Foods of Rainbow Smelt Larvae

(*Osmerus mordax*) in Nearshore

Waters of Northwestern Lake Huron

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Abstract

Larvae of rainbow smelt (*Osmerus mordax*) in nearshore waters of northwestern Lake Huron did not feed until they were 7 mm long. Smaller (7-13 mm) larvae first ate copepod nauplii about 0.26 mm long. Larger larvae (14-23 mm long) ate larger prey (mostly *Diaptomus* spp. up to 0.94 mm long). Smelt larvae ate few algae and no rotifers. The most abundant crustacean zooplankter available in the environment (*Bosmina longirostris*; mean length: 0.35 mm) was not eaten by smelt larvae.

Introduction

The relative abundance of suitable foods in the environment and factors governing selection of first foods by fish larvae sometimes determine the year-class strength of marine and freshwater fish (Hjort 1926; May 1974; Lasker 1975; Werner and Blaxter 1979; and McCullough and Stanley 1981). However, the link between the planktonic foods available to fish in nursery areas and the year-class strength of fish produced in those areas each year is not well documented in the Great Lakes. Information of this sort is particularly needed for forage fish stocks, such as rainbow smelt (Osmerus mordax), because annual stocking rates of salmonids that depend on these stocks could, for optimum management, be geared to the available forage base (Samples and Bishop 1982).

Fry of bluegill (Lepomis macrochirus), yellow perch (Perca flavescens), and rainbow trout (Salmo gairdneri) select prey by size under laboratory conditions (Galbraith 1967; Werner and Hall 1974). However, except for the work of Hohn (1966) on fry of walleye (Stizostedion vitreum vitreum) in southwestern Lake Erie, Norden (1968) on alewife (Alosa pseudoharengus) larvae in Lake Michigan, and Siefert (1972) on the larvae of emerald shiners (Notropis atherinoides) and rainbow smelt in western Lake Superior, very little information is available on foods of fish larvae in the Great Lakes. In a small lake in Maine, rainbow smelt larvae began feeding on copepod nauplii and selected specific sizes and kinds of prey (primarily rotifers). As the smelt grew larger, they ate larger prey, but mimimum prey dimensions fluctuated about a constant value (McCullough and Stanley 1981). In St. Louis Bay, Lake Superior, rainbow smelt larvae ate primarily the crustacean zooplankter Cyclops bicuspidatus thomasi until the smelt reached 21 mm in length (Siefert 1972). The only information we could find in the literature describing size-selective feeding by smelt larvae in the Great Lakes indicated that smelt larvae preyed selectively on copepods at first, in a manner independent of prey size, in two bays of Lake Superior (Siefert 1972, Leslie and Kelso 1977). The objectives of the present study were to identify foods eaten by rainbow smelt larvae, test for size-selective feeding, and determine preference (electivity) of smelt larvae for available prey in nearshore waters of the Great Lakes that serve as nursery grounds for rainbow smelt larvae.

Methods and Materials

Larvae of rainbow smelt were collected during June 1974 and June and July 1975 with a 1/2-m net (350 µm porosity) as part of a larger study to identify important nursery grounds for fish larvae in western Lake Huron (O'Gorman 1983). Larvae were preserved in 10% formaldehyde immediately after collection. In the laboratory, 236 smelt larvae were sorted from debris in the samples, measured, and identified under a binocular microscope at a magnification of 10X by reference to Cooper (1978). The gut tube of each larvae was teased gently from the abdominal cavity, severed at the anus and immediately behind the gill arch, and transferred to a Sedgewick-Rafter cell containing about 10 mL of water. This procedure prevented introduction of extraneous plankton that sometimes adhered to the exterior of the preserved fish. In the Sedgewick-Rafter cell, the contents of the gut were gently removed, identified, measured, and counted. Identification of prey was sometimes difficult because they were

partly digested. Some prey were therefore grouped (for example, the copepodites). Plankters available to the larvae in Hammond Bay were identified to the same taxonomic level as those in the gut contents, counted, and their length measured to the nearest 0.01 mm. To determine whether smelt larvae ate phytoplankton, we combined the gut contents of 115 smelt larvae and examined about 25% of the combined contents for algae at a magnification of 400X using an inverted microscope.

