STUDIES ON FACTORS CONTROLLING TRANSITION OF YOUNG YELLOW PERCH (*PERCA FLAVESCENS*) IN ONEIDA LAKE

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Yao-Sung Lin (1982) Studies of factors controlling transition of young yellow perch (*Perca flavescens*) in Oneida Lake. *Bull. Inst. Zool., Academia Sinica* 22(1): 13-24. The diet and growth of young yellow perch (*Perca flavescens*) at pelagic and demersal stages in Oneida Lake was compared with the abundance and vertical distribution of the limnetic zooplankton in summer 1972 and 1973 to examine factors controlling transition of perch from pelagic to demersal mode. Vertical distribution of perch cohorts and zooplankton were determined at weekly intervals and growth of perch was followed through the summer.

Vertical transition occurred during a 1-2 week period in late July 1972 and late June 1973. Mean length of perch during this transition was 42.8 mm in 1972 and 27.6 mm in 1973. Perch changed from pelagic to demersal at a time when water temperatures were rising rapidly.

Seven species of cladocera were observed in 1972, *D. retrocurva* were abundant in surface water and *D. pulex* predominated near the bottom. In contrast, only *D. pulex* was found in 1973, and they tended to concentrate near the surface. The time of transition was not determined by vertical distribution of food zooplankters.

Perch ate about equal numbers of cladocera and copepods in 1972 and mostly *D. pulex* in 1973 during the pelagic stage. They consumed mostly copepods in the transition period, and after they became demersal, *D. pulex* was the most important food in both years. As the fish increased in size they fed on larger zooplankters in preference to small ones.

Growth rates of pelagic fry in 1972 and 1973 were approximately equal despite marked variation in composition and abundance of zooplankters in lake and in perch stomachs. However, during the demersal stage perch grew more rapidly in 1973. Differences in amount of food consumed in late summer of 1972 and 1973 probably contributed to differences in growth rate.

The yellow perch, *Perca flavescens* (Mitchill), is an important sport fish in Oneida Lake, New York and young-of-the-year yellow perch are the predominant forage of larger predators (Forney, 1971). Perch spawn in shallow areas of Oneida Lake from mid- to late April. Eggs hatch in mid-May and larvae immediately concentrate in the upper 3 m of water. Perch cohorts remain pelagic for several weeks and transition to the demersal stage is usually completed by late July when young perch are 30–40 mm long (Forney, 1980). Young are widely distributed in late summer and occupy both the littoral zone and deeper, mud-bottom areas offshore.

Wong (1972) found that perch moved from the limnetic to littoral zone of West Blue Lake, Manitoba when they attained a length of 30 mm. He suggested migration from the limnetic to

littoral zone was an innate characteristic of perch which was triggered by size or stage of physiologic development. However, in Oneida Lake young perch averaging 25–30 mm appear in the littoral zone in late June but catches in bottom trawls fished in open water peak in July when perch are 40–50 mm long.

To ascertain whether food distribution influenced time of transition from pelagic to demersal, the diet and growth of perch, the composition and vertical distribution of zooplankton were examined in summer of 1972 and 1973. Studies of food preference were undertaken to facilitate interpretation of dietary changes.

MATERIALS AND METHODS

Oneida lake, a large, shallow, eutrophic lake located in central New York, is 33.6 km long, has an average width of 6.1 km, and an area of 206.7 km. Maximum depth is 16.7 m with a mean depth of 6.8 m. The most important sport fishes are walleye (*Stizostedion vitreum*), yellow perch and smallmouth bass (*Micropterus dolomieu*) (Grosslein, 1961).

Factors centrolling transition of perch from pelagic to demersal mode were examined in 1972 and 1973. Vertical distribution of perch cohorts was determined at weekly intervals and growth of young was followed through the summer. Samples of young-of-the-year perch and plankton were taked 1.2 km north of Shackelton Point where the depth was 10 m except in late July and August 1973 when oxygen deficits occurred in deep water. On these few occasions samples were collected nearer shore at a depth of 7 m. The sampling area was exposed to the prevailing westerly wind and the bottom was muddy.

Yellow perch

In June and July 1972, perch were collected at 0900 and 1500 hours on each sampling date. No difference in stomach contents of perch was detected between morning and afternoon catches, hence beginning in August 1972 and through 1973 samples were collected once between 0900 and 1500 hours.

During the pelagic stage young perch were collected with high-speed samplers and midwater trawls. High-speed samplers described by Miller (1961) were towed at depths of 1, 3 and 5 m for 5 min at 13 km/h. Depth of the sample was estimated from the angle and length of cable under tow. Avoidance of high-speed samplers increased with size of perch and after June 20 young perch were captured in semiballoon trawls which were fished off bottom. Trawls with 5- and 8-m head ropes were constructed with 38-mm stretch mesh in the body, 13-mm mesh in the cod-end and a 7-mm mesh liner. They were towed at depths of 2, 5 and 8 m and the depth controlled by adjusting trawl boards and length of towing rope. An echo sounder was used to verify the depth of net. Since the mouth opening was about 2 m in height the depth strata fished were 1–3, 4–6 and 7–9 m. Trawls were towed at 4 km/h for about 5 min.

