GREAT LAKES FISHERY COMMISSION

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Parasitic phase of the Sea Lamprey, (*petromyzon marinus*), in Oneida Lake, New York

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Sea lamprey (Petromyzon marinus) have been quietly killing fish in Oneida Lake for many decades. In a letter to the New York State Forest Fish and Game Commission in 1908, Egbert Bagg complained that he had buried 195 fish washed up on his shoreline on July 16 only to find 125 fish on the same beach the following day (Bean 1909). A game protector who investigated the report observed that most of the fish were ciscoes and suckers killed by lamprey. Adams and Hankison (1928) found lamprey wounds on dead and dying fish in 1916 and listed 11 species which had been attacked. They considered losses very extensive but their recommendations for lamprey control were never implemented.

Efforts to establish a salmonid fishery in Lake Ontario stimulated renewed interest in the Oneida Lake lamprey population (Pearce et al 1980). Surveys documented the presence of numerous sea lamprey ammocoetes in Fish Creek, the largest Oneida Lake tributary. Speculation centered on immigration of young sea lamprey through Oneida Lake into Lake Ontario via the Oneida-Oswego River system, a distance of about 56 km. Capture of recently metamorphosed sea lamprey in the Oneida River 6 km below the lake strengthened the argument that stocks in Oneida Lake were contributing to the parasitic population in Lake Ontario. Treatment of Oneida Lake tributaries to control sea lamprey was recommended by the Lake Ontario Committee of the Great Lakes Fishery Commission and these recommendations were implemented in June, 1984 by the Commission.

Studies to measure pretreatment abundance of parasitic-phase lamprey in Oneida Lake began in 1982. The objective was to evaluate counts of dead fish with lamprey wounds as an index of lamprey abundance. Shoreline counts of dead fish were made in 1982-1983 by student interns at the Cornell University Biological Field Station and continued in 1984 with funds provided by the Great Lakes Fishery Commission. Although tributaries were treated in 1984, transformers had immigrated from streams prior to treatment and abundance of parasitic-phase lamprey in Oneida Lake was representative of pretreatment conditions.

Oneida is a moderately eutrophic lake with a surface area of 207 km^2 and a mean depth of 6.8 m (Mills et al. 1978). Temporary thermal stratification may develop in summer during periods of calm weather and the onset of stratification is followed by a rapid reduction in hypolimnetic oxygen concentrations. Most of the 88 km shoreline is wave swept and the beaches are sand cobble. Emergent vegetation is sparse and urbanization of the shoreline is extensive.

Methods

Dead fish were counted along randomly selected 1 km sections of shore line at weekly intervals from June through early August. Sampling effort was increased from 4, 1-km sections per week in 1982 to 8 in 1983 and varied from 6 to 14 in 1984. Shoreline segments were walked and all fish observed were identified to species, lengths were recorded to the nearest cm and presence of lamprey wounds noted.

Numbers of dead fish observed on the beaches represented some fraction of the fish which died, rose to the surface, and drifted on shore. To determine the proportion of fish which surfaced, fish caught in gillnets were killed and attached to monofilament lines anchored to the bottom at approximately the depth of capture. A weight attached to a release device (candy lifesaver) was used to sink the fish to the bottom. Tethered fish were monitored daily for 10 days and the number floating to the surface recorded.

Other fish killed in gillnets were marked by notching a gill cover or clipping a combination of fins and released on the surface. Marked fish were scattered along a single north-south transect in 1983 and along several transects in 1984 at 6 hr intervals over a 24 hr period. Number released each week was divided by the total length of shoreline (88 km) and expected numbers of marked fish km^{-1} compared with numbers observed during shoreline surveys.

Fish taken in gillnets during the summer and in trapnets during the fall were examined for type A lamprey wounds (King 1980). Gillnets constructed with equal length of 38, 51, 64, 76, 89 and 102 mm stretch-mesh were fished at different sites each week from June to early September. Trapnets were set near Shackelton Point and fished in October 1983-84 for about 20 days each year. Lengths of fish taken in experimental gear were compared with lengths of fish with lamprey wounds for evidence of size selective mortality. To supplement catches in experimental gear burbot (Lota lota) and white suckers (Catastomus commersoni) taken in trapnets set by the Oneida Hatchery in April 1984 were measured.

Abundance of lamprey in July was indexed by counting the number which attached to the stern of a 9 m inboard boat moving at a speed of about 1.5 m/sec. A roughly triangular course was followed with the apex off Shackelton Point and baseline between navigational buoys 125 and 121 (Figure 1). Observations had in earlier years indicated a high frequency of lamprey attachments to boats in the area selected. Counts were made between 900 and 1600 hr and were occasionally aborted when patches of blue-green algae reduced visibility or wave heights exceeded 15 cm. Lamprey were collected from the stern of the boat with a scapnet, anesthetized and lengths and weights recorded.

Results and Discussion

Growth of lamprey

Newly transformed sea lamprey migrate downstream in late fall or early spring (Applegate 1950). Capture of recently metamorphosed lamprey in the Oneida River between November 15-28 and from March 27 - April 6 indicated the period of migration through Oneida Lake spanned the fall to spring period. Recently transformed lamprey were never observed on fish collected in October-November but young 155-185 mm were occasionally found on fish netted in April and anglers have reported small lamprey on walleye and yellow perch caught during winter.

