



Feeding ecology of larval fishes in Lake Roosevelt, Washington  
by Mary P Wunderlich

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management  
Montana State University  
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Abstract:

Food-habits, feeding selectivity, and diet overlap analyses were conducted for larval walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*), sculpins (*Cottus* spp.), and suckers (*Catostomus* spp.) collected from Lake Roosevelt, Washington, May through July 1982. Larval fishes were sampled weekly with 0.5-m tow nets from shoreline sites at four stations. Fish sampled ranged from 4.0 to 27.0 mm TL. Zooplankton were collected concurrently with Miller samplers to characterize food availability. Copepods were dominant in zooplankton samples in June and cladocerans were dominant in July. Copepods were the most abundant food items in walleye, yellow perch, and sculpin stomachs at all stations.

Larval walleye from 9.0-24.0 mm TL also showed dependence on larval fishes as prey. Cladocerans were important as food items only to larval suckers, which fed almost exclusively on *Bosmina* and *Chydorus*. Feeding selectivity, determined by Wilcoxon's nonparametric signed-rank analysis, indicated that walleye selected for calanoid copepods, yellow perch for copepods and *Daphnia*, sculpins for cyclopoid copepods and *Daphnia*, and suckers for *Bosmina*, *Chydorus*, and cyclopoid copepods. Schoener's niche overlap analysis indicated significant diet overlap between walleye and yellow perch and between yellow perch abundance, which could indicate potential competitive interaction.

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A thesis submitted in partial fulfillment  
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of

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in

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MONTANA STATE UNIVERSITY  
Bozeman, Montana

April 1985

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April 12, 1985  
Date

Robert B. White  
Chairperson, Graduate Committee

Approved for the Major Department

12 April 1985  
Date

Robert S. Moore  
Head, Major Department

Approved for the College of Graduate Studies

12 April 1985  
Date

W. B. Malone  
Graduate Dean

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## ABSTRACT

Food-habits, feeding selectivity, and diet overlap analyses were conducted for larval walleye (Stizostedion vitreum), yellow perch (Perca flavescens), sculpins (Cottus spp.), and suckers (Catostomus spp.) collected from Lake Roosevelt, Washington, May through July 1982. Larval fishes were sampled weekly with 0.5-m tow nets from shoreline sites at four stations. Fish sampled ranged from 4.0 to 27.0 mm TL. Zooplankton were collected concurrently with Miller samplers to characterize food availability. Copepods were dominant in zooplankton samples in June and cladocerans were dominant in July. Copepods were the most abundant food items in walleye, yellow perch, and sculpin stomachs at all stations. Larval walleye from 9.0-24.0 mm TL also showed dependence on larval fishes as prey. Cladocerans were important as food items only to larval suckers, which fed almost exclusively on Bosmina and Chydorus. Feeding selectivity, determined by Wilcoxon's nonparametric signed-rank analysis, indicated that walleye selected for calanoid copepods, yellow perch for copepods and Daphnia, sculpins for cyclopoid copepods and Daphnia, and suckers for Bosmina, Chydorus, and cyclopoid copepods. Schoener's niche overlap analysis indicated significant diet overlap between walleye and yellow perch and between yellow perch abundance, which could indicate potential competitive interaction.

## INTRODUCTION

Walleye (Stizostedion vitreum) and yellow perch (Perca flavescens) were introduced into the Columbia River in the late 1940's (Brege 1981). The introduction of these species may have resulted in interactions with each other or with native species related to habitat usage, predation, or feeding. Feeding interactions, especially during larval stages, have been known to affect the growth and survival of walleye and yellow perch (Siefert 1972, Forney 1974, Clady 1977, Keast 1979). The transition of larvae from endogenous to exogenous feeders results in a "critical period" (Bagenal 1978) when availability of suitable prey, the physiological switch to a new energy source, and behavioral change have important effects on survival.

Larval fish utilize zooplankton as a major food source and are selective feeders (Siefert 1972, Wong and Ward 1972, Hansen and Wahl 1981, Crecco and Blake 1983, Raisanen and Applegate 1983). The density and diversity of available zooplankton regulate selectivity (Ivlev 1961), are directly linked to fish survival during the critical period, and can significantly affect the ultimate success of year classes (Braum 1967, Thayer et al. 1974).

Knowledge of the food habits, interspecific

interactions, prey availability, and food selectivity of larval fishes is an essential part of baseline and comparative information and management research. Food habits of larvae of sympatric walleye and yellow perch have been described for other areas (Maloney and Johnson 1957, Bulkley et al. 1976), but have not been investigated in the Columbia River system, which is inhabited by suckers and sculpins (Catostomus macrocheilus, C. columbianus, Cottus asper) not found elsewhere in the range of these species.

Walleye has become an economically important sport fish in Columbia River reservoirs, generating 1.5 to 2.5 million dollars annually in Lake Roosevelt alone (Beckman et al. 1984). This economic significance and a lack of fishery-related information regarding Lake Roosevelt prompted the initiation of a fisheries and limnology study by the U.S. Fish and Wildlife Service in 1980. This thesis was a part of that study.

This research addressed the feeding ecology of larval walleye, yellow perch, sculpins, and suckers in Lake Roosevelt. Specific objectives involved the evaluation of food habits and diet overlap to determine the presence and degree of interspecific interaction, and the analysis of zooplankton availability and utilization to characterize feeding selectivity patterns. Results of the study were

included in the evaluation and formulation of recommendations by the U.S. Fish and Wildlife Service to protect and enhance the fishery resource of Lake Roosevelt (Beckman et al. 1984).

#### DESCRIPTION OF STUDY AREA

Lake Roosevelt, the largest lake in the state of Washington, includes that portion of the Columbia River and its tributaries impounded by Grand Coulee Dam, which was completed in 1941 (Figure 1). Water level in the reservoir fluctuates annually, with minimum pool elevation occurring in April and full elevation occurring from July through December. Surface elevation is lowered 25 m between December and April to accommodate spring runoff and peak seasonal hydroelectric demand.

Lake Roosevelt is 243 km long, has a maximum depth of 122 m, and maximum width of 3.4 km. The southern part of the reservoir is located in the high desert of central Washington, and the middle and northern reaches in the pine-forested mountains of northeastern Washington. Stober et al. (1981) provided a detailed account of the limnology, geography, and climate of the lake and surrounding area.

Sampling was conducted at four stations established by the U.S. Fish and Wildlife Service during the baseline study of Lake Roosevelt (Nigro et al. 1982). These stations included all reaches, habitat types, and areas of major tributary influence (Figure 1). Stations 1, 3, and 4 represented mainstem and tributary embayment areas of

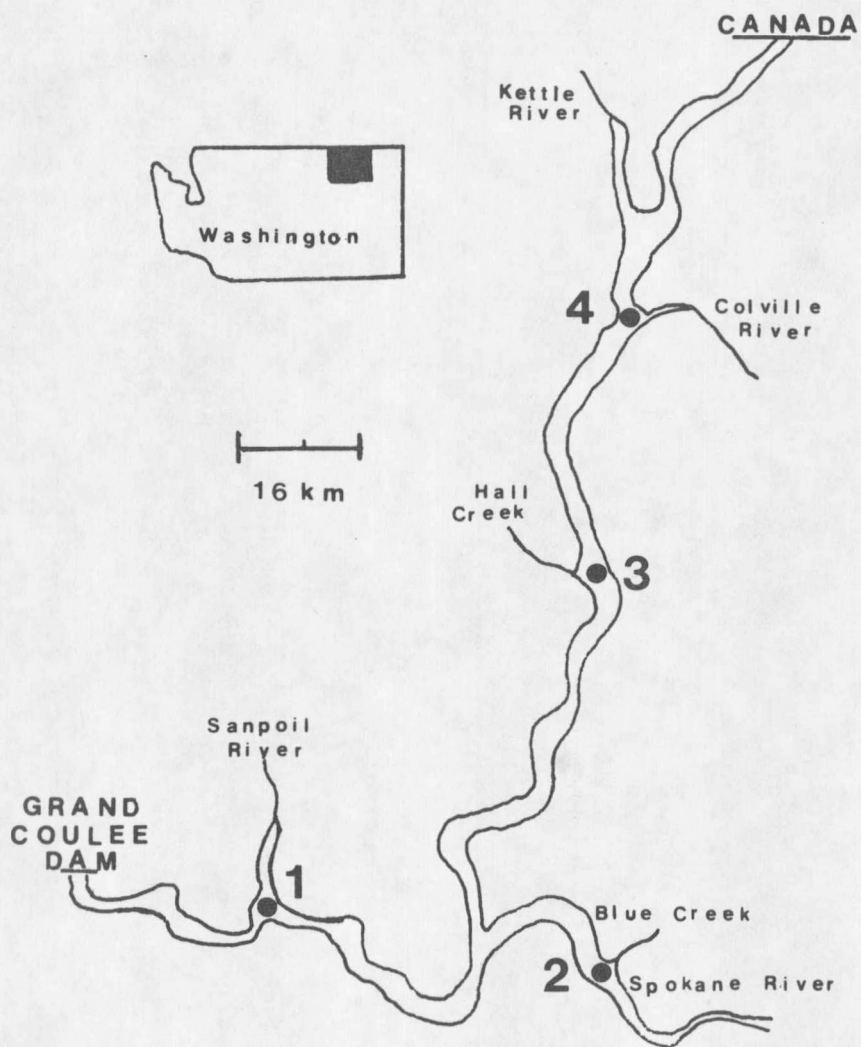


Figure 1. Important features and location of sampling stations in Lake Roosevelt, Washington, May-July 1982.

Lake Roosevelt. Station 2 was chosen to assess the Spokane River arm, which contributes 7% of the mean annual inflow into the reservoir (Beckman et al. 1984). Two habitat types at each station were sampled: a sheltered embayment site, and a tributary confluence site. Station 1, closest to Grand Coulee Dam, encompassed the embayment of the Sanpoil River and its confluence with Lake Roosevelt proper. Station 2, on the Spokane River, included the mouth of Blue Creek, a tributary to the Spokane River. Station 3 was in mid-reservoir, near the confluence of Hall Creek, a minor tributary of Lake Roosevelt. Station 4 typified the northern reservoir and was located near the Colville River.

## METHODS

Collection of Samples

Larval fish and zooplankton were sampled weekly May 26 through July 7 1982 (Table 1) during daylight hours from shoreline sites. Each week was assigned a number (Table 1) which was used in all figures to depict sample dates. Larval fish were sampled also during early May, late July, and mid August, but zooplankton were not regularly collected at those times. Water temperature was measured at each site throughout the sampling season.

Table 1. Dates and corresponding week numbers of concurrent shoreline zooplankton and larval fish sampling in Lake Roosevelt, May-July 1982.

Month	Day	Week number
May	26-27	1
June	2-3	2
"	10-11	3
"	16-17	4
"	23-24	5
July	1	6
"	7	7

Larval fish were collected with paired 0.5 m diameter plankton nets of 760  $\mu$  mesh equipped with flowmeters, lead weights, and plankton cups. Zooplankton were collected with paired Miller high-speed samplers equipped with #10

(153  $\mu$ ) mesh net, weights, and flowmeters. Two 1.8 m opposed outriggers extending from either side of the bow of the boat were used to tow the nets just below the water surface as close as possible to the shoreline. The standard sampling protocol was a 10-minute tow at idle speed for fish larvae, followed by a 2-minute tow at idle speed for zooplankton. Samples were washed into collection jars and preserved in 10% formalin. Potential variability due to offshore habitat differences was removed by analyzing only inshore catches of larval fish and zooplankton.

#### Larval Fish Distribution and Abundance

A calibration factor representing the volume filtered ( $m^3$ ) per flowmeter revolution was derived for each 0.5-m net and flowmeter by towing the net a known distance at a given speed and using the formula:  $C = AL/D$ , where C is the calibration factor, A is the area of the net opening, L is the length of the tow (m), and D is the difference in revolutions between beginning and ending flowmeter readings (Nigro et al. 1982). The total volume of water filtered during a larval fish tow was calculated as the product of the calibration factor and the difference in meter readings:  $V = CD$ .

Larval fish were counted from each tow and densities (no./ $m^3$ ) were calculated. Catches per 100  $m^3$  were used to

compare densities by sample date, taxon, station, and habitat.

Larval fish were identified to species for walleye and yellow perch. The three species of suckers (Catostomus macrocheilus, C. catostomus, and C. columbianus) in Lake Roosevelt exhibited similar morphological characteristics in larval stages and were collectively identified as catostomids or suckers. The three species of sculpins (Cottus asper, C. bairdi and C. rhotheus) were identified together as cottids or sculpins.

