986 in two ways. First, a series of 5-minute horizontal hauls with a 0.5 m diameter, 243 pm mesh plankton net were made in the top meter of the water column. The volume of strained water was computed from flowmeter readings. Zooplankton hauls could be taken effectively only at high tide; at low tide, the net with attached cup would clog with glacial silt within a minute. Zooplankton hauls were conducted in the West Arm, Main Channel, and East Channel (Fig. 2) on 11 June, 15 June, 10 July, 17 July, and 4 September 1986. Two replicate horizontal hauls were taken at each location on each sampling day, and the samples were preserved in 5% formalin for later analysis of density, biomass, and composition.

In the laboratory, organisms in a subsample from each zooplankton sample were identified and counted. Zooplankton were categorized by life-history stage and identified generally to order or family. A total number of each taxon for the sample was computed by dividing the subsample count by the subsample fraction of the total sample volume. Density (no./m^3) of organisms was computed by dividing the total number by the volume of water sampled. Wet weights of organisms were determined for each sample by weighing up to 100 individuals from each taxon. Biomass (mg/m^3) of an organism was computed by multiplying the mean weight of the organisms by the number of organisms in the sample and then dividing by the volume of water sampled.

The second method of measuring prey availability was with a modified Hess benthic sampler (Johnson and Heifetz 1985). Samples were collected at low tide by pushing the 17-cm diameter sampler 5 cm deep into the substrate at water's edge. The 1 ,134 cm^3 of substrate was quickly removed from the sampler, placed on a 243 pm mesh screen, and swirled vigorously to dislodge organisms. Each sample was preserved in 5% formalin and analyzed similarly as samples from horizontal hauls, except that values are reported for the surface area, not volume sampled: density (no./m^2), biomass (g/m^2), and composition. Three replicate benthic samples were collected from four sites (two in the West Arm, one each in the Main Channel and East Channel) near the mouth of Dry Bay on 15 July and 5 September 1986.

RESULTS

Physical Features

Dry Bay is a shallow, tidally intluenced impoundment with cold, turbid, and fast-flowing water. Although surface water temperature in shallow tidal channels away from the Main Channel ranged as high as 9.2°C on hot, sunny days, water temperature at 1 m and 3 m depths exceeded 5°C only once in the West Arm, in June. Water temperature in the East and Main Channels never rose above 4.5°C. Water temperature at 1 m depth did not differ significantly ($P > 0.05$) between sites and periods. Secchi disc visibility ranged from 8 to 12 cm at all sites and periods. Water velocity ranged from 80 to 180 cm/s in the mouth of Dry Bay.

Little salt water intruded into Dry Bay from the Gulf of Alaska (Fig. 3). From June to September, salinity inside Dry Bay never exceeded 2.6% at either 1 m or 3 m depths. Even below 3 m, salt water did not intrude past the mouth of Dry Bay in September.

Catch

In 1985 and 1986, a total of 97 chinook salmon, 363 coho salmon, and 1,380 sockeye salmon were captured by beach seine (Table 1). No salmon was ever captured in the baited minnow traps. Over twice as many salmon were captured in 1985 as 1986, a reflection of the higher sampling effort in 1985 (42 sampling days in 1985, 22 in 1986). In both years, most juvenile salmon were captured in tidal channels.

The highest catch of juvenile salmon in Dry Bay generally occurred in July (Fig. 4). Catch of chinook salmon and sockeye salmon peaked in July in both years. Peak catch of coho salmon in 1985 was also in July, but in 1986, it was in June. By September 1986, most juvenile salmon had left Dry Bay.

Each salmon species comprised several freshwater age classes of different-sized fish (Table 2). Chinook salmon were predominantly (93%) age-l fish, with a small proportion (7%) of age-0 fish. Coho salmon comprised roughly equal proportions of age-l (35%) and age-2 (41%) fish, with smaller proportions of age-0 (20%) and age-3 (5%) fish. Sockeye salmon comprised roughly equal proportions of age-0 (50%) and age-l (48%) fish, with a few (2%) age-2 fish.