Results and Discussion

Of the 236 smelt larvae we examined, 71% had eaten; 99% of the prey were crustacean zooplankton. Only three phytoplankters (the diatom Tabelleria) were found in the sample of combined gut contents. We believe these diatoms were eaten incidentally. Siefert (1972) also found that few phytoplankton were eaten by smelt larvae he collected in Lake Superior.

Smelt larvae we examined did not feed until they absorbed the yolk sac and reached 7 mm in length (Table 1). Some fish between 7.0 and 10.9 mm that possessed remnants of the yolk sac (oil globules) had fed. Copepod nauplii constituted, numerically, 83.3% of prey injested by all smelt larvae we examined. The size of prey eaten by smelt larvae increased as the larvae grew longer (Figure 1). Smelt larvae 7.0-11.9 mm ate copepod nauplii; larvae 10.0-15.9 mm long ate intermediate size prey, such as cyclopoids and smaller calanoids; and larvae 16.0-22.9 mm long ate larger calanoids, such as Diaptomus spp. (Table 2). The average length of diaptomid and cyclopoid copepods consumed by smelt larvae was 0.6 mm for larvae 8.0-13.9 mm long and 0.9 mm for larvae 14.0-22.9 mm long. The average number of food items varied from 1.6 per larva 7.0-7.9 mm long to 5.0 per larva 21.0-22.9 mm long (Table 3). Siefert (1972) reported that copepod nauplii were the second most important prey of smelt larvae in a bay in western Lake Superior.

Selection of larger prey by larger fish larvae has been reported for walleye (Hohn 1966); alewife (Brooks 1968; Wells 1970), herring (Clupea harengus harengus) (Bainbridge and Forstyth 1971), bluegill (Werner and Hall 1974), and rainbow smelt (Siefert 1972). Smelt larvae 18 mm long we examined possessed completely developed pelvic fins. The presence of these fins may increase the ability of smelt larvae to capture food. We found the relation between the size of prey consumed and the length of smelt larvae (Figure 1) was best expressed by $Y = aX^b$, where Y = mean length of prey, and X = length class of smelt larvae. The solution to this equation that best fit the data was $Y = 0.009\ X^{1.54}$.

To determine if smelt larvae selected one species of prey from among those available in the environment, we used Ivlev's (1961) index. In this index, +1 indicates complete positive electivity, 0 indicates random electivity, and -1 indicates complete negative electivity. Ivlev's index assumes the predator and prey are present at the same time and location. This assumption is valid because all zooplankton taxa were distributed homogeneously throughout Hammond Bay (Heberger and Manny 1983). The relative abundance of each zooplankton taxa

available to the smelt larvae during June 1974 and 1975 was calculated as a percent of the total zooplankton (Table 4). Seven taxa represented over 97% of the total zooplankton available to the larvae.

The electivity value for the first prey selected by smelt larvae (copepod nauplii) decreased from +0.55 for smelt 7.0-7.9 mm long to +0.40 for smelt 13.0-13.9 mm long (Figure 2). The size range of copepod nauplii available to these larvae, as determined from samples of zooplankton collected in Hammond Bay in June of 1974 and 1975, was 0.12-0.40 mm ($\bar{x}$ = 0.26 mm, N = 40). Smelt 14.0 mm and longer had a negative electivity value for copepod nauplii. Copepod nauplii made up 28.6% of the total zooplankton in the environment during June 1974 and 1975, slightly less than that of Bosmina longirostris (29.8%; Table 4). Although B. longirostris was the most numerous zooplankton of the proper prey size (0.20-0.55 mm in length; $\bar{x}$ = 0.35 mm; N = 40) available to the smelt larvae, it was not eaten. Perhaps the swimming ability of the smelt larvae was not developed enough to capture B. longirostris, or B. longirostris was not visible to the smelt larvae because it is transparent with no large eye spot and possesses no distracting mode of locomotion. Herring larvae also ate prey other than the most abundant prey available to them (Bainbridge and Forsyth 1971).

