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AVAILABILITY OF WILD FEED TO SALMON IN AQUACULTURE CAGES

by

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ABSTRACT

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The availability of wild feed to aquaculture-reared salmon was investigated by sampling near the cages with purse seine and plankton nets and collecting cage fouling material. Eight aquaculture sites in the vicinity of Quadra Island were sampled 6 times from May 16 to July 29, 1989. Pacific herring, five species of Pacific salmon, and lingcod juveniles were the most abundant fish. Six other fish species occurred sporadically or in low numbers. Crustacean nauplii, copepods, larvaceans, crab zoea, euphausiids (larvae and adults), coelenterates and ctenophores were the major zooplankters. Isopods, pycnogonids, pteriomorphids, polychaetes and insect larvae were the most abundant organisms on the cage webbing. All of these organisms would be available as feed to farmed salmon.

RÉSUMÉ

Haegele, C. W., D. C. Miller, T. J. Brown, P. B. McCarter, and D. E. Hay. 1991. Availability of wild feed to salmon in aquaculture cages. Can. Manuscr. Rep. Fish. Aquat. Sci. 2117: 35 p.

On á examiné l'accessibilité des aliments présents naturellement dans le milieu chez les saumons d'élevage. Pour ce faire, on a prélevé des échantillons au moyen de sennes coulissantes et de filets à plancton près des cages ainsi que des échantillons des salissures qui s'accumulent dans celles-ci. Du 16 mai au 29 juillet 1989, on a prélevé, à six reprises, des échantillons dans huit installations d'aquiculture situées dans les environs de l'île Quadra. Des juvéniles de harengs du Pacifique, de cinq espèces de saumons du Pacifique et de morues-lingues étaient les poissons les plus abondants. On a observé la présence sporadique ou un petit nombre de poissons de six autres espèces. Des nauplius (première forme larvaire des crustacés), des copépodes, des appendiculaires, des larves zoés, des euphausiacés (à l'état larvaire et adulte), des coelentérés et des cténophores dominaient le zooplancton. Les organismes les plus abondants observés dans le treillis des cages étaient des isopodes, des pycnogonides, des ptériomorphes, des polychètes et des larves d'insectes. Les saumons d'élevage pourraient se nourrir de tous ces organismes.

INTRODUCTION

Aquaculture cages in British Columbia are sited in nearshore plankton productive waters (Harrison *et al.* 1983). This area provides habitat for many fish, including such commercially important species as salmon, herring, lingcod, and rockfish (Hay *et al.* 1989). If these wild fish enter cages, they may become prey of farmed salmon. Initial stomach samples showed that farmed salmon ingested wild feed, including herring and plankton (Gillis *et al.* 1991). Consequently, a concurrent study to determine the availability of wild feed to farmed salmon was initiated and the results are the subject of this report.

METHODS

Fish were sampled with a purse seine, set in the immediate vicinity of the fish farms. The seine was 75 m long and consisted of three sections. The anterior section was 30 m long, 9 m deep, and had 2.5 cm meshes; the middle portion was 30 m long, tapered from 15 m to 21 m deep in the first 6 m, and had 1.9 cm meshes; and the posterior portion was 15 m long, 21 m deep, and had 1.3 cm meshes. The seine was hauled by hand from a 6 m power boat. Catches were sorted by species and samples preserved in 10% formalin. Preserved fish were patted dry, weighed and measured for length (standard length for herring, total length for lingcod, and fork length for salmon). Selected juvenile salmon alimentary tracts were examined for contents. Stomachs were rated for fullness (empty, trace, half-full and full). Prey items were removed to a tray and counted under 100 power magnification.

Plankton samples were obtained adjacent to the cages with paired 19 cm diameter bongo nets with 0.35 mm mesh size. Tows were stepped oblique from 20 m, raised 1 m every 15 seconds. Volume of water filtered was estimated with a flowmeter. Catches were preserved in 10% formalin. The formalin was removed by vacuum extraction, using a millipore filter or Buchner funnel. Each catch was weighed and subsamples obtained with a plankton splitter. Between 4 and 7 splits were made, depending on the size of the sample. The plankters in one of the final splits were identified and counted.

Two methods were used to sample material growing on or inhabiting pond webbing. Near the surface, material was scraped off the webbing. At regular intervals to the bottom, divers estimated the amount of material on the webbing by observing the percentage of visible occlusion and by scraping and retaining, in plastic bags, the material from 58 cm^2 (4 meshes by 4 meshes). All material was preserved in 10% formalin and later identified.

RESULTS

The waters near 8 aquaculture sites (Fig. 1, Table 1) were sampled six times between May 16 and July 24, 1989. On June 12 the Quartz Bay site was not sampled due to poor weather and plankton tows were made at only one site because of lost gear.

PURSE SEINE SAMPLES

Young-of-the-year and 2-year-old herring were the most numerous of the 13 species of fish obtained in hand purse seine sets (Table 2), followed by 5 species of salmon (Tables 3a-3h and Fig. 2). Young-of-the-year herring occurred only at the 3 most westerly sites and on the first 2 sampling days, while 2-year-old herring occurred at 6 of the sites and on all but 1 of the sampling days (Fig. 3 and 4). Lingcod juveniles occurred at three of the sites on the first 2 sampling days. Salmon occurred at all sites and on all sampling days. Other species of fish occurred sporadically or in very low numbers.

Length and weight distribution of young-of-the-year herring indicated that those at Kanish Bay were younger by about 2 wk than those at Yellow Island. Young-of-the-year herring were 23-40 mm long and weighed 0.05-0.66 g and 2-year-old herring were 78-139 mm long and weighed 5.5-33.4 g (Table 4). The largest salmon juveniles were coho; chinook, chum and sockeye were of intermediate size; while pinks were smallest (Table 4). Juvenile salmon were 63-172 mm long and weighed 2.45-71.20 g. Lingcod juveniles sampled on May 16 were 41-63 mm long and weighed 0.48-1.76 g (Table 4).

All of the 62 chum and 10 coho stomachs examined had food and over 80% were full. There were 14 prey items identified (Table 5). Major food items of chums were copepods and larvaceans (mostly *Oikopleura* sp.). Coho fed mostly on fish, crab larvae and copepods (Table 6).

PLANKTON SAMPLES

Bongo nets sampled an average volume of 13.23 m^3 (n = 41, S.D.= 3.14). There were 13 categories of plankters identified, as well as pelagic eggs and fish larvae (Table 5). The average density of plankters decreased over the sampling period from 1298 • m^{-3} on May 16 to 134 • m^{-3} on July 24 (Fig. 5). The average weight of plankton decreased initially, but then increased as larger plankters were caught. Average weights ranged from 0.23 g • m^{-3} on May 29 to 0.52 g • m^{-3} on July 24. The sites on the east shore of Quadra Island had the higher mean plankton density and the greater species diversity of plankton (Table 7). Crustacean nauplii were a major component of the plankton to June 19; copepods and larvaceans were a major component throughout the study period; crab zoea and larval euphausiids peaked in the middle of the sampling period; adult euphausiids occurred in low concentrations throughout the study period; coelenterates and ctenophores increased in the latter part of the study period; and the other plankters (polychaetes, cladocerans, barnacle cyprids, amphipods and pteropods) occurred frequently at low levels throughout the study period (Table 8). Pelagic eggs occurred in only 22 samples but occasionally at high concentrations, while fish larvae occurred in only 10 samples and at low levels.

CAGE WEBBING SAMPLES

Clean webbing on cages provided openings of approximately 3.6 cm^2 for 3.8 cm stretch mesh, the standard in the industry. The occlusion by material growing on or inhabiting this webbing reduced openings 10-85% (Table 9), making the effective opening 0.5-3.3 cm^2. The occlusion in 2 cages decreased with depth, while, in the 3rd cage sampled, the occlusion was highest in the middle portion of the cage.

