A SYNOPSIS OF WALLEYE TAGGING EXPERIMENTS IN MICHIGAN, 1929 - 1965.

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A SYNOPSIS OF WALLEYE TAGGING EXPERIMENTS IN MICHIGAN, 1929-1965 [1]

By James C. Schneider and Walter R. Crowe [2]

ABSTRACT

Walleye tagging studies were conducted in 11 areas of Michigan between 1929 and 1965. Tags were returned by fishermen for up to 18 years after the date of release. The estimated age of the oldest walleyes in each study area ranged from 9 to 26 years or older. Estimates of exploitation, based on voluntary tag returns, varied between 1.5 and 10.4% for the first year of fishing and between 3.5 and 28.5% for all years. Total annual mortality varied from 20% for male walleyes in Lake Gogebic to 65% for both sexes in Bay de Noc. Female walleyes were recaptured at a higher rate than males in Lake Gogebic and Burt Lake, but the opposite was true in Bay de Noc. Walleyes inhabiting the Muskegon River and the eastern shore of Lake Michigan were more migratory than walleyes in other stocks.

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Introduction

Numerous tagging studies of walleyes were begun in the 1929-1965 period. Some results of these studies were discussed by Eschmeyer (1950), Eschmeyer and Crowe (1955), Crowe (1955, 1957, 1958, and 1962), Crowe et al. (1963), and Schneider (1969); a few additional tags have been turned in since these reports were prepared. While these new data do not alter conclusions already reached, they do add to our knowledge about walleye mortality and behavior. As no additional tag returns are likely, the following synopsis of results is expected to be the last. Studies were conducted on the Muskegon River system, Hamlin Lake, Lake Gogebic, Saginaw Bay, Van Etten Lake, Lake Cadillac, East Twin Lake, Lake Independence, Fife Lake, the Inland Waterway, and Bay de Noc (Fig. 1).

The Muskegon River System

The Muskegon River originates in Higgins and Houghton lakes, flows through a series of impoundments and then Muskegon Lake before emptying into Lake Michigan. Walleyes are common to all parts of the system but they are especially abundant in Houghton Lake and, until the 1960's, large numbers moved up from Lake Michigan and congregated below the lowermost dam at Newaygo. In an operation known as "the Newaygo Transfer" some of these migrants were captured in dip nets and transferred to other waters. Many of those transferred were tagged before release in up-river impoundments, the north and south Newaygo lakes, and other places. Other migrants were tagged and released at the spawning site below Newaygo. Still others were intercepted at Muskegon Lake. Studies were also made of the walleye populations residing in Houghton Lake, the upper part of the Muskegon River, and Hardy Pond.

Walleyes transferred to lakes in Newaygo County

During the 1947 Newaygo Transfer, 375 jaw-tagged walleyes were released in Newaygo County lakes (Table 1). No new information has been received since the summary by Eschmeyer and Crowe (1955). For the north Newaygo lakes, tag returns were 27.5% during the next 4 years and 3 months. For the south Newaygo lakes, returns were 9.1% during the next 5 years and 11 months. So far as is known, only one fish from each group returned to the Muskegon River.

Walleyes transferred to impoundments on the Muskegon River

Each year between 1923 and 1966 (excepting 1951) large numbers of migrating walleyes were captured and transported in a tank truck to upstream impoundments. In 1932, 172 walleyes were tagged on the operculum. Two of these were retaken in the impoundment of release and one was recaptured after it had passed through two dams (Eschmeyer and Crowe 1955).

In 1947, 1948, and 1950, a total of 3,371 migrants were jaw-tagged before they were transferred. One (1) additional recapture has been made since Eschmeyer and Crowe (1955) summarized these experiments. Fishermen reported the recapture of 18.3% of the tags over the next 7 years and 11 days, but mostly during the first year (Tables 1 and 2). Walleyes transferred to Hardy Pond were recaptured by anglers at a higher rate (27.0%) than walleyes transferred to other impoundments (13.2-19.1%).

These studies demonstrated that most of the transferred walleyes soon migrated back to Lake Michigan, hence the low rate of returns after the first year. None of the tagged walleyes released in Big Rapids Pond were recovered there, all came from Rogers Pond or points further down river (Table 3). Returns from Newaygo Pond were relatively low whereas returns from Hardy and Croton ponds were high--these two

appear to offer the most attractive habitat for walleyes and are impounded by relatively high dams. Eventually, 116 walleyes made their way back to the lower part of the Muskegon River system or to Lake Michigan. Three walleyes planted in Big Rapids Pond in 1950 passed all five hydroelectric dams and were caught in Muskegon Lake that same year (Eschmeyer and Crowe 1955). Tag returns indicated that large numbers of walleyes moved through each of the dams, but passage through the high structures at Hardy and Croton may have been more hazardous (Table 3). The height of the dams varied from 17 to 100 feet. [3]

Supplemental data were obtained for walleyes which had been tagged and released at various locations (mostly Muskegon Lake), then captured again during the Newaygo Transfer, and transferred upstream. Such "multiple" releases were made as late as 1963. By adding more recent data to the summary (through 1961) by Crowe (1962) we have the following final statistics: 3,593 tagged walleyes were transferred to impoundments; about 15% of these were caught in the impoundments by anglers; 28 fish were subsequently recaptured in dip nets below Newaygo Dam 1 to 6 years later; and 92 fish were captured by anglers or commercial fishermen in the lower Muskegon River, Muskegon Lake, or Lake Michigan.