Smelt larvae 11.0-15.9 mm long ate Cyclops bicuspidatus thomasi (0.4-0.8 mm) and smaller (0.4-0.6 mm) members of the genus Diaptomus. Cyclops bicuspidatus thomasi and cyclopoid copepodites combined made up 27.9% by number of the available zooplankton (Table 4), but these zooplankters were eaten only by smelt larvae 14.0-16.9 mm long (Figure 2). Smelt larvae 11.0-15.9 mm long ate small (0.6 mm) diaptomids. Diaptomids and calanoid copepodites combined made up 11.3 % of the available zooplankton prey (Table 4). Larger smelt larvae (16.0-22.9 mm) ate intermediate sized diaptomids (0.9 mm in length). Although we examined only 12 of these larger larvae, our findings agree with those of Siefert (1972) who found that Diaptomus and C. bicuspidatus thomasi were eaten by smelt larve 16.0-22.9 mm long. Daphnia made up 0.4% of the available zooplankton and were eaten only by smelt larvae 12.0-12.9 mm long. Unidentified copepods were eaten by a large percentage of smelt larvae we examined (Table 2).

O'Gorman (1983) found that rainbow smelt was the dominant ichthyoplankter in northern Lake Huron from late May through June, including Hammond Bay where he found the highest density of smelt larvae in western Lake Huron (2,515/1,000 m^3 of water). Heberger and Manny (1983) found that more than twice as many copepod nauplii were available to smelt larvae in Hammond Bay in June 1975 than in June 1974 (Table 4). Our analyses showed that more copepod nauplii were eaten by smelt larvae in June 1975 than in June 1974 (Table 5)--the larvae collected in 1975 contained an average of 1.4 copepod nauplii per fish; the larvae collected in 1974 contained an average of only 0.5 copepod nauplii per fish. Subsequent assessment fishing showed that a weak year-class of smelt was produced in Hammond Bay in 1974 and a strong year-class was produced there in 1975 (O'Gorman 1983; R. Stedman, personal communication). These results support the hypothesis expressed by McCullough and Stanley (1981) that year-class strength of rainbow smelt is largely determined by the relative abundance in the environment of foods eaten by smelt larvae. Further research

would be needed, however, to determine to what extent strong year-classes of smelt in Hammond Bay are dependent on the abundance of the various prey that were eaten by smelt larvae in 1974 and 1975.

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Table 1. Number of smelt larvae of various sizes that were collected in Hammond Bay during June 1975 and had eaten prey.

Length interval (mm)	Number of larvae examined	Number of larvae containing prey
4.0- 4.9	1	0
5.0- 5.9	1	0
6.0- 6.9	6	0
7.0- 7.9	14	11
8.0- 8.9	28	28
9.0- 9.9	23	23
10.0-10.9	28	28
11.0-11.9	6	6

Table 2. Average number of prey eaten by smelt larvae and (in parentheses) the percentage of fish examined that contained that kind of prey.

Total length of fish (mm)	Number of fish examined	Number with food	Copepod nauplii	Cyclopoda[a]	*Diaptomus* spp.	*Bosmina longirostris*	*Daphnia* spp.	Unidentified[b] copepoda
4.0- 4.9	1	0						
5.0- 6.9	11	0						
7.0- 8.9	57	49	1.5 (91)	0.1 (6)				0.2 (17)
9.0-10.9	88	66	2.0 (76)	<0.1 (3)	<0.1 (2)			0.5 (32)
11.0-12.9	48	32	0.8 (69)	0.1 (6)	0.1 (13)	0.1 (3)	0.1 (3)	0.7 (50)
13.0-14.9	14	10	0.4 (40)	0.1 (10)	0.2 (20)			0.8 (70)
15.0-16.9	13	9	0.2 (22)	0.4 (44)	0.5 (55)			0.7 (78)
17.0-18.9	1	1			1.0 (100)			
19.0-20.9	1	1			4.0 (100)			
21.0-22.9	2	2			4.5 (100)			0.5 (50)

a/ Presumed to be mostly *Cyclops bicuspidatus thomasi* because *C. b. thomasi* was 6 times more abundant than *Cyclops vernalis* or *Tropocyclops prasnius*.

b/ Presumed to be mostly *Diaptomus* spp. and *Cyclops bicuspidatus thomasi*.