It was not possible to quantitatively estimate, by weight, the growth on cages, since loss of material, while transferring it from the webbing to the container, was considerable and variable. There were 14 types of organisms, exclusive of algae and bryozoans, in samples from cage webbing (Table 10). Isopods occurred in all the samples and were frequently abundant (Table 11). Pycnogonids occurred in 85% of the samples and were also frequently abundant. Mussels and other pteriomorphids occurred in 70% of the surface samples and in the Yellow Island SCUBA samples. Polychaetes occurred in 40% of the surface samples and in the Yellow Island SCUBA samples. Insect larvae occurred in 30% of the surface samples. The other 9 types of organisms occurred in less than 25% of the samples. Yellow Island samples had the greatest diversity of organisms, with 11 types recorded, of which 9 types occurred in surface samples and 8 types occurred in SCUBA samples. Waiatt Bay and Surge Narrows surface samples had 9 and 8 types of organisms, respectively. Conville Point and Village Bay surface samples had 4 types of organisms, while both Kanish Bay and Okisollo Channel had only 4 types of organisms in both surface and SCUBA samples.

DISCUSSION

All of the fishes obtained with the purse seine, which fished to an approximate depth of 10 m, would be able to penetrate the webbing of all but the most heavily fouled cages and become prey to farmed salmon. Juveniles of herring, rockfish, pollock, lingcod, and five species of salmon occurred near the cages, as did adult sandlance, stickleback, greenling, and perch. This duplicates the list of small fishes (except for anchovy, smelts, eulachons, trout, and char) in Hay *et al.* (1989) that are abundant in shallow depths in Georgia Strait. Young-of-the-year herring were only captured up to the end of May, presumably because they moved out of the immediate vicinity of the cages or into deeper water. Alternately, very few may have survived beyond May.

The estimate of plankton, 0.047-2.442 g wet weight and 30-8527 plankters • m^{-3}, is in the range of estimates made with similar collecting gear in Georgia Strait (Harrison *et al.*). However, Harrison *et al.* suggest that densities of this order of magnitude may be a gross underestimate because of gear selectivity and plankton patchiness. The amount of plankton available to caged salmon depends on tidal flow through the pen. The average cage is a 10 m cube. Assuming no flow restriction from cage webbing and an average current of 1 knot for 6 hr • day^{-1}, then the 1000 m^3 cage volume would be replaced 1112 times per day. At the peak average plankton density of 0.52 g • m^{-3} (July 24), this would make 578.2 kg of plankton available per cage per day. If, on average, each cage contained 50,000 salmon, 11.6 g of plankton would be available per fish per day. Whether that amount of plankton is consumed depends on the food preferences of caged salmon. Gillis et al. (1991) found that 38% of caged salmon consumed wild feed, most of which originated from the fouling community on the cage webbing. The wild juvenile salmon examined for stomach content were all feeding and 83% had full stomachs. None of them fed on any of the organisms found on webbing but not in the wild plankton (eg. isopods, pycnogonids). Hence, it appears that caged salmon did not deplete the plankton in the vicinity of the cages.

The growth and diversity of organisms on cage webbing probably increases with the time that a cage has been submerged. The location may also affect the degree of growth on a cage. In this study the growth on cages ranged from light to heavy, and some of the organisms on the webbing could be prey for the farmed salmon.

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Table 1. Fish farm sites at which sampling was conducted in 1989.

Location	Company
Yellow Island	Yellow Island Aquaculture
Kanish Bay	Quadra Sea Farms
Okisollo Channel	B. C. Packers
Waiatt Bay	Waiatt Bay Sea Farms
Surge Narrows	Norent Inc.
Conville Point	Conville Point Sea Farms Ltd.
Village Bay	Quadra Sea Farms
Quartz Bay	Quartz Bay Sea Farms

Table 2. Fish species landed in hand purse seine sets.

Code	Species and life stage
HER1	*Clupea harengus pallasi* young-of-the-year juvenile
HER2	*Clupea harengus pallasi* 2-year-old juvenile
CHIN	*Oncorhynchus tshawytscha* juvenile
CHUM	*Oncorhynchus keta* juvenile
COHO	*Oncorhynchus kisutch* juvenile
PINK	*Oncorhynchus gorbuscha* juvenile
SOCK	*Oncorhynchus nerka* juvenile
SAND	*Ammodytes hexapterus* adult
STIC	*Gasterosteus aculeatus* adult
LING	*Ophiodon elongatus* juvenile
GREE	*Hexagrammos decagrammus* juvenile
POLL	*Theragra chalcogramma* juvenile
ROCK	*Sebastes* sp. juvenile
SHIN	*Cymatogaster aggregata* adult
UI-J	Unidentified teleost juvenile

Table 3a. Number of fish captured in hand purse seine sets at Yellow Island. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	150[a]	2000[b]	0	0	0	0
HER2	0	0	0	0	0	144
CHIN	0	0	2	0	0	1
CHUM	10	0	0	0	0	126
COHO	0	0	0	0	2	0
PINK	615	0	0	0	0	2
SOCK	0	0	0	0	0	0
SAND	1	0	0	0	0	3
STIC	2	0	0	0	0	1
LING	0	0	0	0	0	0
GREE	0	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	1	0	0
Total	778	2000	2	1	2	277

[a] Estimated from estimated weight of 1-2 lb.
[b] Estimated visually.

Table 3b. Number of fish captured in hand purse seine sets in Kanish Bay. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	0	23	0	0	0	0
HER2	0	0	0	61	1	0
CHIN	0	0	0	11	3	0
CHUM	0	3	5	60	0	0
COHO	0	0	1	18	0	1
PINK	0	0	0	27	0	0
SOCK	0	0	0	0	0	0
SAND	0	0	0	0	0	0
STIC	0	1	0	0	0	0
LING	0	0	0	0	0	0
GREE	0	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	0	0	0
Total	0	27	6	177	4	1

Table 3c. Number of fish captured in hand purse seine sets in Okisollo Ch. (See Table 2 for code to species.)

Species and Life stage	Sampling date					
	May 16[a]	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	7	0	0	0	0	0
HER2	0	0	0	0	0	0
CHIN	0	0	0	3	3	0
CHUM	0	0	0	1	10	0
COHO	0	0	0	0	0	0
PINK	0	0	0	0	0	0
SOCK	0	0	0	2	0	0
SAND	5	0	0	0	0	0
STIC	0	0	0	0	0	1
LING	0	0	0	0	0	0
GREE	0	4	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	1	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	0	0	0
Total	12	5	0	6	13	1

[a] This was a practise set, a subsequent set yielded no fish.

Table 3d. Number of fish captured in hand purse seine sets in Waiatt Bay. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	0	0	0	0	0	0
HER2	0	0	0	2	0	0
CHIN	0	0	0	17	0	0
CHUM	0	0	4	2	16	0
COHO	0	0	0	0	0	0
PINK	0	0	0	1	0	0
SOCK	0	0	2	6	0	0
SAND	0	0	0	0	0	0
STIC	0	0	0	0	0	1
LING	43	1	0	0	0	0
GREE	0	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	0	0	0
Total	43	1	6	28	16	1

Table 3e. Number of fish captured in hand purse seine sets in Surge Narrows. (See Table 2 for code to species.)

