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Temperature, Salinity, and Zooplankton as Indicators of Environmental Suitability for Release of Hatchery-reared Juvenile Salmonids near Juneau, Alaska

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TEMPERATURE, SALINITY, AND ZOOPLANKTON AS INDICATORS OF ENVIRONMENTAL SUITABILITY FOR RELEASE OF HATCHERY-REARED JUVENILE SALMONIDS NEAR JUNEAU, ALASKA

by

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ABSTRACT

Local oceanographic effects on salmon survival were studied near Juneau, Alaska, by Douglas Island Pink and Chum Corporation (DIPAC) and Auke Bay Laboratory of the National Marine Fisheries Service. Two physical and four biological measures were monitored at three locations in Gastineau Channel (Aurora Harbor, Sheep Creek, and Dupont) and two stations north of Juneau (Auke Bay and Amalga Harbor). Temperature, salinity, total plankton settled volume, zooplankton settled volume, and zooplankton composition were monitored at all locations. Zooplankton numerical abundance was also determined at two locations (Auke Bay and Sheep Creek). Samples were collected weekly or semiweekly from 8 April to 10 June 1991.

Temperatures and salinities were higher at Gastineau Channel than at Auke Bay and Amalga Harbor in April; however, the north-south difference did not persist in May and June. The zooplankton bloom in Auke Bay began in late April as water temperatures rose above 5°C, whereas the bloom at Sheep Creek was delayed until temperatures reached about 8°C. During the bloom, zooplankton abundance was two to five times greater at Auke Bay than at Sheep Creek. Neither total nor zooplankton settled volumes were reliable indices of zooplankton abundance.

Zooplankton prey were available sooner and lasted longer at the northern stations. Although DIPAC salmon fry were released into Gastineau Channel during the bloom at Sheep Creek, fry did not reside in lower Gastineau Channel, but quickly left the area; in contrast, peak catches of pink and chum fry were observed in Auke Bay within a few days of channel releases, coinciding with peak zooplankton abundance in Auke Bay. If differences in feeding conditions are affecting survival rates of Gastineau Channel fish, then the mechanism operates within a very short period.

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INTRODUCTION

A cooperative study of local oceanographic effects on salmon survival was initiated in 1991 by Auke Bay Laboratory (ABL), National Marine Fisheries Service (NMFS), and Douglas Island Pink and Chum Corporation (DIPAC) (an Alaskan private nonprofit hatchery). Previous research showed that historical survival rates of wild pink salmon released from Auke Creek Hatchery were higher than survival rates of pink salmon short-term reared in seawater pens and released by DIPAC hatcheries in Gastineau Channel (Appendix A). Our objectives were to determine (1) whether differences in conditions experienced by pink salmon during the early marine period can explain differences in survival, and (2) whether plankton settled volume relates to zooplankton abundance and can be used to predict the density of food organisms to assist in timing fry releases. This report summarizes data collected in 1991; a complete statistical analysis that includes data from 1992 and 1993 will be the subject of a future report.

STUDY AREA

The study area spans approximately 40 km near Juneau (Fig. 1), in the inside waters of Southeast Alaska's northern fjord system. Two stations were located north of Juneau: Amalga Harbor and Auke Bay (Fig. 1). Major sources of fresh water include the Herbert and Eagle Rivers (north of Amalga Harbor) in Lynn Canal and the Mendenhall River (southeast of Auke Bay). Three stations were located on the mainland side of Gastineau Channel, a tidal channel separated from Auke Bay by Fritz Cove: Aurora Harbor, Sheep Creek, and Dupont (Fig. 1). The major source of fresh water for Gastineau Channel is the Taku River, to the south in Taku Inlet.

A comparative study of water circulation in these areas has not been made, although some data are available. In Lynn Canal, circulation patterns are controlled by surface fresh water flowing south from numerous large drainage basins, and deeper seawater flowing north (McLain 1969; Meyers and Harris 1974). By contrast, net water transport in Gastineau Channel is northwest at the surface and southeast at depth. Water flows counterclockwise and inwards at the inner, southern end of Fritz Cove, but the degree of water exchange in the mudflat area of Gastineau Channel remains unknown (U.S. Dep. Interior 1966). Some water from Fritz Cove and the Mendenhall River plume enters Auke Bay (U.S. Dep. Interior 1966; Coyle and Shirley 1990).

The locations of major hatcheries in the Juneau area are shown in Figure 1. DIPAC facilities in Gastineau Channel are located at Salmon and Sheep Creeks. Pink and chum fry are released at both locations and at a remote site, Amalga Harbor. The NMFS operates a hatchery at Auke Creek in Auke Bay. Samples of tagged fish from all these sites were recovered in NMFS beach seine operations during this study (Celewycz et al., in prep.).

METHODS

We used methods typically employed by salmon-production facilities to monitor environmental conditions (Hauser 1982). Samples were collected around midday from 8 April to 10 June 1991, in depths >20 m. DIPAC collected environmental data semiweekly at 1-m depth at Amalga Harbor, Dupont, nearshore Sheep Creek, and Aurora Harbor; ABL collected weekly at Auke Bay Monitor (ABM) station in mid-Auke Bay (eight depths) and at midchannel Sheep Creek (three depths). Inclement weather prevented collection during the week of 24 May at all stations except Auke Bay, and Amalga Harbor was not sampled in June. Water temperature and salinity were measured with a portable salinometer (Beckman[1] Instruments).

[1]Reference to trade names does not imply endorsement by National Marine Fisheries Service, NOAA.

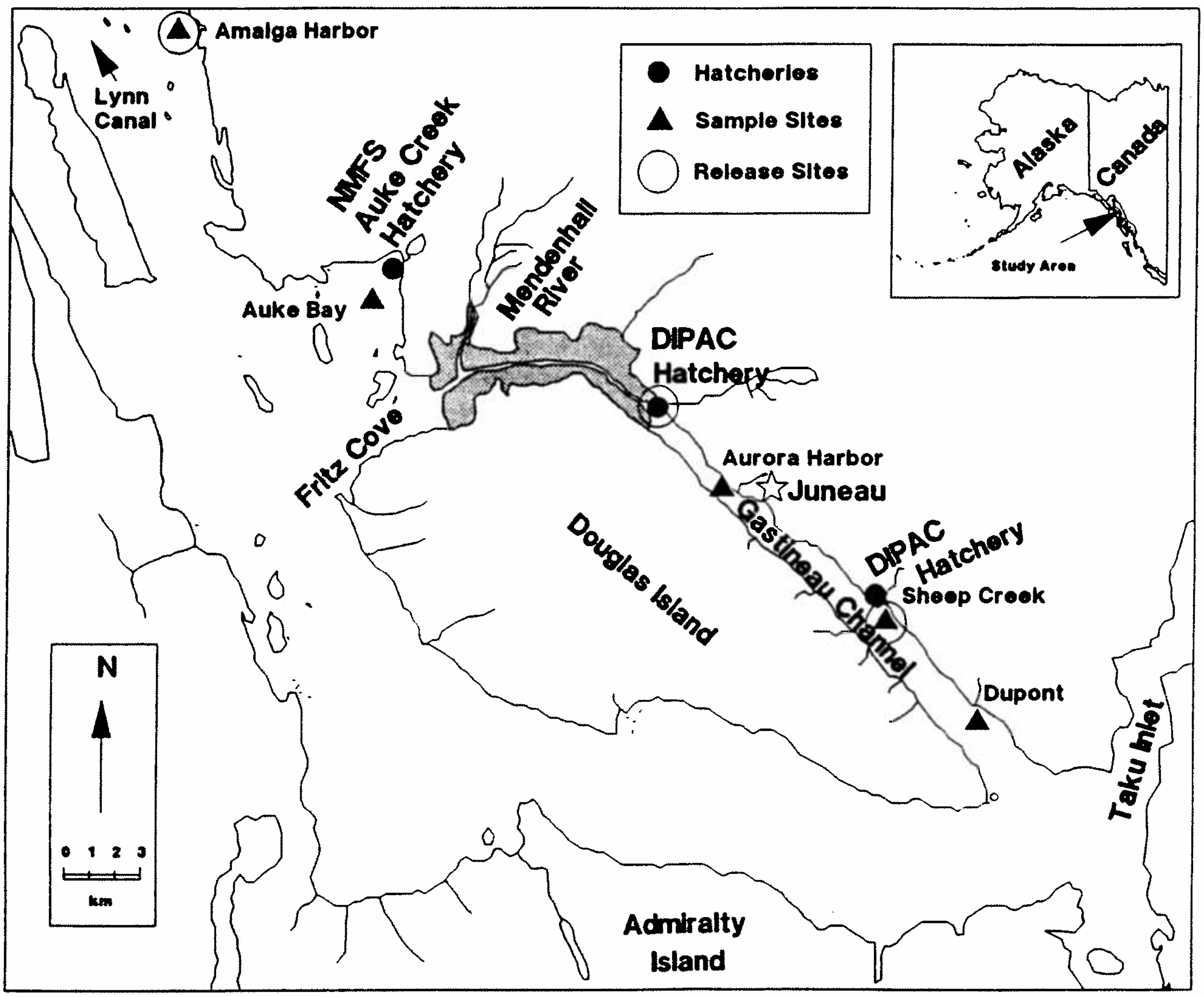

Figure 1.—Study area, sample sites, and fish release sites near Juneau. Hatched area indicates Mendenhall River flats.