Table 3. Size and number of prey consumed by smelt larvae (all dates combined for 1974 and 1975) from the Hammond Bay vicinity.

Smelt length (mm)	Number of smelt examined	Average size of prey (mm)	Average number of prey consumed per fish a/
4.0 - 4.9	1	b/	b/
5.0 - 5.9	1	b/	b/
6.0 - 6.9	10	b/	b/
7.0 - 7.9	19	0.20	1.57
8.0 - 8.9	38	0.24	1.82
9.0 - 9.9	33	0.24	1.69
10.0 - 10.9	55	0.26	1.83
11.0 - 11.9	26	0.29	1.78
12.0 - 12.9	22	0.36	1.64
13.0 - 13.9	12	0.41	1.67
14.0 - 14.9	2	0.60	1.00
15.0 - 15.9	5	0.74	2.00
16.0 - 16.9	8	0.53	2.00
18.0 - 18.9	1	1.20	1.00
19.0 - 19.9	1	0.83	4.00
21.0 - 21.9	1	0.76	5.00
22.0 - 22.9	1	0.94	5.00

a/ Only fish with at least one prey in the gut were used in the calculations.

b/ No prey were found in fish 4.0 - 6.9 mm long.

Table 4. Average daily abundance (No./m3) and composition (as a percent by taxa) of zooplankton in Hammond Bay, Lake Huron, that were used in this study to calculate electivity indices.

	Taxa									
	Bosmina longirostris	Copepod nauplii	Cyclopoid copepodites	*Cyclops bicuspidatus thomasi*	Calanoid copepodites	*Diaptomus* sp.	Total daphnia	Total Cladocerans	Total copepods	Grand total
				June, 1974						
Average abundance (N = 18 days):	1,436	901	806	302	87	112	7	1,460	2,246	3,707
Percent of total zooplankton:	38.7	24.3	21.7	8.1	2.3	3.0	0.2	39.4	60.6	100.0
				June, 1975						
Average abundance (N = 16 days):	1,801	2,260	925	1,024	585	476	41	1,864	5,420	7,284
Percent of total zooplankton:	24.7	31.0	12.7	14.1	8.0	6.5	0.6	25.6	74.4	100.0
				June 1974 and June 1975, combined						
Average abundance:	1,608	1,540	862	641	321	283	23	1,650	3,740	5,390
Percent of total zooplankton:	29.8	28.6	16.0	11.9	6.0	5.3	0.4	30.6	69.4	100.0

Table 5. Number of copepod nauplii eaten by smelt larvae collected from Hammond Bay in 1974 and 1975.

Smelt length (mm)	1974			1975		
	Number of smelt	Number of nauplii	Nauplii per larvae	Number of smelt	Number of nauplii	Nauplii per larvae
7.0 - 7.9	5	4	0.8	14	15	1.1
8.0 - 8.9	9	6	0.7	28	47	1.7
9.0 - 9.9	8	4	0.5	23	29	1.3
10.0 - 10.9	22	13	0.6	28	35	1.3
11.0 - 11.9	18	7	0.4	6	9	1.5
12.0 - 12.9	14	6	0.4	0	0	
13.0 - 13.9	7	2	0.3	0	0	
Average			0.5			1.4