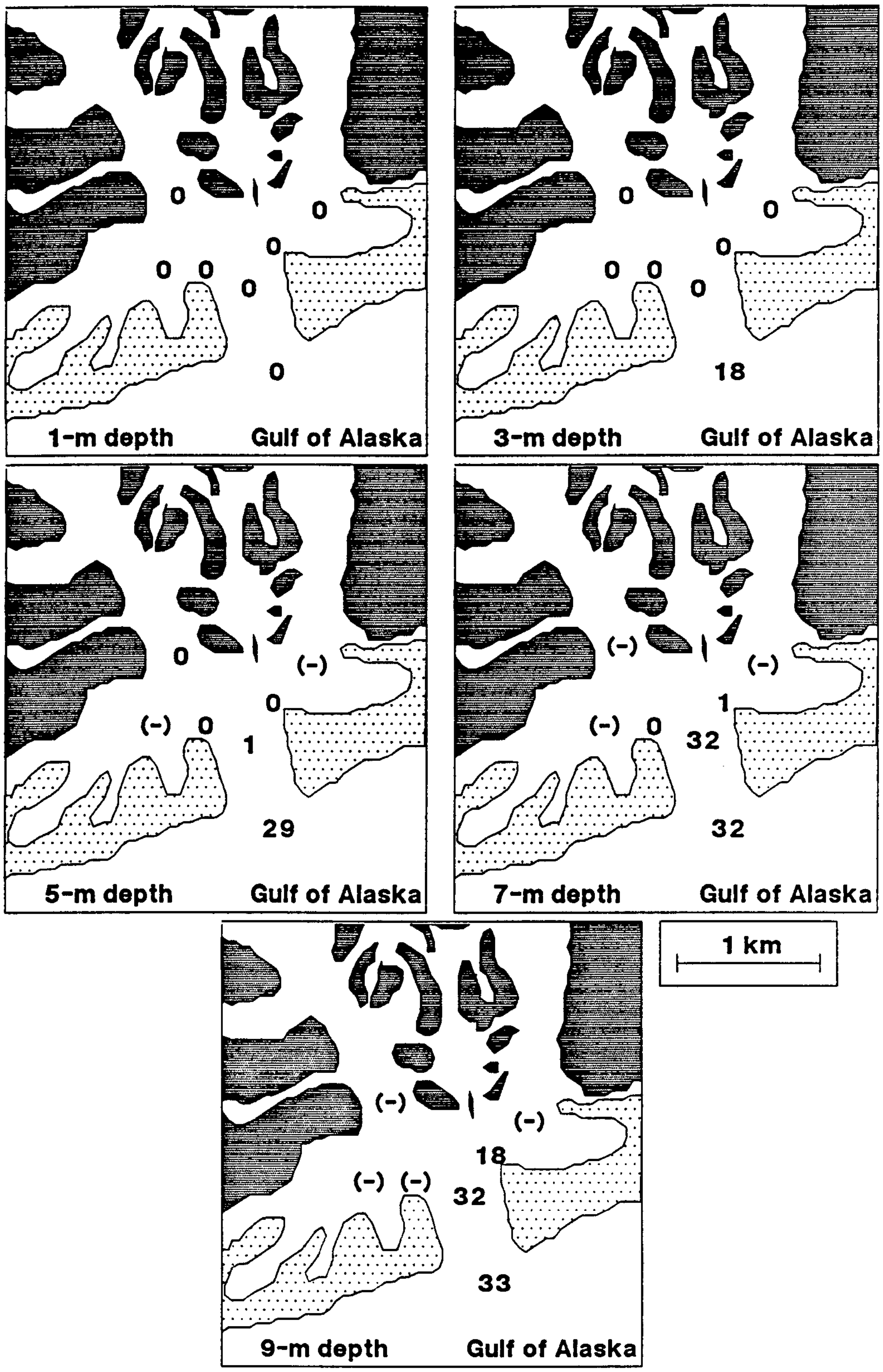

Figure 3.--Salinity (‰) profiles at 1-, 3-, 5-, 7-, and 9-m depths in the mouth of Dry Bay at high tide in September 1986; a (-) indicates insufficient depth for measurement.

Table l.--Catch of fish by habitat in Dry Bay, Alaska, 1985 and 1986. Sculpins, starry flounder, stickleback, and smelt were not counted in 1985.

	1985 Catch			1986 Catch			
Species	Beach Seine[a]	Beach Seine[b]	Total	Beach Seine[a]	Beach Seine[b]	Minnow Traps	Total
Chinook salmon	26	55	81	3	13	0	16
Coho salmon	92	125	217	74	81	0	155
Sockeye salmon	462	536	998	34	348	0	382
Dolly Varden	407	181	588	66	182	41	289
Sculpins	—	—	—	5	44	0	49
Starry flounder	—	—	—	4	56	0	60
Stickleback	—	—	—	3	3	0	6
Smelt	—	—	—	8	1	0	9

[a] Backwater sloughs
[b] Tidal channels

Several other species were also captured in Dry Bay (Table 1). The most abundant non-salmon species caught by beach seine were Dolly Varden char *(Salvelinus malma,* 178 mm mean FL), starry flounder *(Platichthys stellatus,* 184 mm mean FL), and sculpins (Cottidae family, 161 mm mean FL). Dolly Varden was the only species captured in the baited minnow traps; of the 289 Dolly Varden captured in 1986, 14% were captured in traps.