#### Zooplankton Distribution and Abundance

Total volume of water filtered through Miller samplers was calculated in the same manner as described for the 0.5-m nets. Zooplankton samples were diluted or concentrated to a known volume and subsampled with a 1 ml, 5 ml, or 10 ml Hensen-Stempel pipette. Three to five subsample aliquots were counted for each sample. Zooplankters were enumerated from the subsamples using a Ward plankton counting wheel on a dissecting microscope. When the large zooplankter Leptodora kindti was encountered in these subsamples, 10 additional 10 ml subsamples were enumerated, counting Leptodora only. The mean number of organisms of a given taxon from the

subsamples was used to calculate the density (no./m<sup>3</sup>) for each sample site and date. The formula:  $D = (V/S)(Z)/T$  was used to derive densities, where D is the density, V is the diluted or concentrated sample volume, S is the subsample aliquot volume, Z is the mean number of organisms of a given taxon in a subsample of "S" volume, and T is the total volume (m<sup>3</sup>) of water filtered by the Miller sampler (Wetzel and Likens 1979).

Zooplankton from inshore tows were identified to major group for copepods (cyclopoid, calanoid, harpacticoid, or nauplii of all three) and to genus for cladocerans. Taxonomic references included Ward and Whipple (1959), Brandlova (1972), and Pennak (1978). Rotifers were not enumerated due to inadequate sampling with #10 mesh net (Langford 1953).

#### Stomach Analysis

Stomach contents from a minimum subsample of 10 walleye, yellow perch, sculpin, and sucker larvae from each inshore sample were analyzed and the total length (TL) of each fish was measured. Ingested organisms in stomachs of target species were identified to the lowest possible taxon and enumerated. Percent composition by number was determined for each prey taxon. Larvae with empty stomachs and those retaining yolk sacs were recorded, but were not utilized for stomach analysis.

### Diet Overlap

Three measures of diet overlap (Table 2) were calculated for each station among the four fish taxa. Habitat types were combined to provide an adequate sample size for this analysis. Percentages used were the numerical percent composition of each prey taxon in pooled stomachs of a given fish taxa for each sample date. Schoener (1970) and Horn (1966) niche overlap index values range from  $d_{xy} = 0$  and  $C_{xy} = 0$  (no overlap) to  $d_{xy} = 1$  and  $C_{xy} = 1$  (complete overlap), respectively. Values above 0.60 indicate biologically significant diet overlap (Wallace 1981). Spearman rank correlation coefficient (Snedecor and Cochran 1970),  $r_{xy}$ , results in values of -1.0 to +1.0, showing negative or positive correlation.

### Selectivity

A two-sided, Wilcoxon's signed-rank analysis was used to test selectivity of larval fish for major prey taxa in the manner described by Kohler and Ney (1982). For each fish group, the percentage of a prey taxon ( $i$ ) in all stomachs from a given station, habitat and date ( $r_i$ ) was paired with the percentage of that prey item in the zooplankton sample from that same station, habitat, and date ( $P_i$ ) to compute  $Z_i$  (Table 2). The Wilcoxon's nonparametric ranking analysis was applied to absolute

Table 2. Formulae and explanation of symbols for diet overlap and selectivity indices used on larval fishes in Lake Roosevelt, 1982.

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Schoener <sup>a</sup> (1970)	$d_{xy} = 1 - 0.5(\sum  p_{xi} - p_{yi} )$
Horn <sup>a</sup> (1966)	$c_{xy} = 2\sum(p_{xi})(p_{yi}) / \sum p_{xi}^2 + \sum p_{yi}^2$
Correlation coefficient <sup>b</sup> (Snedechor and Cochran 1970)	$r_{xy} = 1 - [6\sum d_i^2 / (n-1)n(n+1)]$
Wilcoxon's signed-rank <sup>c</sup> (Kohler and Ney 1982)	$z_i = r_i - p_i$

---

a:  $p_{xi}$  = percentage of food category i in diet of fish taxa x;

$p_{yi}$  = percentage of food category i in diet of fish taxa y.

b:  $d_i$  = difference between ranks of each food category;

n = number of food categories.

c:  $r_i$  = percentage of food category i in stomach;

$p_i$  = percentage of food category i in habitat.

values of  $Z_i$ . The test was assumed to be significant at the  $P < 0.05$  level for Type I error. When a probability value greater than 0.05 was encountered, "random" selection for that prey item was assumed. Random selection would support the null hypothesis that there was no difference between prey percentages in stomachs and zooplankton.

## RESULTS

Larval Fish Distribution, Abundance, and Growth

Larval walleye density was highest at Station 3, yellow perch and sculpins were most numerous at Station 1, and sucker density was largest at Station 4 (Table 3). The most abundant target fish collected were suckers, followed by yellow perch, sculpins, and walleye, respectively. Collectively, larval fishes were most abundant at Station 4 and least abundant at Station 2. Collective abundance was larger in embayment than mainstem habitats at all sampling locations except Station 4.

With all stations and habitats combined, abundance of sculpins peaked on June 16, of yellow perch on June 24, of walleye on June 30, and of suckers on July 7 (Figure 2). Peak abundances for each fish taxon generally occurred later in the northern stations than in the southern stations (Figure 3).

Walleye, yellow perch, and suckers attained maximum sizes earlier in the sampling period at southern, lower-reservoir stations than at northern, upper-reservoir stations (Figure 4). The average lengths of sculpins showed no consistent patterns over time between stations.

Table 3. Density (mean catch of larval fish per 100 m<sup>3</sup>) at embayment (E) and mainstem (M) sites, Stations 1-4, Lake Roosevelt, May-August 1982.

Station	Habitat	Walleye	Yellow perch	Sculpin	Suckers	All taxa
1	E	0.1	73.2	16.9	661.5	751.7
	M	1.0	18.3	0.7	64.2	84.2
	Mean	0.6	45.8	8.8	362.9	418.1
2	E	0.8	7.6	0.4	423.0	431.8
	M	2.5	15.4	1.0	308.5	327.4
	Mean	1.7	11.5	0.7	365.8	379.9
3	E	8.3	2.5	0.9	760.6	772.3
	M	2.0	3.8	9.4	195.0	210.2
	Mean	5.2	3.2	5.2	477.8	491.4
4	E	0.3	1.3	3.8	520.1	525.5
	M	0.0	1.0	0.2	1614.0	1615.2
	Mean	0.2	1.2	2.0	1067.1	1070.5
Combined	Mean	2.0	15.4	4.2	568.4	590.0

#### Zooplankton Distribution and Abundance

Dominant zooplankton taxa encountered were Daphnia, Bosmina, and calanoid and cyclopoid copepods. Generally, copepod densities peaked in June when cladoceran densities were low; cladocerans peaked during July (Figure 5). Zooplankton populations (all taxa collectively) were lowest in May and increased from late June to July throughout the lake. Peak densities occurred earlier at southern stations than at northern stations (Figure 5). Within stations, embayment and mainstem

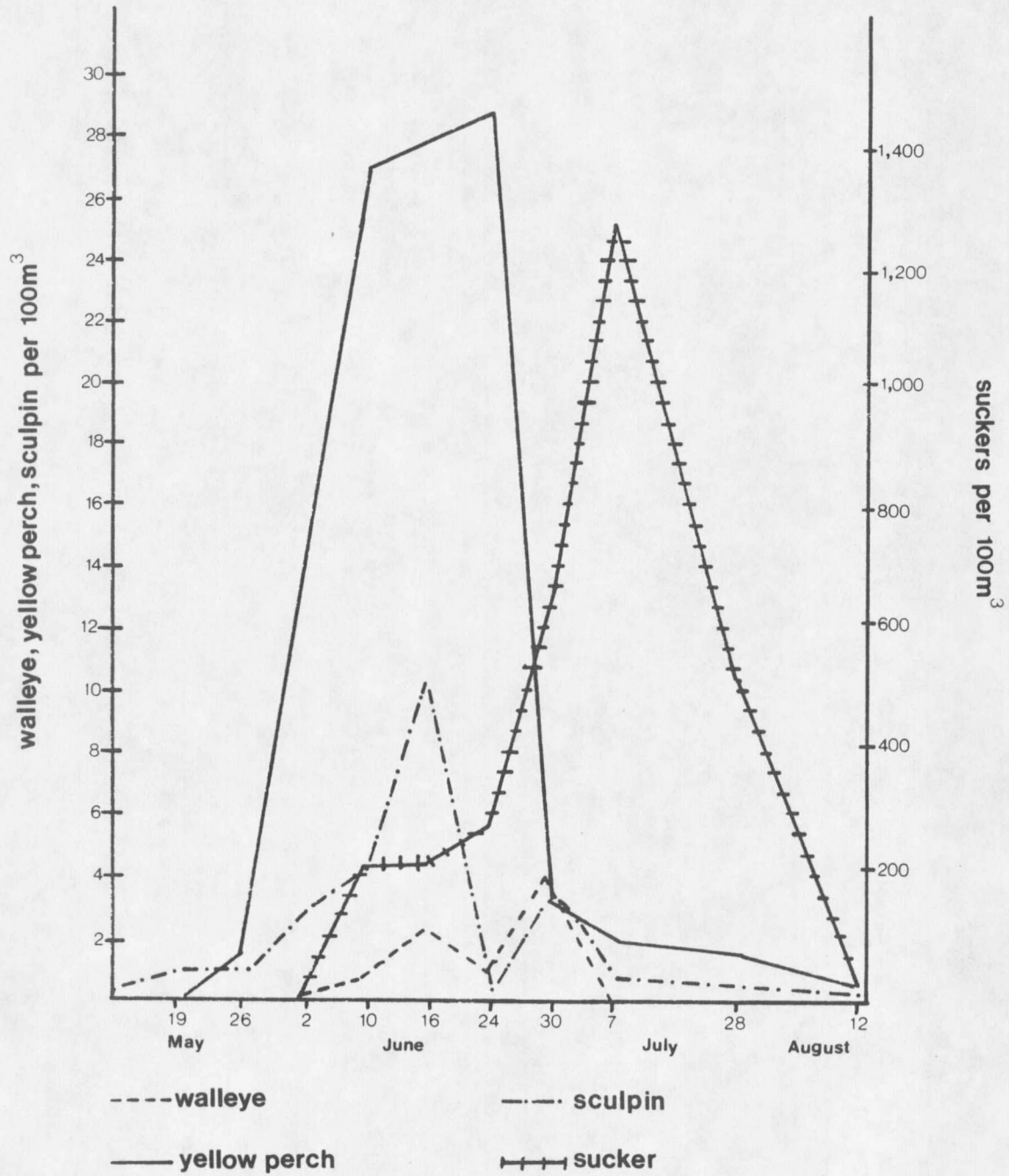


Figure 2. Density (catch per 100 m<sup>3</sup>) of larval fish from Lake Roosevelt, all stations combined, May-August 1982.

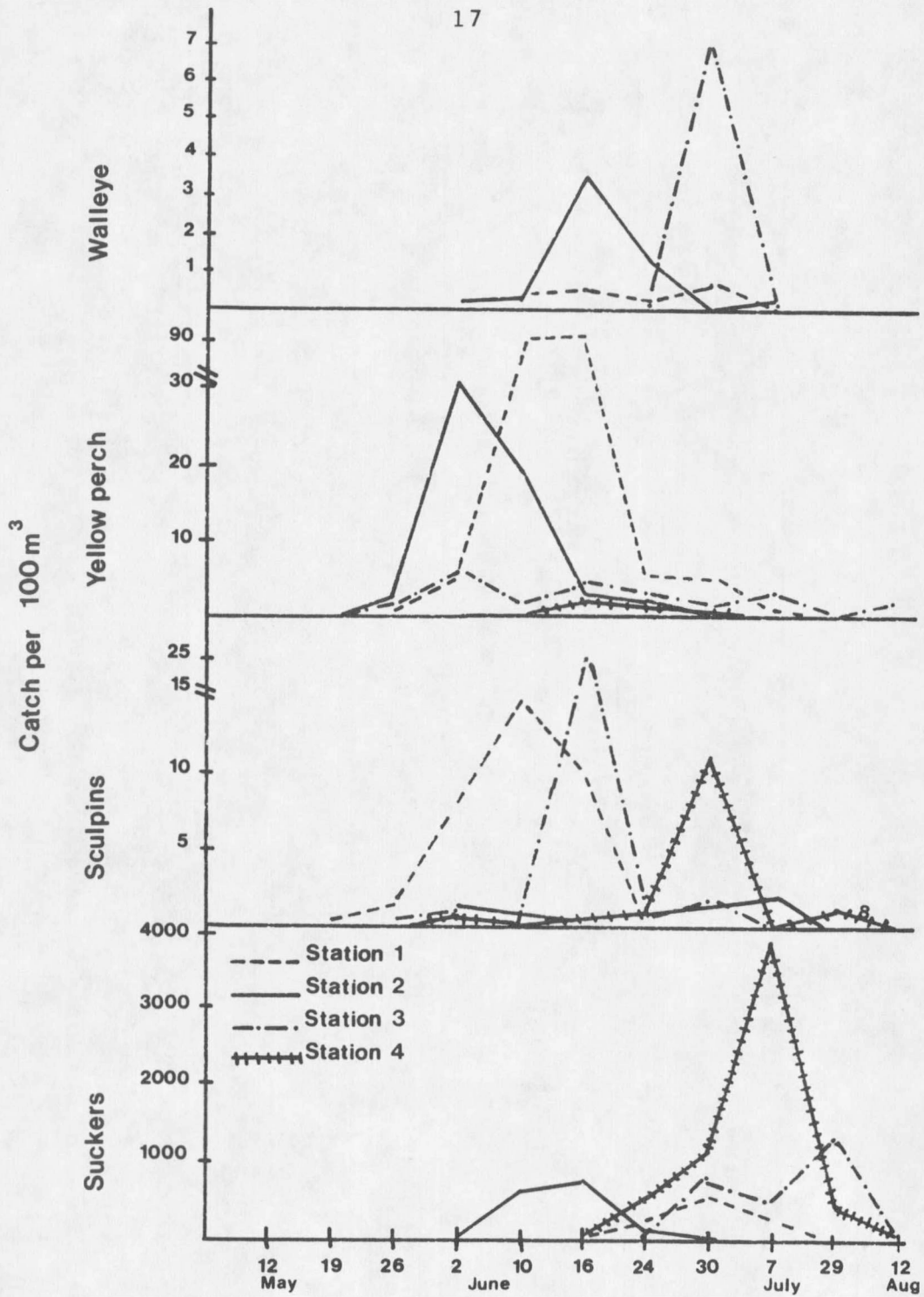


Figure 3. Density (catch per 100 m<sup>3</sup>) of larval fish from Stations 1-4 in Lake Roosevelt, May-August 1982.