Releases below Newaygo Dam

In 1948 and 1950, 765 migrating walleyes were captured in dip nets below the dam at Newaygo, tagged, and released there (Table 1). Exploitation totaled 13.3% (102 recaptures) in the next 5 years: 46 were caught by anglers in the lower part of the river, 18 by anglers in Muskegon Lake, 17 by anglers in Lake Michigan, and 21 were caught in Lake Michigan by commercial fishermen. Twenty-five others were retaken in dip nets 1 to 9 years later. One additional walleye released there in 1955 was recaptured in a dip net 5 years later.

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[3] The Big Rapids Dam was removed in 1966 and the Newaygo Dam in 1969.

Releases in Muskegon Lake

Walleyes migrating toward the spawning ground in the Muskegon River were intercepted in Muskegon Lake during the month of March in 1948, 1952, 1953, and 1954. The number of walleyes tagged and released in these years was 23, 8, 676, and 687, respectively, for a total of 1,394 (Table 1).

Later the same year, and for up to 8 years afterward, 173 of these fish were recaptured at the netting site below Newaygo Dam.[4] Portions of these data were used by Crowe (1954) to estimate the spawning population at 113,882 in 1953 and 138,776 in 1954. Anglers recaptured another 92 tagged walleyes from the lower end of the river. Others were recaptured in Muskegon Lake, Lake Michigan, and other tributaries to Lake Michigan.

Eventually, 12.8% (178) of the tags were reported by anglers and 2.1% (29) by commercial fishermen. First year exploitation rates were 7.3% and 1.4%, respectively. Fishermen returned tags over a long period but only 2 were taken after the third year (Table 1). Five walleyes were found dead--one 9 years after its release. The tag out for the longest time, 12 years and 30 days, had been placed on a male walleye 18.0 inches long. It is likely that this fish was at least 5 years old when tagged; hence it was 17 or more years old when recaptured.

An annual survival rate of 37.6% was calculated for walleyes tagged at Muskegon Lake. This was computed from the data on yearly recaptures (Table 1) by means of the formula of Robson and Regier (Ricker 1975, p. 31). Mortality, the complement of survival, would then be 62.4% per year for the tagged fish. These estimates are affected by long-term rates of fishing mortality, natural mortality, tag loss (i.e., non-retention) and tagging mortality. The most important assumptions in the method are that fishing rate, natural mortality rate, and the degree of cooperation in tag reporting were constant through the years. We

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[4] Crowe's (1962) published figure of 93 recaptures is in error but his calculations and conclusions are not altered.

believe, based on years of field observations at many locations, that long-term rates of tag loss and tagging mortality were low. Consequently, we assume that these estimates of survival and mortality were representative of the entire adult walleye population in the Muskegon River-eastern Lake Michigan area.

While it is true that the Muskegon River run was comprised of relatively old walleyes (for females, either age VI, VII, or VIII predominated in the 9 years which scale samples were collected), the mortality rate of 62.4% seems unusually high. Fishing accounted for 8.7% of the tagged fish which died (plus an unknown fraction for which tags were not reported).[5] Another 5.7% was removed by the Newaygo Transfer (minus those which managed to return to lower waters). Predation by sea lampreys, which were abundant in Lake Michigan at that time, could have been a source of walleye mortality, but it probably was not an important factor in the eventual near-collapse of this stock (Schneider and Leach, MS).

Movements of adfluvial migrants

The movements of walleyes tagged when entering the lower part of the Muskegon River system to spawn have been summarized in Figure 2. After upstream movement and spawning were completed in the Newaygo area during April, the migrants moved quickly back downstream and most had left the Muskegon River drainage by the first of July. Many of the walleyes transferred to impoundments further upstream returned relatively rapidly also, considering the barriers they had to pass. In Lake Michigan they dispersed as far south as Gary, Indiana, and as far north as Good Harbor Bay, on the Leelanau Peninsula.[6] Some were recaptured in the lower reaches of other

[5] According to the tag returns (cited earlier), commercial fishermen exploited 1.4% of the stock; however other estimates of commercial exploitation were 7-12% (Schneider and Leach, MS).

[6] In a recent study, a walleye tagged below Croton Dam (now the lowermost barrier) in April 1975, was recaptured near Green Bay City, Wisconsin, almost exactly one year later.

tributaries: St. Joseph River, Kalamazoo River, Grand River, White Lake, and Lake Macatawa. These data are included with the offshore records in Figure 2. A total of 138 walleyes tagged on the Muskegon River spawning run were recaptured outside of the Muskegon River drainage but none were recaptured elsewhere at spawning time.[6] In addition, of 730 walleyes captured in Lake Michigan and stocked in Hamlin Lake, 8 subsequently appeared at the spawning area below Newaygo Dam (see section on Hamlin Lake). Based on these tagging data and the absence of significant spawning runs of walleyes in other tributaries, it may be concluded that the Muskegon River was the "home" of most of the walleyes in eastern Lake Michigan.