Diet

Most of the salmon captured in Dry Bay were feeding well. For each species of salmon, over 50% of the stomachs were 100% full, and over 75% of the stomachs were at least 75% full (Fig. 5).

Prey were categorized according to three major groups: epibenthos, insects, and fish. Each group contributed to the diet of all three species of juvenile salmon (Table 3). Chinook salmon preyed upon each group in roughly equal proportions, whereas coho and sockeye salmon preyed more heavily on insects and epibenthos than on fish.

Chinook, coho, and sockeye salmon preyed upon similar organisms within the three major food groups (Table 3). Amphipods (primarily Gammaridae, secondarily Corophiidae) were the dominant epibenthic prey, making up at least 85% of the biomass of epibenthos in the diets of each salmon species. Plecoptera was the major order of insects eaten by each of the three salmon species. Plecoptera, Diptera, and Hymenoptera made up at least 94% of the biomass of insects in the diet of each salmon species. Osmerid larvae were the only fish prey identified.

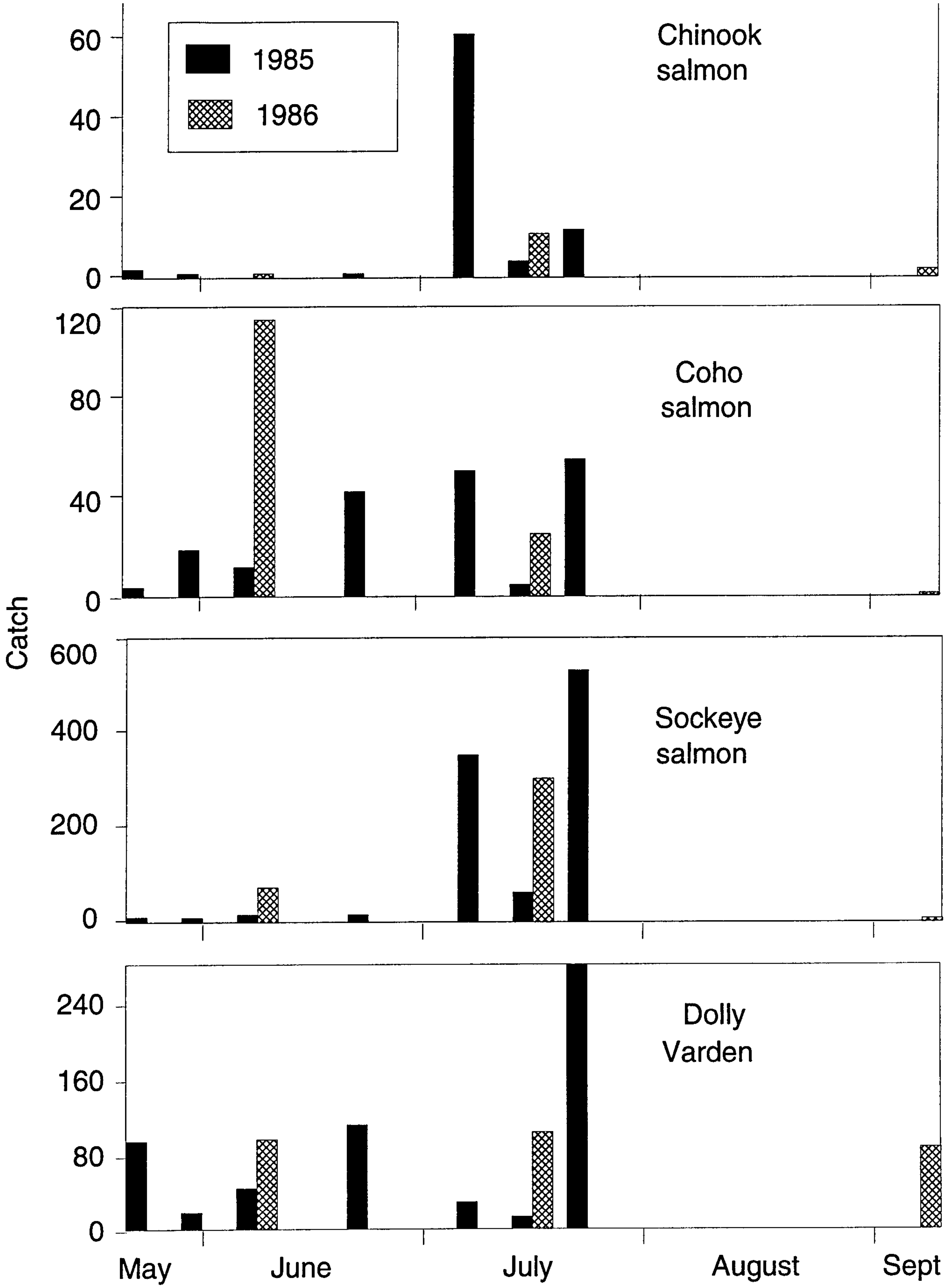

Figure 4.--Catch of salmon over time in Dry Bay, Alaska, 1985 and 1986. The Y-scale differs among graphs.