Species and life stage	Sampling date May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	0	0	0	0	0	0
HER2	0	0	0	0	0	0
CHIN	0	0	1	0	4	0
CHUM	0	3	0	1	0	0
COHO	0	0	0	0	0	0
PINK	0	0	0	0	0	0
SOCK	0	0	0	0	0	0
SAND	0	0	0	0	0	0
STIC	0	0	0	0	0	0
LING	0	0	0	0	0	0
GREE	0	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	0	0	0
Total	0	3	1	1	4	0

Table 3f. Number of fish captured in hand purse seine sets at Conville Point. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	tr[a]	0	0	0	0	0
HER2	170	1	0	0	1	0
CHIN	0	3	10	0	1	0
CHUM	20	6	3	0	0	22
COHO	0	0	0	0	0	4
PINK	2	0	0	0	0	0
SOCK	0	0	42	0	0	0
SAND	0	0	0	0	0	0
STIC	0	0	0	0	0	0
LING	3	2	0	0	0	0
GREE	1	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	1
UI-J	0	0	0	0	1	0
Total	196	12	55	0	3	27

[a] Observed but not landed.

Table 3g. Number of fish captured in hand purse seine sets in Village Bay. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12	Jun 19	Jul 10	Jul 24
HER1	0	0	0	0	0	0
HER2	0	2	0	0	0	0
CHIN	11	5	0	2	1	0
CHUM	0	5	1	4	0	1
COHO	1	0	0	0	0	0
PINK	0	0	0	0	0	0
SOCK	0	0	0	0	0	0
SAND	0	0	0	0	0	0
STIC	0	0	0	0	0	0
LING	0	0	0	0	0	0
GREE	0	0	0	0	0	0
POLL	0	0	0	0	0	0
ROCK	0	0	0	0	0	0
SHIN	0	0	0	0	0	0
UI-J	0	0	0	0	0	0
Total	12	12	1	6	1	1

Table 3h. Number of fish captured in hand purse seine sets in Quartz Bay. (See Table 2 for code to species.)

Species and life stage	Sampling date					
	May 16	May 29	Jun 12[a]	Jun 19	Jul 10	Jul 24
HER1	0	0	-	0	0	1
HER2	34	69	-	0	0	0
CHIN	0	0	-	3	0	0
CHUM	0	6	-	1	0	0
COHO	0	0	-	0	0	0
PINK	0	3	-	0	0	0
SOCK	0	0	-	0	0	0
SAND	0	0	-	0	0	0
STIC	0	0	-	0	0	0
LING	1	1	-	0	0	0
GREE	0	0	-	0	0	0
POLL	0	1	-	0	0	0
ROCK	0	0	-	0	0	0
SHIN	0	0	-	0	0	47
UI-J	0	0	-	6	0	0
Total	35	80	-	10	0	48

[a] Not accessible due to poor weather.

Table 4. Length and weight of frequently occurring teleosts in hand purse seine sets near caged salmon sites. (See Table 2 for code to species.)

Species	Date	Location	N	Length (mm) Range	Length (mm) Mean	Length (mm) SD	Weight (g) Range	Weight (g) Mean	Weight (g) SD
HER1	May 16	Yellow I.	50	23- 30	26.5	1.8	0.1- 0.2	0.10	0.04
HER1	May 29	Yellow I.	50	30- 40	35.1	2.2	0.2- 0.7	0.44	0.10
HER1	May 29	Kanish B.	23	26- 30	28.1	1.0	0.1- 0.2	0.13	0.02
HER1	All	All	123	23- 40	30.3	4.4	0.1- 0.7	0.24	0.18
HER2	May 16	Conville Pt.	50	78-113	95.2	9.1	5.7-17.0	10.77	2.90
HER2	May 16	Quartz B.	34	91-131	105.5	8.8	9.2-29.1	15.48	4.33
HER2	May 29	Quartz B.	50	84-130	107.3	12.3	5.5-31.3	15.13	6.22
HER2	Jun 19	Kanish B.	50	88-139	111.3	11.4	7.5-33.4	16.49	5.39
HER2	Jul 24	Yellow I.	50	106-128	114.4	5.5	13.6-28.8	18.05	3.23
HER2	All	All	234	78-139	106.8	11.8	5.5-33.4	15.16	5.21
CHIN	May 29	Village B.	1	-	116.0	-	-	18.71	-
CHIN	Jun 12	Yellow I.	2	125-129	127.0	-	16.8-21.1	18.90	-
CHIN	Jun 12	Surge Nrs.	1	-	98.0	-	-	9.75	-
CHIN	Jun 12	Conville Pt.	10	99-127	110.8	8.2	9.5-22.2	14.13	3.57
CHIN	Jun 19	Kanish B.	11	92-131	103.3	10.8	7.7-16.1	11.97	5.05
CHIN	Jun 19	Okisollo Ch.	3	95-118	106.3	-	8.3-18.1	14.53	-
CHIN	Jun 19	Waiatt B.	17	75-130	107.1	13.8	4.0-23.8	13.26	5.14
CHIN	Jun 19	Village B.	2	84-100	92.0	-	6.0-11.1	8.55	-
CHIN	Jun 19	Quartz B.	3	66- 84	76.0	-	2.9- 6.5	4.63	-
CHIN	Jul 10	Kanish B.	3	89-160	115.0	-	8.2-55.6	24.47	-
CHIN	Jul 10	Okisollo Ch.	3	103-114	108.7	-	11.6-14.4	13.13	-
CHIN	Jul 10	Surge Nrs.	4	77-113	94.3	14.7	4.7-15.4	9.23	4.48
CHIN	Jul 10	Conville Pt.	1	-	105.0	-	-	13.10	-
CHIN	Jul 10	Village B.	1	-	132.0	-	-	29.20	-
CHIN	Jul 24	Yellow I.	1	-	116.0	-	-	17.80	-
CHIN	All	All	63	66-160	105.8	15.7	2.9-55.6	13.48	7.53
CHUM	May 29	Kanish B.	3	58- 75	65.0	-	1.9- 4.4	2.83	-
CHUM	May 29	Surge Nrs.	3	50- 85	63.7	-	1.1- 6.6	3.24	-
CHUM	May 29	Village B.	5	72-101	82.2	11.5	3.7-11.2	5.76	3.21
CHUM	May 29	Quartz B.	6	63-100	76.7	14.7	2.4-10.3	4.89	3.10
CHUM	Jun 12	Kanish B.	5	64- 93	78.4	13.5	2.5- 8.5	5.13	2.86
CHUM	Jun 12	Waiatt B.	4	59-103	85.5	19.3	2.0- 9.7	6.58	3.47
CHUM	Jun 12	Conville Pt.	3	84- 90	87.0	-	5.5- 6.3	5.92	-
CHUM	Jun 12	Village B.	1	-	57.0	-	-	1.70	-
CHUM	Jun 19	Kanish B.	60	70-107	85.5	8.6	3.3-12.5	6.32	2.10
CHUM	Jun 19	Okisollo Ch.	1	-	91.0	-	-	7.20	-
CHUM	Jun 19	Waiatt B.	2	89-110	99.5	-	7.0-14.3	10.65	-
CHUM	Jun 19	Village B.	4	73- 93	86.3	9.4	4.1- 8.6	6.88	1.96
CHUM	Jun 19	Quartz B.	1	-	57.0	-	-	1.20	-
CHUM	Jul 10	Okisollo Ch.	10	97-111	103.0	3.9	8.3-13.0	10.64	1.50

Table 4 (cont'd)