Triplicate plankton samples were collected at each station using a standard, conical plankton net with 0.5-m-diameter opening and 243-micron mesh hauled from 20-m depth to the surface. Samples were concentrated and fixed in saltwater-buffered 10% formalin. In the laboratory, total settled volume (phytoplankton plus zooplankton) and zooplankton settled volume were measured and converted to $ml \cdot m^{-3}$. Replicate samples from Sheep Creek and Auke Bay were subsampled with a Folsom plankton splitter and examined under a stereomicroscope. Copepods were identified to species; other zooplankters were identified to the lowest practical taxon (Landingham and Mothershead 1988). Organisms were counted in a subsample large enough to achieve a total count of 500 individuals or 100 of the dominant taxon. Counts of individual taxa, life-history stages, and total zooplankton were converted to numbers per cubic meter ($no. \cdot m^{-3}$), and percentage composition was calculated. Replicates from Amalga Harbor, Aurora Harbor, and Dupont were pooled by site and date; 10 random dropperfuls were examined as above, but only percentage composition of taxa was calculated. Zooplankters were categorized into major groups based on abundance, percentage composition, and dietary importance.

RESULTS

Environmental Data

Semiweekly temperatures at 1-m depth increased from approximately 3.3°C in early April to approximately 10.4°C in early June (Table 1; Fig. 2). In late April, temperatures tended to be higher at Gastineau Channel stations (Aurora Harbor, Sheep Creek, Dupont) than at stations to the north (Amalga Harbor, Auke Bay); a north-south difference in water temperatures was not well defined after April (Fig. 2). Temperatures at the southernmost station (Dupont) remained relatively high throughout the season (Table 1).

Salinity at 1-m depth decreased from >30‰ in early April to approximately 20‰ in June (Table 1; Fig. 2). Considerable variability existed in the semiweekly patterns of salinity at each station, but some differences among areas were noted. Salinities in Gastineau Channel were often higher than at Auke Bay and Amalga Harbor from April to mid-May; except for Aurora Harbor, lower salinities were common at the southern stations after mid-May. Relatively high salinities were observed at Aurora Harbor in late May. Extremely low salinities were observed at Amalga Harbor in April and at Dupont at the end of May. Salinities declined fairly uniformly at all stations from 29 April to 20 May (Fig. 2).

Weekly temperature and salinity profiles (Tables 2, 3) were also examined at Auke Bay (Appendix B, C) and the midchannel Sheep Creek station. Little difference in temperature or salinity was found between 0.5- and 1-m depths at a station. Temperatures were lower and salinities were higher at 5 m than at shallower depths. Comparing stations, near-surface temperatures at Auke Bay were higher than those at midchannel Sheep Creek on most dates. At 5-m depth, Auke Bay was at least as warm as Sheep Creek on seven of nine dates (Table 2). Auke Bay was more saline than midchannel Sheep Creek at all depths. Seasonal differences between stations were more pronounced in surface salinities than at the 5-m depth (Table 3).

Table 1.—Semiweekly temperature (°C) and salinity (‰) at 1-m depth at five sites near Juneau, Alaska, from April to June 1991.

Date	Amalga Harbor		Auke Bay		Aurora Harbor		Nearshore Sheep Creek		Dupont	
	°C	‰	°C	‰	°C	‰	°C	‰	°C	‰
8 April			3.3	32.6						
12 April	4.0	30.5								
15 April	5.0	27.8	5.1	28.9	4.3	30.0	4.5	31.0	5.6	31.0
18 April	5.1	21.5			4.8	31.0	5.8	30.0	5.6	31.0
22 April	5.8	20.0	5.1	29.4	6.0	29.0	6.7	25.2	6.4	30.1
25 April	6.0	30.0			6.8	29.2	7.3	29.8	7.6	29.2
29 April	6.5	28.5	6.4	27.7	8.0	30.2	8.0	30.1	6.6	30.0
2 May	8.0	27.0			6.4	30.0	7.1	31.0	7.8	30.0
6 May	8.5	27.0	9.5	26.3	8.5	28.5	8.4	25.0	8.4	29.6
10 May	8.9	28.2				25.2		22.0		22.9
13 May	8.0	25.0	8.3	22.8	9.0	25.0	9.2	25.0	9.1	20.0
16 May	9.0	23.0			7.9	26.0	9.4	22.0	9.9	24.0
20 May	9.5	24.0	9.6	20.5	8.2	21.0	8.4	19.0	9.1	20.0
23 May					9.9	21.0	10.2	20.0	10.7	17.0
28 May			9.4	23.6						
3 June			9.4	22.1	8.6	28.0	8.1	24.0	9.6	14.0
6 June					10.3	17.0	10.8	16.0	10.4	17.0
10 June			8.7	20.2	8.5	17.0	9.3	20.0	8.9	20.0
14 June					9.4	24.0	10.4	20.0	10.2	20.0
Mean[a]	7.2	25.4	7.3	25.9	7.3	27.3	7.5	25.9	7.5	26.8
SD[a]	1.6	2.9	1.9	3.3	1.7	3.3	1.6	3.9	1.4	4.8
Mean[b]	7.0	26.0	7.5	25.4	7.8	25.8	8.2	24.4	8.4	24.1
SD[b]	1.8	3.2	2.2	4.0	1.7	4.5	1.7	4.7	1.7	5.8

