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REACTION OF NEARBY LAKE MICHIGAN FISH STOCKS TO A HEATED DISCHARGE AT THE PALISADES SITE [1]

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ABSTRACT

Fisheries surveys were conducted in Lake Michigan in the vicinity of the Palisades Nuclear Power Plant in 1968-1973. While the plant was in operation in 1972 and 1973, comparative sampling of fish within and outside the plume was accomplished five times (more comparisons were not possible because the plant was shut down so frequently). Forty species of fish were captured near the plant. Carp and alewife concentrated near the discharge outlet but elsewhere it appeared that several species were repelled to some extent and a few others attracted to the warm water.

For the two predominant species in the gill nets (perch and alewife), a paired 't' test showed no statistical difference in abundance before and after plant operation. There was a 37% drop in mean catch of perch after the plant "came on line," but variability in the catches precluded any change under 50% from being termed significant. Likewise, no statistical difference in the catch of perch, alewife, longnose sucker, or white sucker could be detected whether the nets were in the plume or outside of it. Plume temperatures were mostly 4-8° F higher than ambient in 1972; and they were 10-15° higher in 1973 when the plant operated at 100% capacity.

No significant difference in the seine-haul catch of longnose dace and trout-perch before and after plant operation could be demonstrated, despite pronounced drops in average catches of these fish in the last 2 years. There was a significant increase in spottail shiner in the last 2 years, however. The seining area was 3/4 mile north of the discharge point.

Growth and mortality of perch are discussed. It appears that their spawning time in 1973 was advanced about 3-4 weeks, presumably because of the warm effluent. An estimated 80% of the 2-year-old females and 96% of the 3-year-olds were mature.

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[1] Contribution from Dingell-Johnson Project F-28-R and F-35-R, Michigan.

Introduction

Between 1967 and 1970 the Consumers Power Company, Jackson, Michigan, built the Palisades Nuclear Power Plant on the shore of Lake Michigan in Van Buren County about 4 1/2 miles south of South Haven, Michigan. This plant employs a single, pressurized-water, nuclear reactor and initially generates 710,000 kw of electricity. Eventually the output could amount to 800,000 kw. It was originally designed to use a once-through cooling system, drawing over 500 million gallons of water daily through an intake system which extends 3,300 feet out from shore at a depth of 20 feet, and is 6 feet off the bottom of the lake. When the plant is operating at full capacity, this water can be heated as much as 31 F over the ambient, intake water temperature before being returned at a velocity of 2 feet per second to the lake near the shoreline.

Because of construction and court delays, no power was generated until December 31, 1971. Throughout most of 1972 the plant operated at 60% capacity, although there were periodic shut-downs because of malfunctioning equipment. In 1973, full power was achieved on April 12 after permission to do so was granted by the Atomic Energy Commission Licensing Board on March 23. The plant remained in full operation until August 11, after which it was shut down indefinitely for repairs and alterations. In the meantime, mechanical-draft cooling towers were built as a result of an agreement with intervenors who had instituted court proceedings.

The effects of the heated discharge waters on the biota in the vicinity of the power plant were examined by a Canadian consulting firm (T. W. Beak Consultants, Ltd.) hired by the power company in 1968. Concurrently the Michigan Department of Natural Resources instituted investigations of both bottom fauna and fish populations in this area and the possible effects thereon from the heated effluent. Later, investigators from other institutions (U.S. Bureau of Sport

Fisheries, Argonne Laboratories, and University of Michigan) carried out studies at this site.

This report describes the fisheries investigations that were conducted by the Department of Natural Resources during the period 1968-1973. The original plan proposed a 2-year, pre-operational fisheries survey (1968-1969) followed by 3 years (1970-1972) of investigations in the presence of heated water. However, largely because of the many operational problems that plagued the plant, there actually were 4 years of pre-operational surveys followed by 2 years in which the plant operated intermittently--first at 60% of capacity (1972) and then at 100% periodically until August of 1973. Comparative data within and outside a plume were obtained only five times, with two netting periods occurring at a time when the plant was fully operational. On the other hand, 16 surveys were made at times when the plant was not operating. This uneven distribution of the data makes interpretation difficult, in light of the principal objective which was to determine whether or not the heated effluent had a pronounced effect on local fish stocks.

Procedures

The sampling plan consisted mainly of gillnetting and seining four times a year--May, June, August and October (Appendix A). The usual practice was to set four graded-mesh gill nets in the vicinity of the power plant in 10-20 feet and 40 feet of water, but over the 6-year period, weather and equipment problems forced some changes. In 1968, nets also were set at a depth of 60 feet. Gillnets of eight different descriptions were used at one time or another, but three kinds were used consistently throughout the sampling period. Starting in 1971, new nylon gill nets were used that were 250 feet long, had poly-core float lines and lead-core lead lines, and consisted of five 50-foot panels of the following mesh sizes: 1 1/2, 2, 2 1/2, 3 and 4 inches, stretched measure. In June 1971, a complement of the old nets was fished simultaneously with the new ones at the same depths. Net sets were made both perpendicular to, and parallel to the shoreline and within

and outside the plume, when present. Two overnight sets for each net were scheduled for each visitation, but there were occasions when weather or equipment problems forced the curtailment of activities. The amount of netting fished during any one sampling period ranged from 625 to 2,090 feet.

When conditions permitted, shoreline seining was done in addition to the netting, mostly along the beach of Van Buren State Park which adjoins the Consumers Power Company property on the north side. The seined area was approximately 3/4 mile north of the point of plant discharge. One trip was made to the park in December to seine in early winter, but ice packs along shore prevented it. Seine hauls also were made on two occasions at Covert Township Park some 5 miles south of the plant. Whenever possible the seining was done both during the day and at night. A 125-foot bag seine was used during 1968 to 1972. In 1973, a 75-foot bag seine was used, but collections were made with both seines in June for comparative purposes. The 75-foot seine had 1/4-inch mesh in the bag; the rest of the seine contained mesh of 3/4-inch bar measure. Most fish which were captured at night were preserved for later identification and enumeration in the laboratory.

A small amount of trawling was done in 1969 by personnel of the U.S. Fish and Wildlife Service using a 39-foot trawl. In 1972, our own staff used a 15-foot trawl, borrowed from biologists working for Consumers Power Company. The biologists with Consumers Power Company did a considerable amount of trawling as part of their fish sampling program.