Growth during spring and early summer was rapid and sea lamprey averaged about 365 mm by mid-July (Figure 2). Of the 91 lamprey measured in July-August, 84 were removed from hulls of boats. Lengths of the seven lamprey recovered from fish fell within one standard deviation of the mean for the sample from boats which suggested that method of capture was not highly selective. Rapid early summer growth shown by sea lamprey in Oneida Lake more closely matched the seasonal growth pattern observed in Lake Erie than temporal growth patterns for sea lamprey caught in Lakes Superior, Huron and Ontario (Johnson and Anderson 1980). In July sea lamprey caught in Oneida Lake were about 90 mm longer than lamprey taken in Lake Ontario (Christie and Kolenosky 1980). More rapid warming of Oneida Lake in the spring was probably the most important factor contributing to rapid early season growth.

The length-weight relation for 66 sea lamprey ranging in length from 255-448 mm was:

$$\log_{10} W = 2.8694 \log_{10} L - 5.4439$$

where W = weight in grams and L = length in mm. Based on the length-weight relation and mean lengths shown in Figure 1 sea lamprey averaged about 55 g in late June and mean weight increased to 121 g by mid-August.

Boat-attachment as an index of lamprey abundance

Sea lamprey frequently attach to boats and passive transport by ships may have contributed to the rapid and widespread dispersal of this species through the Great Lakes (Morman et al. 1980). Hitchhiking by lamprey is a seasonal activity which begins in September and peaks in the fall in the Great Lakes (Lamsa et al. 1980). A similar late summer-fall temporal pattern of attachment has been observed in Lake Champlain (J. Gersmehl, personal communication). However in Oneida Lake, weekly surveys indicated a mid-summer peak (Table 1). Formal surveys were not continued into the fall but less frequent observation in 1982-84 in earlier years failed to detect any attachments in September or October. More rapid growth of lamprey in Oneida Lake could explain the early-season appearance of lamprey on boats if the hitchhiking behavior is linked to attainment of a specific body size or stage of development.

Cruises were made along a prescribed course where depth of water ranged from 3 to 13 m. Most attachments occurred in areas where depth exceeded 6 m. Multiple attachments were common with 2 or 3 lamprey approaching the boat almost simultaneously. On a larger spacial scale, intervals between attachments suggested lamprey were aggregated with highest concentration between navigation buoy 123 and 125. Some sea lamprey overtook the boat swimming at a sharp angle from a depth of 1-2 m which was the limit of visibility. However, most lamprey attached to the hull forward of the stern and rapidly shifted backward along the hull until reaching the vertical transom. Those not netted voluntarily detached from the trawler after 10-20 minutes.

The mean number of lamprey observed per hour ranged from 0.1 in 1983 to 5.3 in 1984 (Table 1). Cruises in 1984 clearly encompassed the peak period of lamprey attachment in mid-July. In other years fewer lamprey were observed and the period when attachments peaked was poorly defined. This leads to some ambiguity in making between-year comparisons but the large differences in numbers of lamprey observed clearly indicated lamprey were either more abundant or attached more frequently to boats in 1984 than in 1982-83. Cruises were continued in 1985 and 1986 following treatment of tributaries but no lamprey were observed.

Frequency of wounds on dead fish

Less than 10% of the dead fish observed on beaches in 1982-84 had been attacked by lamprey (Table 2). Species showing the highest frequency of wounding were ciscoes (<u>Coregonus artedii</u>), suckers and burbot which was consistent with observations of host preference in the Great Lakes (Smith 1971) and in the laboratory (Farmer and Beamish 1973). Wounding rates shown in Table 2 are probably conservative because all intact fish were counted and some fish were in an advanced stage of decomposition. Examination of dead fish in the summers of 1967-68 indicated over 90% of the ciscoes and about 70% of the suckers and burbot bore lamprey wounds (data on file, C. U. Field Station). In these years fish were collected along transects in open water and only fish which were fresh were examined for wounds.

Weekly counts of wounded fish observed on beaches in 1984 increased in late June and the number km^{-1} of shoreline searched peaked in mid-July (Table 3). Most wounded fish in 1982 were found in late July and in 1983 the seasonal pattern of fatal sea lamprey attacks was bimodal with more wounded fish encountered in late June than July. Because relatively few km of shoreline were searched in 1982 and 1983 and number of wounded fish was low, evidence of annual variation in seasonality of wounding should be viewed with some skepticism. Regularly scheduled shoreline surveys were terminated in mid-August but the search for wounded fish continued along a 2 km section of shoreline each year. A total of 18 km were searched and one wounded white sucker was found in late August.

Appearance of dead fish with wounds on beaches in June was probably triggered by an increase in body size of lamprey and rising water temperatures which are important determinants of host mortality (Farmer et al 1977). The temperature increase in June 1983 was abrupt (Fig. 2) and roughly coincided with the seasonal peak in numbers of wounded fish observed on shore. In other years temperatures rose gradually through early July and most host mortality was observed in mid-to-late July. The subsequent decline in fatal lamprey attacks in late summer could also be temperature dependent.

As body size of lamprey increases during the summer, high temperatures may act to depress intensity of predation. Farmer et al. (1977) showed that lamprey weighing 90 g killed fewer white suckers than smaller lamprey when predator and prey were held in tanks at temperatures of 15 and 20 C. Decrease in mortality of white suckers was attributed to depressed appetite of larger lamprey at higher temperatures. Rising water temperatures in July coupled with increased size of individual lamprey might inhibit feeding and the number of fatal attacks. However, temporary inhibition of feeding would not explain the near absence of wounded fish on beaches in August when water temperatures were often lower than in July.