When perch became demersal, samples were collected with 2.5- and 5-m flat, otter trawl which were constructed with 13-mm stretch mesh cod-ends and a 7-mm liner. Bottom trawls were towed at 4 km/h and the head rope extended about 1 m off bottom.

Fish were preserved in 10% formalin immediately after capture. Fifteen to 25 were picked at random from each haul for stomach analysis and their total lengths were measured to the nearest 0.5 mm. Each stomach was removed and the content were identified and counted under a dissecting microscope. Cladocera was identified to species and copedods to genus. Stomach contents of perch were pooled by days. Since young perch were collected between 0900 and 1500 hours, the mean number of zooplankters per stomach multiplied by 4 was used to approximate the daily ration of the young-of-the-year (Noble, 1972).

Since changes in weight reflect the magnitude of difference in growth more realistically than changes in length, lengths were converted to weights using the regressions: In $W = -11.111 + 2.959$ In L, where W is weight in grams and L is total length in mm. The regression is

based on data for perch 20-70 mm collected in 1968-1971 (J. L. Forney, pers. comm).

To examine food selection by yellow perch, I calculated the "Electivity index" (Ivlev, 1961) using the formula: $E=(r-p)/(r+p)$ where E represents the electivity index, r the relative percentage of any food organisms in the stomachs of the fish, and p the relative percentage of the same food organism in the environment. E values may range between -1 to $+1$; the former indicates complete selection against and the latter complete selection for an item.

It was assumed that perch were feeding at the same depth at which they were captured since differences in depth distribution were not evident between samples taken at 0900 and 1500 hours in 1972. Hence, electivity values were based on the mean percentage of a food item in the stomachs of perch and the percentage of the same item in plankton samples taken at corresponding depths. Since mouth opening of trawls fished off-bottom extended from 1-3, 4-6 and 7-9 m, plankton samples taken at 1 and 3 m and 7 and 9 m were combined.

Zooplankton

Plankton was captured at sunrise, midday and sunset in 1972 and at 0800 and 1400 hours in 1973 on the same day young perch were collected. Samples were pooled to obtain a daily mean. Horizontal tows were made at 1, 3, 5, 7 and 9 m with a closing Clarke-Bumpus sampler fitted with a #10 nylon net. Tows were for 1 min at approximately 3 km/h.

Samples were concentrated to approximately 150 ml and preserved in 5% formalin. One-ml subsamples were drawn from each sample with a Hensen-Stempel pipette and transferred to a Sedgewick-Rafter counting cell. Three 1-ml subsamples were counted and the total number of zooplankters in a sample determined by proportion. Volume of water filtered by Clarke-Bumpus samplers was known from flow-meter counts and zooplankton counts were expressed as number/l.

RESULTS

Duration of pelagic stage

In 1972 and 1973 perch spawned in late April and eggs hatched in mid-May. Recruitment of larvae to the pelagic population was completed by May 25-28 (Clady, 1974). The catch in Miller samplers and trawls showed that the cohorts were still concentrated in the upper 3 m of the water column in July 19, 1972 (Table 1). In the following week most perch were caught between 4-6 m. On August 1 and in subsequent weeks all perch were captured near the bottom. The 1973 cohorts were concentrated near the surface on June 19, at mid-depth on June 29, and near the bottom on July 5. Thus perch in 1972 were pelagic for 8-9 wk following hatching but they remained pelagic for only 4-5 wk in 1973.

TABLE 1

Mean numbers and lengths of young-of-the-year yellow perch caught at three depths in Miller high-speed samplers and trawls in summer of 1972 and 1973

Date	Depth	No. of hauls	Mean length of fish (mm)	Mean catch per haul
1972				
Jun. 14	1 m	2	18.4	51
	3 m	2	17.7	19
	5 m	2	—	0
Jun. 28	S	2	25.7	305
	M	2	26.1	5
	D	2	—	0
Jul. 5	S	2	32.4	1685
	M	2	30.1	5
	D	2	30.7	3
Jul. 12	S	2	35.5	>1000
	M	2	36.5	2
	D	2	35.0	3
Jul. 19	S	5	38.9	>500
	M	3	—	0
	D	2	—	0

TABLE 1 (continued)

Date	Depth	No. of hauls	Mean length of fish (mm)	Mean catch per haul
1972				
Jul. 26	S	5	42.7	4
	M	2	42.8	>500
	D	2	—	0
Aug. 1	S	4	—	0
	M	2	—	0
	D	2	46.6	10
Aug. 8	S	2	—	0
	M	1	—	0
	D	1	50.0	78
Aug. 16	S	2	—	0
	M	2	—	0
	D	1	54.1	92
Aug. 23	S	2	—	0
	M	2	—	0
	D	1	56.1	83
1973				
Jun. 19	1 m	2	18.5	11
	3 m	2	18.9	1
	5 m	2	—	0
Jun. 29	S	2	—	0
	M	2	27.6	51
	D	2	—	0
Jul. 5	S	2	—	0
	M	2	—	0
	D	2	29.6	11
Jul. 12	S	3	—	0
	M	2	—	0
	D	1	36.2	40
Jul. 19	S	2	—	0
	M	2	—	0
	D	1	42.6	32

* Young pearch collected with high-speed Miller samplers, on other occasions perch were captured with trawls.
** S—Surface, 1-3 m;   M—Middle, 4-6 m; D—Deep, 7-9 m.