Native walleyes--Houghton Lake

Carbine and Applegate (1946) described the 1939-40 study at the North Bay of Houghton Lake. Ten of 60 tagged walleyes were recaptured within 2 years and 2 months, all within the lake (Table 1).

Native walleyes--Upper Muskegon River

Carbine and Applegate (1946) also tagged 40 walleyes captured in a two-way fish weir across the Muskegon River, 1 mile below Houghton Lake (Table 1). Nine were retaken by anglers within 2 years and 2 months: 5 from Houghton Lake and 4 from the Muskegon River. Three of the river recoveries were made just above and just below Big Rapids Dam, 130 miles below the release site.

Native walleyes--Hardy Pond

Walleyes were netted, tagged, and released in Hardy Pond in 1948, 1952, 1953, and 1954. The majority were captured during a spring migration to the upper end of the pond. They were assumed to be native walleyes because of their small average size (about 12 inches), but they could have been progeny of transferred, migratory, walleyes. Anglers returned 63 tags (8.8%) in a period of 8.5 years and 1 fish (0.1%) was

caught by a commercial fisherman (Table 1). In addition, 3 walleyes were recaptured in trap nets in Hardy Pond the year after tagging and 3 others were caught in dip nets at Newaygo 3-8 years later. In all, 58 were recaptured in Hardy Pond, 5 in Croton Pond, 6 in the Muskegon River below Newaygo, and 1 in Lake Michigan, just off the port of Muskegon.

In summary, tagging studies in the Muskegon River impoundments showed that there was a strong tendency for both native and, especially, adfluvial walleyes to move towards Lake Michigan. However, there was no clear evidence of migration from Houghton Lake. Dams on the Muskegon River were often passed successfully; on the other hand, mortality could have been substantial, for the rate of recapture in lower waters was inversely related to the number, size, and structure of the dams which had to be passed.

Hamlin Lake

Hamlin Lake drains into eastern Lake Michigan via a short river, the Big Sable. Construction of a dam at the lake's outlet formed a barrier to the upstream movement of modest numbers of walleyes. Between 1929 and 1955, as many as 307 walleyes were netted annually and transferred into Hamlin Lake to supplement the native population. In the following years, the Hamlin Lake Association purchased live walleyes from commercial fishermen on Lake Michigan for stocking purposes. Tagging studies were conducted on transferred walleyes from both of these sources and on native fish.

Native walleyes were tagged in 1930 and 1956. In the earlier study, one recovery was made (a short time after release) from the 14 fish tagged on the operculum (Eschmeyer and Crowe 1955). In the 1956 study, jaw tags were placed on 48 walleyes. Anglers returned 17.8% of these over a relatively long period, 7 years and 14 days (Table 4). The oldest walleye probably attained an age of 9 years. All were caught above the dam.

Hamlin Lake anglers caught a much smaller fraction of the transferred walleyes: 4.6% of those obtained from the Big Sable River and 7.1% of those obtained from Lake Michigan proper (Table 4). The recapture period was surprisingly long--nearly 5 years--but there was ample evidence that many returned to Lake Michigan. One walleye tagged during the spring (spawning?) run up the Big Sable River reappeared a year later in the Muskegon River near the spawning ground at Newaygo; another was retaken 160 miles away, off Brevort in northern Lake Michigan, 14 months afterwards. Eighteen walleyes originally captured in Lake Michigan near Ludington in mid-summer, and transferred to Hamlin Lake, were recaptured in Lake Michigan or had passed through it on their way to other places: 5 were recaptured in the lake proper (including 2 found dead on the beach), 1 was caught in Pere Marquette Lake, and 12 were retaken in the Muskegon River spawning run 1 to 6 years later.

Lake Gogebic

Tagging studies were conducted at Lake Gogebic in 1940 and 1947 (Table 4). Only 94 walleyes were tagged in 1940 and returns extended over just 3 years. In the 1947 study, recaptures from 4,328 jaw-tagged walleyes were made over a span of 18 years (plus 1 day).

The final results of the 1947 experiment were analyzed recently by Schneider et al. (1976). The most notable result was the unusual longevity of walleyes in Lake Gogebic. One tagged walleye reached an estimated age of at least 26 years, and two others probably lived 23 years. Longevity was attributed to low angling mortality (voluntary tag returns were 1.5% the first year and 8.5% for all years) and statistical chance (a result of the large number of walleyes tagged). It is likely that the true exploitation rate was about 4% annually and that natural mortality was in excess of 16% per year.

The sexes differed in rates of fishing mortality and survival. Anglers recaptured 12.6% of the female walleyes as compared to only 7.3% of the male walleyes. Survival was 65.4% for females and 80.4% for males.

Six walleyes were retaken outside of Gogebic Lake, all in the outlet stream (Eschmeyer and Crowe 1955).