Species	Date	Location	N	Length (mm) Range	Mean	SD	Weight (g) Range	Mean	SD
CHUM	Jul 10	Waiatt B.	16	71-128	100.6	17.7	3.3-19.9	10.38	5.13
CHUM	Jul 24	Yellow I.	126	87-139	107.2	10.2	6.4-28.2	13.07	4.44
CHUM	Jul 24	Conville Pt.	22	89-135	102.0	10.7	6.8-27.6	10.92	4.48
CHUM	Jul 24	Village B.	1	-	102.0	-	-	12.40	-
CHUM	All	All	273	50-139	97.5	15.8	1.1-28.2	10.09	4.98
COHO	Jun 12	Kanish B.	1	-	124.0	-	-	21.10	-
COHO	Jun 16	Kanish B.	18	131-165	144.1	9.6	23.6-47.8	32.89	7.02
COHO	Jul 10	Yellow I.	2	163-169	166.0	-	43.3-47.3	45.30	-
COHO	Jul 24	Kanish B.	1	-	155.0	-	-	41.30	-
COHO	Jul 24	Conville Pt.	4	129-170	156.5	18.6	24.5-70.0	51.00	19.13
COHO	All	All	26	124-170	147.4	13.4	21.1-70.0	36.50	11.72
PINK	May 29	Quartz B.	3	63- 73	69.7	-	2.5- 3.6	3.20	-
PINK	Jun 19	Kanish B.	27	70- 97	82.8	6.9	3.5- 8.1	5.53	1.45
PINK	Jun 19	Waiatt B.	1	-	89.0	-	-	6.80	-
PINK	Jul 24	Yellow I.	2	103-105	104.0	-	9.7-11.0	10.35	-
PINK	All	All	33	63-105	83.1	9.3	2.5-11.0	5.65	1.94
SOCK	Jun 12	Waiatt B.	2	90- 92	91.0	-	6.3- 6.5	6.42	-
SOCK	Jun 12	Conville Pt.	42	93-128	105.9	6.9	7.1-20.0	19.96	2.23
SOCK	Jun 19	Okisollo Ch.	2	100-101	100.5	-	9.4-10.4	9.90	-
SOCK	Jun 19	Waiatt B.	6	89-109	97.3	7.2	6.0-12.4	8.53	2.23
SOCK	All	All	52	89-128	104.1	7.7	6.0-20.0	10.44	2.40
LING	May 16	Waiatt B.	32	41- 63	48.8	4.9	0.5- 1.8	0.96	0.28

Table 5. Organisms identified and counted in bongo net tows and stomachs of wild juvenile salmon.

Code	Taxon
COEL[1]	Coelenterate medusae (includes some siphonophores)
CTEN[1]	Ctenophores
POLY[1]	Polychaetes
PTER[1]	Pteropods (Ophisthobranch gastropods); *Clione* sp. and *Limacina* sp.
NAUP[1]	Crustacean nauplii, ~50% cirriped (barnacle)
CLAD	Cladocerans; *Podon* sp. and *Evadne* sp.
COPE	Post-nauplii copepods
SHRI[2]	Natant decapod (shrimp) zoea
CRAB	Reptant decapod (crab) larvae, mostly zoea and some megalopae
BARN	Cirriped (barnacle) cyprids (~5% ostracods)
AMPH	Amphipods, mostly gammarid and hyperiid
EUPL	Euphausiid larvae (nauplii, protozoea, and zoea)
EUPA	Euphausiid adults
LARV	Larvaceans, mostly *Oikopleura* sp., and tunicate larvae
CHAE[2]	Chaetognaths, mostly *Sagitta* sp.
TELA	Teleost larvae
FISH[2]	Teleost postlarvae
EGGS	Pelagic eggs, polychaete or teleost
INSE[2]	Insects or insect larvae

[1]Occurred in plankton samples only.
[2]Occurred in salmon stomachs only.

Table 6. Food in wild juvenile salmon (62 chum and 10 coho) stomachs on June 19, 1989 in Kanish Bay. (For code to prey types see Table 5.)

Predator	Prey		Number of prey in full stomachs			
	Taxon	Occurrence	N	Range	Mean	SD
Chum	All	62	52	31-2004	587.9	487.5
	CLAD	1	1	-	4.0	-
	COPE	62	52	4-1924	304.3	367.9
	SHRI	21	17	1- 16	8.0	5.7
	CRAB	17	15	1- 20	4.3	4.9
	BARN	28	25	1- 36	8.8	8.8
	AMPH	11	10	1- 4	1.6	1.3
	EUPL	27	25	2- 48	14.7	11.6
	EUPA	1	1	-	6.0	-
	LARV	33	25	1-1980	532.2	583.9
	CHAE	1	0	-	-	-
	TELA	3	1	-	4.0	-
	EGGS	30	26	1- 96	22.9	26.9
	INSE	11	9	1- 5	3.0	1.7
Coho	All	10	8	5- 27	12.9	7.9
	COPE	5	3	1- 2	1.7	-
	SHRI	3	3	1- 2	1.7	-
	CRAB	5	4	4- 22	13.0	9.3
	AMPH	2	1	-	1.0	-
	EUPL	1	0	-	-	-
	LARV	2	2	2- 4	3.0	-
	TELA	1	1	-	1.0	-
	EGGS	3	2	2- 2	2.0	-
	INSE	2	2	1- 2	1.5	-
	FISH	8	7	1- 8	3.7	2.6

Table 7. Weight and density of plankters (for code to types see Table 5) from paired stepped oblique bongo net tows.