In both years movement of perch from surface to bottom progressed rapidly in open water. The only signficant catches at mid-
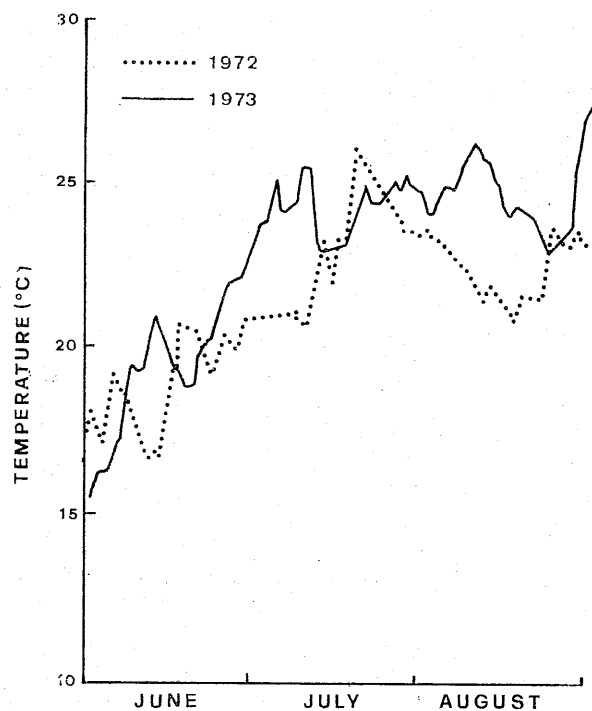

Fig. 1. Water temperatures at 2 m below surface during the summer in Oneida Lake, 1972 and 1973.

depths (4-6 m) were taken in one week each year which suggests transition is limited to a 1-2 wk period. However, young perch were common in seine hauls taken after mid-June in both 1972 and 1973. Apparently some perch moved into the littoral zone at a time when a large segment of population was still pelagic. Those perch which remained pelagic probably constituted a subpopulation which occupied the deeper areas of the lake after transition.

Transition of perch from the pelagic to demersal stage occurred at a time when water temperature was rising rapidly. Continuous temperature recordings near the sampling site at a depth of 2 m indicated that in 1972 surface temperatures increased abruptly from 21° to 25°C in late July and a comparable increase in temperature occurred in late June 1973 (Fig. 1). Although the simultaneous changes in temperatures and depth distribution of perch may be fortuitous, most fish exhibit temperature preferences.

Diet of young perch

The diet of young yellow perch changed during the summer and there were pronounced differences between years. Five species of cladocerans occurred in perch stomachs in 1972 (Table 2). *D. pulex* and *D. retrocurva* were both important food items in 1972 while other cladocerans—*Bosmina longirostris*, *Chydorus sphaericus* and *Leptodora kindtii*—constituted less than than 4% of the food items in perch stomachs. In 1973 only one species of cladoceran, *D. pulex*, occurred in perch stomachs (Table 2).

Adult copepods were more important in 1972 when they constituted 48.7% of the food items than in 1973 when 11.9% of the food items were copepods. Although a few fish consumed large numbers of nauplii in 1972, they constituted only 1.2% of the food and perch stomachs did not contain any nauplii in 1973. Insect larvae (mainly chironomids) constituted a significant part of the diet in August 1972 but they were rare in the stomachs in 1973.

The diet of young yellow perch varied greatly at different stages of development hence samples collected during the pelagic, transition, and demersal stages are discussed separately.

Pelagic stage: Perch consumed about equal numbers of copepods and cladocerans in 1972. *D. retrocurva* was the single most important species in 1972, constituting 30.2% of the total food items eaten by perch while *D. pulex* comprised only 11% of the diet. In contrast, in 1973 *D. pulex* made up 76.5% of the zooplankters in perch stomachs, and cyclopoid copepods were next in abundance.

Transition period: Stomachs of samples captured during the transition from pelagic to demersal stage contained mostly copepods. In 1972 copepods composed over 80% of the diet which was higher than on any date during the pelagic stage. Copepods in 1973 constituted 70% of the diet which was also higher than on other date. Contribution of *Daphnia* to the diet of perch declined during the transition period in both years and *Bosmina*, *Chydorus* and nauplii were not found in perch stomachs.