At each visitation surface water temperatures were taken with a pocket thermometer. In the last 2 years (1972-1973) the presence of a plume was detected both with an electrical thermometer (after ascertaining the ambient water temperatures near South Haven) and with maximum-minimum thermometers attached to float lines of the gill nets.

The fish were measured and counted. Many were weighed, and scale samples were taken. The yellow perch--the only sport fish caught in large numbers--received special emphasis. A total of 1,614 scale samples of perch were obtained during the 6 years. Scales were taken from the middle of the left side of the fish and below the lateral line. Fish were aged from plastic impressions of the scales under a microprojector. For the most part, rates of growth were determined from mean lengths at capture, but back calculations were made for some fish caught in June. Body-scale relationships, computed by U.S. Fish and Wildlife Service biologists at the Great Lakes Fisheries Laboratory (for perch taken mostly from nearby Saugatuck) were used. The relationships, in millimeters, are:

$$(1)\quad \text{Length} = 30 + 1.58345\ (\text{scale length})$$

$$(2)\quad \text{Length} = 14 + 1.72845\ (\text{scale length})$$

Equation (1) is for perch under 105 mm; equation (2) for perch over 105 mm. A length-weight equation was calculated from data on 503 fish taken during our surveys. This equation is:

$$\text{Log } W = -2.388 + 3.240\ (\text{Log } L)$$

The formula is applicable to both males and females. Separate tabulations were made of mean weights at 0.5-inch intervals for each sex, but the data were combined when no appreciable difference between sexes was noted.

Findings

Gill nets

Forty species of fish were captured in the vicinity of the power plant, by all types of gear (see Appendix B). Total catch of each species, and catch per unit of effort for alewives and perch, are given by year and season in Tables 1-4. Alewives and perch predominated in the net catches, comprising 53.2 and 40.0%, respectively, of the 6-year catch of 14,980 fish. The incidental capture of spottail shiners and trout-perch in gill nets was not recorded in the tables. A seasonal sampling plan was

adopted both to coincide with the limnological collection dates of the biologist from Beakes, Inc. and to allow for variability due to periodic movements of many species of fish. All netting was done between May 7 and October 16. Therefore, the presence or absence of fish stocks between late fall and early spring was not accounted for.

Few perch were caught in May, but great numbers of perch moved into the shallow waters (10-20 feet) between mid-May and mid-June and remained there for the rest of the summer. Adult alewives were abundant in May and June, after which the catches diminished because of die-offs and a retreat to deeper waters. Bloaters were scarce; most of those captured were taken in June, and only four were captured in October in the 6 years of netting. The catches of both longnose sucker and white sucker varied little throughout the four sampling periods. Lake trout were taken every month but most frequently in June. Coho salmon outnumbered chinook salmon, and either one or the other was taken throughout the year. Brown trout were captured only in May and June. At no time were large numbers of salmonids taken, the most being 14 in May 1970. Only six round whitefish and four lake herring were caught in the 6 years of sampling; no lake whitefish were taken. It is apparent that very few of these coregonids dwell in the inshore waters, at least during May to October. Except for the salmonids, Wells (1968) reported essentially the same seasonal distribution for these species from his trawling efforts during 1964. No trout were captured in the trawl hauls, most of which were made at depths of no less than three fathoms (18 feet).

Except during 1968 when some nets were set in 60 feet of water, all nets were set either in 40 feet of water approximately 1 mile offshore or in depths of 20 feet or less and no more than 0.5 mile offshore. The catch data were examined for differences. In May many more perch were caught in the 40-foot sets than in the 20-foot sets, with the reverse being true for alewives. Longnose suckers also were more abundant in deeper water. By June, alewives were still much more abundant in shallow waters, and the perch also had moved inshore with

an exception in 1971. In August, perch and alewife catches in 20 feet of water outnumbered those in 40 feet of water. By October, perch had begun their migration into deep water and this was reflected in larger catches in the nets at 40 feet; few alewives were caught in either sets; and white suckers and longnose suckers were more numerous in shallow sets than in 40-foot sets. Most of the bloaters taken were captured in June in the shallower sets; females predominated. Too few of the other species were caught to make a determination as to depth preference.

Prior to 1972 all gill nets were set parallel to the shoreline. In 1972 and 1973 parallel and perpendicular sets were paired and their catches were compared. As shown below, there was a tendency for the parallel sets to be more effective, at least for the four species most frequently caught. Total catch of four species in the June-October sets for the 2 years was as follows:

	Parallel	Perpendicular
Perch	865	639
Alewife	692	565
Longnose sucker	89	47
White sucker	37	34

However, the catch of perch and white suckers in the perpendicular sets slightly outnumbered that in the parallel sets on three of the five occasions when these sets were compared. Parallel sets are preferred because they provide less resistance to the prevailing currents along the shore.

The principal objective of the survey was to determine whether or not the heated discharge from the plant would affect the fish population. In comparing the catch during the period of plant operation, 1972-73, with that of the previous years (1968-71), allowance had to be made for the change in 1971, when old gill nets were replaced by new ones. In June of 1971, both sets of nets were fished interchangeably and the resulting catches were compared. As expected, only large numbers of

alewives and perch were captured (Table 5). Correction factors of 0.57 and 1.45 were applied to catches of alewives and perch, respectively, made prior to 1971 to make them comparable to the catches of 1971-73; then testing was done for differences between pre- and post-operational periods. Catches of other species were not corrected for gear efficiency.