[a]15 April-20 May

[b]all observations

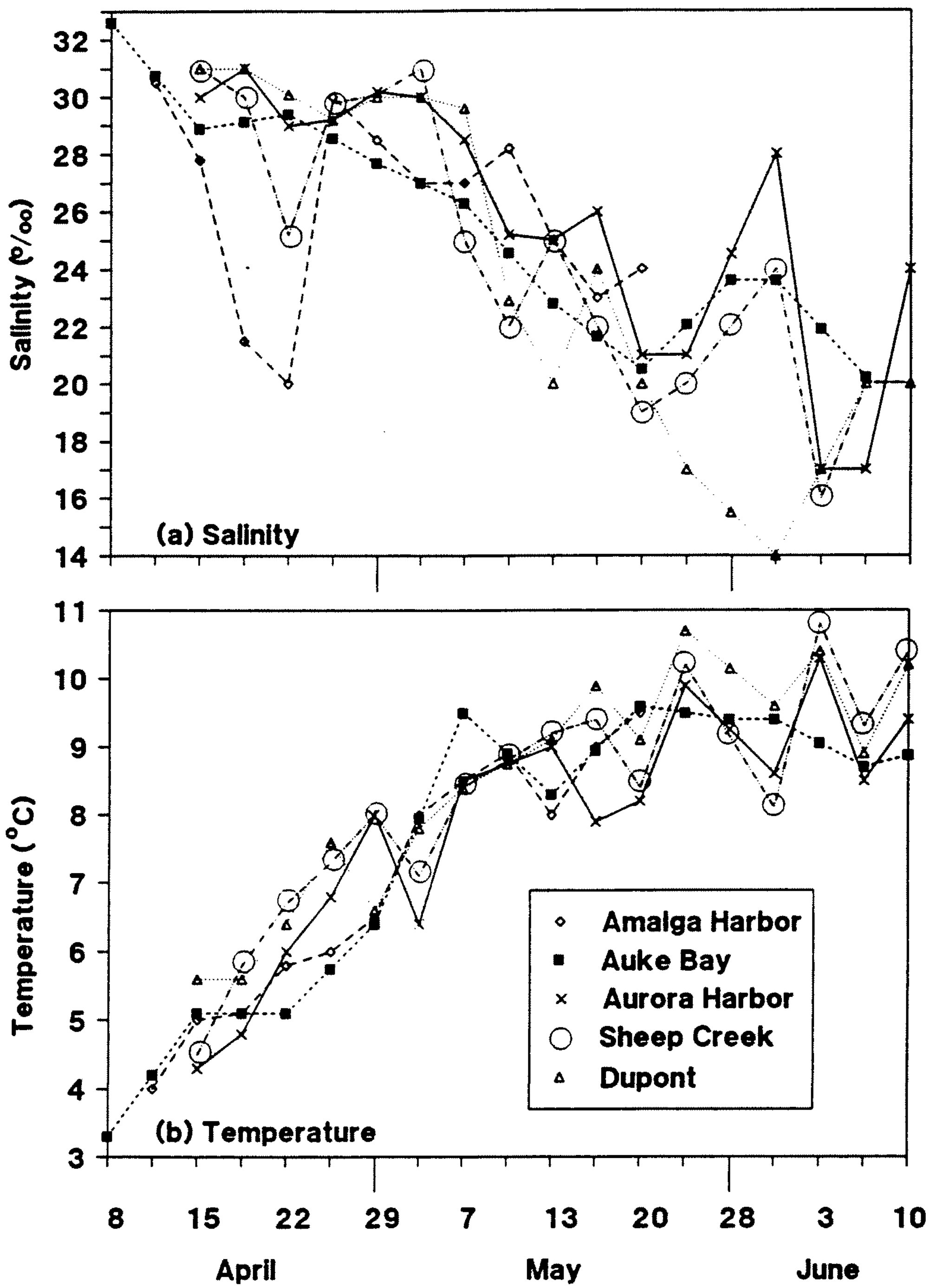

Figure 2.—Biweekly salinity (a) and temperature (b) at 1-m depth, 1991.

Table 2.—Weekly temperature (°C) at three depths at Auke Bay and Sheep Creek (midchannel), Alaska, April to June 1991.

	Auke Bay			Sheep Creek		
	Depth (m)			Depth (m)		
Date[a]	0.5	1	5	0.5	1	5
8 April	3.4[b]	3.3	3.3			
15 April	5.4[b]	5.1	3.8	4.6	4.6	4.0
22 April	5.1	5.1	5.1	7.7	7.2	6.2
29 April	6.6	6.4	5.8	6.0	6.0	5.5
7 May	10.0	9.9	6.5	9.2	9.1	5.8
13 May	8.4	8.3	6.6	7.6	7.6	6.6
20 May	9.5	9.6	7.8	10.0	9.8	6.2
28 May	9.3	9.4	9.0	8.7	8.2	7.3
3 June	9.8	9.4	7.5	9.7	9.6	7.5
10 June	8.8	8.7	8.6	7.8	7.7	6.9
$Mean_{10}$	7.6	7.5	6.4			
SD_{10}	2.2	2.2	1.8			
$Mean_9$	8.1	8.0	6.7	7.9	7.8	6.2
SD_9	1.8	1.8	1.6	1.7	1.6	1.0

[a]Collection dates at Sheep Creek were actually one day later than shown, except 17 April was two days later.

[b]0.5-m depths in Auke Bay on 8 and 15 April were actually 0 m.

Table 3.—Weekly salinity (‰) at three depths at Auke Bay and Sheep Creek (midchannel), Alaska, April to June 1991.

	Auke Bay			Sheep Creek		
	Depth (m)			Depth (m)		
Date[a]	0.5	1	5	0.5	1	5
8 April	33.3[b]	32.6	33.5			
15 April	28.7[b]	28.9	29.6	29.4	30.2	31.5
22 April	29.3	29.4	29.4	25.5	26.0	26.8
29 April	27.7	27.7	28.0	25.4	25.6	26.8
7 May	26.0	26.0	28.3	21.0	21.5	27.3
13 May	22.9	22.8	27.0	18.6	19.1	21.8
20 May	20.3	20.5	23.5	16.2	16.7	25.0
28 May	23.6	23.6	24.5	15.2	16.3	23.9
3 June	22.1	22.1	25.7	15.8	16.1	24.5
10 June	20.2	20.2	20.6	17.0	16.9	22.5
$Mean_{10}$	25.4	25.4	27.0			
SD_{10}	4.1	4.0	3.4			
$Mean_9$	24.5	24.6	26.3	20.5	20.9	25.6
SD_9	3.3	3.3	2.8	4.9	4.9	2.8

[a]Collection dates at Sheep Creek were actually one day later than shown, except 17 April was two days later.

[b]0.5-m depths in Auke Bay on 8 and 15 April were actually 0 m.

Near-surface environmental measurements also differed between the two locations at Sheep Creek. Surface temperature increased steadily over the season nearshore, but erratically at midchannel. By contrast, seasonal salinity declined erratically nearshore, but steadily at midchannel. At 1-m depth, the direction of the temperature difference between the two locations alternated weekly (Tables 1, 2); offshore Sheep Creek was warmer than nearshore Sheep Creek in weeks when the day's tidal exchange was high, and was cooler in weeks when the tidal exchange was relatively low. The offshore area was almost always less saline than nearshore. This led to a more pronounced difference between the environments of midchannel Sheep Creek and Auke Bay than between nearshore Sheep Creek and Auke Bay. Weekly fluctuations in surface environmental data from the Sheep Creek area presumably relate to the dominance of a tidal circulation pattern in Gastineau Channel and relatively high precipitation compared to Auke Bay[2].

Zooplankton Abundance

The seasonal pattern of zooplankton abundance differed between Auke Bay and Sheep Creek in both magnitude and timing (Table 4; Fig. 3). The bloom in secondary production began earlier in Auke Bay than in Gastineau Channel. In May, zooplankton were approximately two to five times more abundant in Auke Bay than at Sheep Creek. Average numbers in Auke Bay increased by a factor of ten over the season, from less than 1,800 organisms$\cdot m^{-3}$ in mid-April to a peak of approximately 19,000 organisms$\cdot m^{-3}$ in early June. Numbers had not begun to decline when sampling was terminated. The earliest samples from Sheep Creek revealed a decline in abundance, primarily attributed to barnacle larvae. Abundance at Sheep Creek was uniformly low (2,000-2,300 organisms$\cdot m^{-3}$) from 22 April through 7 May; only once (15 April) did the numbers of zooplankton exceed those at Auke Bay. Numbers increased fivefold by early June, leveling off at approximately 11,000 organisms$\cdot m^{-3}$ (Fig. 3). This pattern of differences between sites was maintained for the major zooplankton components—calanoids and euphausiid larvae—but was not consistent for barnacle larvae (Table 4; Fig. 4).

Plankton Settled Volumes

The timing and peak abundance of total plankton settled volumes differed between the northern and southern stations (Table 5; Fig. 5). Total plankton settled volumes reached pronounced peaks at Amalga Harbor and Auke Bay, but sustained a slow increase over the season in Gastineau Channel. Mean total plankton settled volumes peaked in May at Amalga Harbor, two weeks earlier than at Auke Bay, but did not peak until early June at Gastineau Channel stations. Total settled volumes reached the highest magnitudes at the northern stations, 43-64 ml$\cdot m^{-3}$ vs. 19-32 ml$\cdot m^{-3}$ (Fig. 5).

Plankton populations bloomed rapidly in Auke Bay in mid-April, when surface temperatures were consistently above 5°C (Fig. 6a). At Sheep Creek, however, although seasonal warming occurred earlier than at Auke Bay, plankton populations did not immediately respond to increasing temperatures (Figs. 2, 6b). Total settled volumes

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[2]Leif Lee, Chief Meteorologist, unpubl. data. National Weather Service, NOAA, Juneau, AK 99801.

roughly tracked zooplankton abundance only during the secondary bloom periods, 22 April to 20 May at Auke Bay and 7 May to 3 June at Sheep Creek; however, zooplankton remained abundant when total settled volume declined in late May, reflecting the lag between phytoplankton and zooplankton peaks (Fig. 6).