Location	Date	g/m³	Number per m³ of															
			COEL	CTEN	POLY	PTER	NAUP	CLAD	COPE	CRAB	BARN	AMPH	EUPL	EUPA	LARV	TELA	EGGS	ALL
Yellow I.	May 15	0.122	0	0	2	0	0	0	133	23	0	2	0	6	34	0	0	200
Yellow I.	May 15	0.133	0	0	4	2	0	0	135	15	0	2	4	14	39	0	0	215
Yellow I.	May 29	0.089	0	0	0	0	9	0	90	6	4	0	4	1	6	0	1	122
Yellow I.	May 29	0.084	0	0	0	0	1	0	106	5	3	0	5	3	5	0	0	129
Yellow I.	Jun 12	0.048	0	0	1	0	13	3	72	12	2	3	5	8	15	0	0	134
Yellow I.	Jun 12	0.052	1	0	0	0	19	6	94	15	2	1	7	7	22	0	52	226
Yellow I.	Jun 19	0.108	0	0	1	0	32	3	136	4	2	1	38	2	27	0	49	296
Yellow I.	Jun 19	0.097	0	0	1	0	31	1	121	10	8	2	34	4	23	0	0	234
Yellow I.	Jul 10	0.085	0	0	0	1	2	0	87	6	2	2	1	2	9	0	0	111
Yellow I.	Jul 10	0.054	2	0	0	0	2	0	87	6	0	8	0	5	20	0	0	129
Yellow I.	Jul 24	0.192	3	5	0	0	0	0	66	6	0	1	0	2	4	0	0	87
Yellow I.	Jul 24	0.226	2	2	1	0	0	0	65	7	0	3	0	3	1	0	0	86
Kanish B.	May 15	0.173	0	0	0	0	0	0	146	18	0	0	2	6	66	0	0	239
Kanish B.	May 15	0.172	0	0	2	0	0	0	131	22	0	2	3	12	85	2	0	257
Kanish B.	May 29	0.082	0	0	4	0	29	0	86	2	6	2	6	2	35	0	0	173
Kanish B.	May 29	0.047	0	0	1	0	10	1	49	3	8	1	1	1	10	0	0	84
Kanish B.	Jun 19	0.122	0	0	1	0	51	8	189	13	0	4	30	9	59	1	0	365
Kanish B.	Jun 19	0.189	2	0	5	0	85	2	235	12	7	2	45	2	85	0	0	484
Kanish B.	Jul 10	0.096	0	0	1	0	1	0	76	26	0	1	0	14	15	0	0	135
Kanish B.	Jul 10	0.107	0	0	0	0	5	1	54	35	0	1	1	8	12	0	0	116
Kanish B.	Jul 24	1.212	0	0	0	0	33	0	188	44	0	0	0	0	166	11	0	443
Kanish B.	Jul 24	0.876	0	0	0	0	17	0	116	22	0	0	0	28	216	0	0	399
Okisollo Ch.	May 15	0.107	0	0	1	0	0	0	114	37	0	4	0	11	13	0	0	181
Okisollo Ch.	May 15	0.127	0	0	1	0	0	0	80	50	0	1	5	17	52	0	0	206
Okisollo Ch.	May 29	0.133	0	0	5	0	192	10	198	6	12	1	20	7	116	0	0	566
Okisollo Ch.	May 29	0.268	0	0	5	0	220	24	321	24	12	2	50	14	160	0	0	833
Okisollo Ch.	Jun 19	0.125	0	0	10	0	219	55	339	6	12	0	25	0	88	0	0	754
Okisollo Ch.	Jun 19	0.138	0	0	0	0	155	52	231	11	4	0	40	4	47	0	0	544
Okisollo Ch.	Jul 10	0.128	7	0	1	0	4	0	117	19	0	1	1	4	7	0	0	161
Okisollo Ch.	Jul 10	0.213	6	0	0	0	10	0	64	5	0	6	1	5	4	0	0	100
Okisollo Ch.	Jul 24	0.212	6	0	0	0	3	1	30	14	0	1	1	3	11	0	0	69
Okisollo Ch.	Jul 24	0.262	5	0	0	0	3	1	43	23	0	1	3	7	5	0	0	91
Waiatt B.	May 15	0.513	0	0	3	0	0	0	284	21	0	0	301	27	264	0	0	901
Waiatt B.	May 15	0.250	0	0	7	0	281	7	212	14	14	7	7	14	349	0	0	911
Waiatt B.	May 29	0.151	0	0	3	0	231	17	134	33	10	0	57	23	421	0	47	975
Waiatt B.	May 29	0.176	0	0	3	0	237	17	104	7	13	0	57	27	371	0	67	902
Waiatt B.	Jun 19	0.104	0	0	1	0	200	10	254	3	15	1	53	1	31	0	0	569
Waiatt B.	Jun 19	0.158	0	0	4	0	244	22	550	2	8	2	55	2	31	0	0	920
Waiatt B.	Jul 10	0.072	0	0	0	0	51	0	94	72	0	0	5	17	51	2	0	292
Waiatt B.	Jul 10	0.086	0	0	1	0	13	0	62	33	1	4	0	9	24	0	0	148
Waiatt B.	Jul 24	0.147	2	0	1	0	20	0	37	36	0	1	2	10	10	0	6	126
Waiatt B.	Jul 24	0.110	1	0	0	0	8	1	30	19	0	2	1	5	11	0	3	84
Surge Nrs.	May 15	0.240	0	0	8	3	434	0	100	33	46	0	30	24	276	0	0	951
Surge Nrs.	May 15	0.226	0	0	5	3	190	0	176	27	43	11	41	41	238	0	0	775
Surge Nrs.	May 29	0.124	0	0	0	0	132	10	33	9	9	1	70	5	47	0	483	799
Surge Nrs.	May 29	0.159	0	0	5	0	227	15	89	15	10	5	111	22	272	0	459	1230
Surge Nrs.	Jun 19	0.323	0	8	2	0	283	14	90	58	3	2	120	13	26	0	0	619
Surge Nrs.	Jun 19	0.603	6	14	0	0	282	22	84	55	3	5	131	1	41	0	0	642
Surge Nrs.	Jul 10	0.234	7	1	0	1	10	1	55	32	3	7	0	5	21	1	15	159
Surge Nrs.	Jul 10	0.128	12	1	0	0	5	1	32	23	1	4	0	1	14	0	15	111
Surge Nrs.	Jul 24	0.112	8	4	0	1	3	0	58	21	10	6	0	7	2	0	0	120
Surge Nrs.	Jul 24	0.093	12	2	0	1	5	0	59	28	11	1	0	4	15	0	0	138

Table 7 (cont'd)

Location	Date	g/m³	Number per m³ of															
			COEL	CTEN	POLY	PTER	NAUP	CLAD	COPE	CRAB	BARN	AMPH	EUPL	EUPA	LARV	TELA	EGGS	ALL
Conville Pt.	May 15	1.327	0	0	36	0	3009	0	338	36	71	0	36	71	1371	0	3561	8527
Conville Pt.	May 15	0.662	0	0	18	18	0	0	125	27	151	0	481	18	650	9	1780	3276
Conville Pt.	May 29	0.169	0	0	2	0	212	5	30	4	4	5	49	0	77	0	192	579
Conville Pt.	May 29	0.162	0	0	0	0	289	10	80	5	5	2	56	2	180	0	146	776
Conville Pt.	Jun 19	0.284	3	12	5	0	217	8	120	50	3	8	87	9	67	0	0	589
Conville Pt.	Jun 19	0.378	5	5	0	0	282	18	145	84	0	5	198	21	90	0	0	854
Conville Pt.	Jul 10	0.280	1	5	0	0	6	0	14	77	0	5	0	7	9	0	62	186
Conville Pt.	Jul 10	0.273	7	2	0	0	2	0	26	104	0	4	0	5	4	0	53	207
Conville Pt.	Jul 24	0.075	2	0	1	0	0	0	13	26	0	0	0	6	2	0	0	51
Conville Pt.	Jul 24	0.111	8	1	0	0	4	1	36	95	0	13	0	19	6	0	0	183
Village B.	May 15	0.765	0	0	11	0	481	0	194	34	0	23	23	46	915	0	0	1728
Village B.	May 15	0.590	0	0	0	23	23	23	206	23	23	11	23	23	789	0	0	1167
Village B.	May 29	0.249	0	0	12	0	247	45	67	38	5	7	36	41	244	0	160	903
Village B.	May 29	0.149	0	0	0	0	183	45	19	37	4	2	17	12	63	0	86	469
Village B.	Jun 19	0.517	2	5	2	0	133	41	82	364	0	2	152	43	29	0	0	856
Village B.	Jun 19	0.540	0	0	0	0	174	36	116	415	0	12	125	36	19	0	0	933
Village B.	Jul 10	1.537	6	16	0	0	0	0	8	53	0	4	2	25	8	0	0	121
Village B.	Jul 10	1.777	6	23	0	0	0	0	4	66	0	0	0	10	10	0	0	119
Village B.	Jul 24	1.704	9	25	0	0	0	0	5	37	0	0	0	4	0	0	0	79
Village B.	Jul 24	2.442	5	23	0	0	0	0	11	55	0	4	0	21	2	0	0	120
Quartz B.	May 15	0.188	0	0	22	0	87	0	511	4	9	9	0	4	114	0	0	760
Quartz B.	May 15	0.134	0	0	0	0	79	4	280	9	4	17	0	0	83	0	0	476
Quartz B.	May 29	1.007	0	37	0	0	5	2	5	17	0	3	2	3	7	0	60	140
Quartz B.	May 29	0.613	1	13	0	0	4	1	8	14	3	6	5	4	4	0	47	109
Quartz B.	Jun 19	0.127	10	1	0	0	4	5	8	14	0	2	5	8	4	0	0	62
Quartz B.	Jun 19	0.106	11	2	1	0	8	3	8	29	0	1	5	8	3	2	0	80
Quartz B.	Jul 10	0.147	3	3	0	0	0	0	7	7	1	4	1	3	1	0	172	202
Quartz B.	Jul 10	0.169	7	3	0	0	0	0	17	6	1	2	0	2	3	0	146	187
Quartz B.	Jul 24	0.235	9	2	0	0	0	4	8	4	0	0	2	0	1	0	0	30
Quartz B.	Jul 24	0.225	13	1	0	0	2	4	5	4	0	0	1	2	4	0	0	38

Table 8. Summary of plankton density in 40 bongo net tows (80 samples) near caged salmon sites. (See Table 5 for code to types.)