The two species for which there were enough data to test were, of course, the perch and alewife. Using individual net catches in water less than 25 feet deep, no significant difference in population abundance could be determined at the 90% level of confidence between the two periods ($t = 1.267$ with 48 d.f.). There was a 37% drop in the mean catch during the operational period (1972-73), but because of the high variability among the catches, nothing less than a 50% change (at the 90% level of confidence) could be termed as statistically significant. It would appear, though, that with the generally increased population of perch in southeastern Lake Michigan since 1969, as suggested by other surveys and angling success, this drop from a mean of 73.8 perch per 250 feet of net to 46.2 in the post-operational period should have some significance. Likewise, no significant difference in alewife catches was found ($t = 0.218$ with 46 d.f.). Respective mean catches in the pre- and post-operational periods were 106 and 97. Because of considerable variation in the catches, a difference of $\pm 67\%$ would have had to occur in order to be picked up by the 't' test used for this analysis. Because so few fish of other species were taken, no statistical test for differences was attempted for those catches. A general overview of Tables 1-4 reveals that many more longnose suckers were captured in 1972-73 than previously (370 to 106) even though more netting was fished during the first 4 years than during the last 2 years. Similarly, white suckers were more abundant in the area in 1972-73 (133 caught) than in 1968-71 (52 caught). On the other hand, 33 lake trout were captured prior to any heated discharge (1.7 per 1,000 feet of net) whereas only 13 were caught thereafter (1.1 per 1,000 feet of net). The virtual disappearance of chubs (bloaters) the past 2 years

primarily reflects the general decline in the stocks noted for the entire lake and cannot be attributed to effects from the thermal discharge. In 1968-71, 92 bloaters were caught; thereafter 20 were taken in 1972, none in 1973. No carp were captured prior to 1972 but 14 were caught in 1972-73.

Control vs. plume

Collections in June, August and October of 1972, were made in the presence of a plume created by a thermal discharge when the plant was operating at 60% capacity. In May and June 1973, the plume was created by the power plant discharge when at 100% capacity. In Table 6 are summarized the water temperatures as recorded during the netting periods at both the plume and control sites. In 1972, the maximum difference in surface water temperatures between the plume and control was 11 degrees in June and on three occasions there was a minimal difference of only 4 degrees. Variations in minimum temperatures that occurred during the netting period (as measured on the maximum-minimum thermometer tied to the float line 6 feet off the bottom) were generally smaller. During 1973, with the plant in full operation, temperature differences on the surface were greater than during 1972, ranging from 10 to 15 degrees above ambient. Again, however, differences between sites in minimum temperatures 6 feet off the bottom were small. By way of comparison, temperatures reported at the intake and discharge were 45 F and 76 F on May 7-9, for a temperature change of 31 degrees; and 58-61 F and 88-90 F on June 11-13, for a temperature change of about 30 degrees. Our temperatures in the plume were taken about 1/2 mile offshore from the discharge point, and the control nets were fishing between 1/4 and 1/2 mile from the plume.

Catch of the four most abundant species in the gill nets is shown for both plume and control sites in Table 7. For these 13 pairs of data for each species, a statistical test (paired 't' test) was performed to determine whether or not statistically significant differences existed at the 90% level of probability. No difference was found, and this holds

even at a 50% level of probability. For the four species shown in Table 7, the respective 't' values were 0.006, 0.12, 0.62, and 0.49. It is probably not surprising that no difference was found, in view of the fact that there was little temperature variation between plume and control sites in the bottom waters. In fact, on June 13, 1972, plume measurements beyond the immediate area of discharge, made by technicians from Argonne Laboratories, indicated a plume depth of only 1.0-1.5 meters. Warm surface waters did not seem to affect the presence of the species sampled. The few salmonids which were caught were taken both in, and without the plume. The actual numbers were:

	Plume	Control
Lake trout	7	1
Brown trout	3	1
Coho salmon	3	5
Chinook salmon	-	1

These data suggest that lake trout and brown trout were attracted to the plume area, whereas salmon were not.

Seining results

Tables 8-11 were prepared to show the monthly catch of fish captured each year in the seine hauls during daylight hours and at night. Alewives, spottail shiners, longnose dace, and trout-perch were taken consistently and, for the most part, abundantly. Other species, including young, planted salmonids, appeared from time to time. On one occasion (June 1971) the seining was hampered by masses of filamentous algae clogging the seine, and in August 1972 shifting sand formed temporary bars in the seining area. Lack of time and unfavorable surf conditions occasionally prevented seining activities.

The least amount of seining was done in May, when only one daytime and two nighttime collections were made. The largest catches of adult smelt and alewives were made at this time of year. June collections were characterized by a large variety of fish, and most of the

young salmonids were captured at this time. Young alewives usually predominated in the catches in August, and this also was the only month when young-of-the-year perch were found in the shallow waters. October seine hauls were characterized by the smallest number of spottail shiners, and by few species. Young alewives were almost as abundant in October as in August.

Night seining was generally much more productive both in total fish and in number of species. This was especially true for the trout-perch, adult alewives in June, perch in August (1969), and frequently spottail shiners and longnose dace. The few adults of the larger species, such as carp, carpsucker, quillback and smallmouth bass, were captured at night. On the other hand, virtually all fingerlings of chinook salmon and lake trout were caught during daylight hours.

As with gill-net catch data, a statistical test was applied to the catch of the most numerous and frequently caught species to ascertain whether or not these inshore populations had changed following the introduction of heated effluent in 1972 and 1973. Southerly or westerly wind plus the prevailing northerly currents conceivably would frequently warm these inshore waters by forcing the plume along the state park beach. In 1973, we apparently did seine in the plume on the night of June 11 (Table 9) at which time several large carp were captured. In 1972, however, water temperatures along the beach at the various times of seining were not noticeably greater than previously (Tables 8-11). Indeed, the warmest temperature ever encountered (80 F) occurred in August 1969--3 years before there were any heated discharges. All water temperatures during the 1972 seining periods were equaled or exceeded in previous years at comparable times of the year. Night-time temperatures in 1973 exceeded previous maximums by 4-9 degrees, but the daytime water temperature in June of 1973 was less than that for the 3 prior years.

The results of the analyses of variance are presented in Table 12; the August 1973 data were not used in the analysis. No significant difference was found between the mean catches of longnose dace and

trout-perch for the "before" years of 1969-71 and the "after" years of 1972-73. The variability encountered was such that there would have to be a change on the order of 57% to be detected. The data in the table show pronounced declines in these mean catches at night but these differences cannot be deemed statistically different because of the overlap of the confidence limits. There was a statistically significant increase in spottail shiners caught in daytime seining in 1972-73 and this was reflected in the "all data" category in Table 12. It should be pointed out here that an adjusted catch value was used for the May 1973 daytime catch of spottail shiners when a smaller seine was used (75-foot). When paired seine hauls (between the old 125-foot seine and the new 75-foot seine) were made in the daytime seining in June, twice as many spottail shiners were caught in the larger seine. Hence, the daytime mean catch value in Table 8 was doubled. The larger seine also captured more longnose dace and yearling alewives in June but the smaller seine captured twice as many chinook salmon fingerlings.