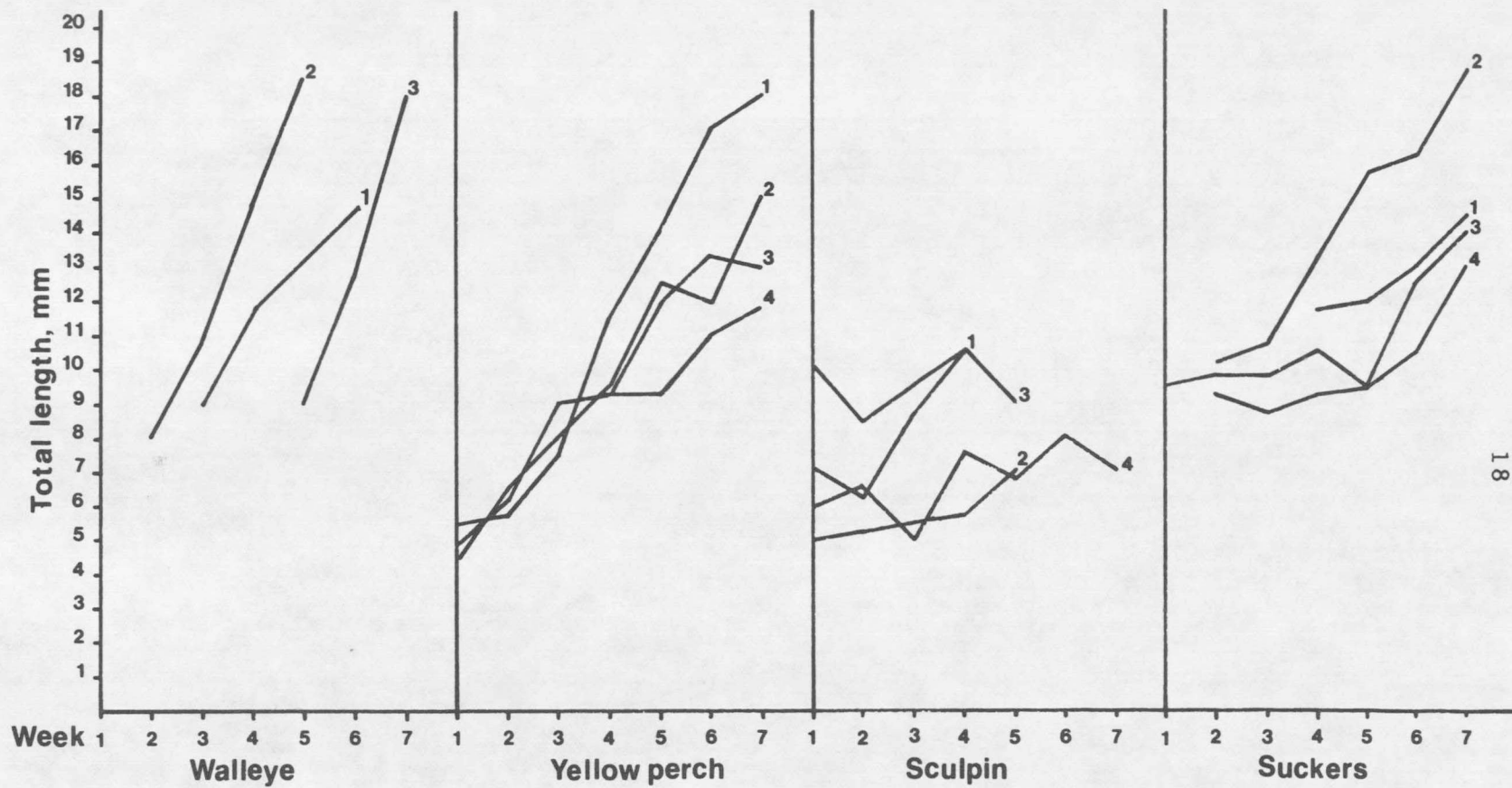


Figure 4. Mean total lengths of larval fish from Stations 1-4, embayment and mainstem habitats combined, Lake Roosevelt, May 26-July 7 1982.

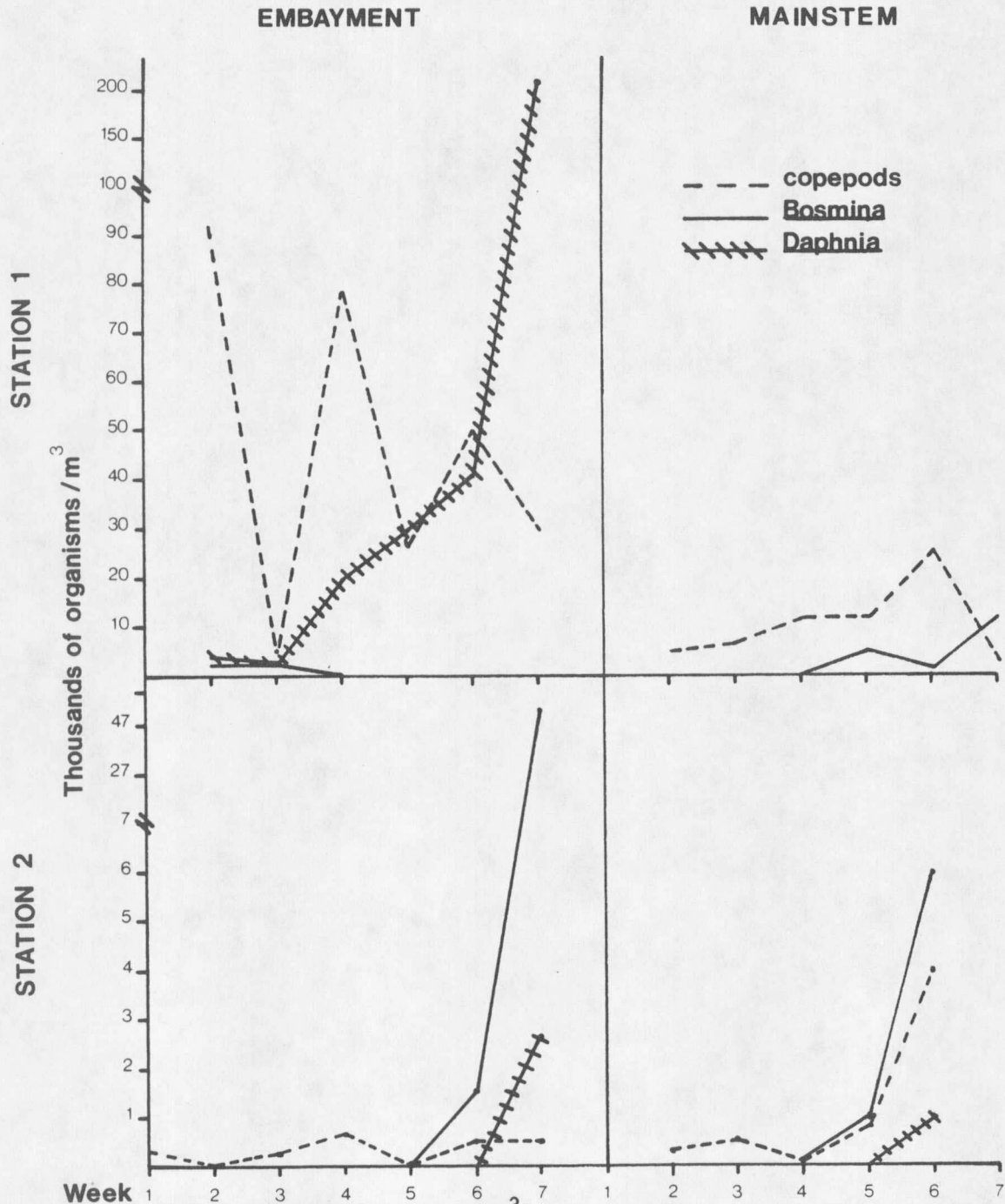


Figure 5. Density (number/m<sup>3</sup>) of dominant shoreline zooplankton from embayment and mainstem sites at Stations 1-4, Lake Roosevelt, May 26-July 7 1982.

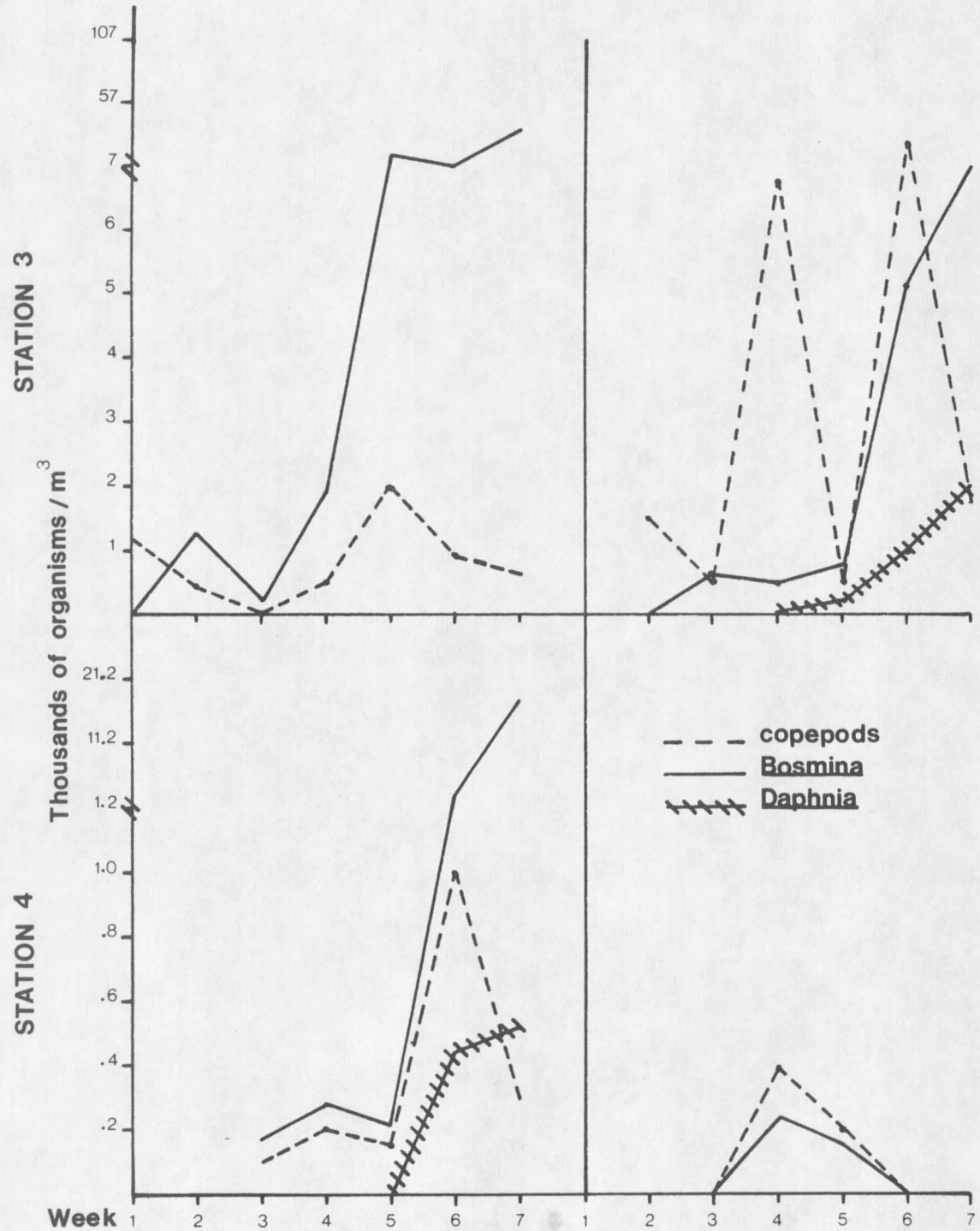


Figure 5. (continued)

percent compositions of Bosmina and Daphnia at Stations 1 and 4, and of calanoid copepods at Stations 1, 2 and 3, were relatively equivalent and exhibited similar trends (Figure 6). Percentages of cyclopoid copepods were consistently higher in mainstem than embayment habitats at all stations except Station 4.