Table 2.--Mean fork length (MFL), standard deviation (SD), and sample size *(n)* of the age classes of juvenile salmon in Dry Bay, Alaska, June-September 1986.

Freshwater Age	Chinook *n*	Chinook MFL (mm)	Chinook SD (mm)	Coho *n*	Coho MFL (mm)	Coho SD (mm)	Sockeye *n*	Sockeye MFL (mm)	Sockeye SD (mm)
0	1	80	—	21	36	4.55	53	57	8.48
1	14	81	8.05	37	77	17.70	50	72	8.13
2	—	—	—	44	104	9.71	2	82	4.24
3	—	—	—	5	116	8.22	—	—	—

The major prey of Dolly Varden was fish. Their diet was composed of 50% Pacific sand lance *(Ammodytes hexaptera)* and 32% juvenile salmonids. After fish, gammarid amphipods were the next largest component of diet, and insects were seldom preyed upon. In contrast to salmon stomachs, which were generally full, one-half of Dolly Varden stomachs were empty or nearly empty (Fig. 5).

Prey Availability

The highest density, biomass, and variability of organisms sampled with the horizontal zooplankton haul occurred at the West Arm (Fig. 6). Density and biomass of zooplankton at the West Arm (where most of the salmon were captured) peaked in July (the peak month of salmon abundance). However, density and biomass in the West Arm were highly variable: in July, density increased two orders of magnitude in just 1 week. September was the least productive month; the West Arm was the only site with a substantial number of organisms, but biomass was still low. In both the East and Main Channels, density and biomass were relatively consistent over time; however, density never exceeded 3 organisms/m^3, and biomass never exceeded 5 mg/m^3.

In the horizontal zooplankton haul, more than 70% of the biomass and 54% of the density at each site consisted of potential prey items of juvenile salmon. The dominant potential prey organisms were osmerid larvae, insects of the orders Plecoptera and Diptera, and arnphipods of the families Gammaridae and Corophiidae. Osmerid larvae were the most ubiquitous organism at all sites and the only prey captured in September. In the West Arm, osmerid larvae made up 77% of the total biomass and 90% of the total density.

Prey generally consisted of several life-history stages, except Osmeridae (larva only). Amphipods of the family Corophiidae were primarily juveniles (77%) and secondarily adults (23%), whereas amphipods of the family Gammaridae were primarily adults (80%) and secondarily juveniles (20%). Insects of the order Plecoptera were mostly nymphs (94%), with a few adults (6%). Insects of the order Diptera were mostly larvae (58%), then pupae (24%) and adults (17%).