A limited amount of daytime seining was done at Covert Township Park on October 13, 1970, and August 13, 1973. In 1970, young-of-year alewives and longnose dace predominated in the catch, as they did at Van Buren State Park. Likewise in 1973 the species composition was similar at both sites, except for the presence of one spotfin shiner at the township site. The results of this limited amount of seining at a site 5 miles from the plant support the observation that there was no change in the shoreline fish population at the state park over the years.

Trawl

A limited amount of offshore trawling was done in 1969 (May 3 and July 25) with a 39-foot trawl by personnel from the Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service. Large numbers of smelt and alewives were captured in May and July, and the July trawling also revealed the presence of bloater chubs and trout-perch in the deeper waters. No small perch were caught despite later evidence of a large 1969 year class. Apparently the trawling was done in water that

was too deep. However, in 1972, perch also were absent from the catches when a 15-foot trawl was used in 10-15 feet of water in August. This trawl was borrowed from Consumers Power Company and the trawling was done both in the plume and outside of it. Among the few fish captured were smelt fry in all hauls and one fingerling lake herring.

Biological statistics of yellow perch

Information pertaining to the population age structure, growth, maturity, mortality, annulus formation, and spawning time for perch was obtained during the course of this investigation. Age composition of the monthly gill net catches is shown in Table 14 and summarized by year in Table 15. Few perch older than 6 years were caught, and the oldest perch was an 11-year-old taken in the spring of 1968. No fish older than 6 years were captured after 1970. Yearlings were first taken by our gear in August.

The perch catch was relatively small in 1968 and 1969, but much greater in 1970 with the advent of the strong 1969 year class as 1-year-old fish (Table 15). This year class predominated in the catch in subsequent years as age-groups II, III, and IV (which are underlined in the table). The entrance of this year class almost coincides with the cessation of commercial fishing for perch in Lake Michigan in 1970. Indeed, the high survival of the 1969 brood in later years might well be linked with this cessation of commercial fishing.

Total mortality rates for perch were computed for several age groups in the 1965- to 1969-year classes, based on the catch per unit of effort by the gill net for these age groups. These rates are shown below by year class, for age-groups II, III, and IV. The average rate shown for age-group IV occurred during the period when commercial fishing was in effect and is considerably higher than for younger age groups.

Age group	Year class					Average
	1965	1966	1967	1968	1969	
II	---	---	---	.19	.24	.22
III	---	---	.43	.55	---	.49
IV	.85	.92	.79	---	---	.85

Seasonal growth of male and female perch is depicted in Tables 16 and 17 and expressed as mean length at capture. Scale collections for May and June were examined for new annulus formation and none was noted except for the June 1970 collection which was not obtained until June 22. By then new growth had started by most age groups and this required back calculations to the last annulus so that all June data represent lengths at the start of the growing season. All other June collections were made between June 12 and 16, before new growth had commenced. Collections prior to 1970 were omitted to eliminate a possible bias for the pre-operational block of data because of the commercial harvesting in effect at that time. The fact that female perch grow faster than males has been demonstrated many times and is further corroborated by the following comparison of mean length at capture in June 1973:

Sex	Age group				
	II	III	IV	V	VI
Male	6.1	7.5	8.5	9.1	...
Female	6.3	8.1	10.2	11.8	12.2

The data in Tables 16-18 were subdivided by year of capture because prior to 1972 there was no thermal discharge, whereas in 1972 the plant operated at 60% capacity and, until August in 1973 at full capacity. Although fish were free to move in and out of the plume, and the plume might shift with the prevailing winds, there remained the

possibility that perch could spend much of their time in the warm water and this could affect their growth. It is also recognized, however, that yellow perch are primarily bottom dwellers and would be beneath the warm, upper strata most of the time, but the warmer temperatures might indirectly promote a better supply of bottom food.

Growth in 1972 and 1973 was generally slower than in other years of no thermal discharge. This is reflected in the mean lengths of fish older than 1 year caught in 1973 (Tables 16 and 17). Among the females the only exception was age-group V in June.

In the August collections, 2-year-old and 5-year-old males did not conform to the over-all pattern. The only comparison possible for yearling fish (age-group I) was in mid-August, at which time perch captured in 1973 were larger than those taken prior to 1972.

Instantaneous rates of growth are useful in production calculations, and they reflect growth in weight (Table 18). By mid-August all age groups of females reflected a slower rate of growth by weight in 1973 than previously, but this was not entirely true for males. For the entire 1972 season, 3-year-olds were lighter than were their counterparts, but 2-year-old female perch gained more weight, on the average, in 1972 than did fish of their age in prior years.

If, indeed, a slower growth rate did occur in 1973 (and 1972), it could have been caused by one or a combination of factors such as the higher water temperature, overcrowding in the plume, too many fish because of the high survival of the 1969 year class, and/or reduction in food availability. However, within limits, the warmer the water, the faster the growth, and overcrowding in the plume was not confirmed by netting evidence. The 1969 year class is represented by age-group III in 1972 and age-group IV in 1973. Referring to Tables 16 and 17, 3-year-olds of both sexes in October 1972, and 4-year-olds in August 1973, were smaller than their counterparts prior to 1972. Other age groups showed no consistent trend either way. The abundance of the 1969 brood may have had a greater influence on growth rate than any other factor.

While the heated effluent may not have affected growth rates, there is some evidence that spawning time was advanced for fish in the vicinity of the plume. In most years perch in southeastern Lake Michigan spawn in early June. For example, on June 23 and 24, 1969, all but one of the mature females captured had spawned recently. In mid-June of 1971, 95% of the females had spawned; 93% in 1972; and 98% in 1973. All perch caught in early or mid-May in 1968-1970 had not spawned. However, in 1973, one-third of the females captured on May 8 were spent. Plume temperatures at that time were 58-64 F; elsewhere in the lake the water temperature was 48F. Most female perch were first mature at 3 years of age (spawned in their fourth year of life). Of the fish examined during this investigation, 8% of the 47 2-year-old females were mature whereas 96% of 92 3-year-olds were mature. All older perch were mature. Of seven 2-year-old males examined in June 1973, three were immature.