Saginaw Bay, Lake Huron

Saginaw Bay walleyes were tagged in 1929 and 1942. No new data have been received since the summary by Eschmeyer and Crowe (1955). One recovery was made from 177 fish tagged on the gill covers in 1929. Seven out of 198 jaw-tagged walleyes released in the inner part of the Bay in the spring of 1942 were recaptured there within 13 months (Table 4).

Van Etten Lake

A small study was conducted at Van Etten Lake in 1931. No recoveries were obtained from a release of 53 walleyes. The lack of returns was attributed, in part, to poor retention of operculum tags (Eschmeyer and Crowe 1955).

Lake Cadillac

Returns from 297 jaw-tagged walleyes released in Lake Cadillac in 1947 were received for up to 10 years and 54 days (Table 4). If the walleye tagged for the longest period of time had been growing at a rate similar to other walleyes in the lake (Schneider and Kelly 1973), it was about 5 years old when tagged and 15 years old when retaken. It had grown from 15.4 to 17.5 inches in the 10 years.

The rate of return was low, 3.4% in the first year and 11.1% over-all. None of the walleyes was caught outside of Lake Cadillac.

East Twin Lake

No returns have been received from the 1939 study at East Twin Lake since the summary by Eschmeyer and Crowe (1955). Of the 103 walleyes tagged, 9.7% were recaptured (Table 4). Considering the relatively small number of tagged fish released, the return of 3 as

late as 9.5 years later is remarkable. The maximum age achieved by these walleyes was about 12 years.

Lake Independence [7]

Lake Independence is about 2 miles from Lake Superior via the Iron River. Since 1912, an 8- to 10-foot dam at the lake's outlet has blocked the upstream migration of small numbers of walleyes. The run was roughly estimated at 500-800 adults in 1947 and 500 adults in 1953. The presence of ripe fish and some viable eggs below the dam indicated that spawning occurred there. [8] Attempts to capture walleyes below the dam and transfer them into Lake Independence proved to be inefficient and costly. The numbers of walleyes transferred in various years were: 1939--4, 1940--129, 1942--13, 1947--33, 1948--40, 1953--131, and 1963--82. Walleyes were tagged or fin-clipped in three of those years.

In 1942, 13 tagged walleyes were transferred into Lake Independence. One was recaptured in the lake 3 years later.

In 1953, 131 transferred walleyes were fin clipped. Three quickly swam 2 miles across the lake, went over the dam, and were recaptured in the nets before the transfer operation was completed. Nine others were among 323 walleyes netted during a survey of the lake, June 10-24. Anglers reported catching 20 (15.3%), all within the first year.

In 1963, employees of the U.S. Fish and Wildlife Service jaw-tagged and transferred 82 walleyes, averaging 17.4 inches long, which had been caught in the sea lamprey weir (installed in 1954) on the Iron River. Anglers recaptured 13 (15.8%) of these walleyes from Lake Independence, all but 1 in the first year (Table 4). Two others were among 219 walleyes examined during a netting survey of the lake

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[7] Information in this section was obtained from MDNR files, mainly from reports by Clifford Long.

[8] The viable eggs were noted by Paul H. Eschmeyer in a letter dated March 30, 1949.

that summer. The following spring (1964), 9 of the tagged fish were among 173 walleyes caught in the weir.

These data indicate that the transferred walleyes contributed little to the fish population or the fishery of Lake Independence. The lake already had a large population of slow-growing walleyes. Many of the transferred walleyes returned over the dam to join the small stock inhabiting the Iron River and Lake Superior proper. Recruits to this stock are likely supplied by migrants from Lake Independence and by walleyes spawning in the area below the dam.

Fife Lake

Fife Lake walleyes were tagged in 1964 and 1965 to evaluate the contribution of hatchery-reared fingerlings (stocked a couple of years earlier) to the very small native population (Schneider 1969). The total adult population was estimated by the mark-and-recapture method at 1,397 in 1964 and 1,087 in 1965. Of the 22.2% loss during the year, 5.1% was attributed to angling. The estimate of angling mortality was (as usual) based on voluntary tag returns but the rate of return may have been bolstered by the presence of a part-time census clerk.

Tag returns, which totaled 8.4%, trickled in for 6 years and 11 months (Table 4). The maximum age obtained by a walleye here was 10 years. All were retaken in the lake; none is known to have passed over the low dam at the lake's outlet.

Inland Waterway

Walleyes were tagged in the Inland Waterway (composed of the Cheboygan River, Black Lake, Mullett Lake, Burt Lake, Crooked Lake, Pickerel Lake, and connecting rivers) from 1931 to 1956. A substantial number of tags have been returned since Crowe (1958) summarized results through 1957. The tagged walleyes were either "transfers" or "natives."

Transferred walleyes

Between 1931 and 1949, modest numbers of walleyes (average, 1,240 per year) migrating up the Cheboygan River from Lake Huron were captured below the dam at Cheboygan and transferred to up-river waters of the Inland Waterway in an operation known as "the Cheboygan Transfer." A large number of transferred walleyes were tagged in 1931-32, and again in 1942 (Table 5). Anglers returned only 1.4% of the earlier group, all in the first year. These fish had been tagged on the operculum. Returns from the 1942 group, which had been tagged on the jaw, were much better--11.1% over 8.5 years.