The alternative explanations for the late summer decline in number of wounded fish are high mortality of lamprey or downstream emigration of lamprey. Although lamprey in Oneida Lake showed no obvious signs of stress when exposed to surface temperatures of 25-26 C, prolonged exposure to high temperatures coupled with depressed rates of feeding could lead to death. Emigration of lamprey in response to adverse, environmental conditions is also possible but frequent flow reversals in the outlet of the lake caused by seiches and low discharge rates in July-August could thwart escape.

Lamprey Abundance and Impact on Fish

Number of wounded fish observed on beaches represented a small fraction of the fish killed by lamprey. Less than three percent of the dead fish which surfaced drifted onto beaches, judging from a comparison of the number of marked fish recovered and the number expected (Table 4). Expected number of recoveries was calculated by dividing the numbers of dead fish released by the length of shoreline and multiplying by the number of km of shoreline searched for marked fish. Of the 23 marked fish recovered in 1983-84, 21 were found within two weeks after release. The two exceptions were fish found above the strandline where dessication had delayed decomposition for over 28 days.

Scavengers, particularly gulls, were probably responsible for the disappearance of many dead fish before they reached shore. Few dead fish escaped detection during the day and transects along which dead fish were released were often marked by a line of feeding gulls. Comparison of species composition of marked fish released and those recovered on beaches suggested scavenging was not highly species selective (Table 5). However, the number of recoveries was low and any scavenger preference for species most frequently attacked by lamprey would lead to a serious underestimate of lamprey kills from counts of wounded fish on beaches.

Most fish killed by lamprey probably rose to the surface and were subjected to wind driven transport toward shore. An average of 74% of the fish placed on bottom during periods when the lake was homothermal surfaced within six days (Table 6). Effect of thermal stratification on surfacing of fish was not evaluated but temperatures would be lower in the hypolimnion and fish in cooler water are less likely to surface (Parker 1967).

Contrary to expectations a positive relation between thermal stratification and number of dead fish on beaches was not evident. More dead fish were found in 1983 than in 1984 (Table 7) despite persistent thermal stratification in 1983 (Fig. 3). Other abiotic factors may have contributed to annual variation in numbers of wounded and non-wounded fish beached but the role of abiotic factors was probably of secondary importance. The most compelling reason for assuming counts of dead fish reflected changes in mortality was the absence of a direct relation between total numbers of fish and numbers of wounded fish found on shore (compare Tables 3 and 7). Number of fish km^{-1} was highest in 1982 but more wounded fish were found km^{-1} in 1984.

Total number of fish killed by lamprey was approximated by reverse projection of shoreline counts (Table 8). Mean weekly counts of wounded fish km^{-1} of shoreline (Table 3) were multiplied by the total length of shoreline and expanded assuming that 0.74 of the fish killed surfaced and 0.025 of these were beached. These expanded weekly counts were halved based on evidence the turn-over time for marked fish on beaches was about two weeks.

Projections from shoreline counts of wounded fish indicated mortality from lamprey predation ranged from 8500 to 48,300 in June through August, 1982-84 or roughly 0.4 to 2.3 fish ha-1 (Table 8). Losses from lamprey predation appear negligible when compared to estimates of abundance for the predominant species. In most years density of adult walleye exceeded 20 ha^{-1} and for every walleye there were 4 to 5 yellow perch (Forney 1980). However, lamprey were selective predators and the species most frequently attacked comprised a minor fraction of the fish community.

Ciscoes, suckers and burbot were proportionately more abundant in samples of dead fish than in catches of live fish (Table 9). Among fish observed on beaches, 15% were ciscoes, suckers and burbot but their combined contribution to the pooled catch in gillnets and trapnets was only 6% . Low vulnerability to nets could explain differences in species composition but catches in trawls and other gear supported the conclusion the species most frequently attacked by lamprey were present in relatively low numbers. Thus losses of over two fish ha^{-1} from lamprey predation could represent a significant source of mortality for those species targeted by lamprey.

Age composition of cisco taken in gillnets in 1960 through 1970 indicated high mortality of older fish (Smith 1972). Of the 528 cisco aged, 72% were ages 1 and 2 and only 28% ages 3 and older. Cisco are rarely caught by fishermen which leaves lamprey predation as a likely explanation for the sharply truncate age distribution. Burbot and suckers should also show an attenuated age distribution if lamprey-induced mortality was intense but these species have not been aged.

Lamprey killed about 31,000 fish during a four-week period between June 22 and July 19, 1984 (Table 8). Weights of host species calculated from lengths of dead fish on shore averaged 0.7 kg thus the total weight of fish killed was roughly 22,000 kg. Mean weight of lamprey during this period of relatively high host mortality probably increased from near 50 g to over 100 g. Weight gain was estimated from lengths shown in Fig. 2 and the length-weight relationship for lamprey.

Assuming all attacks between June 22 and July 19 were fatal, population of lamprey in 1984 was approximated from the rate of host mortality in tanks where lamprey were allowed to feed <u>ad lib</u> on suckers (Farmer et al. 1977). In the trial which most closely simulated conditions in Oneida Lake lamprey with an initial weight of 50 g were held with white suckers averaging 715 g at a water tamperature of 20 C. Total weight of suckers killed in 30 days was 7.5 kg. If similar feeding rates prevailed in Oneida Lake, a population of 2,900 lamprey (22,000/7.5) or 0.14 ha^{-1} could account for the estimated loss of host species in 1984.