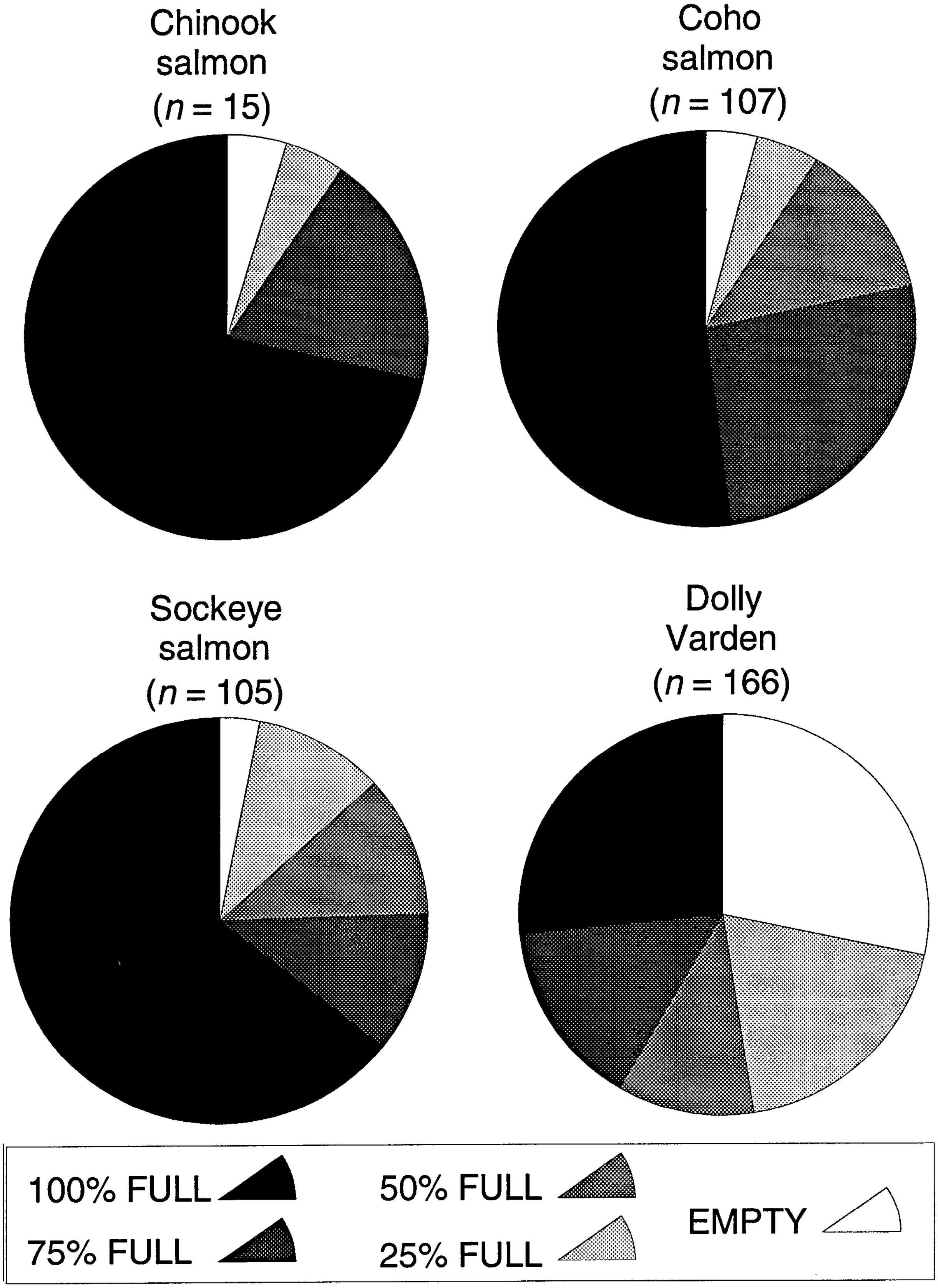

Figure 5.--Stomach fullness of juvenile chinook, coho, and sockeye salmon and Dolly Varden captured in Dry Bay, Alaska, June-September 1986.

Table 3.--Percent biomass of the major food items in stomachs of juvenile chinook salmon, coho salmon, sockeye salmon, and Dolly Varden in Dry Bay, Alaska, June-September 1986.

	Chinook Salmon (%)	Coho Salmon (%)	Sockeye Salmon (%)	Dolly Varden (%)
1. Epibenthos				
Amphipoda				
Corophiidae	6	15	3	2
Gammaridae	31	28	30	11
Other epibenthos (11 orders)	0	5	7	1
Epibenthos (subtotal)	(37)	(48)	(39)	(14)
2. Insects				
Diptera	9	5	11	1
Hymenoptera	8	1	2	0
Plecoptera	15	32	31	1
Other insects (23 orders)	2	2	1	0
Insects (subtotal)	(34)	(40)	(45)	(2)
3. Fishes				
Perciformes				
Ammodytidae	0	0	0	50
Salmoniformes				
Osmeridae	29	1	16	1
Salmonidae	0	0	0	32
Unidentified	0	11	0	1
Fishes (subtotal)	(29)	(12)	(16)	(84)
TOTAL	100	100	100	100