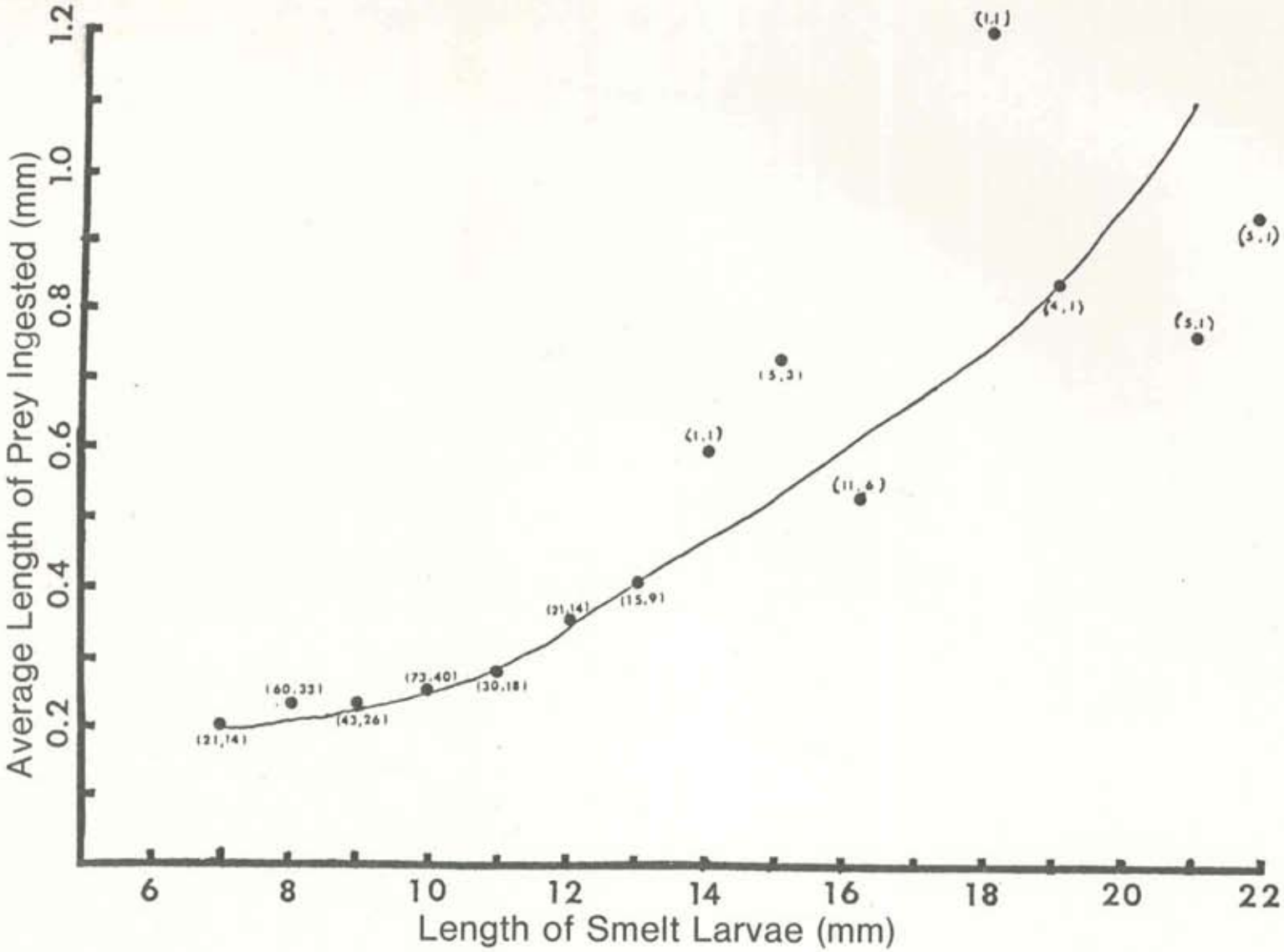

Figure 1. Relation between length of smelt larvae and average length of prey ingested. The curve was fitted by visual inspection. The first number in parentheses next to each point represents the total number of prey ingested; the second number is how many larvae of that size were examined.