Four transferred walleyes were eventually recovered below the Cheboygan Dam (Eschmeyer 1950); all other recoveries (91) were made above the dam, often in waters above the point of release. Eschmeyer (1950) and Eschmeyer and Crowe (1955) described the movements of transferred walleyes in greater detail. The Inland Waterway affords excellent habitat for walleyes and, unlike the Muskegon River system, there was little tendency for transplanted walleyes to migrate down to the Great Lakes. Consequently, the number of migrants becoming blocked from native spawning grounds by the Cheboygan Dam was relatively small.

Native walleyes

Walleyes native to the upper waters of the Inland Waterway were netted at five locations, jaw-tagged, and released at the point of capture during the years 1948-1956. The tables of results compiled by Crowe (1958) have been updated and appear here as Tables 5 and 6. More specific data on homing tendencies of spawning walleyes can be found in Crowe (1962).

Tagged native walleyes were recaptured as late as 1966 (Table 5). One tagged walleye was out in Mullett Lake for 12 years and 75 days. The age of this fish was not determined, but judging from its length when tagged (16.7 inches), it probably lived 16 years or more.

The rate of tag return was higher in Crooked Lake than any other part of the waterway, 28.5% as compared to 16.5-20.5%. The rate of exploitation of walleyes in Crooked Lake during the first year, 10.4%, was the highest among the native populations which are reviewed in this report.

A survival rate of 63.4% was calculated for native walleyes from the data on annual recaptures (Table 5). Total mortality would then be 36.6%. Losses to sport fishing were a small part of the total mortality. Only 6.9% of the tags were returned the first year, and 19.4% over all, but these estimates are minimal because they are based on voluntary returns. Eschmeyer and Crowe (1955) noted that female walleyes were exploited at a higher rate than males in Burt Lake. Expectation of death from natural causes was likely about 20-30% annually.

Native walleyes were most often recovered from the lake where they had been captured and released, but there was a considerable amount of interchange between Crooked Lake and Burt Lake (Table 6). The Black Lake population was discrete; the Alverno Dam prevented passage of fish into that lake and the Black Lake walleyes showed no inclination to move down through the dam. Most of the walleyes congregating below Alverno Dam seemed to come from Mullett Lake. They could reach this spawning area by dropping down the Cheboygan River, then ascending the Black River to the dam. Two marked walleyes dropped from the area below Alverno Dam to the mouth of the Cheboygan River, passing the Cheboygan Dam enroute.

Bay de Noc

Jaw tags or dart tags were used to mark 6,915 walleyes in Big and Little Bay de Noc in 1957-1963. Crowe (1962) and Crowe et al. (1963) have already reported on the tendency for these walleyes to "home" to specific spawning grounds, on the relatively high exploitation rate by sport fishermen as compared to commercial fishermen, and on

the similar rate of return for the two types of tags. Final analyses of tag returns and walleye movements are possible now.

Tag return rates from the annual releases varied from 3.8 to 13.0% and were 8.4% over-all (Table 7). The highest yearly exploitation rate was only 6.3%. The extent to which tags were not reported cannot be accurately judged but the return of several tags by secondary processors indicated that some tags were not noticed by commercial fishermen. On the basis of tag returns, fishing mortality may be partitioned into 62.8% by angling and 37.2% by commercial fishing.

The rate of tag return declined during the study, probably as a result of declining fishing effort caused by decreasing walleye abundance. The population dropped from an all-time high in the 1950's to a record low by the late 1960's.

Data on tag returns are extensive enough so that walleye mortality can be estimated. A survival rate of 35% was calculated from the pooled recapture data in Table 7 (excluding the first year because many small tagged walleyes were not fully vulnerable to the commercial fishery). Total mortality would then be a rather high 65%. The low rate of voluntary tag returns suggested that fishing mortality was low and that natural mortality was high. Predation by sea lamprey may have been a cause of high natural mortality but it was probably not a major factor in the collapse of walleye recruitment (Schneider and Leach 1977). The high mortality rate is reflected in the relatively short period of tag returns, 7 years and 11 months.

Following the spring spawning run, walleyes from discrete spawning stocks mingled in the deeper waters of northern Green Bay. Only 9 were recaptured elsewhere, and none of these was recovered during the spawning period (April). Eight walleyes tagged on spawning grounds in Little Bay de Noc, and one walleye tagged near the Bark River, were retaken 1 to 37 months later in the Wisconsin waters of Green Bay, mostly along the Door Peninsula.

Considerable wandering was done by a group of 201 ripe walleyes which were captured in Little Bay de Noc in 1961 and

transported about 87 miles to Epoufette Harbor, northeastern Lake Michigan, in an attempt to establish a spawning population there. None was subsequently caught in their "home" area of Little Bay de Noc, but one was seen at the extreme southern end of Green Bay 13 months afterward. Eight were recaptured within 15 miles, either direction, of Epoufette--seven during the first few months, one over 3 years later. One was retaken in St. Martin's Bay, just east of the Straits of Mackinac, 40 days later; another was caught below the dam at Cheboygan 1 year and 42 days later. A twelfth walleye from this group wandered into Lake Charlevoix where it was found dead 4 months after its release.