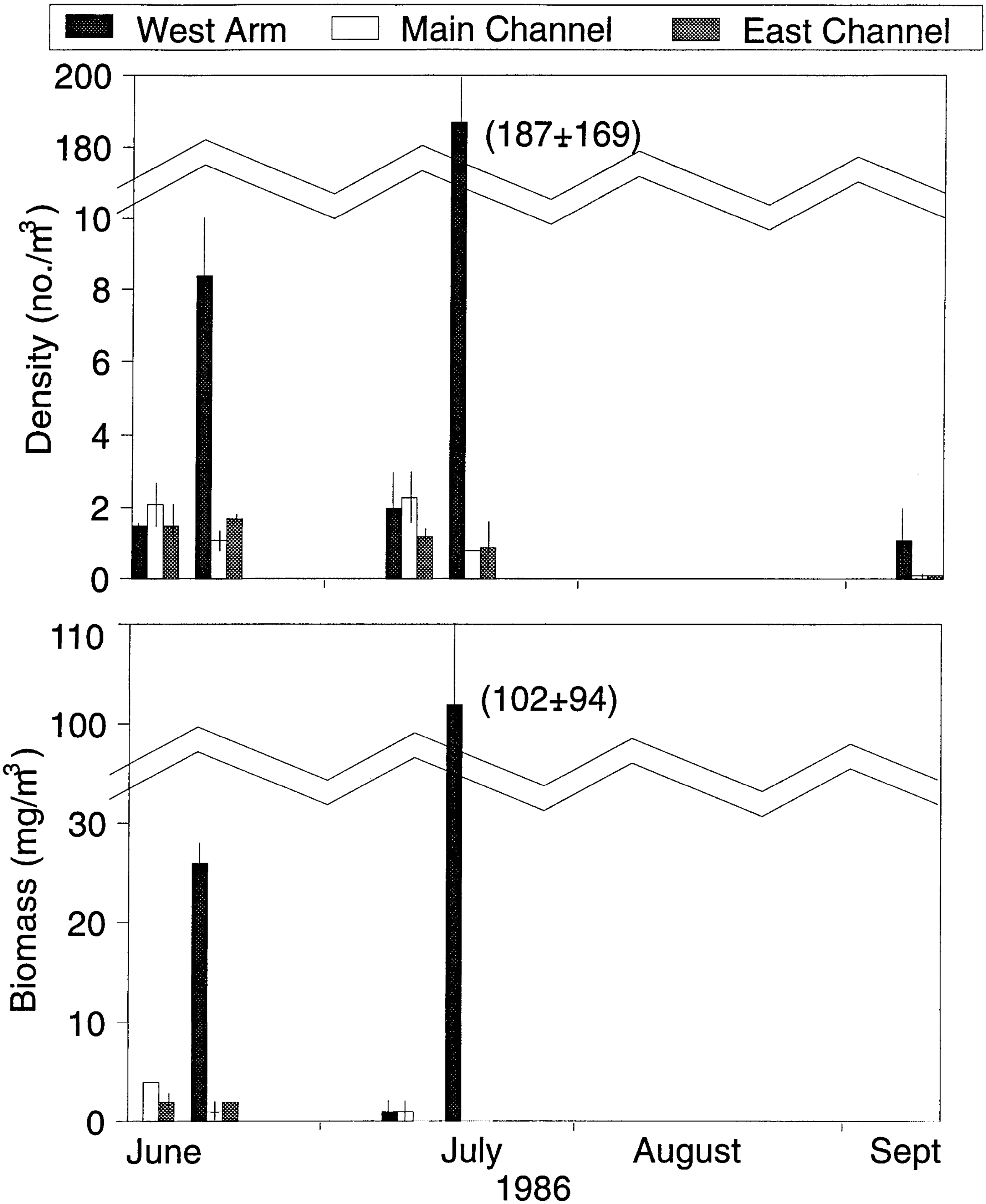

Figure 6.--Mean density and biomass (+l standard error) of organisms sampled by horizontal plankton haul in Dry Bay, Alaska, June-September 1986.

The West Arm was also the most productive location for benthic organisms, based on the catch from the Hess benthic sampler in July and September (Fig. 7). At both West Arm sites, density and biomass were similar between July and September. In contrast, benthic organisms were present in the East Channel only in July, and no benthic organism was recovered in the Main Channel in July or September.

Potential prey items made up at least 40% of the density and 50% of the biomass of benthic organisms sampled. Gammarid amphipods were the dominant component of the biomass of prey in both the West Arm and East Channel. In the East Channel, gammarid amphipods were also the dominant component of the density of prey, whereas in the West Arm, gammarid amphipods and harpacticoid copopods contributed equally to the density of prey.

DISCUSSION

Dry Bay is an unproductive rearing area for juvenile salmon; the river is characterized by low temperature, extreme turbidity, strong currents, high discharge, and frequently shifting channels. At high tide, Dry Bay is a large freshwater lagoon with impounded water covering about 80 km^2 of shallow tideflat delta. At low tide, however, the impounded water moves into the Gulf of Alaska at velocities of 80-l 80 cm/s at the mouth. In the Taku River, Alaska, a large glacial river system comparable to the Alsek River, rearing juvenile sockeye, coho, and chinook salmon were virtually absent when currents exceeded 30 cm/s (Murphy et al. 1989). In Dry Bay, sand is the predominant substrate type, and coupled with swift currents and high discharge, results in an unstable streambed with rapidly shifting channels. Between 1975 and 1982, the main channel shifted several miles (Gmelch 1982).

As a result of the sand substrate, swift water, high discharge, and frequently shifting channels in Dry Bay, large woody debris or even boulders behind which back eddies could form are virtually non-existent. Woody debris in streams improves both the quality and quantity of fish habitat by providing cover and varying stream velocity and depth (Bustard and Narver 1975, Lisle 1986). Typically, juvenile salmon take refuge from strong currents in stream margin cover and in back eddies formed behind large rocks and submerged vegetation (Macdonald et al. 1987).