Host mortality rates reported by Farmer et al. (1977) were measured in 2000 l tanks and a host-lamprey ratio of 1:1 was maintained by replacing suckers as they were killed. Much lower host mortality rates/lamprey may occur in lakes where the host-lamprey ratios are higher and host species abundant. Under these conditions lamprey may behave more like parasites than predators by switching to an alternate host before the initial host dies (Kitchell and Breck 1977). High incidence of fish with lamprey wounds would be evidence lamprey in Oneida Lake were functioning as faculative parasites.

Incidence of non-fatal attacks

Lamprey wounds were seldom observed on fish taken in gillnets during the summer or on fish caught in trapnets during October. Of the 7935 fish captured in gillnets (Table 9) only 11 or 0.14% bore type A1 and A2 wounds as defined by King (1977). All 11 were caught in July and 10 of the wounded fish were ciscoes. Considering only the primary host species, ciscoes, burbot and suckers, 2.8% of those taken in gillnets were wounded but 60% of those found dead on shore bore lamprey wounds.

Trapnets fished in October caught over 400 burbot and suckers (Table 9) but none of these fish were wounded. The only fish with wounds were two carp and a channel catfish each weighing over 6 kg. Christie and Kolenosky (1980) attributed more frequent attacks on carp and catfish in the fall to an inshore movement of lamprey in Lake Ontario and similar temporal shifts in distribution of lamprey may occur in Oneida Lake. Although evidence for a switch to larger bodied host species was more speculative than convincing, selection of larger hosts which are more likely to survive a lamprey attack could explain the decline in number of fatal lamprey attacks observed in late summer.

Lengths of host species

Lengths of white suckers killed by lamprey in June-August 1984 roughly matched the lengths of suckers taken in nets from April through October 1984 (Table 10). Proportionately more of the suckers with lamprey wounds were over 400 mm but differences in length distributions were subtle (62% vs 53%) and not statistically significant (Chi square 2.91; df 1). However, size composition of the catch in nets was probably not representative of the length distribution of the population. Most of the suckers caught were taken in trapnets and large fish are usually more vulnerable to capture (Latta 1959). Relative abundance of larger suckers was probably lower than suggested by the catch in nets and lamprey selection for larger hosts more pronounced than indicated by comparison of length distributions. A decline in relative abundance of white suckers over 38 cm (fork length) in Green Bay was attributed to size selective mortality by sea lamprey (Coble 1967) and lamprey under laboratory conditions have shown a preference for large host species (Farmer and Beamish 1973).

Implications and inferences

Presence of a large population of ammocoetes in the tributary system of a warm, shallow lake where percids are predominant has contributed to the belief that most lamprey which enter Oneida Lake emigrate to Lake Ontario. Oneida Lake tributaries were treated with larvaecide in 1984 with the expectation that the contribution of migrants from the Oneida Lake Basin to the parasitic population in Lake Ontario could be assessed from a comparison of pre- and post-treatment wounding rates on salmonids. However, the anticipated reduction in wounding rates may prove difficult to detect if annual recruitment from the Oneida Lake Basin fluctuated.

Shoreline counts of wounded fish and numbers of lamprey observed on boats in 1982-84 indicated over five fold annual differences in abundance of lamprey in Oneida Lake. Either the number of transformers which entered Oneida Lake in these years was variable or losses from mortality and out migration were variable. Both explanations for population instability in Oneida imply that recruitment of lamprey to the parasitic population in Lake Ontario has been variable.

Newly transformed lamprey have been captured in the Oneida River below Oneida Lake (Pearce et al. 1980) but the proportion of young which emmigrate remains speculative. Applegate (1950) inferred from the absence of wounds on fish that transformers moved rapidly through Ocqueoc Lake located on the lower reaches of the Ocqueoc River. In contrast netting in the outlet of Cayuga Lake failed to detect any out migration (Pearce et al. 1980) although the lake supports a substantial population of sea lamprey.

Transformers drift passively in streams (Applegate 1950) which suggests inland lakes with high flushing rates would not seriously impeed downstream migration. But out migration in large lakes may be negligible as observed in Cayuga or substantial as indicated by fyke net catches in the outlet of Oneida. Differences in hydraulic retention times of 18 years for Cayuga Lake (Ogelsby 1978) and 235 days for Oneida Lake (Mills et al. 1978) are consistent with the hypothesis that downstream migration is passive. If correct, annual fluctuations in numbers of parasitic phase lamprey which remain in Oneida Lake may reflect differences in time of migration from nursery areas.

Nearly 75% of the annual discharge from Oneida Lake occurs in December through April (Pearson and Meyers 1970). Sea lamprey generally metamorphose in the fall and migrate downstream in late fall or early spring depending on stream flow rates, temperatures and other variables (Potter 1980). Transformers which enter Oneida Lake in the fall would have a greater probability of being flushed downstream than spring migrants.

Numbers of lamprey which remained in Oneida Lake through early summer could not be determined directly but rates of host mortality measured in the laboratory by Farmer et al. (1977) suggested that fewer than 3000 lamprey could account for the estimated mortality of fish from lamprey predation in 1984. Projections of lamprey abundance from numbers of fish killed are inherently conservative estimates of population size because some hosts survive attack. Failure to detect wounds on some dead fish probably led to a further underestimate of lamprey abundance. Despite these technical deficiencies it must be concluded that the population of parasitic lamprey was small relative to the numbers of larvae present in tributaries (Braem and Moore 1977). Either larvae produced in tributaries experienced high mortality between transformation and first feeding or substantial numbers emigrated.