Discussion

During this investigation there was a 4-month period in 1973 (mid-April to mid-August) when water was discharged into the lake that was 10-15 degrees warmer than the ambient temperature; throughout 1972 it was 4-11 degrees warmer periodically. This warm water, however, cooled rather quickly as it dispersed out into the lake and the bottom temperature regime was hardly affected at all. Did this have any noticeable effect on the local fish populations? The answer is yes, but different species reacted in different ways. Dense concentrations of alewives and carp were visible from the retaining walls bordering the discharge area, but the mean catches of some species of fish in both gill nets and seine hauls 1/2 to 3/4 mile away were smaller in 1973 than in years prior to the operation of the plant. This was apparent for yellow perch, alewife, lake trout, longnose dace and trout-perch. The catches of spottail shiner increased. On the other hand there was some evidence that longnose suckers, white suckers, lake trout and brown trout were attracted to the

plume, but not the salmon. However, none of these differences (except for spottail shiners) could be supported statistically because of the considerable variability among the gill-net and seine catches from year to year. Lending further credence to the apparent decline in the local population of perch is the fact that elsewhere throughout southeastern Lake Michigan the perch population had increased dramatically because of a strong 1969 year class and the cessation of commercial fishing in 1970.

Perch were affected in other ways too. The warmer water seemed to have advanced their spawning time by about 3 weeks. Growth rate was depressed in 1973, but other factors such as the high survival of the aforementioned 1969 year class could have had a greater effect than the higher temperature.

Carp were definitely attracted by the warm waters. Not only did they swarm around the discharge area but, on the only evening when we had an opportunity to seine in the plume along shore, 16 adult carp were captured in the small seine we were using. Only one had been taken prior to 1973. Some of the cold-water species such as the salmon, lake trout, and steelhead were also attracted to the thermal discharge early in the spring and provided a brief sport fishery near the plant. No whitefish were ever captured in this part of the lake by our nets.

It was unfortunate that there was not more opportunity to gill net in the presence of a thermal discharge other than the two times we did so in 1973. There was some discharge of heated effluent in 1972, but the plant only operated at 60% of its capacity and there were frequent shut downs during the year. Warmer temperatures were encountered along shore at the time of seining in previous years than we found in 1972.

The fact that some species apparently were attracted to the thermal discharge while others were repelled is only part of the story. Other considerations must be given to survival of eggs and fry, impingement on intake screens, food organisms, and over-all biological productivity. These factors were not incorporated in this study of power plant effluents.

Table 1.--Number of fish caught in gill nets set in May 1968-1973, in Lake Michigan near the Palisades Power Plant

(Number per 100 feet of net in parentheses)

Species of fish	Year and feet of net						Total number
	1968	1969	1970	1971	1972	1973	
	750	805	2090	--	--	2000	
Alewife	154 (20.5)	1163 (145.0)	945 (45.2)	--	--	694 (34.7)	2956
Yellow perch	23 (3.1)	11 (1.4)	17 (0.8)	--	--	56 (2.8)	107
Longnose sucker	--	3	62	--	--	153	218
White sucker	3	5	12	--	--	17	37
Lake trout	--	1	13	--	--	2	16
Smelt	--	1	15	--	--	1	17
Coho salmon	--	2	1	--	--	1	4
Chinook salmon	--	--	--	--	--	1	1
Brown trout	--	--	--	--	--	3	3
Golden redhorse	--	--	3	--	--	--	3
Lake herring	--	--	4	--	--	--	4
Brown bullhead	--	--	--	--	--	1	1
Round whitefish	3	--	--	--	--	--	3
Bloater	--	--	3	--	--	--	3
Totals	183	1186	1075	--	--	929	3373

Table 2.--Number of fish caught in gill nets set in June 1968-1973, in Lake Michigan near the Palisades Power Plant

(Number per 100 feet of net in parentheses)

Species of fish	Year and feet of net						Total number
	1968	1969	1970	1971	1972	1973	
	625	920	2090	2000	2000	1750	
Alewife	2 (0.3)	131 (14.2)	608 (29.1)	1365 (68.2)	508 (25.4)	1700 (10.0)	4314
Yellow perch	94 (14.9)	161 (17.5)	384 (18.4)	339 (16.9)	222 (11.1)	646 (37.1)	1846
Longnose sucker	--	1	10	4	44	27	86
White sucker	3	--	--	4	11	20	38
Bloater	16	18	27	--	19	--	80
Smelt	1	2	2	--	--	--	5
Lake trout	1	4	5	1	4	--	15
Coho salmon	--	--	--	5	6	--	11
Brown trout	--	--	--	--	1	1	2
Channel catfish	--	--	--	--	--	1	1
Burbot	--	--	--	--	1	--	1
Totals	117	317	1036	1718	816	2395	6399

Table 3.--Number of fish caught in gill nets set in August 1968-1973, in Lake Michigan near the Palisades Power Plant

(Number per 100 feet of net in parentheses)

Species of fish	Year and feet of net						Total number
	1968	1969	1970	1971	1972	1973	
	1020	920	1500	2000	2000	1800	
Alewife	3 (0.3)	58 (6.3)	154 (10.0)	31 (1.6)	171 (8.6)	29 (1.6)	446
Yellow perch	30 (3.0)	473 (51.4)	595 (39.7)	380 (19.0)	850 (42.5)	648 (35.4)	2976
Longnose sucker	--	10	3	2	23	63	101
White sucker	--	--	4	--	3	42	49
Bloater	11	1	1	11	1	--	25
Smelt	1	4	5	2	--	6	18
Lake trout	5	--	--	2	--	--	7
Chinook salmon	--	--	3	--	--	--	3
Channel catfish	--	--	4	--	--	8	12
Carp	--	--	--	--	2	6	8
Burbot	--	--	--	--	2	--	2
Golden redhorse	--	--	--	--	1	1	2
Northern pike	--	--	--	--	--	3	3
Round whitefish	--	--	--	--	--	1	1
Totals	50	546	769	428	1053	807	3653

Table 4.--Number of fish caught in gill nets set in October 1968-1972 in Lake Michigan near the Palisades Power Plant

(Number per 100 feet of net in parentheses)