TABLE 2

Diet composition (mean No./fish) of young yellow perch during the pelagic (P), transition (T), and demersal (D) stages in 1972 and 1973. Percentage of total food items in parentheses. Duration of the pelagic, transition, and demersal periods for 1972 and 1973 were June 14–July 19, July 26, Aug. 1–Aug. 23 and June 14, June 29, July 12–Aug. 31, respectively

Food item	Stage		
	P	T	D
1972			
D. pulex	27.2 (11.0)	32.4 (9.1)	142.1 (64.0)
D. retrocurva	74.6 (30.2)	17.6 (4.9)	1.1 (0.5)
Leptodora	8.0 (3.0)	12.0 (3.4)	0
Bosmina	5.8 (2.4)	0	0
Chydorus	2.0 (0.8)	0	0
Cyclopoids	79.4 (32.2)	148.4 (41.7)	66.1 (29.8)
Calanoids	44.0 (17.8)	144.4 (40.6)	1.0 (0.5)
Nauplii	5.8 (2.4)	0	0
Insect	0	0.8 (0.2)	11.7 (5.3)
1973			
D. pulex	31.2 (76.5)	31.6 (29.1)	605.6 (88.9)
Calanoids	3.2 (7.8)	63.8 (58.9)	56.0 (8.2)
Cyclopoids	6.4 (15.7)	13.0 (12.0)	19.6 (2.9)

Demersal stage: *D. pulex* was the most important food of young perch during the demersal stage and made up 64 and 88.9% of the food items eaten by perch in 1972 and 1973, respectively. There was a progressive decrease in consumption of copepods during the demersal stage but cyclopoid copepods remained common in the diet in 1972. In 1972 insect larvae constituted a significant part of the diet during the demersal stage but few insects were consumed in 1973 when consumption of *D. pulex* was high.

Growth of perch and its relation to diet

Growth rate of young-of-the-year perch during early summer was approximately the same in 1972 and 1973 (Table 1, Fig. 2). The 1972 cohort averaged 8 mm in late May and reached 35.5 mm on July 12, the corresponding figures for the 1973 cohort were 8 mm and 36.2 mm, respectively. However, pronounced differences in growth of these perch cohorts appeared after mid-July and size of perch diverged rapidly during late summer. Although early growth was almost identical, perch started the transition to demersal mode in late July 1972 and late June 1973 when they reached a mean length of 42.8 mm and 27.6 mm, respectively. Obviously, there was no threshold size at which perch become demersal and factors other than size must influence the time of transition.

To analyze the relation of diet to growth, I compared the growth and daily food consumption of yellow perch in 1972 and 1973 during two periods, June to July 12, when the growth rates of fish were similar, and July 19 to late August, when the growth rates were decidedly different. Because of large differences in size of zooplankters, I further calculated the wet weight of zooplankters from pooled stomach contents during these two periods. Length of individual zooplankters from pooled stomach
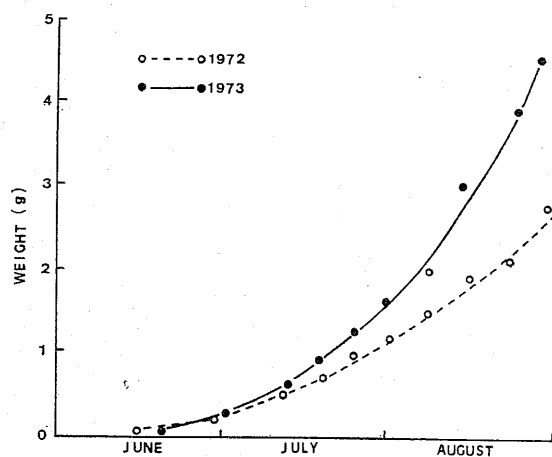
TABLE 3

Mean consumption of zooplankters by yellow perch from June to July 12, 1972 and 1973

Food items	1972		1973	
	No. per fish	Wet wt. (mg) per fish	No. per fish	Wet wt. (mg) per fish
Daphnia	95.6	13.01	82.1	15.20
Chydorus & Bosmina	9.6	0.04	0	0
Leptodora	1.4	0.38	0	0
Cyclopoids	83.5	0.55	17.1	0.09
Calanoids	45.9	1.08	30.3	0.39
Nauplii	7.2	<0.01	0	0
Total	243.2	15.06	129.5	15.68

contents were measured and the mean length was calculated. Mean weights of zooplankters eaten were calculated by converting mean length to weight, using length-weight regressions (Edmondson, 1971).

Growth rates of pelagic fry in 1972 and 1973 were approximately the same despite marked variation in diet composition and the estimated wet weight of food consumed was very similar before mid-July in these two years (Table 3). Apparently pelagic perch weighing less than 1 g were able to maintain about the same energy intake in both years although fish fed on much smaller organisms in 1972 than 1973. Energy costs associated with the capture of greater numbers of small zooplankters in 1972 probably were not significant since the weight increments of perch were about the same in 1972 and 1973.

Pronounced differences in growth of the fish in late summer of 1972 and 1973 were probabley related to the amount of food consumed. During the postpelagic period the consumption of copepods, Leptodora and chironomids was higher in 1972 than in 1973, while substantially fewer Daphnia were ingested in 1972 than in 1973. As a results the daily consumption per gram of perch was generally higher in 1973 (Table 4). The slower growth rates of perch in 1972 also indicated that the consumption of benthos in 1972 did not com-

Fig. 2. Growth in weight (g) of young perch during the first summer in Oneida Lake, 1972 and 1973.

TABLE 4

Mean consumption of zooplankters by yellow perch from July 19 through August, 1972 and 1973.