Transformers entered a hostile environment where piscivorous fish were abundant, density of preferred host species low and summer temperatures were marginal for survival. These conditions appear conducive to high mortality of lamprey but only three dead lamprey were observed in 20 years of intensive fishery studies. These three lamprey were observed while examining stomachs of 237 walleye netted in late April at the mouth of Fish Creek in the 1960's. Probably 100,000 to 200,000 walleye enter Fish Creek to spawn in April, thus predation could have a substantial impact on spring transformers. Failure to find lamprey in stomachs of over 10,000 walleye taken in Oneida Lake during the post-spawning period in 1957-1985 indicates predation on lamprey was transitory and localized.

Lamprey behaved more as predators than parasites judging from the lower frequency of wounding on live than dead fish. Less than 0.2% of the fish taken in gillnets had wounds compared to 15% of those on beaches. Admittedly many of the fish caught in gillnets were yellow perch and other small bodied species seldom attacked by lamprey, but excluding these, rates of wounding remain low relative to frequency of wounding observed on walleye and other warmwater species in Lake Ontario in years prior to lamprey control (Christie and Kolenosky 1980).

Kitchell and Breck (1980) have argued that the lamprey is a faculative parasite which may act as a predator when food resources are limited. Low density of preferred hosts, cisco, burbot and suckers, would presumably discourage host switching and increase the probability that most attacks would be lethal. The preferred hosts were small bodied and lacked the blood supply needed to survive a prolonged attack. In addition, high water temperatures may have prevented cisco and burbot from shunting energy into tissue replacement. Growth of cisco declined in summer (Smith 1972) and burbot showed a weight loss from late June through August (unpublished) which suggested little surplus energy was available.

Seasonal pattern of host mortality should reflect rates of consumption by lamprey which in turn are governed by temperature regime and lamprey size (Ketchell and Breck 1980). The shallow waters of Oneida Lake warmed rapidly in spring and lamprey attained a weight of 100 g in July. As expected, observed mortality of host species in Oneida Lake peaked in June-July several months earlier than the colder waters of the Great Lakes where most host mortality occurs in late summer and fall (Cristie and Kolenosky 1980; Spangler and Collins 1980). More difficult to explain was the apparent decline in host mortality during late summer when water temperatures were still near their summer maximum.

Death or emigration of lamprey in late summer are plausible explanations for the decline in host mortality but these explanations leave unanswered the question of how the tributary system is repopulated. Dams and locks on the Oneida-Oswego River system may be passible but no upstream migration has been documented. More biologically appealing is the possibility that the decline in host mortality reflects a shift to larger hosts which were less likely to succumb. Although the incidence of wounding was low in the fall a small residual population might be sufficient to maintain a large larval population in the tributaries.

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Table 1. Relative abundance of parasitic-phase sea lamprey in Oneida Lake based on numbers attaching to stern of an 8.5 m inboard boat during cruises in 1982-86.

Year	Date	Hours	Lamprey observed	Attachments per hour: Daily mean	Attachments per hour: Annual mean
1982	6/27	2.0	1	0.5	
	7/2	2.0	0	0	
	7/7	2.0	2	1.0	1.86
	7/15	2.5	2	0.8	
	7/27	1.5	6	2.0	
	8/1	2.0	1	0.5	
	8/7	2.0	0	0	
1983	7/3	2.0	0	0	
	7/10	2.0	1	0.5	
	7/17	2.0	0	0	0.10
	7/24	2.0	0	0	
	8/6	1.5	0	0	
1984	7/3	1.0	7	7.0	
	7/9	1.5	6	4.0	
	7/14	1.8	27	15.0	
	7/19	2.5	29	11.6	
	7/22	1.5	16	10.6	
	7/28	2.5	7	2.8	5.39
	7/29	1.0	2	2.0	
	8/4	2.0	2	1.0	
	8/11	2.0	0	0	
	8/18	2.0	0	0	
1985	6/28	2.0	0	0	
	7/6	2.0	0	0	
	7/7	2.5	0	0	
	7/12	2.0	0	0	0
	7/14	1.5	0	0	
	7/20	2.0	0	0	
	7/26	2.0	0	0	
1986	6/28	2.0	0	0	
	7/5	2.0	0	0	0
	7/12	1.5	0	0	
	7/17	2.0	0	0	

Table 2. Number and species of dead fish observed during shoreline surveys in 1982-84 and percent with lamprey wounds.

Species	Number examined	Number wounded	Percent wounded
Yellow perch	1642	6	0.3
Walleye	370	11	3.0
White sucker	411	192	46.7
Cisco	90	65	72.2
Burbot	59	33	55.9
Brown bullhead	522	41	7.8
Drum	21	2	9.5
White perch	88	1	1.1
Pumpkinseed sunfish	396	3	0.8
Channel catfish	42	2	4.7
Smallmouth bass	68	2	2.9
Other species	310	0	0

Table 3. Number of fish with lamprey wounds observed during weekly shoreline surveys and number of km of shoreline searched for dead fish in 1982-84.

Period	1982			1983			1984		
	Total	km	No/km	Total	km	No/km	Total	km	No/km
June 2-7	0	4	0	0	4	0	-	-	-
June 8-14	0	4	0	1	8	0.12	0	6	0
June 15-21	5	4	1.25	13	8	1.62	5	18	0.28
June 22-28	0	4	0	3	8	0.38	7	12	0.58
June 29-July 5	0	4	0	0	8	0	7	13	0.53
July 6-12	0	4	0	1	8	0.12	92	22	4.18
July 13-19	13	4	3.25	1	8	0.12	87	12	7.25
July 20-26	27	4	6.75	2	8	0.25	33	12	2.75
July 27-Aug 2	7	4	1.75	3	8	0.38	17	12	1.42
Aug 3-9	0	4	0	4	8	0.50	30	12	2.50
Aug 10-16	-	-	-	-	-	-	0	12	0
Mean (June 8-Aug 9)	52	36	1.44	28	72	0.39	278	131	2.16

Table 4. Numbers of marked fish expected per km and numbers observed during shoreline surveys in 1983-84. Dead fish were marked and released in June through July and the shoreline searched for dead fish at intervals of 2 to 21 days following release.