Discussion

Exploitation of walleyes was low in all the areas studied, as can best be judged from voluntary tag returns. There was firm evidence of non-reporting of tags by commercial fishermen and surely many tags were not returned by anglers, but it seems unlikely that the true exploitation rate was excessive anywhere. The early studies in which tags were applied to gill covers yielded little useful information, apparently because these tags detached easily--none was recovered after more than 6.5 months at liberty. For native stocks in which significant numbers of walleyes were jaw tagged (excluding Newaygo Pond where only 6 natives were tagged), exploitation was 1.5-10.4% in the first year and 3.5-28.5% overall. For transferred stocks, 0.9-21.0% were exploited in the first year and 3.9-27.3% were eventually caught.

The contribution of transferred walleyes to the fisheries of the study areas differed markedly. In the Muskegon system, the transferred fish were caught more easily than the natives during the first year, but they quickly moved down through the impoundments. In the Cheboygan River system, the transferred fish were not especially vulnerable to anglers and they tended to remain up-river, blending into the fishery for native stocks. In Hamlin Lake, the native population made a much larger contribution to the fishery than the transferred fish at all times. High costs, migratory tendencies, and a large native

population made the transfer of walleyes into Lake Independence impractical. The differences in behavior of the transferred walleyes presumably reflect differences in the quality of the habitats and inbred migratory tendencies.

Often the rates of tag return and survival were sex-related. Female walleyes were more vulnerable to anglers and shorter-lived than male walleyes in Burt Lake and Lake Gogebic. In the Muskegon River, there was no consistent difference between the sexes in rates of tag return; however females predominated in the adfluvial run, especially in samples taken with dip nets. In Bay de Noc, 12.3% of the tagged males were recaptured as compared to 7.6% of the marked females, and females had a slight edge in longevity. Higher exploitation and lower survival of females is likely the more typical pattern for the species. Male walleyes generally grow slower, implying that they have a less aggressive feeding behavior and a lower vulnerability to anglers. However, in many fisheries the tendency for males to be less vulnerable than females is offset by a tendency for males to be more available to anglers in the early spring because they remain concentrated near the spawning areas longer. In Bay de Noc, for example (where males predominated in the catch), the fishery was primarily directed at the spawning run. According to trap net samples, males made up 70.5% of that run.

Longevity differed greatly among the populations (and groups of populations) which were studied. The unusual longevity of walleyes in Lake Gogebic is unique in the literature on walleyes, although other populations reportedly have a lower rate of natural mortality. In these situations old age can be accurately determined only by tagging because the growth of scales and other body parts virtually ceases after a dozen or so years of age. At Lake Gogebic, three tags were out 16 to 18 years. Those walleyes probably reached ages of 23 to 26 years, and many others lived more than 15 years. In the Muskegon River-eastern Lake Michigan population, one tag, out 12 years, was on a male walleye which likely reached 17-20 years of age; another fish was roughly 17 years

old. In another Great Lakes stock, Bay de Noc, the "oldest" tag return of about 8 years came from a walleye 14 or more years old. In the Inland Waterway (Mullett Lake), one tag was out for 12 years. That walleye was at least 16 years of age, and a few other tagged ones may have lived more than 15 years. The oldest walleyes in East Twin, Fife, and Hamlin lakes were estimated at 12, 10, and 9 years, respectively. Too few walleyes were tagged in Saginaw Bay to provide data on longevity but Hile (1954) reported ages up to 15 years based on scale samples.

It appears that natural mortality may be relatively high in Michigan walleye stocks. The following total mortality rates (actually rate of mortality plus rate of tag loss) were obtained for tagged adult walleyes: Lake Gogebic--20% for males and 35% for females; Inland Waterway--37%; Muskegon River-eastern Lake Michigan--62%; and Bay de Noc--65%. At Fife Lake, the total mortality between age III and IV was estimated at 22%. Because the fishing mortality and tag loss components of these estimates did not appear to be high for these stocks, natural mortality was at least 17% (Fife Lake), and much more in some localities (Great Lakes). By contrast, natural mortality rates as low as 4-5% have been reported elsewhere (Forney 1967, Olson 1957). The high mortality occurring in the two Great Lakes walleye stocks may be attributed, in part, to their late maturity, hence low life expectancy after tagging. These stocks were also subjected to commercial fishing and sea lamprey predation in addition to sport fishing. The walleye stock in Nipigon Bay, Lake Superior, which was subjected to similar stresses, also had a relatively high natural mortality rate (41%) just before it crashed (Ryder (1968).

Walleyes in some of the populations studied migrated much more than walleyes in others. The Muskegon River-eastern Lake Michigan population was very mobile compared to the stock in Bay de Noc. Walleyes migrated extensively among the waters of the Inland Waterway and out of Lake Independence. Elsewhere, there was very little tendency for walleyes to move out of the study areas.