The density of the phytoplankton bloom interfered with our ability to measure zooplankton settled volumes (Table 6). For example, during the bloom, samples from Auke Bay were a denser green than those from Sheep Creek, indicating a greater density of phytoplankters; zooplankters were interspersed in this green matrix rather than distributed in an even band. Because of such dispersion, it was not possible to obtain an accurate reading of zooplankton settled volumes at Auke Bay for 5 of the 10 sample weeks, and estimates of zooplankton settled volume from the other stations are considered subjective approximations (Table 6). Therefore, zooplankton settled volume was not a reliable measure and could not be used to predict zooplankton abundance.

Table 4.—Density (mean number·m^{-3} and standard deviation (SD)) of major zooplankton categories at Auke Bay and Sheep Creek, Alaska, April to June 1991.

	Auke Bay		Sheep Creek		Auke Bay		Sheep Creek	
Date	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Calanoids				Barnacles			
8 April	1,107	977			557	333		
15 April	782	76	861	63	295	30	4,036	419
22 April	949	126	482	142	457	161	913	210
29 April	2,530	278	578	113	3,539	1,222	1,230	497
7 May	4,508	1,773	467	28	1,748	985	1,120	97
13 May	8,721	666	2,307	1,254	1,813	339	1,462	405
20 May	9,136	1,077	2,706	424	1,379	410	1,713	187
28 May	6,851	1,140			3,224	296		
3 June	7,611	2,075	2,000	758	792	253	2,068	742
10 June	6,596	450	923	277	5,564	671	6,064	1,870
	Euphausiids				Total zooplankton			
8 April	0				1,782	1,344		
15 April	0		0		1,193	99	5,623	712
22 April	536	65	10	9	2,486	399	2,025	698
29 April	2,215	134	23	5	9,283	1,719	2,266	749
7 May	2,828	771	75	29	10,395	4,171	2,107	196
13 May	2,898	594	675	218	16,937	1,338	5,732	2,541
20 May	2,481	585	1,045	250	15,895	2,124	8,911	919
28 May	2,855	382			16,204	1,373		
3 June	299	73	584	314	11,655	2,875	10,827	5,383
10 June	776	311	22	9	18,661	2,512	11,250	5,396

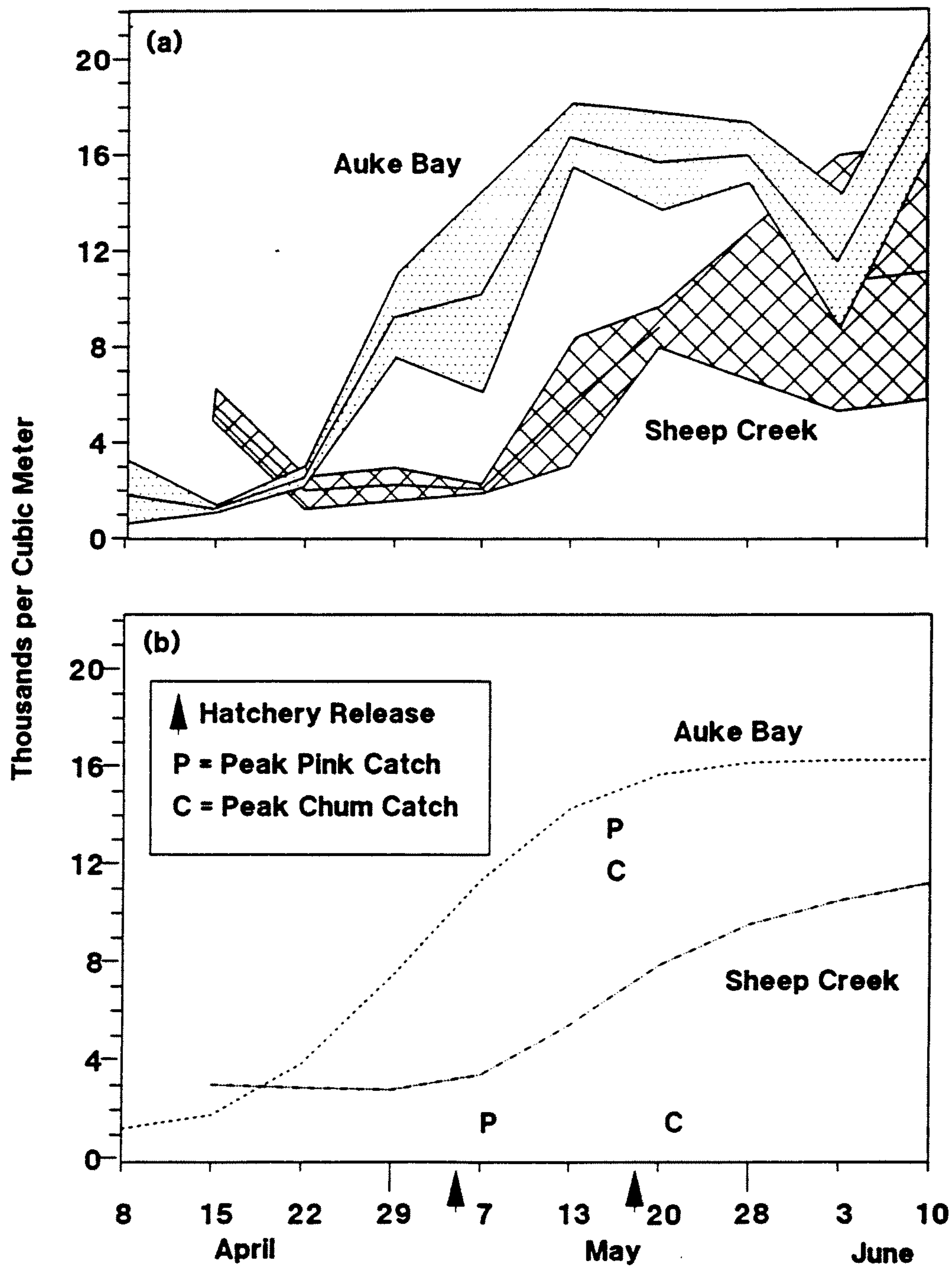

Figure 3.—Mean and standard deviation of total numbers of zooplankters (**a**), and smoothed mean number (**b**), 1991, with dates of hatchery releases and peak fry abundance in nearshore areas.

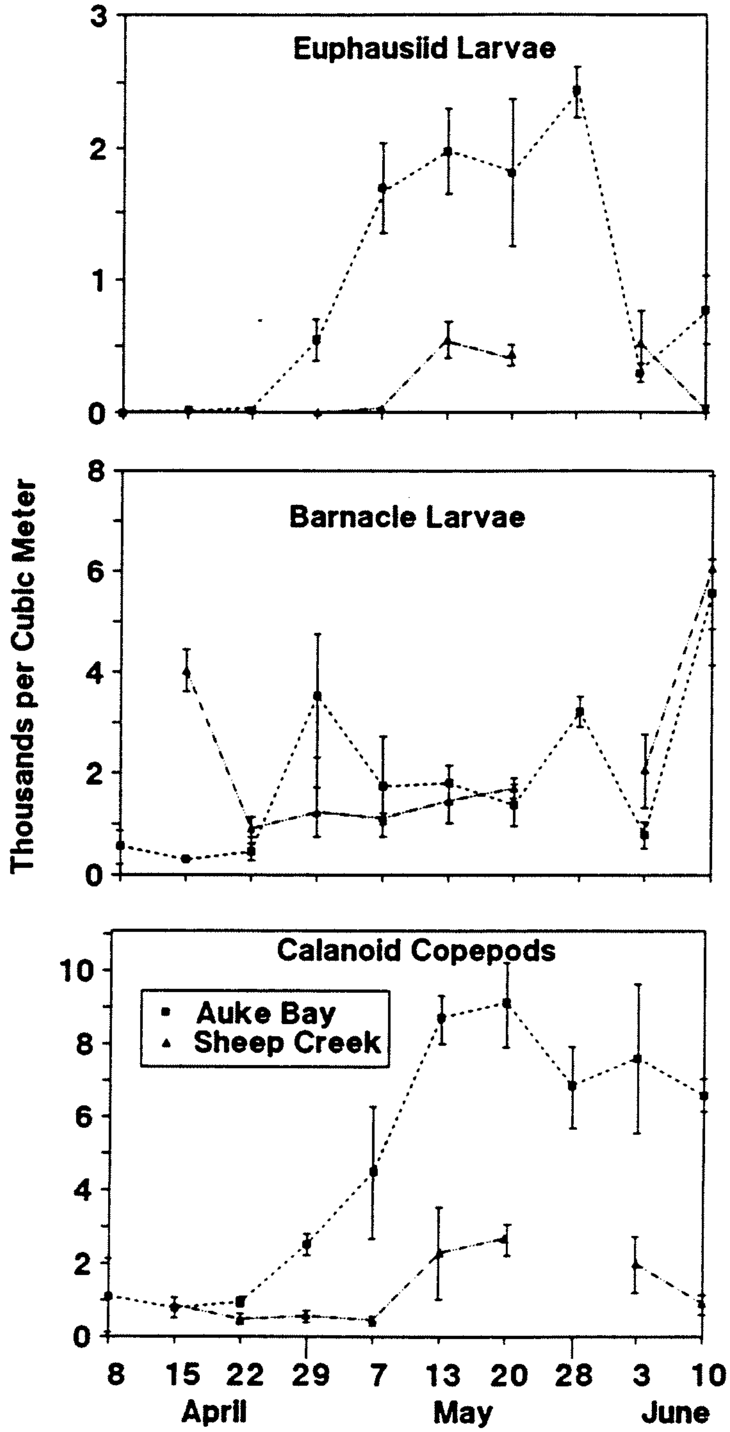

Figure 4.—Mean ± standard error of major zooplankton categories, 1991.