Zooplankton densities varied considerably between habitats but followed similar seasonal trends (Figure 5). Bosmina and Daphnia densities were higher in embayments, and copepod densities higher in mainstem habitats at all stations except Station 1. There, Bosmina densities were higher in the mainstem habitat, and copepod and Daphnia densities higher in the embayments.

#### Stomach Analysis

##### Walleye

The major food items present by number in walleye stomachs throughout Lake Roosevelt were copepods (Table 4). Larval fish and the larger cladocerans Leptodora and Daphnia represented minor percentages in walleye diet. Ten of the 80 fish subsampled had empty stomachs. Sample sizes of walleye from individual stations and habitats were too inconsistent to compare temporal changes in diet with prey size, prey abundance, and larval fish length (Table 9). Pooling of fish lengths, sample stations, times, and habitats was not justified due to the

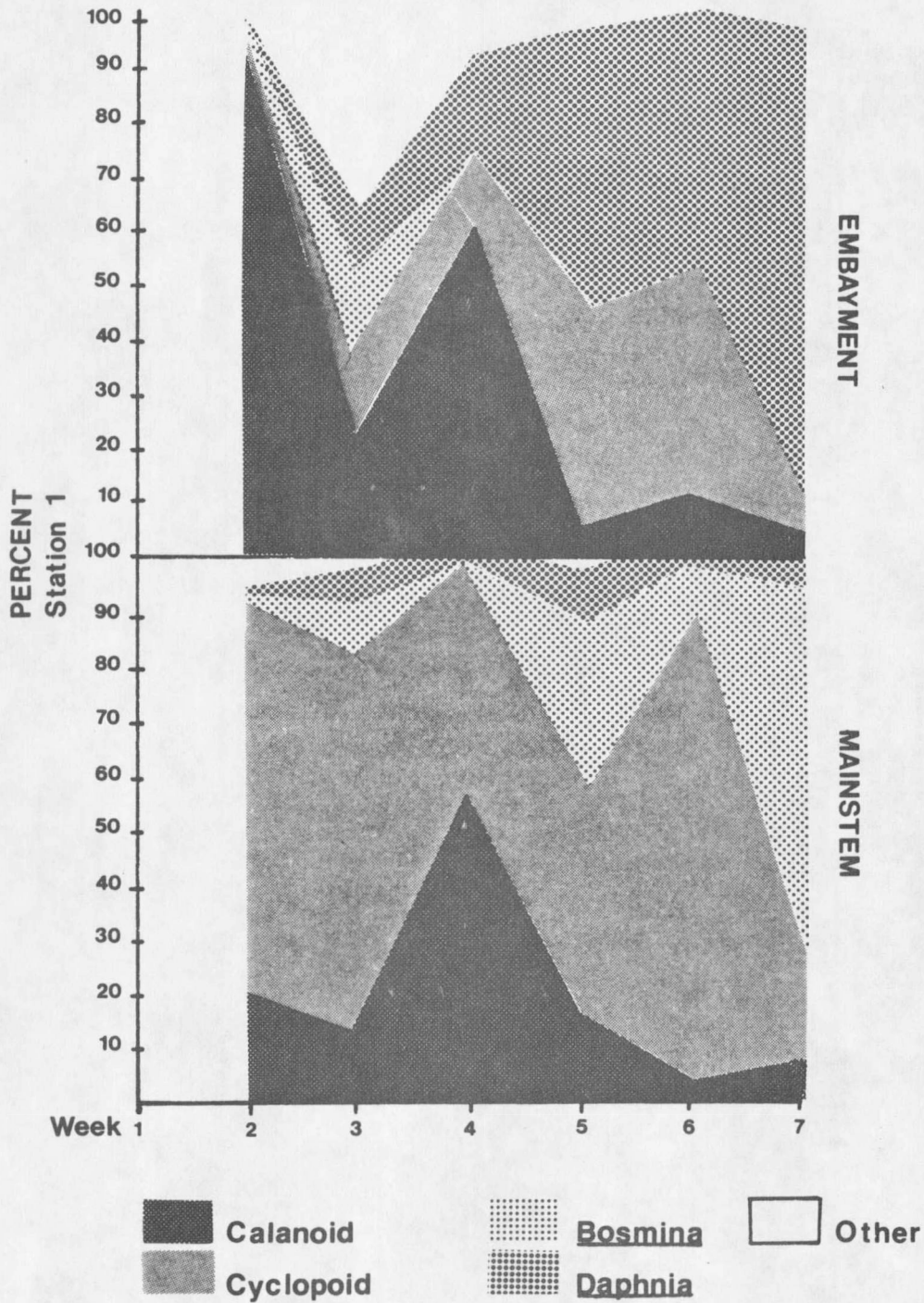


Figure 6. Numerical percent composition of dominant shoreline zooplankton from embayment and mainstem sites at Stations 1-4, Lake Roosevelt, May 26-July 7 1982.

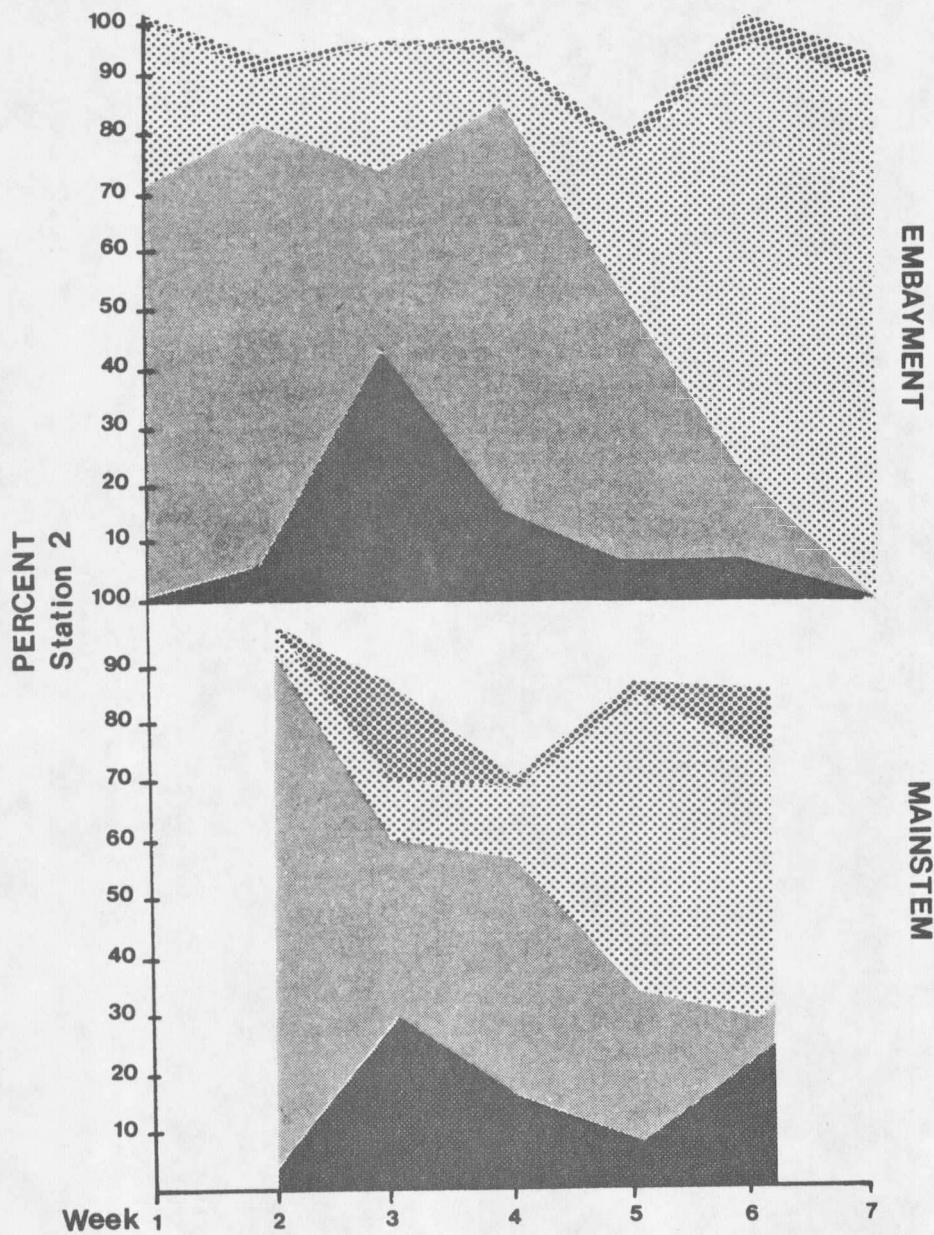


Figure 6. (continued)