Taxon	Occurrence (No. of samples)	Density (no. • m^3) when present Range	Mean	SD
COEL	33	1- 13	5.8	3.4
CTEN	27	1- 37	8.0	9.3
POLY	41	1- 36	4.9	6.8
PTER	8	1- 23	6.2	8.9
NAUP	63	1-3009	149.5	385.2
CLAD	42	1- 55	13.1	15.4
COPE	45	1- 151	12.6	25.0
CRAB	80	4- 550	110.8	107.3
BARN	80	2- 415	34.5	61.5
AMPH	66	1- 23	4.0	4.2
EUPL	58	1- 481	45.9	80.5
EUPA	75	1- 71	12.1	13.0
LARV	79	1-1371	110.1	221.3
TELA	10	1- 11	3.0	3.8
EGGS	22	1-3561	345.9	811.3
Total plankters	80	30-8527	537.4	1024.7

Table 9. Visual observation of percent occlusion of interstitial spaces of cage webbing by organisms inhabiting the webbing.

Station	Yellow Island		Kanish Bay		Okisollo Ch.	
	Depth (m)	Percent occlusion	Depth (m)	Percent occlusion	Depth (m)	Percent occlusion
1	0.3	50	0.3	30	0.3	20
2	2.4	40	3.0	10	3.0	50
3	4.9	20	6.1	5	6.1	70
4	6.7	20	9.1	10	9.1	85
5	9.1	10	-	-	12.2	10
6	-	-	-	-	15.2	20

Table 10. List of organisms identified in cage webbing samples.

Code	Description	Taxon
NEME	nemertean worms	Phylum Nemertea
POLY	polychaete worms	Class Polychaeta
CHIT	chitons	Subclass Polyplacophora
SNAI	snails, limpets	Subclass Prosobranchia
NUDI	nudibranchs	Subclass Opisthobranchia
MUSS	mussels, jingle shells, scallops	Sublass Pteriomorpha
COPE	copepods	Subclass Copepoda
CRAB	crabs	Order Decapoda
ISOP	isopods	Order Isopoda
AMPH	amphipods	Order Amphipoda
PYCN	pycnogonids	Class Pycnogonida
INSE	insect larvae	Orders Diptera, Coleoptera
URCH	sea urchins	Order Echinoidea
TUNI	tunicates	Class Ascideacea

Table 11. Presence of organisms (+ = few, ++ = some, +++ = many) in samples from cage webbing. For code to types, refer to Table 9. Depth is in m and is estimated at 0.5 m for scrapings taken at the surface.

Location	Date	Depth	NEME	POLY	CHIT	SNAI	NUDI	MUSS	COPE	CRAB	ISOP	AMPH	PYCN	INSE	URCH	TUNI
Yellow I.	Jun 12	≈0.5		++			+	+		+	++	++	+	+++		
Kanish B.	Jun 12	≈0.5									++		+		+	
Okisollo Ch.	Jun 12	≈0.5		+							+					
Waiatt B.	Jun 12	≈0.5						++			+++		+++	+		
Surge Nrs.	Jun 12	≈0.5			+	+		+			++		+			
Village B.	Jun 12	≈0.5				+					++		+++			
Yellow I.	Jun 19	≈0.5				+		+			+			+		
Okisollo Ch.	Jun 19	≈0.5									++	+				
Waiatt B.	Jun 19	≈0.5		+		+		+			+		+	+		
Surge Nrs.	Jun 19	≈0.5	+	++				+++			+		+			
Village B.	Jun 19	≈0.5									+		+			
Quartz B.	Jun 19	≈0.5						+++			+		++			
Yellow I.	Jul 10	≈0.5						+			++	++		+		
Kanish B.	Jul 10	≈0.5						+++			+++		+++			
Okisollo Ch.	Jul 10	≈0.5									+++		++			
Waiatt B.	Jul 10	≈0.5		+				+		+	+++	+	+			
Conville Pt.	Jul 10	≈0.5		+		+	+	+++			+++		+++			
Surge Nrs.	Jul 10	≈0.5						+		+	+		+	+		
Village B.	Jul 10	≈0.5		+				+	++		++		++			
Quartz B.	Jul 10	≈0.5		+				+++			++		++			
Yellow I.	Jul 24	0.3		+			+	+		+	++		+			+
Yellow I.	Jul 24	2.4		+				+			+		+		+	+
Yellow I.	Jul 24	4.9		+				+			++		++			+
Yellow I.	Jul 24	6.7		+			+	+		+	++		++			+
Yellow I.	Jul 24	9.1		+			++	+		++	+		+			
Kanish B.	Jul 24	0.3									+					
Kanish B.	Jul 24	3.0									+		++			
Kanish B.	Jul 24	6.1									+		+			
Kanish B.	Jul 24	9.1									+		+			
Okisollo Ch.	Jul 24	0.3									+		+			
Okisollo Ch.	Jul 24	3.0									++		+			
Okisollo Ch.	Jul 24	6.1									+		+			
Okisollo Ch.	Jul 24	9.1									+		+			
Okisollo Ch.	Jul 24	12.2									+++		+			
Okisollo Ch.	Jul 24	15.2									++		+			

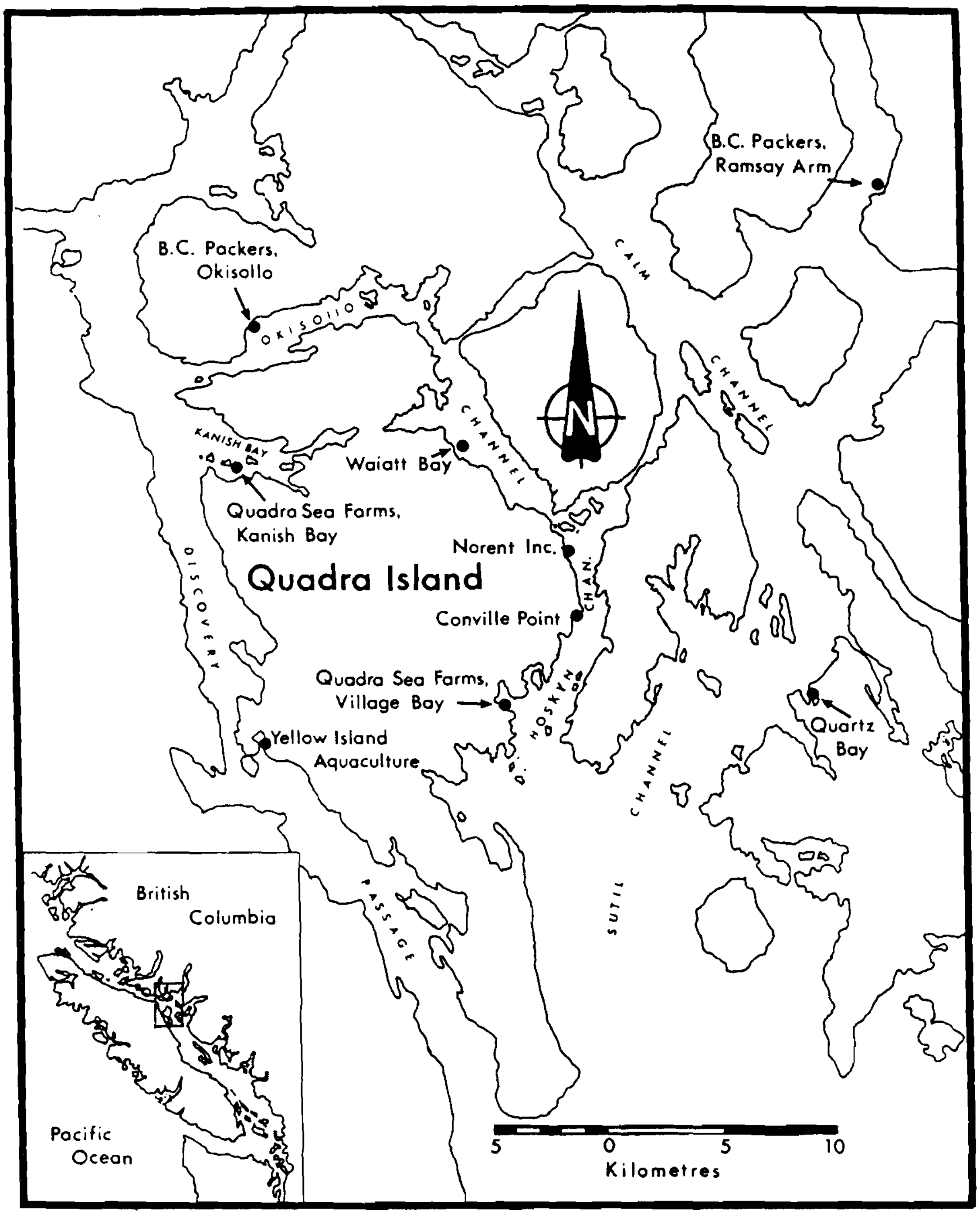

Fig. 1. Study sites for fish and plankton sampling outside salmon cages. (The Ramsey Arm site was not sampled.)