Year		Days following release				
		2-5	6-9	10-13	14-17	18-21
1983	Expected	88	88	81	81	81
	Observed	2	4	3	0	0
1984	Expected	315	248	56	247	72
	Observed	8	3	1	0	0
	Expected/ Observed	0.025	0.021	0.029	0	0

Table 5. Species and numbers of dead fish marked and released and numbers observed on beach during shoreline surveys.

Marked fish	Year	Yellow perch	Walleye	White perch	White sucker	Cisco	Other
Released	1983	1005	252	378	15	266	25
	1984	1293	233	461	42	13	81
	Total	2298	485	839	57	279	106
Recovered	1983	9	0	1	0	1	0
	1984	3	3	4	1	0	0
	Total	12	3	5	1	1	0

Table 6. Number of fish placed on the bottom of Oneida Lake in June-July 1982-84 and percent which surfaced in a subsequent 10-day period.

Species	Number of fish	Number surfacing	Percent surfacing
Yellow perch	11	9	82
Walleye	7	4	57
White perch	5	5	100
Burbot	5	3	60
Sucker	5	4	80
Cisco	5	4	80
Other	5	3	60
Combined	43	32	74

Table 7. Mean number of dead fish observed per km of shoreline during weekly surveys conducted in 1982-84.

Period	Year 1982	1983	1984
June 1-7	9.5	2.0	--
June 8-14	12.2	4.2	7.8
June 15-21	26.5	61.8	10.5
June 22-28	25.0	26.3	8.5
June 29-July 5	4.2	11.2	12.5
July 6-12	14.8	14.6	13.9
July 13-19	40.0	12.1	37.4
July 20-26	84.5	18.8	15.4
July 27-Aug 2	16.5	16.0	9.3
Aug 3-9	9.0	4.9	5.8
Aug 10-16	--	--	2.3
Total fish observed	958	1368	1693
Km searched	40	76	131
Number km^{-1}	24	18	12.9

Table 8. Total number of fish killed by lamprey in June-August 1982-84 calculated from shoreline counts of dead fish with lamprey wounds.

Period	Year 1982	1983	1984
June 2-7	0	0	-
June 8-14	0	300	0
June 15-21	3,100	4,000	700
June 22-28	0	1,000	1,400
June 29-July 5	0	0	1,300
July 6-12	0	300	10,400
July 13-19	8,200	300	18,000
July 20-26	16,800	600	6,800
July 27-Aug 2	4,400	1,000	3,600
Aug 3-9	0	1,200	6,200
Aug 10-16	-	-	0
Total	32,500	8,700	48,400
Number ha^{-1}	1.6	0.4	2.4

Table 9. Total numbers and percent species composition of dead fish observed during shoreline surveys and fish taken in gillnets and trapnets in 1982-84.

Source	Year	Total Number	Yellow Perch	Wall -eye	White Perch	Centrar -chids	White Sucker	Cisco	Burbot	Brown Bullhead	Carp	Other
Shore-line Survey	1982	958	58.2	6.8	2.1	6.5	10.0	0.5	1.9	7.8	4.9	1.2
	1983	1368	38.4	6.7	2.3	24.8	3.8	0.2	0.6	18.6	2.5	2.1
	1984	1693	33.0	12.6	2.2	11.3	15.5	4.8	1.9	11.4	4.5	2.7
Gillnets	1982-84	7935	55.3	20.7	16.8	1.4	1.2	3.5	0.1	0.1	0.3	1.8
Trapnets	1983-84	2910	24.7	31.2	4.0	13.8	0.5	>0.1	4.5	8.7	4.0	8.4

Table 10. Length distributions for white suckers and burbot taken in gillnets and trapnets in April 1984 and lengths of suckers and burbot with lamprey wounds found on beaches in June-August 1984.

Length class (mm)	Suckers		Burbot	
	Beached	Netted	Beached	Netted
260–279	4	6		
280–299	4	5		
300–319	3	3		
320–339	13	5		
340–359	14	7	1	1
360–379	9	29	1	6
380–399	15	33	3	21
400–419	22	33	2	26
420–439	29	25	7	39
440–459	20	15	1	28
460–479	11	11	6	29
480–499	13	10	3	35
500–519	4	5	5	16
≥520	4	2	4	14