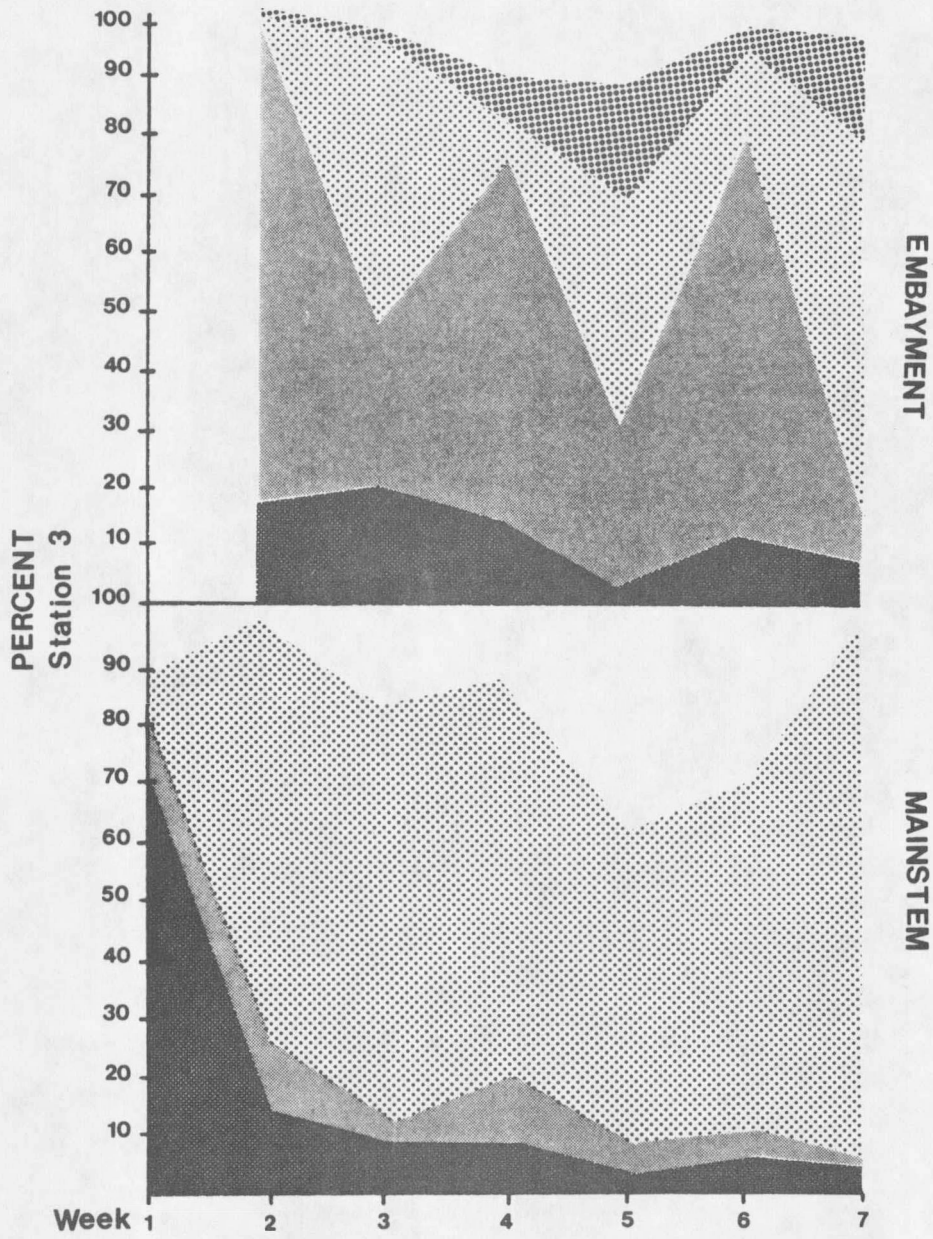


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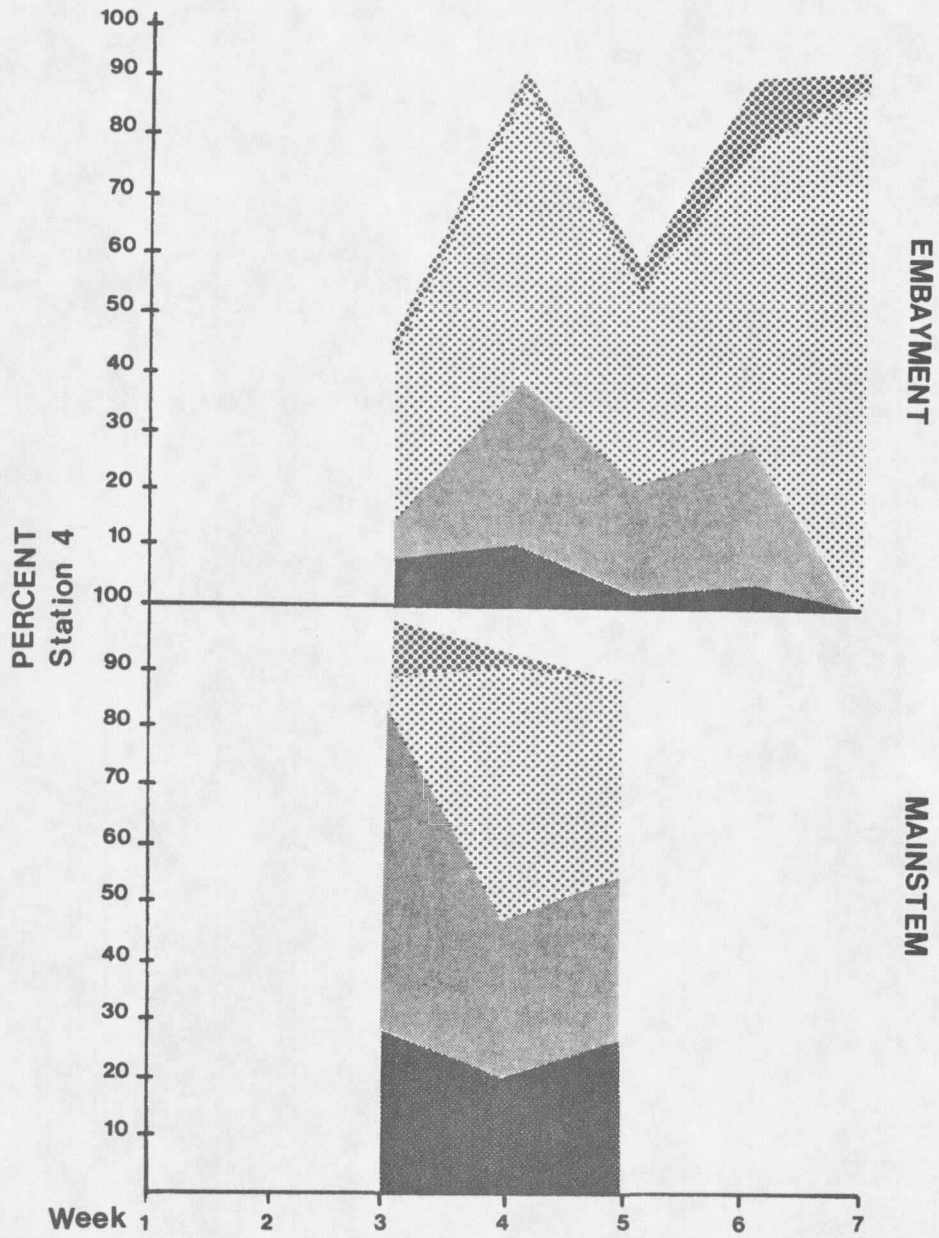


Figure 6. (continued)

variability in prey abundance between stations, habitats, and sample times (Figure 6).

Table 4. Numerical percent composition of prey items in larval fish stomachs, all stations combined, Lake Roosevelt, May-July 1982.

	Walleye	Yellow perch	Sculpin	Suckers
n (with prey)	70	417	93	85
n (empty)	10	72	67	60
Prey	Percent Composition			
<hr/>				
COPEPODS				
Calanoid	70.9	49.0	26.2	0.1
Cyclopoid	11.3	28.6	55.1	5.2
Nauplii	0.0	1.3	0.0	0.1
CLADOCERANS				
Bosmina	0.0	3.1	1.2	48.5
Daphnia	3.2	9.7	8.0	1.3
Ceriodaphnia	0.2	0.7	0.0	2.1
Leptodora	5.4	1.2	0.4	3.1
Chydorus	0.0	0.0	0.0	38.3
ROTIFERS	0.0	0.3	0.0	0.1
LARVAL FISH	9.1	0.0	0.0	0.0
UNIDENTIFIED	0.0	6.0	9.2	1.1

Walleye was the only fish taxon observed which preyed on other larval fish. Stomachs containing larval fish seldom contained other food items. Percentages of ingested larval fish were highest at Station 2 (Table 5). The smallest walleye with larval fish as ingested prey measured 9.0 mm TL, and ingested larval fish measured from 3.0-6.0 mm TL. Not all larval fish in walleye stomachs could be positively identified, but those that were included walleye, yellow perch, sculpins, and suckers.

Calanoid copepods were the most numerous prey items of larval walleye from every station, with the highest percentage at Station 3 (Table 5). The small sample size (one fish) at Station 4 precluded reliable analysis of walleye food habits at that station.

Table 5. Numerical percent composition of major prey items from larval walleye, yellow perch, and sculpins at Stations 1-4, Lake Roosevelt, May-July 1982.

Prey	Station			
	1	2	3	4
<u>Walleye</u>				
n	16	30	23	1
Calanoid	53.3	66.7	93.3	(100.0)
Cyclopoid	31.7	3.0	0.0	0.0
<u>Leptodora</u>	11.7	3.0	1.7	0.0
<u>Daphnia</u>	3.3	4.5	1.7	0.0
Larval fish	0.0	22.7	3.3	0.0
<u>Yellow perch</u>				
n	237	70	71	39
Calanoid	54.7	5.3	53.6	73.0
Cyclopoid	23.2	75.2	13.9	13.5
<u>Bosmina</u>	0.3	10.6	7.2	10.8
<u>Daphnia</u>	12.2	5.3	3.6	1.8
<u>Sculpin</u>				
n	34	7	32	20
Calanoid	8.3	(23.1)	75.0	39.1
Cyclopoid	76.4	(23.1)	18.2	56.5
<u>Bosmina</u>	0.0	0.0	2.3	4.3
<u>Daphnia</u>	15.3	(53.8)	4.3	0.0

( ) indicates suspect percentages due to low sample size (n)

Yellow perch

The principal food items of larval yellow perch included calanoid and cyclopoid copepods and Daphnia (Table 4). Calanoid copepods were the dominant prey items from every location except Station 2, where cyclopoid copepods were the most numerous (Table 5). Yellow perch stomachs from Station 4 contained higher percentages of calanoid copepods and lower percentages of Daphnia than those from any other station. Considering all stations, stomachs from Station 1 contained the lowest percentages of Bosmina and the highest percentages of Daphnia.

Calanoid copepod utilization was temporally bimodal at all habitats and stations except the mainstem habitat at Station 4 and the embayment habitat at Station 2 (Figure 7). Peaks in calanoid copepod use occurred earlier at Station 1 than at Stations 3 and 4. This prey item was used minimally by yellow perch at Station 2.

Cyclopoid copepods comprised over 75% of the total yellow perch stomach contents during the last 2 weeks of June at Station 2 (Figure 7). Cyclopoid copepod utilization was much lower at other stations. Peaks in utilization generally occurred later in mainstem habitats than embayment habitats (Figure 7).

Seasonal utilization of calanoid and cyclopoid copepods exhibited similar trends between embayment and



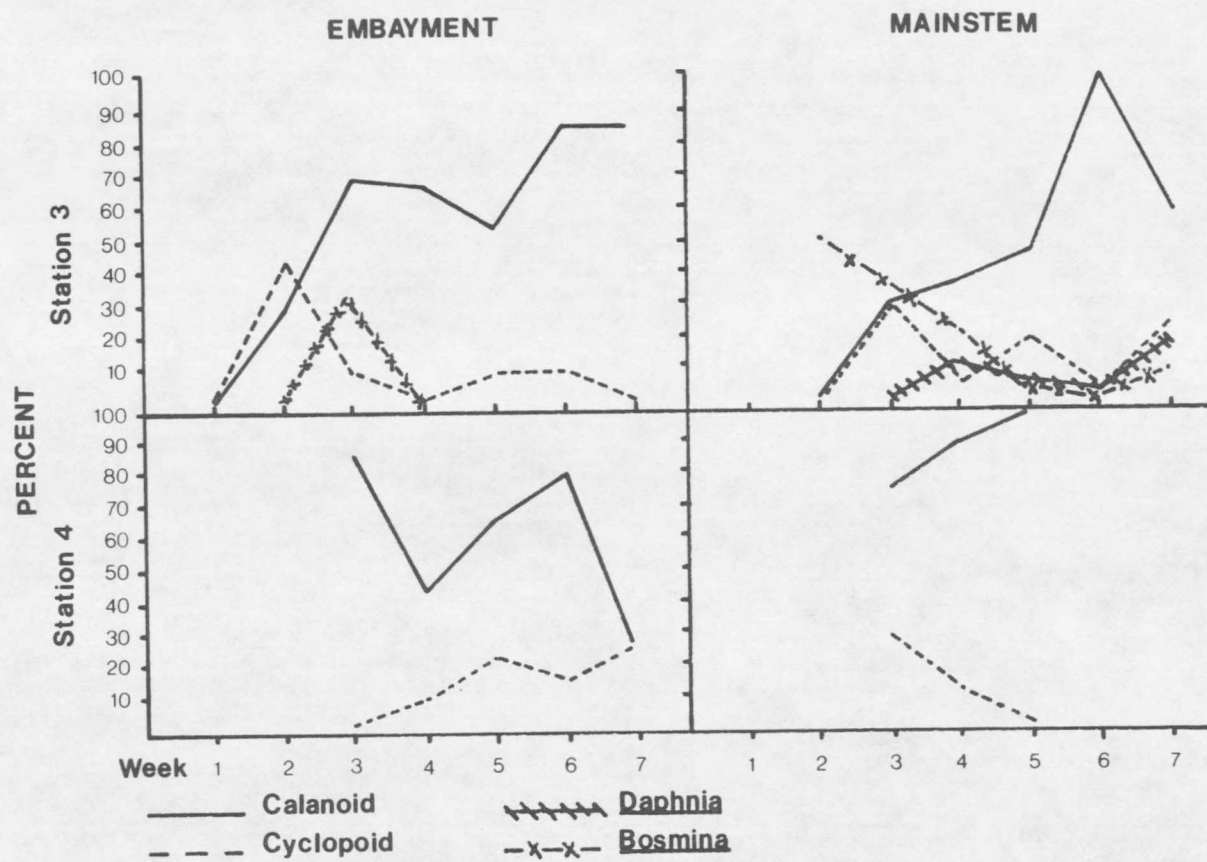


Figure 7. (continued)

mainstem habitats at Stations 1, 2, and 3 (Figure 7). The low sample size of yellow perch at the mainstem habitat at Station 4 prevented a complete seasonal analysis of food habits there.

### Sculpins

Forty percent of the sculpin stomachs analyzed were empty (Table 4). Most of these were from Station 2, where only 7 of the 32 analyzed stomachs contained prey. The most numerous prey of larval sculpins (all stations combined) were calanoid copepods, cyclopoid copepods, and Daphnia. Dominant food items at Stations 1 and 4 were cyclopoid copepods and at Station 3 were calanoid copepods.

Small sample sizes of sculpins from individual habitats, stations and dates precluded accurate temporal comparison with prey abundance (Table 10).