Table 5.—Total plankton settled volumes (mean ml·m^{-3} and standard deviation (SD)) from five sites near Juneau, Alaska, from April to June 1991.

Date	Amalga Harbor		Auke Bay		Aurora Harbor		Sheep Creek		Dupont	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
8 April			14.0	10.1						
12 April	9.8	1.5								
15 April	8.5	0.7	3.0	1.5	1.6	0.1	6.8	0.7	5.0	0.1
18 April	15.7	2.0			1.2	0.3	3.1	0.1	7.1	1.5
22 April	47.5	8.2	13.2	0.7	1.3	0.5	6.5	0.4	6.3	1.0
25 April	17.7	3.1			1.6	0.4	2.7	0.5	7.6	0.7
29 April	27.2	1.5	7.9	1.8	3.1	0.7	4.7	2.2	14.9	2.0
2 May	48.4	3.4			1.3	0.5	6.9	1.6	7.0	1.0
6 May	63.7	0	22.7	0.9	0.8	0.2	5.1	1.3	4.5	0.6
10 May	57.3	5.8			8.2	3.0	19.1	6.6	17.2	7.8
13 May	45.4	5.2	24.6	1.5	6.1	0.3	6.7	2.6	14.9	6.2
16 May	21.4	2.0			2.4	0.5	11.6	3.4	11.7	1.6
20 May	6.1	3.8	43.3	2.2	4.4	2.6	15.7	4.1	15.2	1.0
23 May					4.1	0.8	12.1	3.2	20.0	0.7
28 May			5.6	1.4						
3 June			6.5	0.6	1.8	0.5	12.4	8.9	6.5	1.0
6 June					18.9	4.5	32.3	7.2	30.6	4.4
10 June			7.7	1.2	7.6	2.6	9.1	3.3	9.1	3.6
14 June					4.0	2.3	10.2	3.8	2.4	0.3
Seasonal[a]	33.1	21.4	19.1	13.3	2.9	2.1	7.6	4.2	10.1	5.4
Seasonal[b]			7.8	11.4	3.6	4.5	8.7	8.1	9.5	8.0

[a]15 April-20 May

[b]all observations

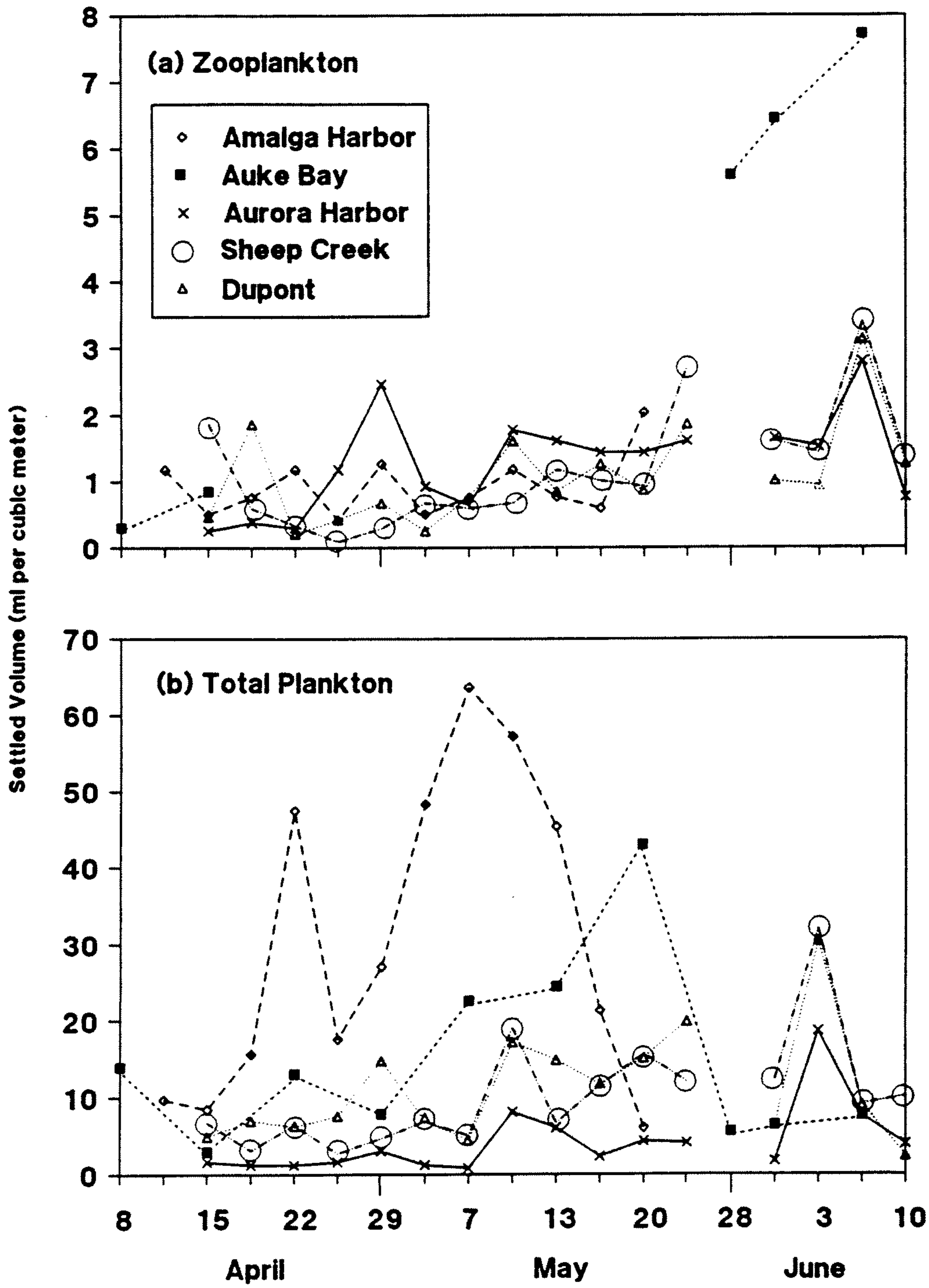

Figure 5.—Zooplankton (a) and total plankton (b) settled volumes, 1991.