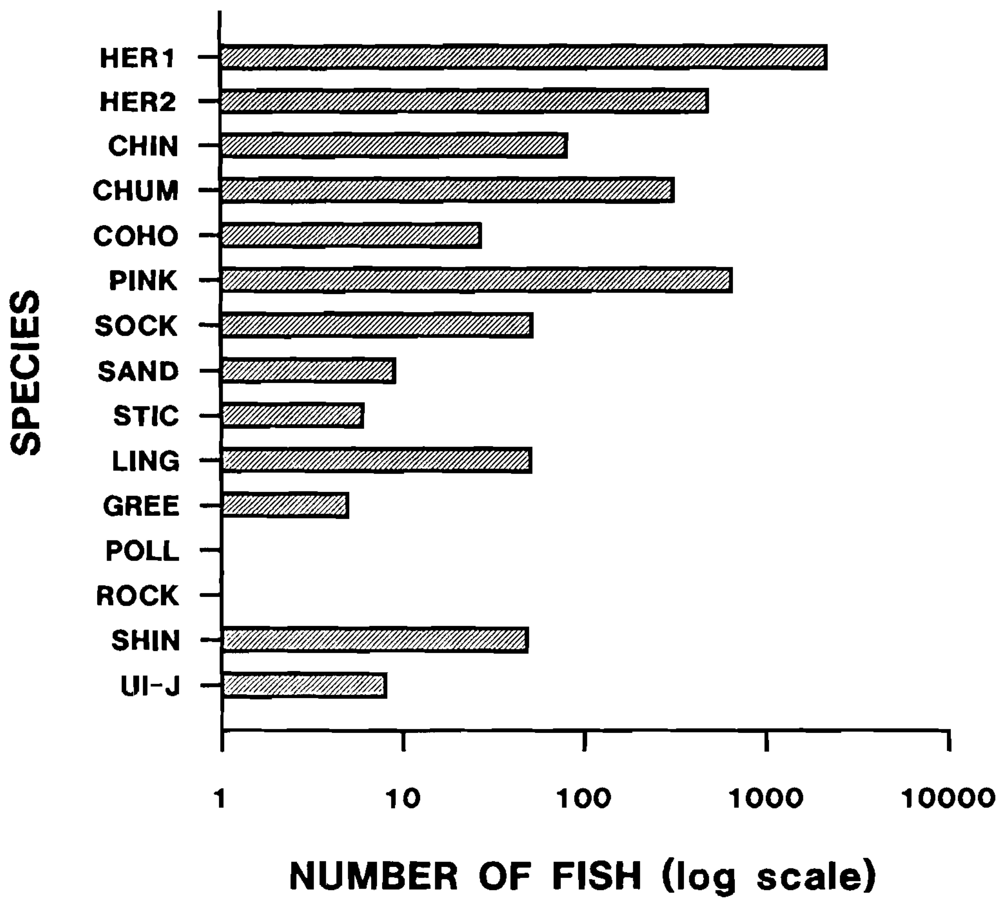

Fig 2. Total number of fish, by species (see Table 2), captured in hand purse seine sets.

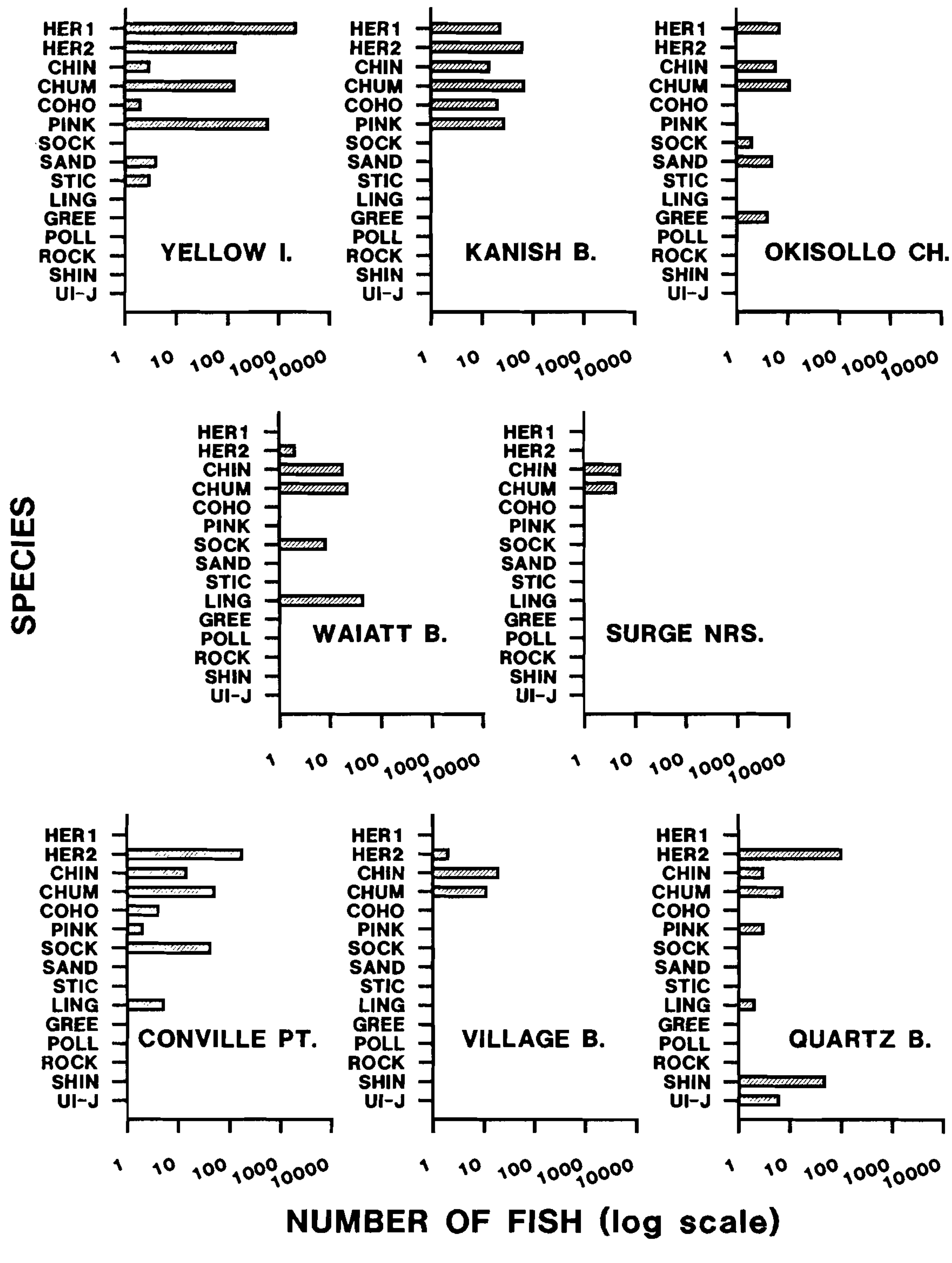

Fig. 3. Number of fish, by location and species (see Table 2), captured in hand purse seine sets.