Species of fish	Year and feet of net					Total number
	1968	1969	1970	1971	1972	
	1260	1025	1500	1000	2000	
Alewife	90 (7.1)	49 (4.8)	66 (4.4)	2 (0.2)	24 (1.2)	231
Yellow perch	124 (9.8)	13 (1.3)	522 (34.8)	314 (31.4)	76 (3.8)	1049
Longnose sucker	--	2	--	9	51	62
White sucker	1	2	18	12	28	61
Smelt	1	2	6	--	13	22
Lake trout	--	--	1	--	7	8
Coho salmon	3	--	2	--	1	6
Channel catfish	1	1	--	1	2	5
Carp	--	--	--	--	6	6
Round whitefish	--	--	--	--	2	2
Bloater	3	--	--	1	--	4
Northern pike	--	1	4	--	--	5
Burbot	--	--	--	1	1	2
Golden redhorse	--	5	1	--	--	6
Chinook salmon	--	1	--	--	--	1
Gizzard shad	--	--	--	--	1	1
Lake sturgeon	--	--	--	--	1	1
Totals	223	76	620	340	213	1472

Table 5.--Number of fish caught in June 1971 in new gill nets vs. an equal footage of the old complement used in 1968-70

Species	New	Old
Alewife	497	868
Yellow perch	201	138
Longnose sucker	4	...
White sucker	3	1
Coho salmon	3	2
Lake trout	...	1
Totals	708	1,010

Table 6.--Water temperature (F) at the control and plume netting sites in 1972 and 1973

Date and Set No.	Depth (feet)	Temperature[1] Set	Min.	Date and Set No.	Depth (feet)	Temperature[1] Set	Min.
1972				1973			
June 12				May 7			
1	15	54	53	1	10-19	48	48
2*	15-22	65	55	4*	10-21	58	47
June 13				May 8			
1*	18	64	58	1*	10-11	60	50
2*	10-20	67	54	2*	18-20	64	52
3	20	60	52	3	10	49	49
4	26	60	56	4	18	50	48
August 14				June 11			
1*	14-25	72	60	3	10-20	67	65
2	10-20	68	53	4*	17-20	82	64
August 15				June 12			
1*	9-15	69	70	1	15-16	71	60
2	11-11	63	60	2*	10-19	83	60
				3	15-18	72	62
October 2							
1	15	61	56				
2*	15	69	61				
October 3							
1*	10-18	67	57				
2*	15	63	51				
3	10	59	58				
4	10-17	59	58				

[1] Set = surface temperature when nets were set; minimum = minimum temperature at float-line depth during netting period.

* Plume set.

Table 7.--Catch of four species of fish in individual gill nets set both in the plume (P) and outside (C) at comparable depths in 1972 and 1973

	Yellow perch		Alewife		Longnose sucker		White sucker	
	P	C	P	C	P	C	P	C
1972								
June	23	45	114	68	8	6	3	1
	41	21	80	45	7	1	2	1
	35	7	98	47	16	2	2	...
August	105	122	46	64	5	4	2	...
	208	154	...	52	7	4	...	1
October	6	5	...	5	7	7	5	5
	7	1	6	2	5	...	5	2
	4	7	7	3	4	2	2	4
1973								
May	1	7	101	224	42	31	2	4
	1	...	108	106	2	1	4	2
	2	2	88	18	7	16	1	2
June	59	104	690	81	6	2	4	1
	110	125	74	389	1	7	6	4
Totals	602	600	1,412	1,704	117	83	38	27

Table 8.--Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in May 1970 and 1973

(Number in parentheses is total number caught)

	Day	Night	
Date	5/9/73	5/14/70	5/7/73
Water temperature (F)	57	46	54
Lineal feet seined	800	420	800
Spottail shiner	35.5	36.2	8.4
Longnose dace	....	55.6	1.1
Alewife (adult)	100.0+	553.6	100.0+
Alewife (yearling)	....	10.6	....
Sculpin	....	(1)	....
Black bullhead	....	(1)	....
Chinook salmon	....	(1)	....
Trout-perch	....	1.7	1.1
Rainbow trout	1.3	....	1.9
Brown trout	0.3	....	0.3
Smelt (adult)	....	....	12.9
Carp (adult)	....	....	(1)
Largemouth bass	....	....	(1)

Table 9.--Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in June 1969-1973

(Number in parentheses is total number caught)

	Day					Night			
	1969	1970	1971	1972	1973	1970	1971	1972	1973
Date	6/25	6/22	6/16	6/15	6/13	6/22	6/16	6/13	6/11
Water temperature (F)	56	65	69	69	64	67	69	64	73
Lineal feet seined	1200	900	1000	550	450	900	1000	550	1050
Spottail shiner	19.3	0.9	40.7	36.7	100.0	91.0	43.6	106.2	18.3
Longnose dace	3.8	12.7	3.7	5.3	7.8	11.7	10.2	16.0	0.6
Trout-perch	...	(1)	...	...	...	8.4	4.1	(1)	0.2
Coho salmon	...	...	...	...	...	...	(2)	...	...
Brown trout	...	...	...	2.2	0.3	...	...	...	...
Lake trout	(2)	...	(2)	...	...	...	...	...	...
Chinook salmon	(3)	0.7	(2)	1.8	7.6	...	...	...	(1)
Rainbow trout	...	...	...	(1)	...	...	...	...	(1)
Alewife (adult)	(1)	...	...	...	(1)	43.9	0.9	33.5	17.2
(yearling)	0.3	...	12.9	0.9	25.1	0.2	(1)	0.5	5.5
Perch	...	...	5.6	...	(1)	0.4	0.7	...	0.3
Carp (adult)	...	...	...	...	...	...	...	...	1.6
Bluegill	(1)	...	...	...	...	(2)	...	...	(1)
Golden redhorse (adult)	...	...	...	...	...	...	...	...	(1)
Johnny darter	0.3	...	0.3	...	...	(1)	...	...	...
Emerald shiner	(2)	...	...	...	...	...	...	...	...
Bloater	(2)	...	...	...	...	...	...	...	...
Sculpin	(1)	...	...	...	...	...	...	(2)	...
Grass pickerel	...	(2)	...	...	...	(1)	...	...	...
Black bullhead	...	...	...	...	...	(1)	...	(1)	...
Smelt	...	...	...	(2)	...	...	...	...	...
Pumpkinseed	...	...	...	...	...	...	...	(1)	...
Creek chub	...	...	...	...	...	...	...	(1)	...