Date	No. of fish	Fish mean wt. (g)	Zooplank. mean wt. (mg)	Zooplank. mean wt. (mg)/g fish
1972				
Jul. 19	40	0.72	23.17	32.18
Jul. 26	45	0.96	34.30	35.73
Aug. 1	45	1.23	14.17	11.52
Aug. 8	25	1.52	23.86	15.70
Aug. 16	15	1.91	5.78	3.03
Aug. 23	15	2.13	118.30	55.54
Average				25.62
1973				
Jul. 19	15	0.94	36.44	38.77
Jul. 25	30	1.26	43.09	34.20
Jul. 31	30	1.64	61.58	37.55
Aug. 8	15	2.05	57.20	27.90
Aug. 16	15	3.09	482.35	156.10
Aug. 23	15	4.61	305.69	66.31
Average				60.14

pensate for the lower consumption of zooplankton.

Zooplankton abundance

Pronounced differences occurred between relative abundance of various zooplankters in 1972 and 1973 (Table 5). Seven species of cladocerans were observed in zooplankton samples in 1972, but only *D. pulex* was found in 1973. Differences in zooplankton composition and density between 1972 and 1973 explain some of the changes in diet of perch observed by comparing food consumption in the two years (Table 2). The greater diversity of the diet in 1972 mirrors the greater diversity of food organism available to perch. However, not all changes in zooplankton abundance were reflected in perch diet. Despite a marked increase in abundance of *Chydorus* and moderate increase in *D. galeata, Diaphanosoma,* and copepod nauplii in late summer 1972, few of these zooplankters were observed in perch stomachs. Furthermore, density of *Daphnia* was higher in late summer of 1972 than 1973, but

TABLE 5

Mean density of zooplankters (no./l) from samples collected at weekly intervals from mid-June through August, 1972 and 1973

Organism	1972		1973	
	June to July 12	July 19 to Aug.	June to July 12	July 19 to Aug.
D. pulex	2.8	9.2	21.9	9.4
D. retrocurva	21.4	7.0	0	0
D. galeata	0	2.3	0	0
Bosmina	10.1	2.9	0	0
Chydorus	0.4	31.6	0	0
Leptodora	0.2	0.1	0	0
Diaphanosoma	0	4.5	0	0
Calanoids	9.9	6.3	18.5	15.0
Cyclopoids	12.1	7.7	4.9	5.3
Nauplii	4.1	6.7	6.4	4.9
Total	61.0	78.3	51.7	34.6

substantially less *Daphnia* were eaten in 1972 than in 1973. The reverse was true for copepods. Hence, selectivity in feeding may be one of the factors that affect food habits of perch.

Vertical distribution of zooplankton

Vertical distribution of zooplankton (Table 6) was examined to determine if differences in relative abundance of *Daphnia* and copepods between depths and associated changes in food preference of perch controlled the time of transition from pelagic to demersal mode.

When helmeted and round-headed *Daphnia* occur in the same lake, the helmeted species, almost without exception, have their maxima at lesser depths than the non-helmeted ones (Hutchinson, 1967). My results agreed with the above statement, the helmeted *D. retrocurva* was concentrated near the surface and the mean densities were 29.2 and 5.1/l at 1 and 9 m, respectively in 1972, whereas *D. pulex* (round-headed) was more abundant near the bottom, with mean densities of 3.4/l at 1 m and 13.3/l at 9 m (Fig. 3). In contrast, when *D. pulex* was the only daphnid present in 1973 it was concentrated near the surface with lower densities in deep water.

TABLE 6

Number of zooplankters per liter at five
depths during perch pelagic (P),
transition (T) and demersal (D)
stages in 1972 and 1973

Organism	Stage	Depth (m)				
		1	3	5	7	9
1972						
D. retrocurva	P	42.4	25.5	15.9	8.7	8.4
	T	0.4	0.9	0.8	0.4	0.1
	D	9.1	7.3	4.9	4.0	3.6
D. pulex	P	1.4	2.1	1.9	3.4	4.9
	T	0.6	0.9	0.8	4.1	23.0
	D	7.7	5.5	7.0	15.4	22.1
Calanoids	P	11.6	20.8	10.4	5.2	2.9
	T	9.1	9.3	8.7	2.3	2.5
	D	6.0	5.8	4.8	3.0	2.0
Cyclopoids	P	11.6	11.8	9.4	9.2	12.8
	T	15.9	12.4	12.6	5.6	6.4
	D	10.1	8.7	7.6	5.3	5.5
1973						
D. pulex	P	48.5	31.0	24.9	25.1	7.2
	T	25.7	18.2	14.1	13.8	10.9
	D	19.7	11.0	9.1	5.3	5.6
Calanoids	P	8.3	14.2	9.4	3.7	2.5
	T	34.4	65.3	24.7	16.4	7.3
	D	16.5	23.0	17.2	12.8	10.6
Cyclopoids	P	1.7	1.3	3.1	2.8	2.9
	T	7.0	6.6	4.6	3.0	7.5
	D	5.5	6.1	5.3	4.1	4.3