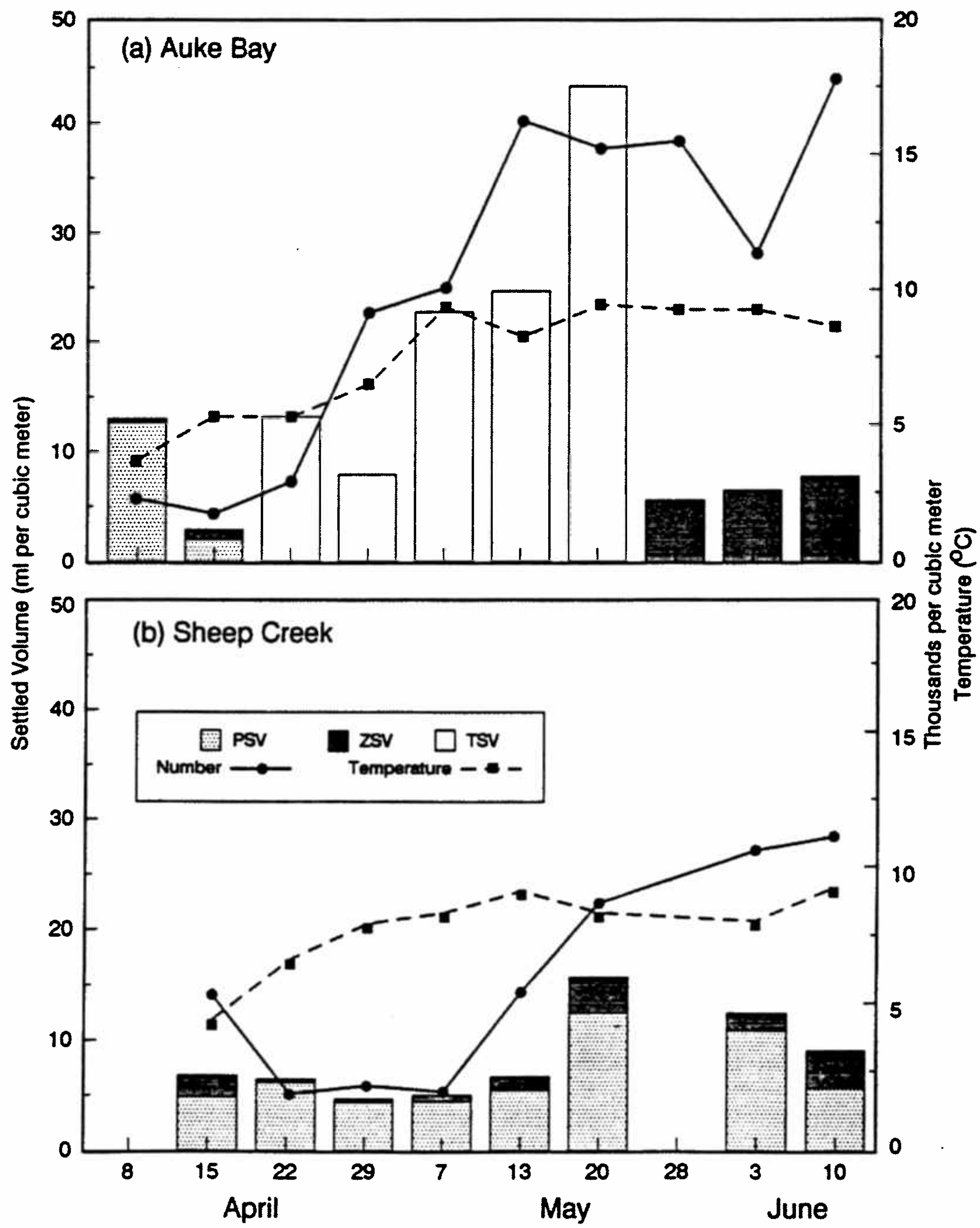

Figure 6.—Zooplankton abundance (No.), total settled volume (TSV), zooplankton settled volume (ZSV), and temperature (°C), 1991.

Table 6.—Zooplankton settled volumes (mean $ml \cdot m^{-3}$ and standard deviation (SD)) from five sites in the vicinity of Juneau, Alaska, from April to June 1991.

Date	Amalga Harbor		Auke Bay		Aurora Harbor		Sheep Creek		Dupont	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
8 April			0.3	0.2						
12 April	1.2	0.1								
15 April	0.5	0	0.9	0.5	0.3	0.1	1.9	0.4	0.5	0.1
18 April	0.8	0.3			0.4	0	0.6	0.1	1.9	0.5
22 April	1.2	0.1	*	*	0.3	0.2	0.3	0.2	0.2	0.1
25 April	0.4	0.3			1.2	0.4	0.1	0.1	0.4	0.2
29 April	1.3	0	*	*	2.5	0.4	0.3	0.1	0.7	0.1
2 May	0.5	0			0.9	0.3	0.7	0.1	0.3	0
6 May	0.8	0	*	*	0.6	0.1	0.6	0.1	0.8	0.3
10 May	1.2	0.1			1.8	0	0.7	0.3	1.6	0.8
13 May	0.8	0.3	*	*	1.6	0.1	1.2	0.1	0.9	0.2
16 May	0.6	0.1			1.4	0.2	1.0	0.3	1.3	0.3
20 May	2.0	1.0	*	*	1.4	0.2	0.9	0.3	0.9	0.2
23 May					1.6	0.4	2.7	0.3	1.9	0.2
28 May			5.6	1.4						
3 June			6.5	0.6	1.7	0.4	1.6	0.4	1.0	0.3
6 June					1.5	0.4	1.4	0.3	0.9	0.2
10 June			7.7	1.2	2.8	0.9	3.4	1.5	3.1	1.7
14 June					0.8	0.5	1.4	0.6	1.3	0
Seasonal[a]	0.9	0.5	*	*	1.1	0.7	0.8	0.5	0.8	0.6
Seasonal[b]	0.9	0.5	*	*	1.4	0.9	1.2	1.0	1.1	0.9

[a] 15 April-20 May

[b] all observations

*Zooplankton settled volumes not readable.

Zooplankton Percentage Composition

The percentage composition of zooplankton differed among the five stations in both magnitude and seasonality (Table 7; Fig. 7). Seasonal patterns in the percentage composition of a given taxon differed between the northern and southern stations, but were similar within areas. The dominant taxa at all locations were barnacle larvae, calanoid copepods, and euphausiid eggs and larvae. Together these made up a minimum of 55-63% of total zooplankton at the Gastineau Channel stations and a minimum of 70-78% at the northern stations (Table 7). Other taxa usually occurred briefly and formed small proportions of the total zooplankton (Fig. 7). Appendix D presents a complete species composition list for the season.

The proportion of calanoids initially peaked in early April at the northern stations, two to four weeks earlier than at the southern stations (Table 7). Following a brief decline in production in late April, the proportion of calanoids increased throughout May at Amalga Harbor and Auke Bay, as a succession of species contributed to the total (Appendix D; Coyle et al. 1990). Calanoids usually made up a larger proportion of the zooplankton at the northern stations, especially at Auke Bay.

Barnacles were proportionally more abundant in Gastineau Channel than in Auke Bay or Amalga Harbor (Table 7). Peak percentages of barnacle larvae occurred in April at all locations. Barnacles were uniformly important at Aurora Harbor; second peaks were observed at Dupont in mid-May, and at Auke Bay and Sheep Creek in June.

Euphausiid production began in April and continued as barnacle production declined (Table 7). Euphausiids occurred earlier, were present longer, and were proportionally more abundant at the northern stations than at the southern stations. Euphausiids were virtually absent at Aurora Harbor.

DISCUSSION

Environmental conditions at Amalga Harbor and Auke Bay differed from Gastineau Channel. Temperature and salinity patterns reflected the proximity of fresh water, seasonal runoff, and water circulation patterns. Although temperatures at the southern stations were higher than at the northern stations early in the season, the zooplankton bloom in Gastineau Channel lagged behind the northern stations by approximately two weeks. Within Gastineau Channel, salinities were consistently highest at the northernmost station, where relatively little fresh water is recirculated. Salinities were lower at the southernmost stations, where major sources of fresh water combined with strong tidal exchanges. The difference between nearshore and midchannel environments of Sheep Creek further indicated the influence of circulation patterns. Greater current velocities in the channel than in the nearshore region of Sheep Creek have previously been reported (Bureau of Land Management 1991). These environmental differences can influence zooplankton distribution.

From the patterns of zooplankton abundance, composition, and total settled volume, we conclude that feeding conditions for salmon fry varied among the study locations. Neither temperature nor settled volume measurements were adequate indices of feeding conditions. Food resources were available sooner, lasted longer, and were more abundant at the northern stations than in Gastineau Channel (the southern stations).

Table 7.—Numerical percentage composition of zooplankters collected at five sites in the vicinity of Juneau, Alaska, from April to June 1991. Barn. = barnacle larvae, Calan. = calanoid copepods, Euph. = euphausiid eggs and larvae, Larv. = larvaceans, Moll. = juvenile mollusks, Oth. = other, Poly. = juvenile polychaetes.