Table 10.--Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in August 1969-1973

(Number in parentheses is total number caught)

	Day				Night				
	1969	1970	1971	1972	1969	1970	1971	1972	1973
Date	8/4	8/24	8/17	8/16	8/4	8/24	8/17	8/16	8/13
Water temperature (F)	80	76	66	65	73	71	66	72	78
Lineal feet seined	900	820	1020	1045	600	820	1020	1045	1200
Spottail shiner	0.7	(1)	0.7	13.2	9.7	0.9	1.0	8.0	14.0
Longnose dace	2.1	1.6	(1)	1.3	11.7	4.8	(2)	1.3	0.5
Alewife (adult)	(1)	...	...	...	(1)	(3)	2.4	(4)	(3)
Alewife (yearling)	...	...	...	...	...	4.1	...	...	...
Alewife (young)	418.0	2.0+	*	*	...	5.1	*	...	8.3+
Common shiner	...	(2)	...	...	...	...	...	...	...
Yellow perch (young)	...	...	2.6	...	...	...	...	...	...
(yearling)	...	...	(1)	...	13.5	(3)	...	...	1.5
(adult)	...	...	...	...	...	...	4.4	(3)	...
Brown trout	...	...	...	(1)	...	...	...	(2)	...
Trout-perch	...	...	...	...	2.5	6.0	(1)	1.1	0.8
White sucker	...	...	...	...	(1)	...	...	...	...
Sculpin	...	...	...	...	...	(1)	...	...	...
Black bullhead	...	...	...	...	...	(2)	...	...	...
Smelt	...	...	...	...	...	(2)	...	...	...
Carp (adult)	...	...	...	...	...	(1)	...	...	(1)
Quillback (adult)	...	...	...	...	...	(2)	...	(1)	(1)
Smallmouth bass (adult)	...	...	...	...	...	(2)	...	...	(1)
Rainbow trout	...	...	...	...	...	...	...	0.5	...
Northern pike	...	...	...	...	...	...	...	...	(1)
Bluegill (adult)	...	...	...	...	...	...	...	...	(1)

* Numerous

Table 11.--Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in October 1969-1972

(Number in parentheses is total number caught)

	Day			Night		
	1969	1970	1972	1969	1970	1972
Date	10/2	10/12	10/2	10/1	10/12	10/4
Water temperature(F)	64	59	59	64	59	62
Lineal feet seined	1200	840	780	1260	840	780
Spottail shiner	1.1	....	....	....	....	14.1
Longnose dace	12.0	9.4	1.1	....	....	6.8
Alewife (adult)	(1)	....	....	....	....	(1)
Alewife (young)	(1)	13.7+	*	....	....	50.1
White sucker	(1)	....	....	....	....	....
White sucker (adult)	....	(1)	....	....	....	....
Smelt (yearling)	(1)	....	(2)	....	....	....
Smelt (young)	(2)	....	....	....	....	....
Trout-perch	....	....	....	....	....	2.0
Rainbow trout	....	....	....	....	....	(1)
Longnose gar (adult)	....	....	....	....	....	(1)

* Numerous

Table 12.--Mean catch (number per 100 feet of seine haul) and 95% confidence limits for spottail shiners, longnose dace, and trout-perch taken before plant operation (1969-71) and during operation of the plant (1972-73)

Data source	Mean ± Limits	
	Pre-operational	Operational
Spottail shiner		
All data	20.55 ± 8.28	45.20 ± 8.89
Daytime	10.40 ± 9.67	55.20 ± 11.96
Night	30.70 ± 9.67	35.20 ± 11.96
Longnose dace		
All data	10.12 ± 5.81	4.37 ± 6.24
Daytime	4.00 ± 6.79	3.60 ± 8.40
Night	16.23 ± 6.79	5.15 ± 8.40
Trout-perch		
Night	3.77 ± 2.13	0.73 ± 2.64

Table 13.--Species composition and total number of fish captured in trawl tows made in 1969 and 1972 in the vicinity of the Palisades Nuclear Power Plant [1]

Species	39-foot trawl					15-foot trawl
	May 3, 1969		July 25, 1969			August 17, 1972
	Depth (feet)		Depth (feet)			Depth (feet)
	24	42	18	42	72	10-15
Smelt (adult)*	1	52	...	17	89	...
Smelt (yearling)	264	86	...	...	...	...
Smelt (young)	...	...	...	...	...	numerous
Alewife (adult)	...	150	67	195	190	35
Spottail shiner	1	26	27	3	...	5
Trout-perch	...	18	...	254	...	...
Bloater	...	...	1	21	72	...
Yellow perch	...	...	1	...	...	...
Lake herring	...	...	...	...	...	1

[1] In 1969, one 5-minute tow was made at each depth under 50 feet; one 10-minute tow at 72 feet. Five 5-minute tows were made in 1972.

* Fish over 100 mm (4.0 inches) in length.

Table 14.--Percent age composition of yellow perch in monthly gill net catches near the Palisades Power Plant, 1968-1973

(Number in parentheses is number of fish)

Month and year	Age-group								Total number caught
	I	II	III	IV	V	VI	VII	VIII	
May									
1968	..	22	30	22	13	9	..	(1)*	23
1969	..	(3)	(3)	(2)	(2)	(1)	..	..	11
1970	..	(1)	47	21	16	..	11	..	17
1973	..	9	23	29	16	9	..	..	56
June									
1968	..	54	43	(1)	..	2	..	..	94
1969	..	12	40	25	..	5	3	2	161
1970	..	6	35	49	8	1	..	1	384
1971	..	37	22	37	4	(1)	..	..	339
1972	..	10	64	16	10	..	..	..	222
1973	..	3	5	20	4	1	..	..	646
August									
1968	..	70	17	(1)	(1)	7	..	..	30
1969	29	23	27	21	..	..	..	..	473
1970	31	27	19	21	2	..	..	..	595
1971	1	81	11	5	1	1	..	..	380
1972	(1)	45	50	3	1	..	..	..	850
1973	3	5	46	43	4	(2)	..	..	648
October									
1968	17	31	35	10	2	4	..	..	116
1969	(1)	(5)	(5)	(2)	..	..	..	..	13
1970	55	15	19	11	..	..	..	..	522
1971	15	73	10	1	1	..	..	..	314
1972	16	17	41	20	5	(1)	..	..	76

* XI

Table 15.--Percentage age composition of yellow perch in gill net catches near the Palisades Power Plant for the years 1968-1973 [1]

(tr = trace or < 1.0%)

Age group	Year					
	1968	1969	1970	1971	1972	1973
I	8	22	31	5	1	1
II	43	21	17	64	37	4
III	35	32	24	14	52	31
IV	7	24	24	14	7	54
V	2	tr	3	2	3	7
VI	4	1	tr	1	tr	1
VII-IX	tr	1	tr	..	..	..
Total number caught	262	631	1,518	1,033	1,148	1,350

[1] Underlined values pertain to the 1969 year class.