Juvenile salmon outmigrating from the Alsek River encounter few low-current refuges in which to hold up before being swept out to sea by the strong currents associated with dropping tides and high discharge. In Dry Bay, most juvenile salmon were captured in backwater sloughs and tidal channels away from the main channel. Faced with strong currents, juvenile salmon typically use low-current areas for refuge (Lister and Genoe 1970, Macdonald et al. 1987). Low-flow, backwater sloughs are important rearing areas for juvenile salmon (Birtwell et al. 1987, Macdonald et al. 1987). However, such refuges are rare in Dry Bay and occur only near the mouth.

Because they were captured together in the same areas and consumed similar prey, juvenile chinook, coho, and sockeye salmon appeared to be in direct competition with each

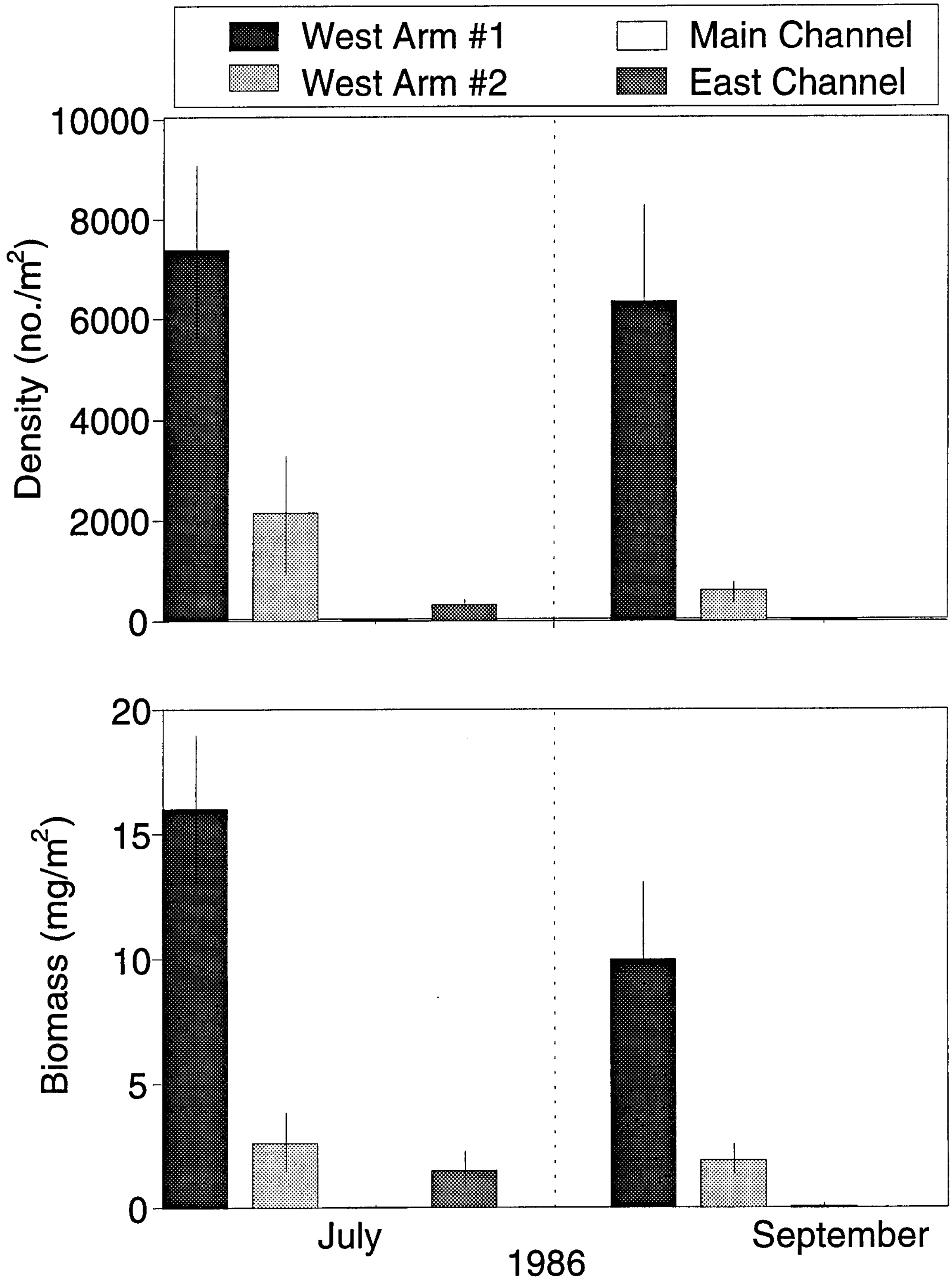

Figure 7.--Mean density and biomass (+l standard error) of organisms sampled by benthic sampler in Dry Bay, Alaska, July and September 1986.