### Suckers

Sucker stomachs were analyzed from Station 2 only. Most empty stomachs were from fish between 10 and 12 mm TL. Bosmina, Chydorus, and cyclopoid copepods were the most numerous food items encountered (Table 4). Suckers represented the only fish taxon that utilized Bosmina heavily and Chydorus at all.

At both embayment and mainstem habitats, cyclopoid

copepods were dominant prey items during early June, then declined in importance for the rest of the sampling period (Figure 8). Utilization of Chydorus by suckers peaked in mid-June at the embayment habitat and in late June at the mainstem habitat, then declined at both sites in July. Utilization of Bosmina was low during the June Chydorus peaks, then increased throughout the sampling period, reaching maxima on the last sampling date. As sucker larvae grew, utilization of Bosmina increased steadily while use of Chydorus only increased until a length of 16-17 mm TL, then declined (Figure 9).

#### Diet Overlap

The Schoener index exhibited more conservative overlap estimates than the other methods used (Table 12). Schoener values were highly significant (Wallace 1981) between walleye and yellow perch at Station 1 and between yellow perch and sculpins at Stations 3 and 4 (Table 6). Overlap values were significant between all fish taxa at Station 3. Values were never significant between suckers and any other fish taxa, nor between any fish taxa at Station 2.

Percent utilization of shared prey items by fish taxa exhibiting overlap suggested potential sources of diet overlap (Table 5). Temporal periods of overlap were determined by isolating the times of highest shared

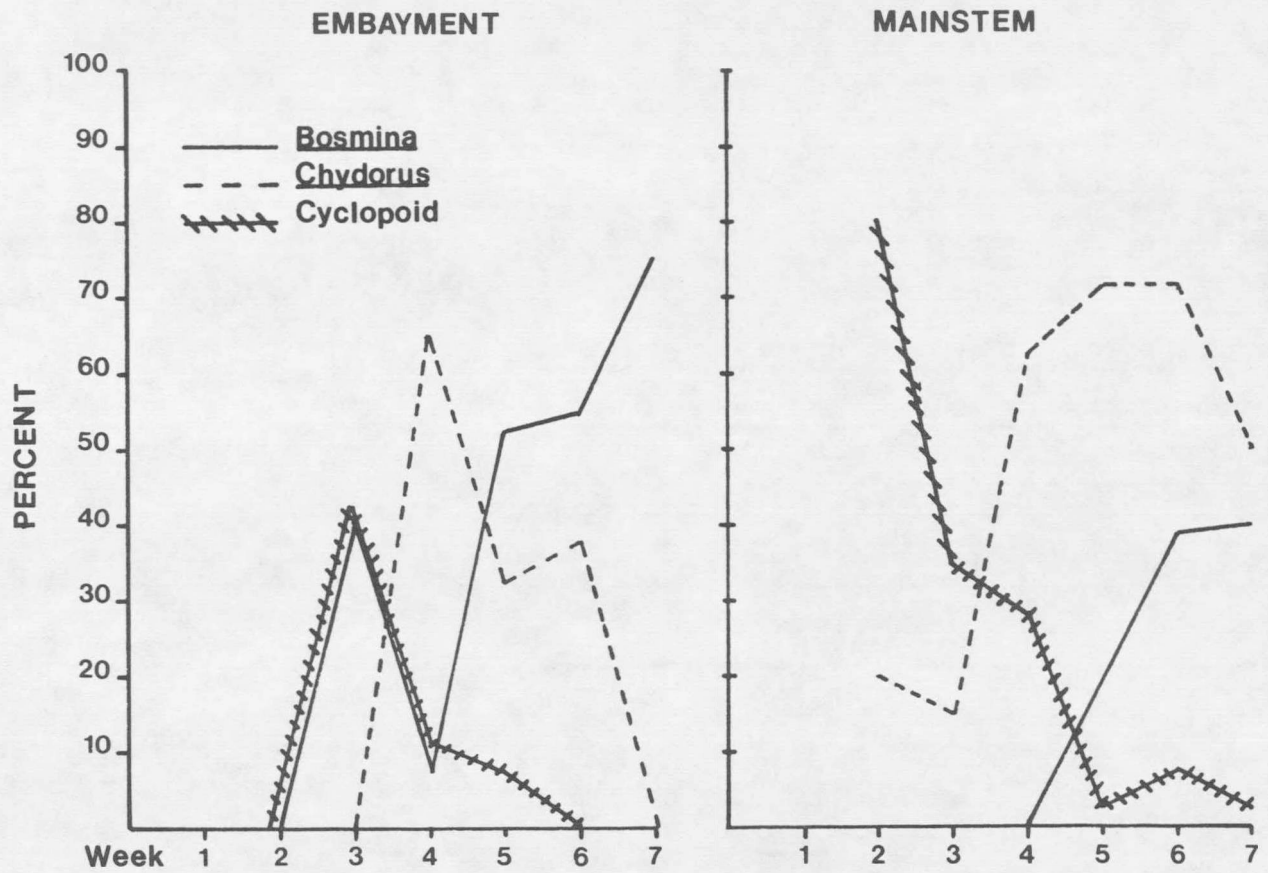


Figure 8. Numerical percent composition of dominant food items larval suckers in embayment and mainstem sites at Station 2, Lake Roosevelt, May 26-July 7 1982.

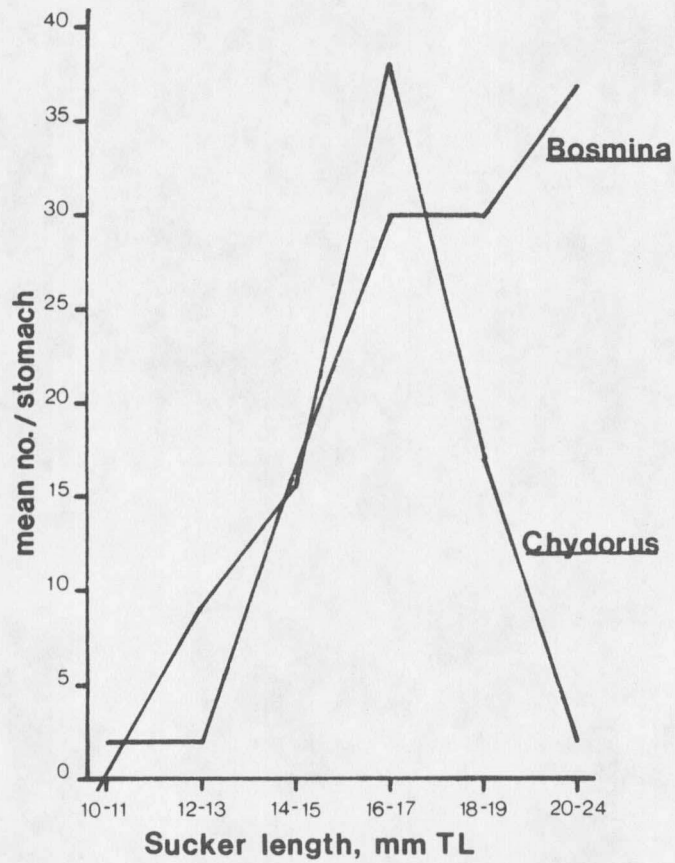


Figure 9. Mean number/stomach of *Bosmina* and *Chydorus* from larval suckers at Station 2, Lake Roosevelt, May-July 1982.

utilization of those sources. Walleye and yellow perch at Station 1 (mainstem) heavily utilized calanoid copepods during weeks 4 and 5 (Figure 8 and Appendix 2). Yellow perch and sculpins showed dominant utilization of cyclopoid copepods at Station 1 (mainstem) during week 2, of calanoid copepods at Station 3 (embayment) during week 4, and of calanoid copepods at Station 4 (embayment) during weeks 4 and 5 (Figure 8 and Table 10).

Table 6. Schoener niche overlap values between larval fish at Stations 1-4, Lake Roosevelt, May-July 1982.

	1	2	Station 3	4	All
Walleye x yellow perch	0.84	0.21	0.65	x	0.69
Walleye x sculpin	0.35	0.13	0.67	x	0.39
Walleye x sucker	x	0.16	x	x	0.15
Yellow perch x sculpin	0.50	0.57	0.94	0.87	0.66
Yellow perch x sucker	x	0.19	x	x	0.15
Sculpin x sucker	x	0.07	x	x	0.12

Values  $\geq 0.60$  indicate biologically significant diet overlap (Wallace 1981)

x: Sample inadequate for niche overlap analysis

Selectivity

Selectivity values of larval fish taxa for eight prey items were averaged over station, habitat, and date (Table 7). Larval walleye were selective for calanoid copepods only. Larval yellow perch selected for Daphnia, Ceriodaphnia, and calanoid and cyclopoid copepods. Cyclopoid copepods and Bosmina were selected by larval sculpins and suckers. Larval suckers also selected for Chydorus. Yellow perch represented the only fish taxon selective for Daphnia, and suckers were the only taxon to select for Chydorus. None of the fish taxa showed positive selectivity for copepod nauplii or Leptodora.

It was necessary to combine stations, habitats and dates to achieve an adequate number of cases on which to perform the Wilcoxon's analysis (Georgia Ziemba, personal communication). When selectivity was analyzed with this method for embayment and mainstem habitats at each station, P-values less than 0.05 were rarely encountered.

Table 7. Larval fish selectivity values and probability values (P) from Wilcoxon's signed-rank comparison tests for eight prey items, Lake Roosevelt, May-July 1982.

Prey	Walleye	Yellow perch	Sculpin	Sucker
<u>COPEPODS</u>				
Calanoid	+(.00)	+(.00)	R(.06)	R(.05)
Cyclopoid	R(.21)	+(.00)	+(.01)	+(.00)
Nauplii	-(.00)	-(.00)	-(.00)	-(.00)
<u>CLADOCERANS</u>				
<u>Bosmina</u>	-(.00)	R(.69)	+(.00)	+(.02)
<u>Daphnia</u>	R(.75)	+(.00)	R(.69)	R(.24)
<u>Chydorus</u>	-(.00)	-(.00)	-(.00)	+(.00)
<u>Ceriodaphnia</u>	-(.03)	+(.01)	-(.00)	R(.11)
<u>Leptodora</u>	-(.06)	-(.00)	-(.00)	-(.00)

Symbols: + = positive selection ( $P < 0.05$ )  
 - = negative selection ( $P < 0.05$ )  
 R = random selection ( $P > 0.05$ )

DISCUSSION

Peak abundance and length frequency of larval fish groups indicated that walleye spawned from May through early June, yellow perch and sculpins spawned from April through May, and suckers spawned in June and early July. In general, larval fish were larger, grew faster, and exhibited earlier density peaks at more southerly, lower-reservoir stations (Figures 3 and 4). Warmer water temperatures were also consistently observed at the more downstream stations and are thought to be responsible for the observed accelerated growth (Table 8 and Stober et al. 1980). Warmer water temperature favors shorter hatching periods and faster rates of development in larval walleye and yellow perch (Busch et al. 1975, Hokanson 1977). Early abundance peaks resulting from early spawning induced by faster water-warming rates have been observed for yellow perch in Lake Opinicon, Ontario (Amundrud et al. 1974). Seasonal trends in cladoceran and copepod abundance were similar to those encountered in other large northwestern lakes and reservoirs, with an early dominance of copepods and a later bloom of cladocerans (Goldman and Horne 1983). The relatively large abundance of zooplankters at the embayment of Station 1 (Figure 5) could have been a result of the warmer water temperatures there

(Table 8), since there is a strong positive correlation between zooplankton abundance and epilimnion temperature (Patalas and Salki 1985, Patalas 1975). The abundance at Station 1 could also have been due to its distant location from the mainstem Columbia (Figure 1). This would minimize effects of water level fluctuations, which can influence zooplankton population densities (June 1976).

The significance of larval fish and Leptodora in larval walleye diet (Table 5) may have been underestimated in the numerical analysis due to the size differences between ingested Leptodora and larval fish (3.0-10.0 mm) and other ingested zooplankton (0.5-2.0 mm). The size difference of these larger prey suggests a greater contribution to walleye diet in terms of biomass than numerically indicated (Table 5). Walleye stomachs collected at Station 2 contained nearly three times the percentage of larval fish than those collected at other stations (Table 5). Total abundance of larval fish at Station 2, though lowest overall, was not markedly different from that at other stations where walleye were collected (Table 3). But due to the earlier density peak of larval fish at this southerly station, more larval fish may have been available as prey at that time. The larger percent utilization of larval fish at Station 2 could also have been due to the larger size and faster growth of

walleye at this station compared to other stations (Figure 4). Larval fish become increasingly more important in walleye diet as growth increases (Walker and Applegate 1976, Mathias and Li 1982). The Spokane River arm of Lake Roosevelt, where Station 2 was located (Figure 1), is known to be an optimal location for walleye spawning (Harper et al. 1981), and is a more southerly station with warmer water temperatures. Earlier and more successful spawning at Station 2 may have resulted in larger larvae and increased utilization of larval fish, compared to other stations, during the sampling period.