Table 16.--Average length (inches) at capture and calculated weight for male yellow perch of five age groups captured near the Palisades Power Plant before (1970-1971) and after (1972-1973) release of thermal discharge

Age group and year of capture	June 12-14			August 16-17			October 4-6		
	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish
I*									
1970-71	3.2	....	18	5.0	....	20	5.8	....	10
1973	....	....	..	5.3	....	21	....	....	..
II									
1970-71	6.3	1.6	22	7.1	2.3	18	7.9	3.3	18
1972	6.1	1.4	10	7.7	3.0	5	7.5	2.8	2
1973	6.1	1.4	10	7.1	2.3	3	....	....	..
III									
1970-71	7.8	3.2	7	9.2	5.4	8	9.4	5.8	6
1972	7.9	3.3	21	8.2	3.7	13	8.9	4.9	3
1973	7.5	2.8	5	8.3	3.9	35	....	....	..
IV									
1970-71	9.2	5.4	9	9.7	6.5	9	....	....	..
1972	9.2	5.4	5	....	....	..	....	....	..
1973	8.5	4.2	35	9.2	5.4	32	....	....	..
V									
1970-71	9.6	6.2	4	9.9	6.9	3	....	....	..
1972	10.2	7.6	5	....	....	..	10.9	9.4	1
1973	9.1	5.2	2	10.3	7.8	3	....	....	..

*Sex not determined.

Table 17.--Average length (inches) at capture and calculated weight for female yellow perch of five age groups captured near the Palisades Power Plant before (1970-1971) and after (1972-1973) release of thermal discharge

Age group and year of capture	June 12-14			August 16-17			October 4-6		
	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish
I*									
1970-71	3.2	....	18	5.0	....	20	5.8	....	10
1973	....	....	..	5.3	....	21	....	....	..
II									
1970-71	6.9	2.1	20	8.1	3.6	19	8.7	4.6	23
1972	6.4	1.7	12	7.2	2.5	9	8.4	4.0	11
1973	6.3	1.6	12	....	....	..	....	....	..
III									
1970-71	8.9	4.9	28	10.2	7.6	19	11.2	10.3	2
1972	9.1	5.2	43	9.6	6.2	43	10.0	7.1	26
1973	8.1	3.6	22	9.0	5.1	12	....	....	..
IV									
1970-71	10.2	7.6	25	11.4	10.9	9	....	....	..
1972	11.2	10.3	23	11.6	11.5	14	11.9	12.5	14
1973	10.2	7.6	93	10.8	9.1	31	....	....	..
V									
1972	11.7	11.8	10	12.5	14.7	11	12.7	15.4	4
1973	11.8	12.2	27	12.2	13.5	4	....	....	..

* Sex not determined.

Table 18.--Instantaneous rate of perch growth for the periods mid-June to mid-August, and mid-June to October 4, in Lake Michigan near the Palisades Power Plant

Age group	Year of capture	June-August		June-October	
		Males	Females	Males	Females
II	1970-71	.37	.54	..	.79
	1972	.76	.39	..	.86
	1973	.50	..	..	..
III	1970-71	.53	.44	.60	.74
	1972	.11	.18	.48	.37
	1973	.28	.35	..	..
IV	1970-71	.18	.36	..	..
	1972	.55	.11	..	.19
	1973	.25	.18	..	..
V	1972	..	.22	..	.27
	1973	..	.10	..	..

Appendix A.--Date of sampling of the fish population at the Palisades Nuclear Power Plant by fisheries personnel of the Michigan Department of Natural Resources, 1968-1973

Month	Year and date					
	1968	1969	1970	1971	1972*	1973*
May	14-17	12-14	11-14	---	---	7-9
June	25-28	23-24	22-25	14-16	13-14	11-13
August	28-30	25-27	24-27	16-18	14-18	13-16
October	14-16	15-16	12-15	4-6	2-4	---

* Power plant in operation periodically.

Appendix B.--List of species of fish captured in southeastern Lake Michigan near the Palisades Nuclear Power Plant, 1968-1973 *

Common name	Scientific name
Lake sturgeon	Acipenser fulvescens
Longnose gar	Lepisosteus osseus
Alewife	Alosa pseudoharengus
Gizzard shad	Dorosoma cepedianum
Lake herring	Coregonus artedii
Bloater	Coregonus hoyi
Coho salmon	Oncorhynchus kisutch
Chinook salmon	Oncorhynchus tshawytscha
Round whitefish	Prosopium cylinderaceum
Rainbow trout	Salmo gairdneri
Brown trout	Salmo trutta
Lake trout	Salvelinus namaycush
Rainbow smelt	Osmerus mordax
Grass pickerel	Esox a. vermiculatus
Northern pike	Esox lucius
Carp	Cyprinus carpio
Spottail shiner	Notropis hudsonius
Common shiner	Notropis cornutus
Spotfin shiner	Notropis spilopterus
Emerald shiner	Notropis atherinoides
Longnose dace	Rhinichthys cataractae
Creek chub	Semotilus atromaculatus
Quillback	Carpiodes cyprinus
White sucker	Catostomus commersoni
Longnose sucker	Catostomus catostomus
Golden redhorse	Moxostoma erythrurum
Black bullhead	Ictalurus melas
Brown bullhead	Ictalurus nebulosus
Channel catfish	Ictalurus punctatus

Appendix B.--concluded

Common name	Scientific name
Trout-perch	Percopsis omiscomaycus
Burbot	Lota lota
Ninespine stickleback	Pungitius pungitius
Bluegill	Lepomis macrochirus
Pumpkinseed	Lepomis gibbosus
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Iowa darter	Etheostoma exile
Johnny darter	Etheostoma nigrum
Yellow perch	Perca flavescens
Slimy sculpin	Cottus cognatus

* Names follow Special Publication No. 6 of the American Fisheries Society (1970).

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