other for the limited food and habitat resources in Dry Bay. Food and space are probably the most important variables regulating growth and abundance of juvenile salmonids in streams (Chapman 1966, Koski and Kirchhofer 1984). In contrast to other rivers where different species of rearing juvenile salmon occupied different habitats or ate different prey if they occurred in the same habitat (Stein et al. 1972, Levy and Northcote 1982, Murphy et al. 1989), in Dry Bay, all three species were most abundant in the same low-current refuges and consumed the same prey. The only available prey that was not consumed was harpacticoid copepods.

Juvenile salmon diets in Dry Bay differed from diets in other river systems; many food resources found in other systems were unavailable or available only in small quantities in Dry Bay. For instance, although cladocerans, calanoid copepods, and shrimp are important in the diets of rearing juvenile salmon in the lower Fraser River and Squamish River, British Columbia (Levy and Levings 1978, Anderson et al. 1981, Birtwell et al. 1987), these prey were unavailable in Dry Bay.

Although few juvenile salmon were captured throughout this study, those that were captured generally had full stomachs. This is probably not indicative of the general feeding conditions in Dry Bay as a whole so much as an artifact of where and when most salmon were captured: in tidal channels and backwater sloughs in the West Arm on falling tides. Levings (1982) noted that the increased concentration of prey in reduced water volumes may influence food availability for juvenile salmon and that low tide refuges may be critical habitats for juvenile salmon. As noted before, however, only a small proportion of Dry Bay is composed of such refuges.

We speculate that changes in the geomorphology of Dry Bay may have reduced its suitability as rearing habitat for juvenile salmon and may help explain the lack of rebuilding of the Alsek River chinook salmon stock to former historic high levels. In the early 1900s, Dry Bay was deeper, encompassing 200-250 km^2, with three major channels to the Gulf of Alaska (Moser 1902, Gmelch 1982). Nowadays, Dry Bay encompasses about one-third of that area, has only one main channel to the Gulf of Alaska, and is much shallower because of 1) the heavy silt load brought down by the Alsek River, and 2) the rising of the land mass caused by the recession of glaciers in the area (Gmelch 1982). Skiffs today may run aground in places where an ocean-going cannery tender could cruise inside Dry Bay 60 years ago (Brogle 198 1). Because of these geomorphic changes, the currents in Dry Bay now are probably much stronger than before. Weaker currents are more conducive to the rearing of juvenile salmon and allow the accumulation of large organic debris, thus providing more habitat. Salt water may also have intruded into Dry Bay to a greater degree in the past, providing a better seawater transition zone for Alsek River salmon populations.

Increased predation pressure may be another consequence of a smaller Dry Bay. We counted up to 750 harbor seals *(Phoca vitulina richardsi)* in Dry Bay in the spring of 1986. The harbor seals were presumably congregating to feed on the eulachon run, but harbor seals also eat both juvenile and adult salmon. In addition, although Pacific sand lance was the primary prey of Dolly Vaden char, juvenile salmon were also an important component of the diet. Predation pressure on migrating salmon may have increased because both predators and prey are now concentrated in a smaller area.

Other explanations for the lack of rebuilding of the Alsek River chinook stock may also be possible, because little is known of the ocean distribution or exploitation patterns of these fish. However, harvest in Alaska fisheries was not considered to be a factor in the lack of rebuilding (Pacific Salmon Commission 1993), and the Canadian Aboriginal and sport fisheries typically harvest fewer chinook salmon than the U.S. fishery (Transboundary Technical Committee 1996). From a total of 79,328 juvenile chinook salmon (brood years 1983-92) released with CWTs, only 13 have been recovered, all in U.S. fisheries.[1] Of those 13 fish, 12 (92%) were recovered in the Alsek River set gill-net fishery, and only 1 (8%) was recovered outside the Alsek River, in Yakutat Bay, 50 km from Dry Bay.

Habitat changes in the upper river are unlikely to be the cause for the continued lack of rebuilding of the Alsek River chinook stock. The upriver adult spawning and juvenile rearing habitats are still considered to be pristine, with no major habitat changes over the years to suggest a reduced capacity to produce salmon.[2]

Even though the Alsek River historically supported chinook salmon harvests exceeding 20,000 fish, the chinook population has remained at a lower and relatively stable level after decades of conservation efforts. Although too little historical data exist for conclusive proof, we speculate that changes in the physical characteristics of Dry Bay may have permanently altered the capacity of the Alsek River to produce chinook salmon. If so, the population is unlikely to return to its previous historic peak abundance.

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