Percent composition of prey items in stomachs of larval fishes generally indicated preferences for certain categories of prey. The dominant prey of walleye were calanoid copepods, of yellow perch and sculpin were calanoid and cyclopoid copepods, and of suckers were Bosmina and Chydorus (Table 4). For preference, or selection, to be reliably documented, frequency of a prey item in the diet must be statistically greater than its availability or frequency in the environment (Ivlev 1961, Strauss 1979). The Wilcoxon's signed-rank analysis statistically verified the apparent feeding preferences of larval fish in Lake Roosevelt (Table 7), as indicated by percent composition of prey items in stomachs (Table 4).

Feeding selectivity in planktivorous fishes is

influenced by age and size of fish (O'Brien 1979), size of prey (Brooks and Dodson 1965, Gardner 1981, Hansen and Wahl 1981), by the swimming, capture, and escape ability of predator and prey, visibility of prey, and by seasonal availability and abundance of prey (Mathur and Robbins 1971, Rajasilta and Vuorinen 1983). These factors contributed to interpretation of food preferences of larval fish in Lake Roosevelt.

Larval walleye were selective for calanoid copepods, the largest zooplankters consistently encountered in Lake Roosevelt, even when other prey items were more abundant (Table 9 and Figure 5). Larval walleye have larger mouth gapes and better-developed teeth than yellow perch, sculpin, and suckers of the same size, which morphologically enables them to ingest larger prey (Mathias and Li 1982). Calanoid copepods are predaceous planktivores (O'Brien 1979) and were the largest zooplankter available to walleye. If so, minimum energy was expended for maximum dietary input when selecting for calanoid copepods (Confer and Blades 1975). It is well known that some planktivorous fish prefer larger zooplankton (Brooks and Dodson 1965, Galbraith 1967), and similar size selectivity has been documented for walleye elsewhere. Larval walleye in Oneida Lake, New York, were selective for cyclopoid copepods, which were larger than the co-occurring calanoid

copepods in that system (Houde 1967). Walker and Applegate (1976) found positive selection for calanoid copepods, the largest prey available, in young-of-the-year walleye in South Dakota. In field and laboratory studies in Manitoba, larval walleye exhibited size selectivity for cyclopoid copepods (Mathias and Li 1982).

Not all larval fish groups selected for large prey. Larval suckers selected for Chydorus and Bosmina (Table 6), the smallest mature zooplankters sampled in Lake Roosevelt (with the exception of rotifers). Mouth size of young-of-the-year suckers has been shown to limit food intake to small prey items such as smaller cladocerans, rotifers, and diatoms (Stewart 1926, MacPhee 1960). This, and the later date of peak larval sucker abundance, could explain the absence of diet overlap between suckers and any other fish taxa (Table 6).

Size selectivity for larger prey items was also indicated for yellow perch. Although selectivity values were positive for the larger copepods and for Daphnia (Table 6), percent utilization of copepods was much higher than for Daphnia (Table 4). Yellow perch larvae in northern Minnesota (Siefert 1972) and in Iowa (Bulkley et al.) also showed dependence upon copepods, however larval yellow perch in Oneida Lake, New York (Hansen and Wahl 1981) and in Manitoba (Wong and Ward 1972) utilized

Daphnia almost exclusively. These discrepancies may be explained by variation in temporal and spatial prey abundance and utilization.

Due to the statistical restraints on the Wilcoxon tests chosen for selectivity analysis, seasonal and spatial variation in prey selection were obscured. However, visual comparison of seasonal prey composition in stomachs (Figures 7 and 8) and in zooplankton samples (Figure 6) from each sample location indicated some temporal and spatial patterns in feeding selectivity for yellow perch and suckers. Low sample sizes of walleye and of sculpin prevented accurate seasonal analysis of these taxa.

Utilization of the cladocerans Bosmina and Daphnia by yellow perch occurred primarily during the early part of the sampling period (Figure 7), when cladoceran abundance was low throughout the lake (Figure 4). The significant positive selectivity values for these prey items (Table 7) reflect this high utilization during a period of low abundance. Peak abundance of Daphnia occurred late in the sample period (Figure 5). At Station 1, where Daphnia densities were highest, percent utilization by yellow perch was also highest. (Table 5). There, prey utilization appeared to be influenced by prey abundance. Yellow perch may have fed upon Daphnia to a greater extent

during peak availability at other stations, but during those times the number of captured fish decreased as result of increasing size and evasion ability (Figures 2 and 4), and further determination of Daphnia utilization was not possible.

Percent utilization of copepods by yellow perch was consistently higher than the corresponding percentages in the zooplankton, but shifts in use did not appear to be influenced by shifts in seasonal prey abundance. Utilization increased and then decreased along with availability at Stations 1, 2, and 4, but increased while availability decreased at Station 3.

Sucker utilization of Bosmina was greater than percent availability early in the sampling period. The dependence of suckers upon Bosmina, numerically the most abundant zooplankter at Station 2, suggests that suckers are highly opportunistic feeders (Rajasilta and Vuorinen 1983). Chydorus was rarely collected in zooplankton samples, therefore utilization was consistently greater than availability. Chydorus is bottom-dwelling and probably not effectively sampled by our towed nets, and may have been more available to fish larvae than indicated by its presence in zooplankton samples.

Sculpins rapidly adopt benthic lifestyles during early life history stages (Sheldon 1968, Wallus and

Granneman 1978). This would explain the patchy distribution (Table 10) and small size (Figure 4) of the sculpin collected in this study. The high incidence of empty stomachs (Table 4), similarly reported by Bailey (1952) for larval sculpins, indicates that exogenous feeding had not yet begun in most sculpins that were vulnerable to collection gear. It is probable that by the time complete exogenous feeding had been attained, sculpins were able to evade the townets or had become benthic.

The Schoener index was chosen as the most reliable of the three overlap indices used due to its more conservative overlap estimates (Table 11). It has been considered superior to the correlation coefficient and Horn index by other researchers (Hurlbert 1978, Wallace 1981). The most useful application of the index in this study was to suggest statistically where and which fish taxa overlapped in their food habits. Analysis of diet overlap (Table 6), seasonal utilization (Figures 7 and 8, Appendices 2 and 3), and prey availability (Figure 5) together signalled possible competition between fish taxa.

Overlap and competition can be defined as follows (Zaret and Rand 1971): "Overlap is the use, typically at the same time, by more than one organism of the same resource regardless of resource abundance. Competition is

the demand, typically at the same time, of more than one organism for the same resource of the environment, in excess of immediate supply."

Diet overlap, then, could suggest competition for a shared prey resource only when that prey resource is in short supply (Hurlbert 1978, Abrams 1980). During every time period that walleye and yellow perch and that sculpin and yellow perch exhibited overlap on calanoid copepods, that prey was present in very low densities in the zooplankton samples (Figure 5). In addition, walleye and yellow perch were both selective for calanoid copepods (Table 7). Based on these analyses and on competition as defined, competition for food may have occurred between larval walleye and yellow perch and between yellow perch and sculpins in Lake Roosevelt during late June 1982. The consequence of competitive interaction between species can be competitive exclusion, interactive segregation, or character divergence (Zaret and Rand 1971). Segregation and ultimately character divergence would be expected if two nonnative species such as walleye and yellow perch exhibited competition with each other or with native species when introduced into a new system such as the Columbia. The potential competition, indicated by positive overlap, may have been induced by seasonal changes in calanoid copepod abundance locally within the

reservoir. In Schoener's discussion of the controversy over interspecific competition (1982), he indicates that when competition occurs only seasonally during infrequent "lean" times, it is considered too weak to significantly influence character divergence or species exclusions. Schoener (1982) also notes that morphological differences between species can affect the degree of competition. Larval walleye, yellow perch, and sculpin all change morphologically and hence behaviorally after surviving the potential competition period observed in Lake Roosevelt. Walleye become and piscivorous, yellow perch become gregarious and feed pelagically, sculpin become benthic and carnivorous, and all become much larger.

In conclusion, though competition could have occurred between fishes in this study, its short duration and localized nature, due to larval ontogeny and seasonal prey abundance patterns, lessen its significance and in turn the probability of exclusion-derived character divergence.

## CONCLUSIONS

A positive relationship between increased water temperatures and earlier larval fish hatching, faster larval fish growth, and increased zooplankton densities was indicated. This relationship was observed between warmer, lower-reservoir stations and cooler, upper-reservoir stations.

Several types of feeding selectivity were exhibited by larval fish. Walleye were consistently selective for the largest prey available, calanoid copepods. Yellow perch were size-selective to a lesser extent and appeared to be more influenced by zooplankton prey availability. Suckers were selective for the smallest prey available, and also for the most numerically abundant prey.

Utilization of Daphnia by yellow perch, larval fish by walleye, and Bosmina by suckers was influenced by seasonal abundance of those prey items. Sample sizes of sculpin were too low to accurately define seasonal shifts in diet with prey abundance.

Competitive feeding interactions may have occurred for a short time period between walleye and yellow perch and between yellow perch and sculpin. Due to the short duration of the interaction, effects on growth, survival, and character displacement were considered minimal.

LITERATURE CITED

## LITERATURE CITED

- Abrams, P. 1980. Some comments on measuring niche overlap. *Ecology* 61:44-49.
- Amundrud, J.R., D.J. Faber, and A. Keast. 1974. Seasonal succession of free-swimming perciform larvae in Lake Opinicon, Ontario. *Journal of the Fisheries Research Board of Canada* 31:1661-1665.
- Bagenal, T.B. 1978. Methods for assessment of fish production in fresh waters. Third edition. Blackwell Scientific Publications, Oxford and Edinburgh, Great Britain.
- Bailey, Jack E. 1952. Life history and ecology of the sculpin, Cottus bairdi punctulatus, in southwestern Montana. *Copeia* 4:243-255.
- Beckman, L.G., W.R. Persons, J.F. Novotny, and T.T. Terrell. 1984. Assessment of the fisheries and limnology of Lake F. D. Roosevelt, 1980-1983. Final Report. U.S. Fish and Wildlife Service, Seattle National Fisheries Research Center. #FWS-14-06-009-904.
- Brandlova, J. 1972. The Cladocera of Ontario with remarks on some species and distribution. *Canadian Journal of Zoology* 50:1373-1403.
- Braum, E. 1967. The survival of fish larvae with reference to their feeding behavior and food supply. In: The biological basis of freshwater fish production. S. D. Gerking, editor. John Wiley and Sons, New York, USA.
- Brege, D.A. 1981. Growth characteristics of young-of-the-year walleye, Stizostedion vitreum vitreum, in John Day Reservoir on the Columbia River, 1979. *NOAA Fisheries Bulletin* 79(3):567-569.
- Brooks, J.L. and S.I. Dodson. 1965. Predation, body size, and composition of plankton. *Science* 150(1):28-35.

- Bulkley, R.V., V.L. Spykermann and L.E. Inmon. 1976. Food of the pelagic young of walleyes and five cohabiting fish species in Clear Lake, Iowa. Transactions of the American Fisheries Society 105(1):77-83.
- Busch, W.D.N., R.L. Scholl, and W.L. Hartman. 1975. Environmental factors affecting the strength of walleye year-classes in Western Lake Erie, 1960-1970. Journal of the Fisheries Research Board of Canada 32(10):1733-1743.
- Clady, M.D. 1977. Crustacean zooplankton populations and concurrent survival of larval yellow perch in Oneida Lake. New York Fish and Game Journal 24(1):46-52.
- Confer, J.L. and P.I. Blades. 1975. Omnivorous zooplankton and planktivorous fish. Limnology and oceanography 20(4):571-579.
- Crecco, V.A. and M.M. Blake. 1983. Feeding ecology of coexisting larvae of American shad and blueback herring in the Connecticut River. Transactions of the American Fisheries Society 112:498-507.
- Forney, J.L. 1974. Interactions between yellow perch abundance, walleye predation, and survival of alternate prey in Oneida Lake, New York. Transactions of the American Fisheries Society 103(1):15-24.
- Galbraith, M.G., Jr. 1967. Size-selective predation on Daphnia by rainbow trout and yellow perch. Transactions of the American Fisheries Society 96(1):1-10.
- Gardner, M.B. 1981. Mechanisms of size selectivity by planktivorous fish: a test of hypotheses. Ecology 62(3):571-578.
- Goldman, C.R. and A.J. Horne. 1983. Limnology. McGraw-Hill, Inc., U.S.A.
- Hansen, M.J. and David H. Wahl. 1981. Selection of small Daphnia pulex by yellow perch fry in Oneida Lake, New York. Transactions of the American Fisheries Society 110:64-71.