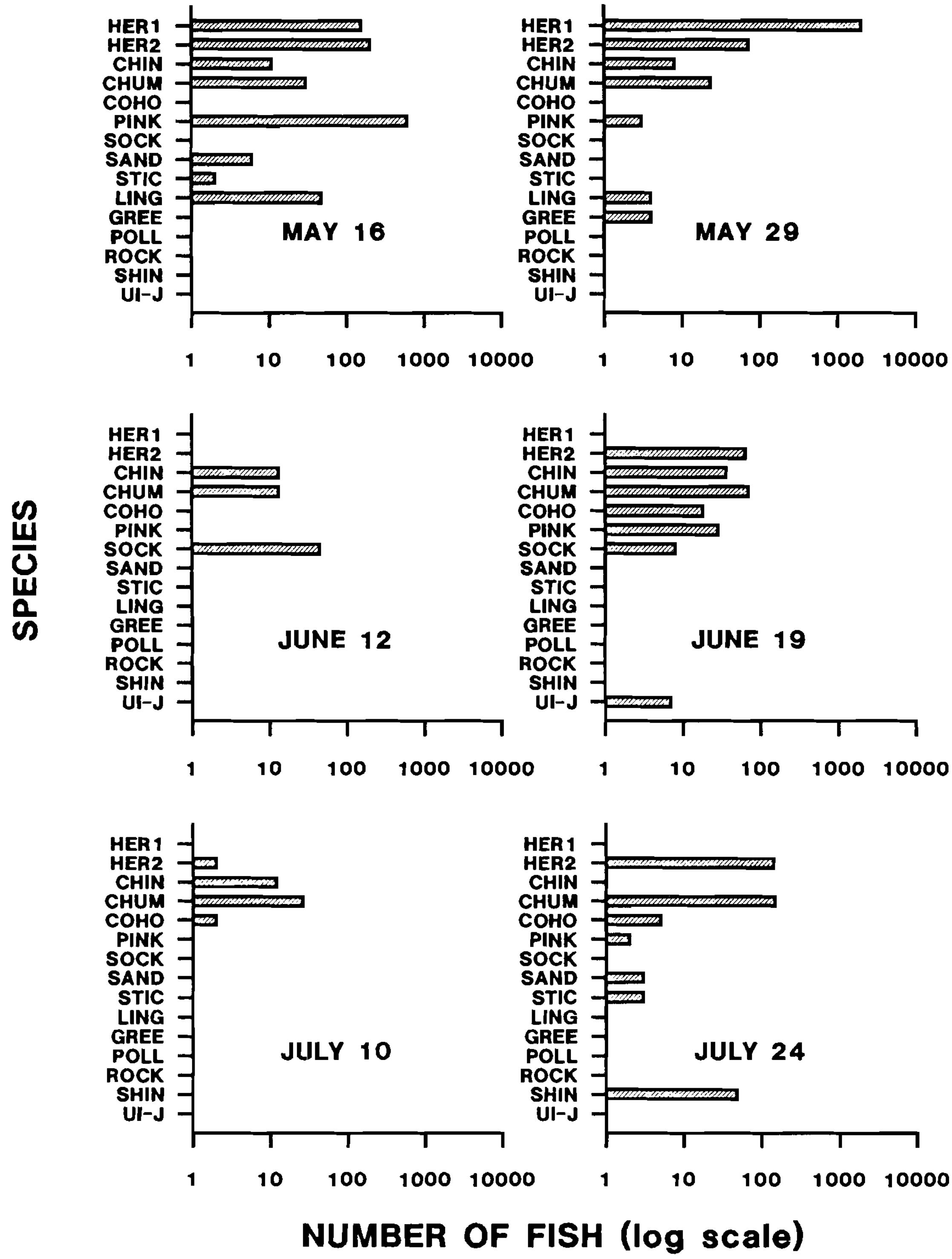

Fig. 4. Number of fish, by sampling day and species (see Table 2), captured in hand purse seine sets.

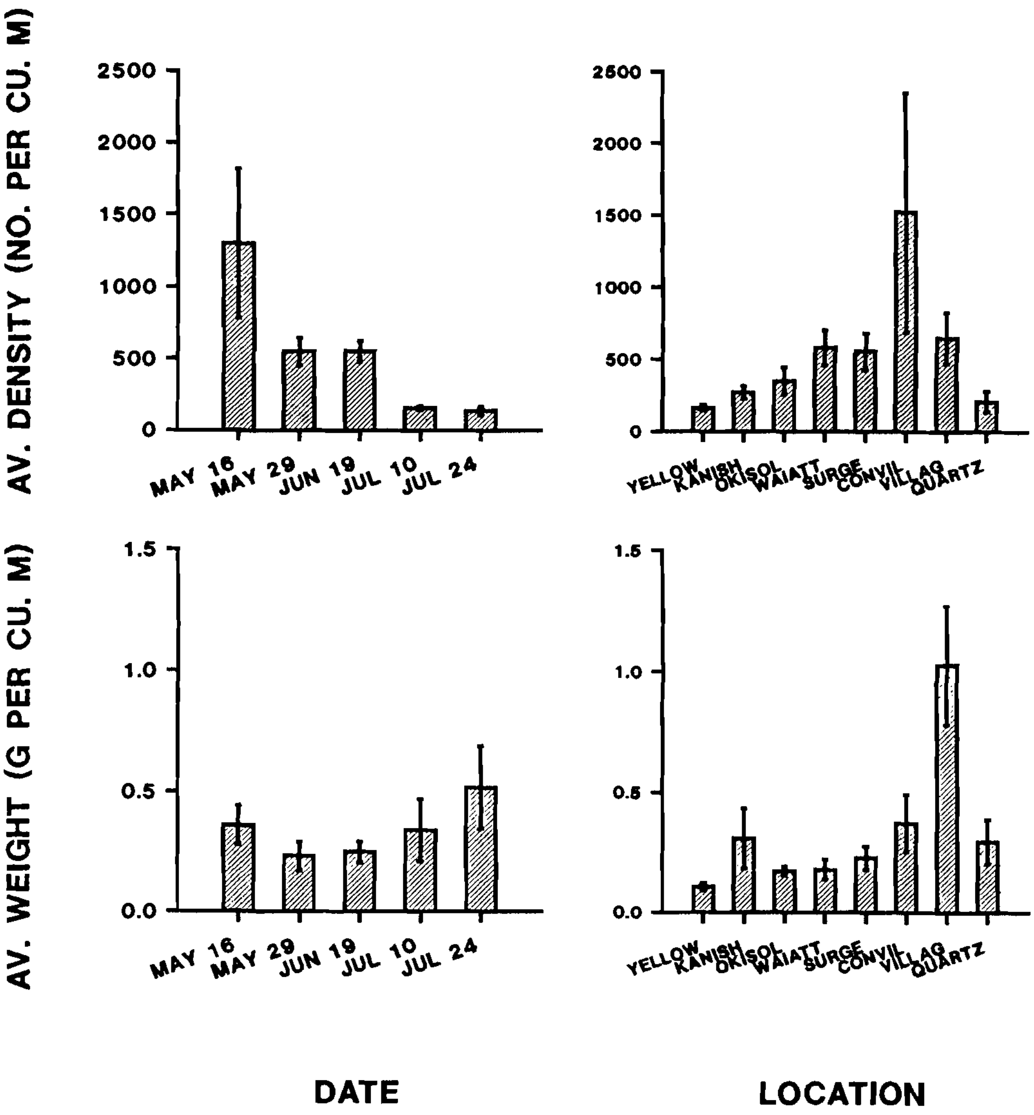

Fig. 5. Average plankton density, by date and location. (Bars show 1 SE from the mean.)