Date	Barn.	Calan.	Euph.	Larv.	Moll.	Oth.	Poly.
			Amalga Harbor				
18 April	29.6	45.8	0.6	4.7	1.2	13.4	4.7
22 April	34.3	33.3	17.2	0	0	11.2	4.0
29 April	20.5	20.0	45.3	0.9	1.1	10.6	1.6
6 May	5.5	32.4	49.6	1.5	0.6	8.3	2.1
13 May	2.7	37.4	49.1	2.2	0.8	6.8	1.0
20 May	2.4	50.1	39.3	1.8	0.6	5.5	0.3
			Auke Bay				
8 April	31.3	62.1	0	0	0.3	1.3	5.0
15 April	24.7	65.5	0	2.6	0.2	5.0	1.9
22 April	18.4	38.1	21.6	1.9	0.9	13.8	5.3
29 April	38.1	27.3	23.9	1.3	0.8	4.3	4.4
7 May	17.0	43.8	27.5	1.7	0.9	4.4	4.9
13 May	10.7	51.5	23.0	2.3	1.1	8.2	3.2
20 May	8.7	57.5	15.6	5.6	0.4	8.8	3.5
28 May	19.9	42.3	17.6	8.1	2.1	8.1	1.8
3 June	6.8	65.3	2.6	8.6	6.6	8.8	1.4
10 June	29.8	35.3	4.2	1.5	20.1	7.7	1.4
			Aurora Harbor				
18 April	48.7	26.9	0	0	0	16.0	8.4
22 April	32.2	24.4	0	6.1	0	20.1	17.2
29 April	38.8	39.1	0	0.2	0	14.0	7.9
6 May	47.8	33.9	0.4	0.5	0	13.3	4.1
13 May	37.0	19.6	2.0	0.8	0	30.8	9.8
20 May	47.3	18.2	0	0.6	0	28.1	5.8
3 June	28.1	26.1	0.6	4.3	12.9	22.0	6.0
11 June	32.6	26.0	0.2	0	18.2	16.1	6.9
			Sheep Creek				
22 April	45.1	23.8	0.3	4.0	0.1	16.1	10.7
29 April	54.3	25.5	1.0	1.6	0.1	13.9	3.7
7 May	53.1	22.2	3.5	2.0	0.6	10.4	8.2
13 May	25.5	40.2	11.8	2.6	0.7	15.9	3.3
20 May	19.2	30.4	11.7	7.1	0.5	23.5	7.6
3 June	19.1	18.5	5.4	4.2	1.7	50.7	0.5
11 June	53.9	8.2	0.2	4.5	19.1	12.4	1.7
			Dupont				
18 April	67.0	23.0	0	0.2	0	4.9	4.9
22 April	45.4	20.4	0.9	2.3	1.0	17.1	12.9
29 April	17.3	61.3	3.3	1.0	0.3	13.5	3.3
6 May	31.7	9.4	50.5	1.2	0	3.8	3.4
13 May	40.3	22.3	18.4	1.4	1.0	13.8	2.8
20 May	21.1	30.5	13.6	5.9	0.7	23.2	5.0
3 June	17.3	24.3	7.3	7.7	14.9	21.3	7.2
11 June	15.4	54.3	3.5	3.8	11.6	8.7	2.7

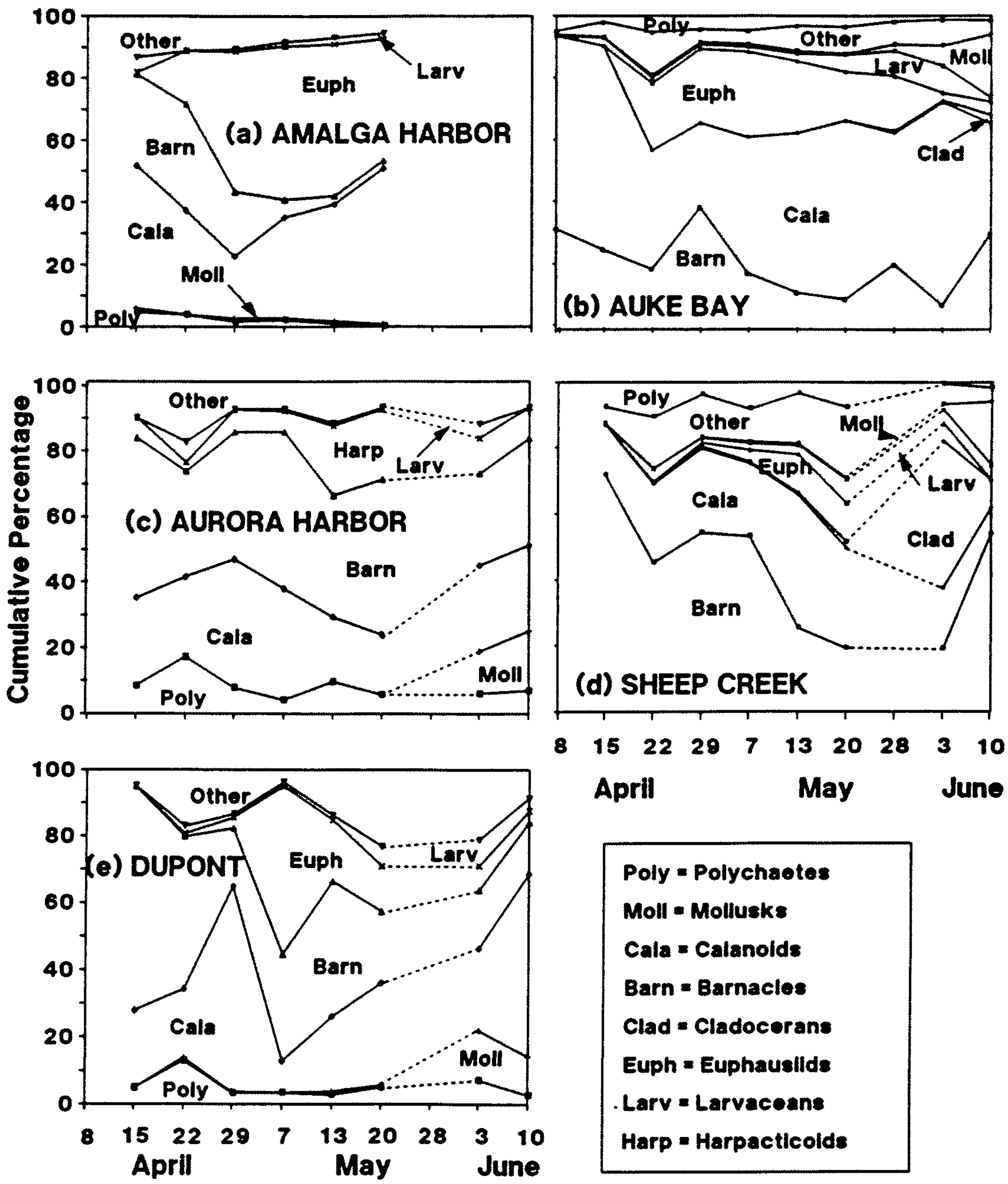

Figure 7.—Cumulative percentage composition of zooplankton at five sites near Juneau, Alaska, April to June 1991. The percentage of a taxon over time is represented by the area labeled between 2 lines.

Similar taxa were available, but important prey items were proportionally more abundant at the northern stations. Calanoid copepods, a preferred planktonic prey of salmon fry, were more abundant at Auke Bay than at Sheep Creek. Euphausiid larvae, an alternative prey, were plentiful at Amalga Harbor and Auke Bay, but contributed little or nothing to the food resources available in Gastineau Channel.

DIPAC releases of fry from Gastineau Hatchery in the first and third weeks of May were followed by peak catches of fry in nearshore areas of Gastineau Channel; thus the releases corresponded with the steepest increasing phase of the zooplankton bloom at Sheep Creek. However, fry did not reside in lower Gastineau Channel, but moved quickly out of the area; peak catches of salmon fry, 5- to 10-fold greater than peak catches in the channel, were observed in Auke Bay within a few days of their release in the channel (Celewycz et al., in prep.), corresponding with the earlier peak in zooplankton at Auke Bay. If differences in feeding conditions are affecting survival rates of Gastineau Channel fish, then the mechanism operates within a very short period.

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APPENDICES

Appendix A.—Number released and percent return of pink salmon at Auke Creek[a] and Sheep Creek[b] hatcheries, brood years 1980-1989. Auke Creek fish include wild pink salmon only[c].

Brood year	Auke Creek Fry released	Auke Creek Percent return	Gastineau Channel[d] Fry released (millions)	Gastineau Channel[d] Percent return
1980	83,526	8.3	1.14	0.53
1981	253,273	9.8[c]	9.00	0.89
1982	164,784	3.1	14.49	0.37
1983	169,552	14.2	32.01	1.34
1984	110,000	1.9	14.94	0.13
1985	70,459	10.1	35.70	2.16
1986	26,253	26.9	8.40	0.24
1987	74,912	6.0	11.80[e]	0.11
			29.80[f]	0.22
1988	74,170	26.1	15.00[e]	0.39
1989	98,355	6.8	9.67[e]	0.85
			17.96[f]	1.45

[a]Source: J. Taylor, Auke Bay Laboratory, NMFS.