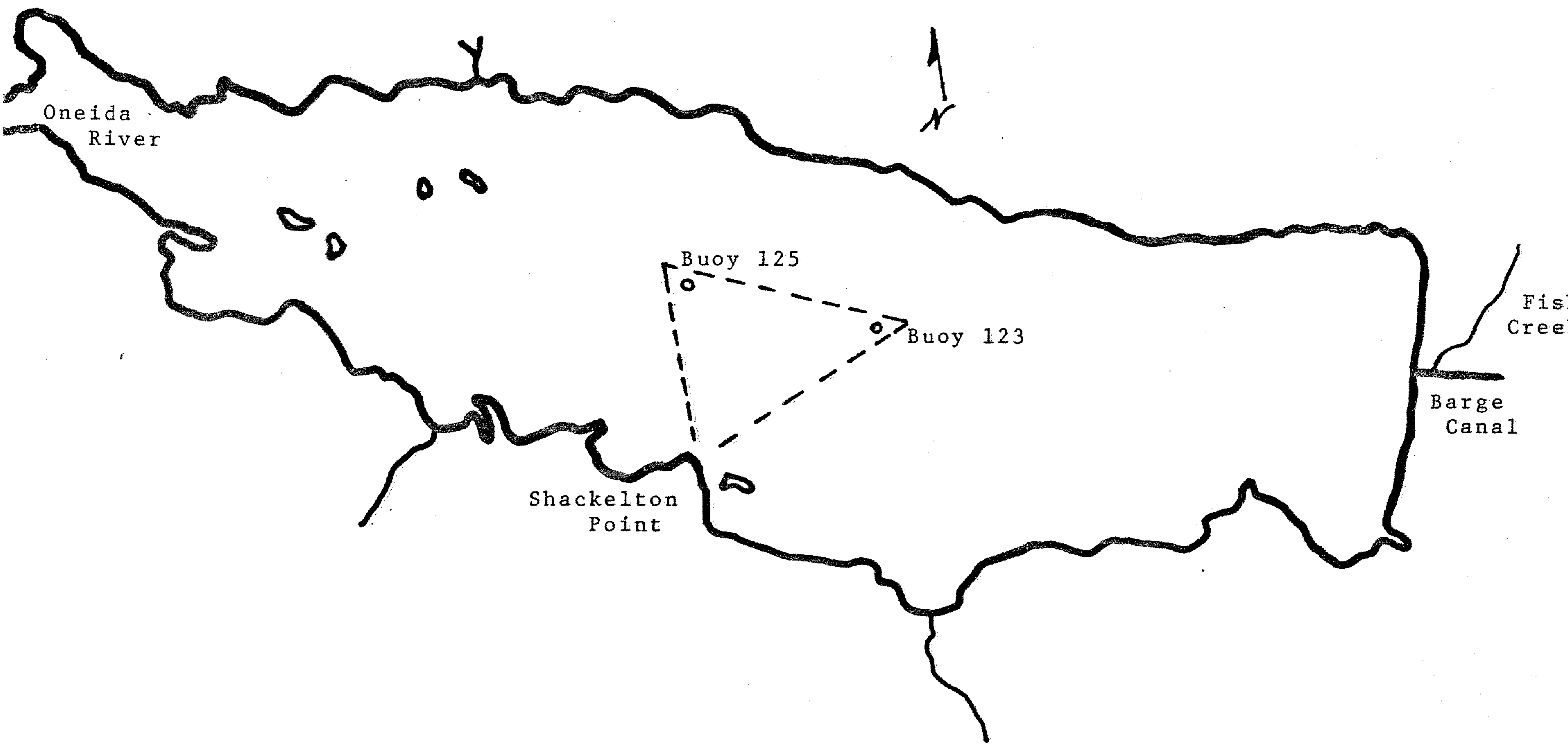

Figure 1. Outline of Oneida Lake showing survey track followed for indexing lamprey abundance from attachments to boats.