Table 1.--Numbers of jaw-tagged walleyes (transferred, migrating or native) released in the Muskegon River drainage, 1939-1954,[a] and percentages recaptured by sport and commercial fishermen

Release data: Locality and year	Number	Year of recapture: 0 (Same)	1	2	3	4	5	6	7	8	12	Total
Studies on transferred walleyes												
N. Newaygo lakes 1947	200	21.0	4.0	2.0	...	0.5	...	...	..	...	..	27.5
S. Newaygo lakes 1947	175	5.1	1.7	0.6	0.6	0.6	...	0.6	..	...	..	9.1
Impoundments[b] 1947-50	3371	16.7	1.2	0.3	tr[c]	0.1	...	...	tr	...	..	18.3
Studies on migrating walleyes												
Lower river 1948, 1950	765	5.6	4.4	0.9	1.2	0.6	0.5	...	..	...	..	13.3
Muskegon Lake 1948-54	1394	8.7	4.6	1.2	0.2	...	0.1	...	..	...	0.1	14.9
Studies on native walleyes												
Houghton Lake 1939, 1940	60	8.3	5.0	3.3	...	...	...	...	..	...	..	16.6
Upper river 1939, 1940	40	2.5	15.0	5.0	...	...	...	...	..	...	..	22.5
Hardy Pond 1948-54	721	2.2	4.3	1.2	0.8	0.3	...	...	..	0.1	..	8.9
Newaygo Pond 1948	6	16.7	16.7	...	...	...	...	...	..	...	..	33.4

[a] Additional tagged fish were released in other years (see text).

[b] See Table 2 for more detailed records.

[c] tr = less than 0.05%.

Table 2.--Numbers of jaw-tagged, transferred walleyes released in Muskegon River impoundments in 1947, 1948, and 1950, and percentages recovered by sport and commercial fishermen

Impoundment of release	Number tagged	Year of recapture								Total
		0 (Same)	1	2	3	4	5	6	7	
Big Rapids	356	18.3	0.2	...	...	...	...	...	...	18.5
Rogers	825	12.8	0.4	...	...	...	...	...	...	13.2
Hardy	667	25.5	1.5	...	...	...	...	...	...	27.0
Croton	916	17.5	1.1	0.4	...	0.1	...	...	...	19.1
Newaygo	507	9.7	2.8	1.4	0.2	0.4	...	...	0.2	14.6
Morley	100	13.0	1.0	...	...	...	...	...	...	14.0
Total	3371	16.7	1.2	0.3	tr[a]	0.1	...	...	tr	18.3

[a] tr = less than 0.05%.

Table 3.--Numbers tagged, numbers recovered by fishermen or nets, and percentages of the total recoveries made in various localities, for transferred walleyes released in five Muskegon River impoundments, 1947-1950. Also given are the numbers of tagged walleyes recovered after passing the dams separating the localities.

Impoundment of release	Number tagged	Number recovered	Locality of recovery					
			Big Rapids	Rogers	Hardy	Croton	Newaygo	Downstream from Newaygo Dam [a]
Big Rapids	356	66	0.0	71.2	21.2	3.0	0.0	4.6
Rogers	825	109	...	28.4	66.1	5.5	0.0	0.0
Hardy	667	181	...	....	90.1	7.2	0.0	2.8
Croton	916	187	...	....	....	79.1	2.7	18.2
Newaygo	507	88	...	....	....	....	16.5	84.1
Total number of walleyes recovered after passing dams [b]			66	97	29	47	116	

[a] Includes the lower part of the Muskegon River, Muskegon Lake, and Lake Michigan.

[b] For example: 66 walleyes were recovered after passing Big Rapids Dam, 97 after passing Rogers Dam, etc.

Table 4.--Numbers of jaw-tagged walleyes (mostly natives) released in certain Michigan waters, 1939-1965, and percentages recaptured by fishermen

Release data: Locality, Year	Number	Year of recapture: 0 (Same)	1	2	3	4	5	6	7	8	9	10	Total
Lake Gogebic													
1940	94	8.5	2.1	2.1	...	...	...	...	...	...	...	...	12.8
1947	4328[a]	1.5	1.8	1.1	1.3	0.9	0.4	0.2	0.4	0.1	0.2	0.2[b]	8.5
Lake Cadillac													
1947	297	3.4	2.0	2.7	1.0	0.3	0.7	0.7	...	...	...	0.3	11.1
East Twin Lake													
1939	103	...	5.8	1.0	...	...	...	...	...	...	...	2.9	9.7
Saginaw Bay													
1942	198	1.5	2.0	...	...	...	...	...	...	...	...	...	3.5
Fife Lake													
1964-5	346	3.8	1.4	...	...	0.9	0.9	0.9	0.6	...	...	...	8.4
Lake Independence[c]													
1963	82	14.6	...	1.2	...	...	...	...	...	...	...	...	15.8
Hamlin Lake													
1956	45	2.2	4.4	6.7	...	...	...	2.2	2.2	...	...	...	17.8
Big Sable River[d]													
1949-55	110	0.9	2.7	0.9	...	...	...	...	...	...	...	...	4.6
Lake Michigan[d]													
1956-8	603	1.0	5.0	1.0	...	...	0.1	...	...	...	...	...	7.1

[a] A total of 4,400 were released but 72 were found dead a short time after tagging.