In 1972, *D. retrocurva* was abundant in June
and July while perch were pelagic, but *D. pulex*
became the predominant species at about the
time perch turned demersal (Fig. 4). The
change in abundance of the two species and the
difference in their vertical distribution caused
the mode of *Daphnia* density to shift from 1 m
to 9 m in late July. This change in distribu-
tion of *Daphnia* coincided with the movement
of perch from the surface to the bottom. In
1973, however, transition of perch from pelagic
to demersal mode occurred in late June despite
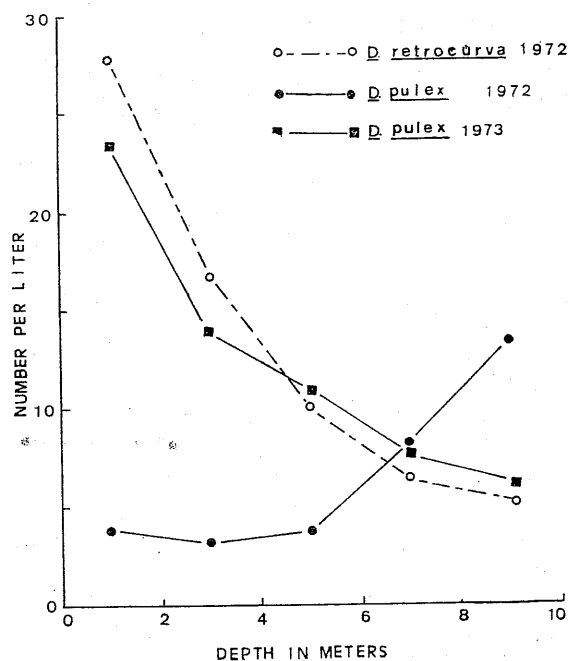high daphnid density near the surface (Table 6).

Fig. 3. Mean density of *D. retrocurva* and *D. pulex* at five depths from June through August, 1972 and 1973.
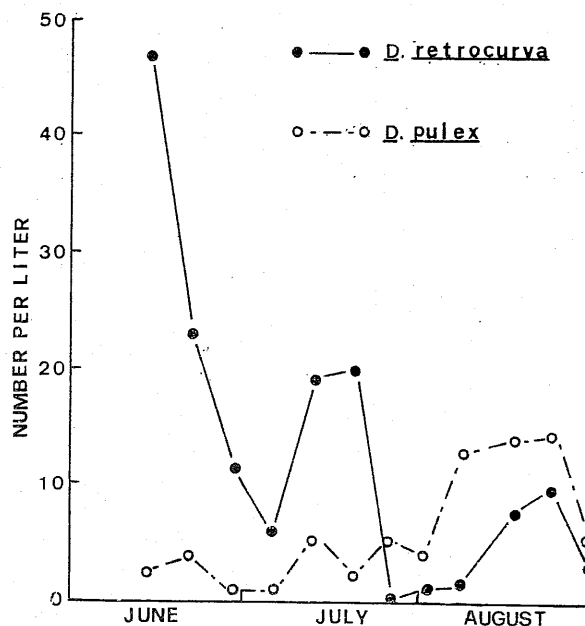

Fig. 4. Abundance of *D. pulex* and *D. retrocurva* in Oneida Lake from June through August, 1972.

The vertical distribution patterns of calanoid copepods in 1972 and 1973 were similar, being more concentrated in depths above 5 m at all times (Table 6). On the other hand, the vertical distribution of cyclopoid copepods was different between those two years. Cyclopoid copepods were rather uniformly distributed at all depths in the summer of 1973 as well as in 1972 when perch were in pelagic stage. But in late summer of 1972 they were more concentrated near surface water when perch were in transition and demersal stages. The predominance of copepods in the water at mid-depths coincided with their high contribution to the diet of perch during the transition period (Table 2).

Food selection by yellow perch

Food selection by perch was measured by comparing the relative occurrence of a food item in zooplankton samples with its relative occurrence in perch stomachs. Electivity (E) values for the major food items of young perch were calculated for each day on which plankton and perch samples were taken in 1972 and 1973 (Figs. 5 and 6). Data from both years indicated that, except in mid-June when perch were less than 19 mm long, E values for *D. pulex* were on the positive side, the values declined to near 0 in August 1972 while they remained high through August 1973. In 1972 when both *D. pulex* and *D. retrocurva* were pre-
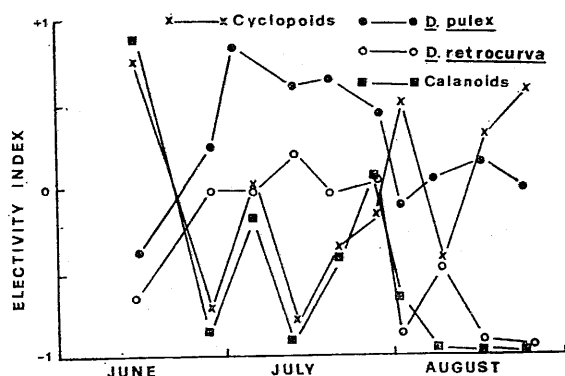

Fig. 6. Electivity indices for *D. pulex*, cyclopoid copepods and calanoid copepods from June through August, 1973.