- Harper, R.J., K.M. McMaster, and L.G. Beckman. 1981. Assessment of fish stocks in Lake F. D. Roosevelt. Annual Report to U.S. Bureau of Reclamation. U.S. Fish and Wildlife Service, Seattle National Fisheries Research Center. 74pp.
- Hokanson, K. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. Journal of the Fisheries Research Board of Canada 34:1524-1550.
- Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. American Midland Naturalist 100:419-424.
- Houde, E.D. 1967. Food of the pelagic young of the walleye, Stizostedion vitreum vitreum, in Oneida Lake, New York. Transactions of the American Fisheries Society 96:17-24.
- Hurlbert, S.H. 1978. The measurement of niche overlap and some relatives. Ecology 59:67-77.
- Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven, Connecticut, U.S.A. 302pp.
- June, F.C. 1976. Changes in young-of-the-year fish stocks during and after filling Lake Oahe, an upper Missouri River storage reservoir. U.S. Fish and Wildlife Service Technical Paper 87.
- Keast, A. 1979. Food and feeding relationships of young fish in the first weeks after the beginning of exogenous feeding in Lake Opinicon, Ontario. Environmental Biology of Fishes 5(4):305-314.
- Kohler, C.C. and J.J. Ney. 1982. Comparison of methods for quantitative analysis of feeding selection in fishes. Environmental Biology of Fishes 7(4): 363-368.
- Langford, R.R. 1953. Methods of plankton collection and a description of a new sampler. Journal of the Fisheries Research Board of Canada 10:238-252.

- MacPhee, C. 1960. Postlarval development and diet of the largescale sucker, Catostomus macrocheilus. *Copeia* 1960:119-125.
- Maloney, J.E. and F.H. Johnson. 1957. Life histories and interrelationships of walleye and yellow perch, especially during their first summer, in two Minnesota lakes. *Transactions of the American Fisheries Society* 85:191-202.
- Mathias, J.A. and S. Li. 1982. Feeding habits of walleye larvae and juveniles: comparative laboratory and field studies. *Transactions of the American Fisheries Society* 111:722-735.
- Mathur, D. and T.W. Robbins. 1971. Food habits and feeding chronology of young white crappie in Conowingo Reservoir. *Transactions of the American Fisheries Society* 100:307-311.
- Nigro, A.A., T.T. Terrell, and L.G. Beckman. 1982. Assessment of the limnology and fisheries in Lake F. D. Roosevelt. Annual Report to U.S. Bureau of Reclamation. U.S. Fish and Wildlife Service, Seattle National Fisheries Research Center. 83pp.
- O'Brien, W.J. 1979. The predator-prey interaction of planktivorous fish and zooplankton. *American Scientist* 67(5):572-581.
- Patalas, K. and A. Salki. 1984. Effects of impoundment and diversion on the crustacean plankton of Southern Indian Lake. *Canadian Journal of Fisheries and Aquatic Science* 41: 613-637.
- Patalas, K. 1975. The crustacean plankton communities of fourteen North American great lakes. *Proceedings of the International Association for Theoretical and Applied Limnology* 19:504-511.
- Pennak, R.W. 1978. *Freshwater invertebrates of the United States*. Second Edition. John Wiley and Sons, New York, USA.
- Raisanen, G.A., and R.L. Applegate. 1983. Prey selection of walleye fry in an experimental system. *Progressive Fish-Culturist* 45(4): 209-214.

- Rajasilta, M. and I. Vuorinen. 1983. A field study of prey selection in planktivorous fish larvae. *Oecologia* 59:65-68.
- Schoener, T.W. 1970. Non-synchronous spatial overlap of lizards in patchy habitats. *Ecology* 51:408-418.
- Schoener, T.W. 1982. The controversy over interspecific competition. *American Scientist* 70: 586-595.
- Sheldon, Andrew L. 1968. Drift, growth and mortality of juvenile sculpins in Sagehen Creek, California. *Transactions of the American Fisheries Society* 97 (4):495-496.
- Siefert, R.E. 1972. First food of larval yellow perch, white suckers, bluegill, emerald shiner, and rainbow smelt. *Transactions of the American Fisheries Society* 101(2):219-225.
- Snedecor, G.W. and W.G. Cochran. 1967. *Statistical methods*. Iowa State University Press, Ames, Iowa.
- Stewart, N.H. 1926. Development, growth, and food habits of the white sucker, Catostomus commersoni. U.S. Bureau of Fisheries Bulletin 42:147-184.
- Stober, Q.J., M.E. Kopache, and T.H. Jagielo. 1980. The limnology of Lake Roosevelt. Final report. U.S. Fish and Wildlife Service, Seattle National Fisheries Research Center, Contract No. 14-16-0009-80-004.
- Strauss, R.E. 1979. Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. *Transactions of the American Fisheries Society* 108:344-352.
- Thayer, G.W., D.E. Hoss, M.A. Kjelson, W.F. Hettler, Jr., and M.W. LaCroix. 1974. Biomass of zooplankton in the Newport River estuary and the influence of postlarval fishes. *Chesapeake Science* 15(1):9-16.
- Walker, R.E. and R.L. Applegate. 1976. Growth, food, and possible ecological effects of young-of-the-year walleyes in a South Dakota prairie pothole. *Progressive Fish-Culturist* 38(4):217-220.

- Wallace, R.K., Jr. 1981. An assessment of diet overlap indices. Transactions of the American Fisheries Society 110:72-76.
- Wallus, Robert and Kenneth L. Granneman. 1978. Spawning behavior and early development of the banded sculpin, Cottus carolinae (Gill). In: Proceedings, Tennessee Valley Authority Workshop on Freshwater Larval Fishes. Robert Wallus and C.W. Voightlander, editors.
- Ward, H.B. and G.C. Whipple. 1959. Freshwater biology. Second edition. W.T. Edmondson, editor. John Wiley and Sons, New York, USA.
- Werner, E.E., and D.J. Hall. 1974. Optimal foraging and size selection of prey by the bluegill sunfish (Lepomis macrochirus). Ecology 55: 1042-1052.
- Wetzel, R.G. and G.E. Likens. 1979. Limnological analyses. W.B. Saunders Company, Philadelphia, Pennsylvania. USA.
- Wong, B. and F.J. Ward. 1972. Size selection of Daphnia pulicaria by yellow perch (Perca flavescens) fry in West Blue Lake, Manitoba. Journal of the Fisheries Research Board of Canada 29(12)1761-1764.
- Zaret, T. and A.S. Rand. 1971. Competition in tropical stream fish: support for the competitive exclusion principle. Ecology 52: 336-342.

APPENDIX

Table 8. Surface water temperatures ( $^{\circ}\text{C}$ ) at embayment (E) and mainstem (M) sites, Stations 1-4, Lake Roosevelt May-August 1982.

Date		Station			
		1	2	3	4
5/10/82	E	12.0	-	9.8	10.5
	M	9.9	10.3	11.1	-
5/17/82	E	11.6	-	11.2	13.0
	M	12.0	11.8	13.5	9.9
5/24/82	E	-	-	11.8	11.0
	M	-	-	12.0	10.9
5/31/82	E	16.0	14.0	12.8	12.9
	M	13.1	14.9	12.3	11.3
6/07/82	E	17.8	17.1	19.7	16.4
	M	13.8	19.7	19.3	13.2
6/14/82	E	21.7	17.7	18.7	17.4
	M	21.9	20.4	18.5	14.9
6/21/82	E	21.0	20.2	20.8	18.7
	M	20.8	20.5	18.3	16.6
6/28/82	E	20.1	21.2	17.8	17.4
	M	17.2	20.9	17.0	16.0
7/05/82	E	21.0	19.8	18.6	16.8
	M	19.0	19.9	17.2	15.8
7/26/82	E	24.5	25.2	21.2	21.1
	M	24.1	24.5	21.5	17.9
8/09/82	E	21.2	21.9	17.3	17.6
	M	21.5	22.0	16.9	17.6

Table 9. Numerical percent composition of major prey items from larval walleye by sample week at embayment (E) and mainstem (M) sites, Stations 1-3, Lake Roosevelt, May-July 1982.

Week #	STATION					
	1		2		3 <sup>1</sup>	
	E	M	E	M	E	M
	<u>Calanoid</u>					
*						
3 (6/10)	0	80	-2	-	-	-
4 (6/16)	-	83	33	44	-	-
5 (6/24)	75	83	33	44	-	-
6 (7/1)	-	52	-	-	100	100
7 (7/7)	0	0	-	-	86	0
	<u>Cyclopoid</u>					
3	0	0	-	-	-	-
4	-	8	0	6	-	-
5	0	11	0	0	0	-
6	-	42	-	-	0	0
7	0	50	-	-	0	0
	<u>Daphnia</u>					
3	67	0	-	-	-	-
4	-	0	8	6	-	-
5	0	3	0	0	0	-
6	-	0	-	-	0	0
7	0	0	-	-	0	0
	<u>Larval fish</u>					
3	33	0	-	-	-	-
4	-	3	58	40	-	-
5	25	0	95	100	0	-
6	-	0	-	-	0	0
7	100	0	-	-	0	0

\*: Walleye not captured before 6/10

1: Walleye not captured at Station 4

2: Indicates no fish on that date

Table 10. Numerical percent composition of major prey items from larval sculpins at each station in Lake Roosevelt, May-July 1982.

Week #	STATION							
	1		2		3		4	
	E	M	E	M	E	M	E	M
<u>Calanoid</u>								
1 (5/26)	0	0	-	0	0	100	-	-
2 (6/2)	0	23	0	0	100	100	-	0
3 (6/10)	18	0	-	43	-	-	0	0
4 (6/16)	17	0	0	0	44	0	50	33
5 (6/24)	-	-	-	0	44	0	50	33
6 (7/10)	-	-	-	-	-	50	38	0
<u>Cyclopoid</u>								
1	100	60	-	0	0	0	-	-
2	100	77	100	50	0	0	-	0
3	47	100	-	0	-	-	0	100
4	59	100	0	0	0	19	67	50
5	-	-	-	50	11	33	50	67
6	-	-	-	-	-	0	50	0
<u>Daphnia</u>								
1	0	0	-	0	0	0	-	-
2	0	0	-	50	0	0	-	0
3	0	0	-	57	-	-	0	0
4	28	0	0	100	0	0	0	0
5	-	-	-	50	11	0	0	0
6	-	-	-	-	-	0	0	0

Table 11. Horn, Schoener, and correlation coefficient diet overlap values for larval fish at Stations 1-4, Lake Roosevelt, 1982.

	Horn	Schoener	Correlation coefficient
STATION 1			
walleye x yellow perch	0.97	0.84	+0.98
walleye x sculpin	0.44	0.35	+0.33
yellow perch x sculpin	0.54	0.50	+0.45
STATION 2			
walleye x yellow perch	0.15	0.21	-0.03
walleye x sculpin	0.10	0.13	-0.14
walleye x sucker	0.07	0.16	-0.19
yellow perch x sculpin	0.74	0.57	+0.70
yellow perch x sucker	0.19	0.19	0.00
sculpin x sucker	0.07	0.07	-0.20
STATION 3			
walleye x yellow perch	0.84	0.65	+0.97
walleye x sculpin	0.81	0.67	+0.97
yellow perch x sculpin	0.99	0.94	+0.99
STATION 4			
yellow perch x sculpin	0.96	0.87	+0.99

Table 12. Sample size (n) of larval fish used for stomach analysis at embayment (E) and mainstem (M) sites, Stations 1-4, Lake Roosevelt, May-July 1982.

Date (1982)	<u>STATION 1</u>														
	05-26		06-02		06-10		06-16		06-24		07-01		07-07		
	E	M	E	M	E	M	E	M	E	M	E	M	E	M	
Walleye	0	0	0	0	1	3	0	5	3	11	0	5	1	1	
Yellow perch	0	12	1	12	39	0	42	64	20	32	19	8	4	4	
Sculpins	2	1	10	7	10	1	0	3	0	0	0	0	0	0	
	<u>STATION 2</u>														
	Walleye	0	0	0	2	1	0	10	11	0	0	0	0	0	0
	Yellow perch	0	10	10	10	10	10	10	10	8	5	3	3	1	0
Sculpins	0	1	5	10	3	7	1	3	0	1	0	0	0	1	
Suckers	0	0	12	11	12	28	10	10	10	10	10	10	10	10	
	<u>STATION 3</u>														
	Walleye	0	0	0	0	0	0	0	0	10	0	11	1	2	1
	Yellow perch	9	0	10	9	7	6	6	10	9	10	7	4	0	5
Sculpins	1	2	6	4	0	0	5	10	2	3	6	2	0	0	
	<u>STATION 4</u>														
	Walleye	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Yellow perch	0	0	0	0	4	1	5	5	8	7	8	0	4	0
Sculpins	1	0	5	2	1	0	3	1	7	1	10	1	1	1	