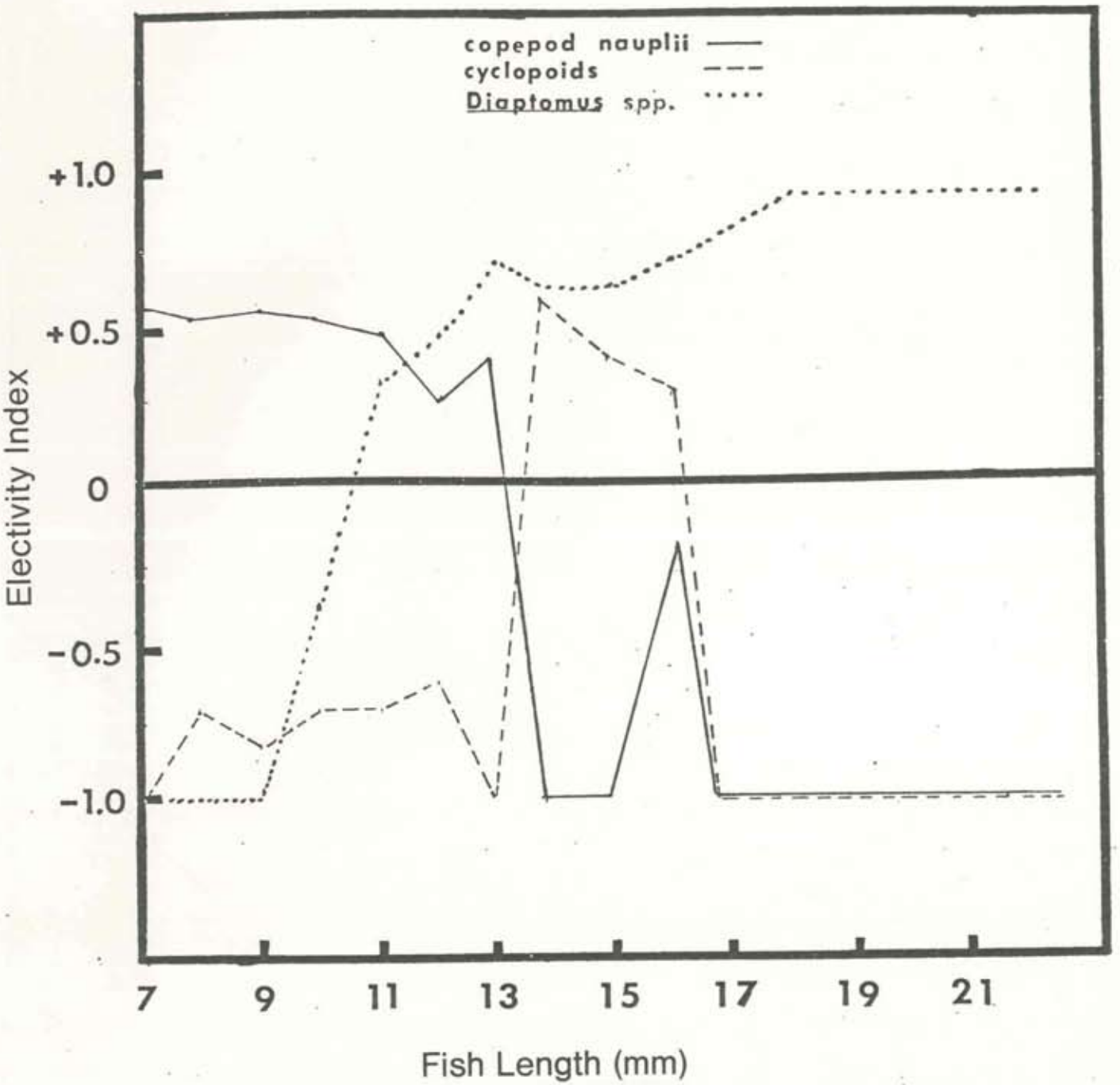

Figure 2. Electivity index values for the three major foods eaten by rainbow smelt larvae in northwestern Lake Huron in 1974 and 1975.