Fig. 5. Electivity indices for *D. pulex*, *D. retrocurva*, calanoid copepods and cyclopoid copepods from June through August, 1972.

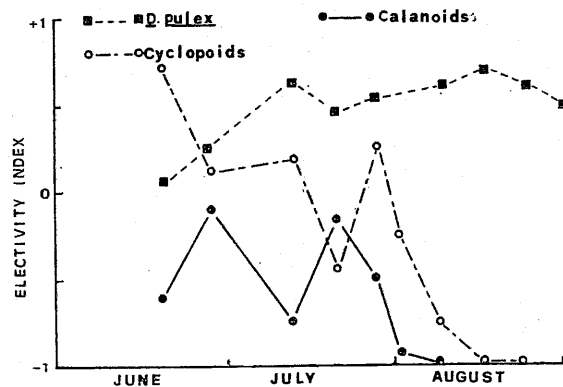sent, E values for the former were consistently higher than that of the latter. This clearly indicated that yellow perch fed on *D. pulex* in preference to *D. retrocurva*.

Differences between years were also apparent upon examining copepods. Although cyclopoids were always strongly selected for by young perch less than 19 mm long in mid-June, the pattern of preference for cyclopoids on later occasions varied with the years. The 1972 cohort exhibited negative selection for cyclopoids between late June and late July, but they showed preference for the same food item most of the time in August. However, the 1973 cohort generally selected for cyclopoids between late June and late July, but rejection for cyclopoids increased with time in August. Perch usually exhibited negative selection for calanoids in both years, except only on one occasion (i. e. mid-June 1972) did perch showed exceptionally high preference for calanoids.

Changes in electivity between years are probably related to differences in size of plankters and perch. Mean length of *D. pulex* was generally greater in 1973 than in 1972, while cyclopoid copepods were larger in 1972 than in 1973 (Fig. 7). Also, yellow perch were larger in late summer of 1973 which may have further increased preference for *D. pulex* and rejection of copepods. It seemed that selection for small zooplankters decreased and selection for larger zooplankters increased as young perch grew
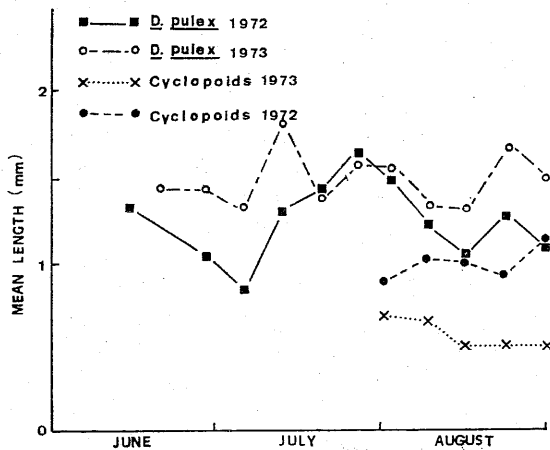
Fig. 7. Seasonal variation in mean length of
D. pulex and cyclopoid copepods in
plankton samples collected in 1972
and 1973.

larger. However, perch selected cyclopoid
copepods in preference to calanoid copepods in
late August 1972, and throughout the summer
of 1973 (Figs. 5 and 6) even though cyclopoid
copepods were sometimes smaller than calanoid
copepods. Differential selection for certain
species of zooplankters has been observed in
other freshwater fishes (Cramer and Marzolf,
1970; Houde, 1965; Ivelev, 1961; Lindström,
1955). Cramer and Marzolf (1970) and Lind-
ström (1955) suggested that relative mobility
of cyclopoid copepods and calanoid copepods
may affect their vulnerability to capture by fish.

Some organisms were consistently rejected
by young perch. Chydorus was very abundant
in late-July through August 1972 (Table 5), but
was not found in yellow perch stomachs (Table
2). Copepod nauplii were fairly common in
plankton samples in both 1972 and 1973, but
few were observed in perch.

DISCUSSION

The primary objectives of this study was
to identify factors which controlled the time of
transition of perch from pelagic to demersal
stage. Examination of the fish's growth and
diet and distribution of food organisms suggests
these are not the primary variables which
regulate the time of transition but the exact

cause remains obscure.

Early development of perch cohorts in 1972
and 1973 were similar. Both years perch
spawned in late April and eggs hatched in mid-
May. Young perch became demersal in late
June 1973 when young had attained a mean
length of 27.6 mm and in late July 1972 at a
length of 42.8 mm. Obviously length did not
control time at which perch in open water be-
came demersal. Movement of young perch into
the littoral zone at a length of about 30 mm
has been observed in West Blue Lake, Manitoba
(Wong, 1972) and in Oneida Lake (J. L. Forney,
pers. comm.). Movement inshore is probably
independent of transition from the pelagic to
demersal mode in open water.