[b]Sources: DIPAC Tech. Rev. Comm. 1990; R. Mattson, DIPAC, 2697 Channel Dr., Juneau, AK 99801, pers. commun.

[c]Number available only for hatchery and wild fish combined.

[d]Releases before 1988 were only at Sheep Creek.

[e]Gastineau Hatchery releases.

[f]Sheep Creek releases.

Appendix B.—Weekly temperature (°C) at eight depths at Auke Bay, April to June 1991, and seasonal means and standard deviations (SD).

Date	Depth (m)							
	0.5	1	2	3	4	5	10	15
8 April	3.4	3.3	3.3	3.3	3.3	3.3	3.4	3.3
15 April	5.4	5.1	5.1	4.4	3.7	3.8	3.4	3.2
22 April	5.1	5.1	5.1	5.1	5.1	5.1	5.0	4.0
29 April	6.6	6.4	6.4	6.2	5.8	5.8	5.4	4.8
7 May	10.0	9.9	8.6	7.8	7.1	6.5	5.3	4.1
13 May	8.4	8.3	7.7	7.0	6.7	6.6	5.7	4.8
20 May	9.5	9.6	9.6	9.3	8.7	7.8	5.4	4.7
28 May	9.3	9.4	9.1	8.9	8.9	9.0	7.3	5.2
3 June	9.8	9.4	9.4	9.3	9.3	7.5	6.5	6.4
10 June	8.8	8.7	8.7	8.9	8.7	8.6	7.9	6.4
Mean	7.6	7.5	7.3	7.0	6.7	6.4	5.5	4.7
SD	2.2	2.2	2.1	2.1	2.1	1.8	1.4	1.1

Appendix C.—Weekly salinity (‰) at eight depths at Auke Bay, April to June 1991, and seasonal means and standard deviations (SD).

Date	Depth (m)							
	0.5	1	2	3	4	5	10	15
8 April	33.3	32.6	33.2	33.3	32.8	33.5	33.3	33.1
15 April	28.7	28.9	28.9	29.5	29.9	29.6	30.2	30.1
22 April	29.3	29.4	29.4	29.3	29.3	29.4	29.4	30.2
29 April	27.7	27.7	27.7	27.8	28.0	28.0	28.4	28.9
7 May	26.1	26.3	26.9	27.3	27.7	27.7	27.9	27.2
13 May	26.0	26.0	27.2	27.9	28.2	28.3	29.1	29.1
20 May	22.9	22.8	24.1	25.4	26.6	27.0	28.9	29.8
28 May	20.3	20.5	20.9	21.7	22.6	23.5	29.0	29.6
3 June	22.1	22.1	22.1	22.6	22.4	25.7	27.4	27.7
10 June	20.2	20.2	20.2	20.2	20.3	20.6	23.2	27.9
Mean	25.4	25.4	25.8	26.2	26.5	27.0	28.6	29.6
SD	4.1	4.0	4.0	3.9	3.7	3.4	2.4	1.4

Appendix D.—Seasonal occurrence of taxa from 20-m vertical plankton hauls at five sites near Juneau, Alaska, April-June 1991. (D = Dupont, SC = Sheep Creek, AUR = Aurora Harbor, AB = Auke Bay, AH = Amalga Harbor; A = April, M = May, J = June.

	Site				
Taxon	D	SC	AUR	AB	AH*
RADIOLARIA	MJ	MJ	MJ	MJ	M
CNIDARIA (Medusa)	AMJ	A	AMJ	AMJ	M
POLYCHAETA					
Unidentified					
larva	AMJ	AMJ	AMJ	AMJ	AM
juvenile	AMJ	AMJ	AMJ	AMJ	AM
adult		M			
MOLLUSCA					
Gastropoda					
egg		A			
juvenile	AMJ	AMJ	MJ	AMJ	AM
Limacina helicina	J		J	J	
Bivalvia					
juvenile	AMJ	MJ	J	MJ	
CLADOCERA					
Evadne sp.				AMJ	
Podon sp.	AMJ	AMJ	AMJ	AMJ	M
COPEPODA					
CALANOIDA					
Unidentified					
nauplius	MJ	AMJ	AMJ	AMJ	AM
large copepodite	MJ	MJ	MJ	MJ	M
small copepodite	AMJ				
adult				AM	
Calanus marshallae					
copepodite	AM	AM	AM	AMJ	AM
adult	AM	A	A	AMJ	M
Neocalanus plumchrus					
copepodite	AM	AMJ	AM	AMJ	AM
adult	M			A	
Centropages abdominalis					
copepodite	AM	AMJ	AM	AMJ	AM
adult	AM	AMJ	AMJ	AMJ	M
gravid female				J	
Metridia pacifica					
copepodite	J	A J	A J	AMJ	M
adult	J		A J	AMJ	A
Metridia okhotensis					
copepodite			M	AM	
adult			M	A	

Appendix D.—Continued.

Taxon	Site				
	D	SC	AUR	AB	AH*
CALANOIDA, continued.					
Pseudocalanus spp.					
copepodite	AMJ	AMJ	AMJ	AMJ	AM
adult	AMJ	AMJ	AMJ	AMJ	AM
gravid female				AMJ	
Acartia clausi					
copepodite	AMJ	AMJ	AMJ	AMJ	AM
adult	AMJ	MJ	AMJ	AMJ	AM
gravid female			A		
Acartia longiremis					
copepodite	J	MJ	MJ	MJ	M
adult	MJ	AMJ	MJ	MJ	M
Tortanus discaudatus					
copepodite	A	AM		AMJ	M
adult	AM	AMJ	AMJ	AMJ	AM
HARPACTICOIDA					
Unidentified					
ovisac		M	MJ		
copepodite		AM		M	
adult	M	AM	AM	AMJ	
Harpacticus sp.		AMJ			
copepodite		AM			
adult female		AM	M		
adult male		J	M	A	
Zaus sp.		MJ	M		
Tisbe spp.					M
copepodite		AMJ	AM	M	
adult	AM	AMJ	AMJ	AMJ	M
gravid female	M	AMJ	AMJ	A J	
Laophontidae				M	M
Dactylopodia sp.	M				
CYCLOPOIDA					
Oithona sp.					
copepodite		MJ	AM	AMJ	AM
adult	AMJ	AMJ	AMJ	AMJ	AM
gravid female	M		A	AMJ	M
MONSTRILLIDA	J				
CIRRIPEDIA					
Unidentified					
nauplius	AMJ	AMJ	AMJ	AMJ	AM
cypris	AMJ	MJ	AMJ	AMJ	M
CUMACEA					
Unidentified	M				
ISOPODA					
Unidentified					
juvenile		A			

Appendix D.—Continued.

Taxon	Site				
	D	SC	AUR	AB	AH*
AMPHIPODA					
Hyperiidea					
Unidentified		A	J	J	AM
EUPHAUSIACEA					
Unidentified					
egg	AMJ	AMJ	M	AM	AM
nauplius	MJ	AMJ	MJ	AMJ	AM
calyptopis	MJ	AMJ	MJ	MJ	M
furcilia	J	A J	J	AMJ	A
DECAPODA					
Unidentified					
larva	AMJ	AMJ	MJ	AMJ	M
ECHINODERMATA					
Unidentified					
larva	AMJ	AMJ	AMJ	AMJ	AM
PHORONIDAE					
Unidentified					
larva		M			
ECTOPROCTA					
Unidentified					
cyphonautes larva	AMJ	AMJ	A	AMJ	AM
CHAETOGNATHA					
Unidentified	A	A	M	AMJ	AM
LARVACEA					
Oikopleura dioica	AMJ	AMJ	AMJ	AMJ	AM
Fritillaria sp.	MJ	MJ	MJ	MJ	M
OSTEICHTHYES					
Unidentified					
egg	AMJ	AMJ	AMJ	AMJ	AM
larva	J	AMJ		AMJ	
UNIDENTIFIED					
Invertebrate egg	AM	AM	A	AM	AM
Invertebrate larva		J		J	

*Samples were not collected in June in Amalga Harbor.