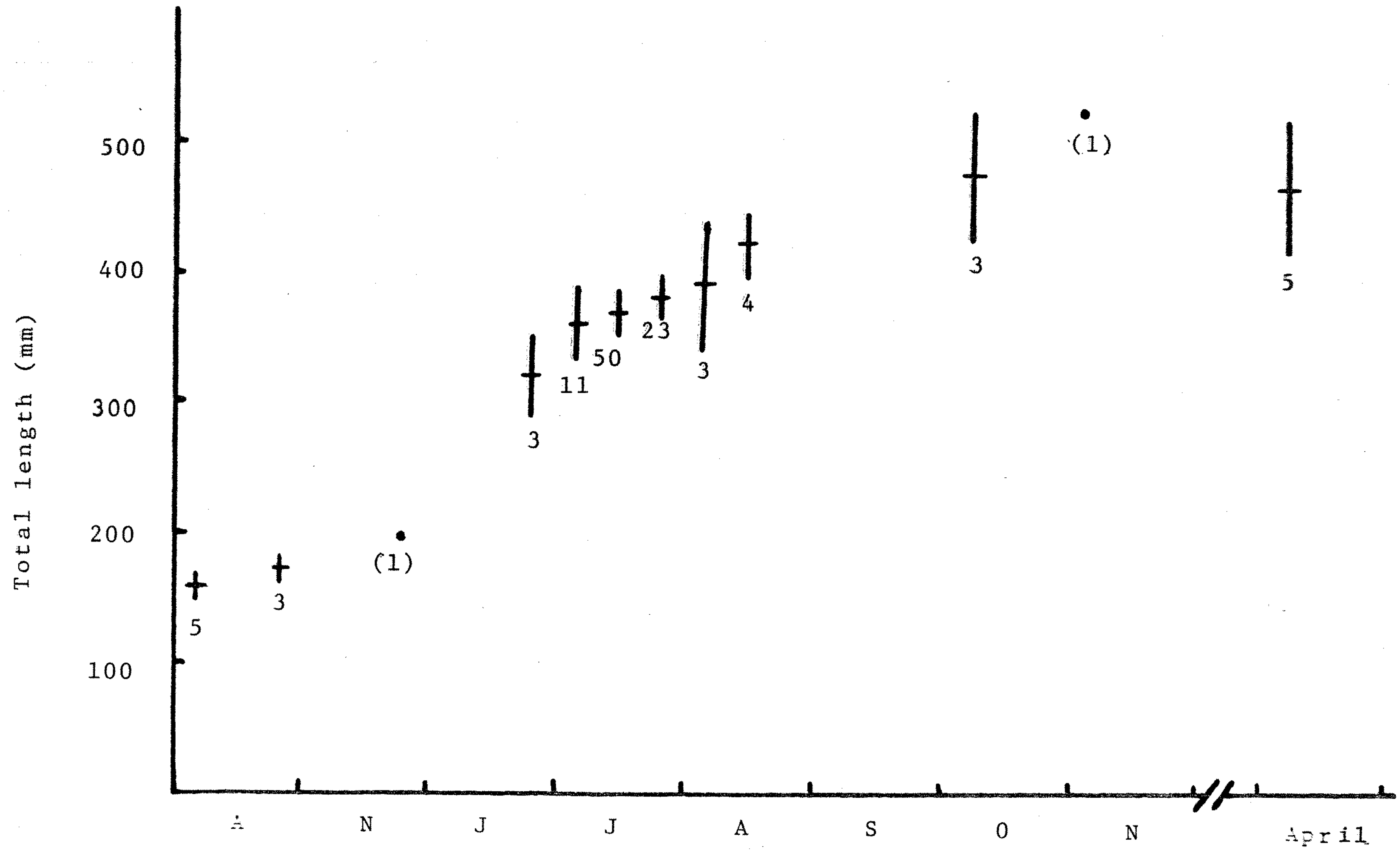

Figure 2. Growth of parasitic-phase sea lamprey in Oneida Lake, 1972-84. Numbers measured, means and two standard deviations shown for 10-day periods.

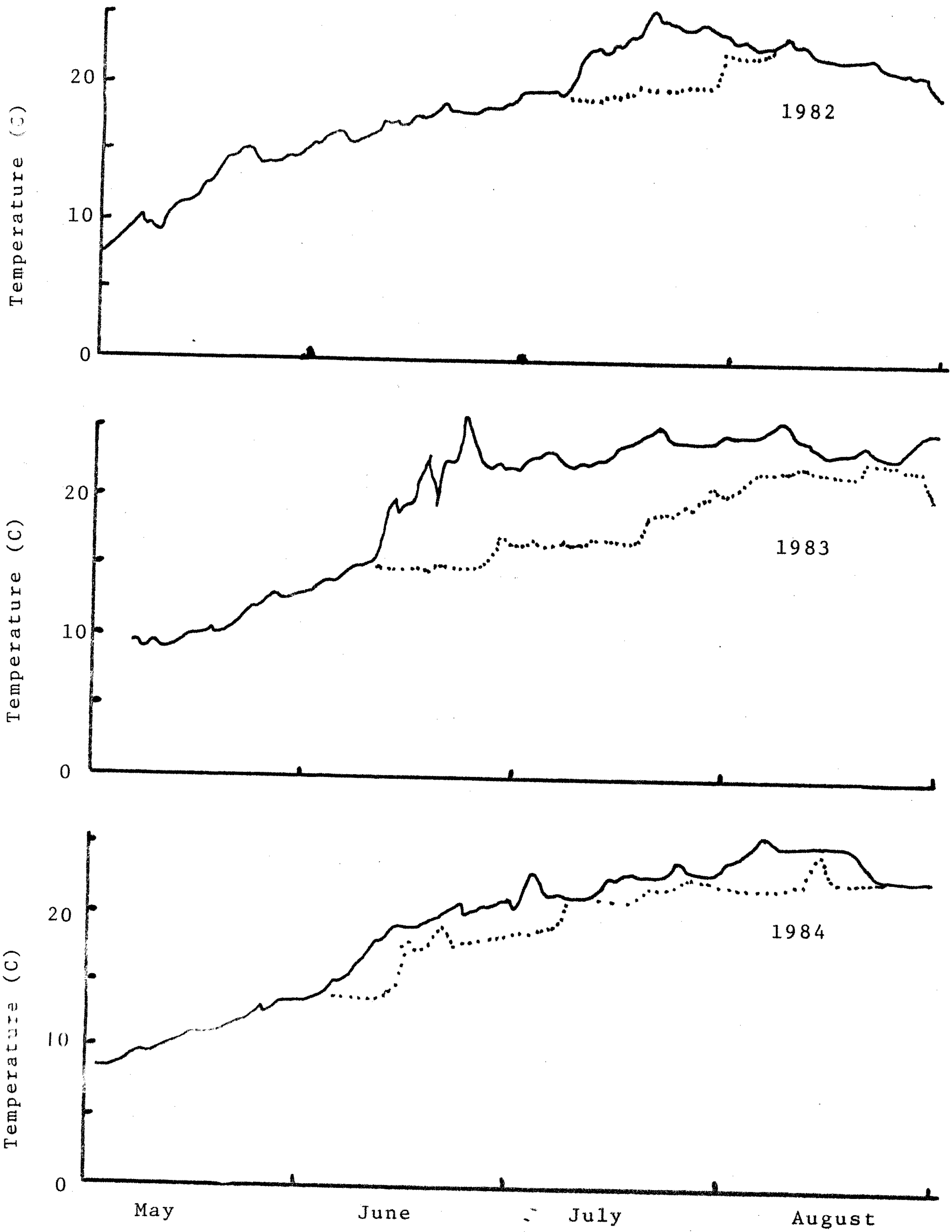

Figure 3. Water temperatures in Oneida Lake measured at 3 m (solid line) and 10 m (dotted line) during May-August 1982-84