There was no evidence that changes in food
preference associated with the increase in size
of perch during the summer triggered transition
from pelagic to demersal. Prior to transition
in 1972 and 1973 Daphnia were the preferred
food organisms and perch continued to select
Daphnia when living demersally. Appearance
of larger numbers of copepods in perch
stomachs during transition in 1972 and 1973
seemed to have been the result of vertical
changes in the fish's distribution rather than
the cause. During transition copepods were
the predominant zooplankton at mid-depths.
Although benthic organisms were available after
perch became demersal, most perch fed on
Daphnia which were smaller. Possibly low
density or availability of benthic organisms
made them less attractive prey.

Vertical distribution of food organisms did
not play a significant role in determining the
time of transition. Daphnia were an important
component of the zooplankton in both 1972 and
1973 as well as preferred food of young perch.
In 1972 D. pulex were most abundant in deep
water whereas D. retorcurva were concentrated
near the surface. In 1973 D. pulex was the only
Daphnia present and its density was greater in
the surface water. If Daphnia distribution was
the cause of vertical transition of yellow perch,
they should have remained pelagic longer in
1973. On the contrary, perch became benthic

in 1973 much earlier and at a smaller size than 1972, which indicated that food distribution did not control vertical distribution of young perch.

Transition of perch from pelagic to demersal stage occurred at a time when water temperature was rising rapidly in both 1972 and 1973. Surface water temperatures were below 21°C through June 1972 then rose abruptly to 25°C in late July. In 1973 surface water temperature increased from 21°C on June 25 to 24°C on July 5. Transition of perch in 1972 and 1973 began when temperature exceeded 21°C and was completed before temperature reached 25°C. Movement of perch to deeper water might be interpreted as avoidance of high surface water temperature.

In 1972 and 1973, growth rates of pelagic fry were similar despite marked variation in composition and abundance of zooplankton both in the lake and in perch stomachs. But differences in diet during the demersal stage contributed to great differences in first-year growth. This confirmed Noble's (1975) observation that zooplankton did not limit growth of fry during the pelagic period.

The near absence of chironomids in stomachs of perch collected in 1973 was surprising since perch were larger and primarily would select larger benthic organisms. Young yellow perch frequently shift from a diet of zooplankton to benthic invertebrates at a length of 60–70 mm (Mills and Forney, 1981). Temporary oxygen deficits near bottom (4.1–7.6 ppm in 1972 and 3.0–7.1 ppm in 1973) may have limited consumption of chironomids but does not explain differences between years. The mean number of chironomids present in the benthos estimated by Ekman dredge samples were 24.7 and 16.1 individuals per 625 cm² for 1972 and 1973 respectively (M. J. Tarby, pers. comm.). This showed that approximately 1.5 times more chironomids were present in the benthos in 1972 than in 1973. The size of young yellow perch in late summer was larger in 1973 than in 1972. Yet the mean number of chironomids in perch stomachs was nearly 22 times greater in 1972 perch cohorts than that of 1973, suggesting that yellow perch selected *D. pulex* in preference to

chironomids. Milles and Forney (1981) indicated that selection of *D. pulex* was the optimal strategy of yellow perch and the net energy return from feeding on benthos organisms was lower than that of *D. pulex*. Galbraith (1967) found that yellow perch (>68.6 mm in length) in Lake Michigan lost interest in *D. pulex* and fed on other organisms when the size of *D. pulex* dropped below 1.3 mm. This may partly explain why perch consumed more benthos in 1972, because *D. pulex* averaged 1.28 mm in August 1972 and 1.50 mm in August 1973.

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黃鱸魚幼魚在歐奈湖潛移因素的探討

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為了探討控制黃鱸魚幼魚在歐奈達湖由表層水中潛移到底層水中棲息的因素，茲就該魚在潛移前及潛移後的食性及生長狀況與湖水中動物性浮游生物的數量與垂直分布狀況進行比較研究。研究期間 (1972 及 1973 年 6～8 月) 每星期測定黃鱸魚幼魚與動物性浮游生物的垂直分布，同時也追踪幼魚的成長狀況。

黃鱸魚幼魚之潛移行為發生在 1972 年 7 月末以及 1973 年 6 月末，兩年之潛移過程均於 1～2 星期內完成，當時幼魚的平均體長分別為 42.8 與 27.6 公釐。潛移發生時也正是湖水表層溫度急速昇高之時。

1972年湖水中有 7 種枝角類，其中 *D. retrocurva* 主要分布在表層水，而 *D. pulex* 却以底層水中居多，然而在 1973，湖中僅有 *D. pulex* 一種枝角類，多集中於表層水中，推測動物性浮游生物的垂直分布並不能左右黃鱸魚的潛移時間。

1972年黃鱸魚在表層水中生活的期間，攝取之枝角類與撓脚類的數量相同，但在 1973 年潛移前的幼魚却以 *D. pulex* 為主食。幼魚在潛移時主要攝取撓脚類，但到了底層水中則以 *D. pulex* 為最重要的食物。隨著幼魚的成長，它們也逐漸喜食較大型的動物性浮游生物。

儘管湖水中或魚胃中的浮游生物組成與數量有顯著的年間差異，但 1972 與 1973 年的幼黃鱸魚在表層水中生活時之生長度却相近，潛移之後却以 1973 年之幼魚生長較快，這可能與此二年中晚夏時黃鱸魚的攝食數量之差異有關。