[b] Continuation for Lake Gogebic, 1947 release, years 11-18 respectively: 0.1, 0.1, 0.1, 0.1, tr, tr, tr, and tr percents. Tr equals less than 0.05%.

[c] Walleyes were transferred into Lake Independence from the Iron River.

[d] Walleyes were transferred into Hamlin Lake from the Big Sable River or Lake Michigan.

Table 5.--Numbers of tagged walleyes (transferred or native) released in the Inland Waterway, 1931-1956, and percentages recaptured by anglers[a]

Release data: Locality, Year	Number	Year of recapture: 0 (Same)	1	2	3	4	5	6	7	8	9	10-13	Total
Studies on transferred walleyes													
Inland Waterway													
1931-2	2367	1.4	...	...	...	...	...	...	...	...	...	...	1.4
Cheboygan River													
1942	154	1.9	0.6	0.6	...	...	...	...	0.6	...	...	...	3.9
Mullett Lake													
1942	87	1.1	1.1	3.4	2.3	1.1	...	...	...	...	...	...	9.2
Burt Lake													
1942	82	6.1	2.4	4.9	...	...	...	...	...	...	...	...	13.4
Crooked Lake													
1942	109	6.4	0.9	1.8	1.8	0.9	1.8	...	0.9	0.9	0.9	...	16.5
Black Lake													
1942	136	3.7	2.2	3.7	0.7	2.2	0.7	0.7	...	...	0.7	...	14.7
Total													
1942	568	3.7	1.4	2.6	0.9	0.9	0.5	0.2	0.4	0.2	0.4	...	11.1
Studies on native walleyes													
Black River													
1952-5	555	5.8	6.3	3.1	2.9	0.7	0.7	0.4	0.4	0.4	...	...	20.5
Black Lake													
1954-6	864	6.7	3.0	1.6	2.6	1.3	0.5	0.4	0.2	0.1	0.1	0.2	16.7
Burt Lake													
1948	300	6.7	7.3	1.3	1.0	0.3	...	...	1.0	...	...	0.3	18.0
Crooked Lake													
1952,4	365	10.4	5.8	4.1	3.3	0.6	2.2	0.8	0.6	...	0.8	...	28.5
Mullett Lake													
1954	249	5.2	3.6	3.2	2.4	1.2	...	0.4	...	...	...	0.4	16.5
Total													
1948-56	2333	6.9	4.8	2.5	2.5	0.9	0.7	0.4	0.4	0.1	0.1	0.1	19.4

[a] Data through 1957 from Crowe (1958). In 1931 and 1932, tags were applied to the operculum; jaw tags were used in all other years.

Table 6.--Locality of recapture of tagged native walleyes released at five localities in the Inland Waterway, 1948-1956 [a]

Locality of recapture	Locality and number released				
	Crooked Lake (365)	Burt Lake (300)	Mullett Lake (249)	Black River [b] (555)	Black Lake (864)
Crooked Lake	51	..	..	1	..
Pickerel Channel	1	..	..	..	..
Pickerel Lake	7	2	..	..	..
Crooked River	5	2	..	1	..
Burt Lake	35	36	4	6	..
Sturgeon River	2	11	1	2	..
Indian River	5	3	2	6	..
Mullett Lake	1	..	27	70	..
Cheboygan River	..	..	3	12	..
Lake Huron [c]	..	..	..	2	..
Black River (below Alverno Dam)	..	..	2	14	..
Black River (below Black Lake)	..	..	..	..	3
Black Lake	..	..	..	..	154
Black River (above Black Lake)	..	..	..	..	6
Mud Creek	..	..	..	..	2
Total recaptures	107	54	39	114	165

[a] Recaptures were made by anglers, nets, or other means. Recaptures by nets were not included unless fish had been at liberty for 6 months or longer.

[b] Below Alverno Dam.

[c] Including mouth of Cheboygan River.

Table 7.--Numbers of tagged walleyes released in northern Green Bay, 1957-1963, and percentage returned by sport and commercial fishermen

Release data: Year	Number	Year of recapture: 0 (Same)	1	2	3	4	5	6	7	8	Total
1957	770	6.3[a]	4.3	2.0	0.1	...	...	0.3	...	...	13.0
1958	917	5.5	3.4	2.5	0.2	0.1	0.1	...	...	...	11.8
1959	1981	6.2	3.3	0.6	0.2	...	...	...	...	0.1	10.4
1960	1022	3.1	3.3	0.7	0.2	0.1	...	...	...	...	7.4
1961	1814	1.6	0.9	0.8	0.3	0.1	0.1	...	0.1	...	3.8
1962	264	2.6	2.3	1.5	...	...	...	0.4	...	...	6.8
1963	147	3.4	0.7	...	0.7	...	...	...	...	...	4.8
All	6915	4.2	2.7	1.1	0.3	0.1	tr[b]	tr	tr	tr	8.4

[a] For the 1957 series of data on recapture: year 0 includes data for 1957 and 1958 because the walleyes were tagged after the fishing season (fall) rather than before (spring), as in other releases; data shown for year 1 were obtained in 1959, year 2 in 1960, etc.

[b] tr = less than 0.05%.

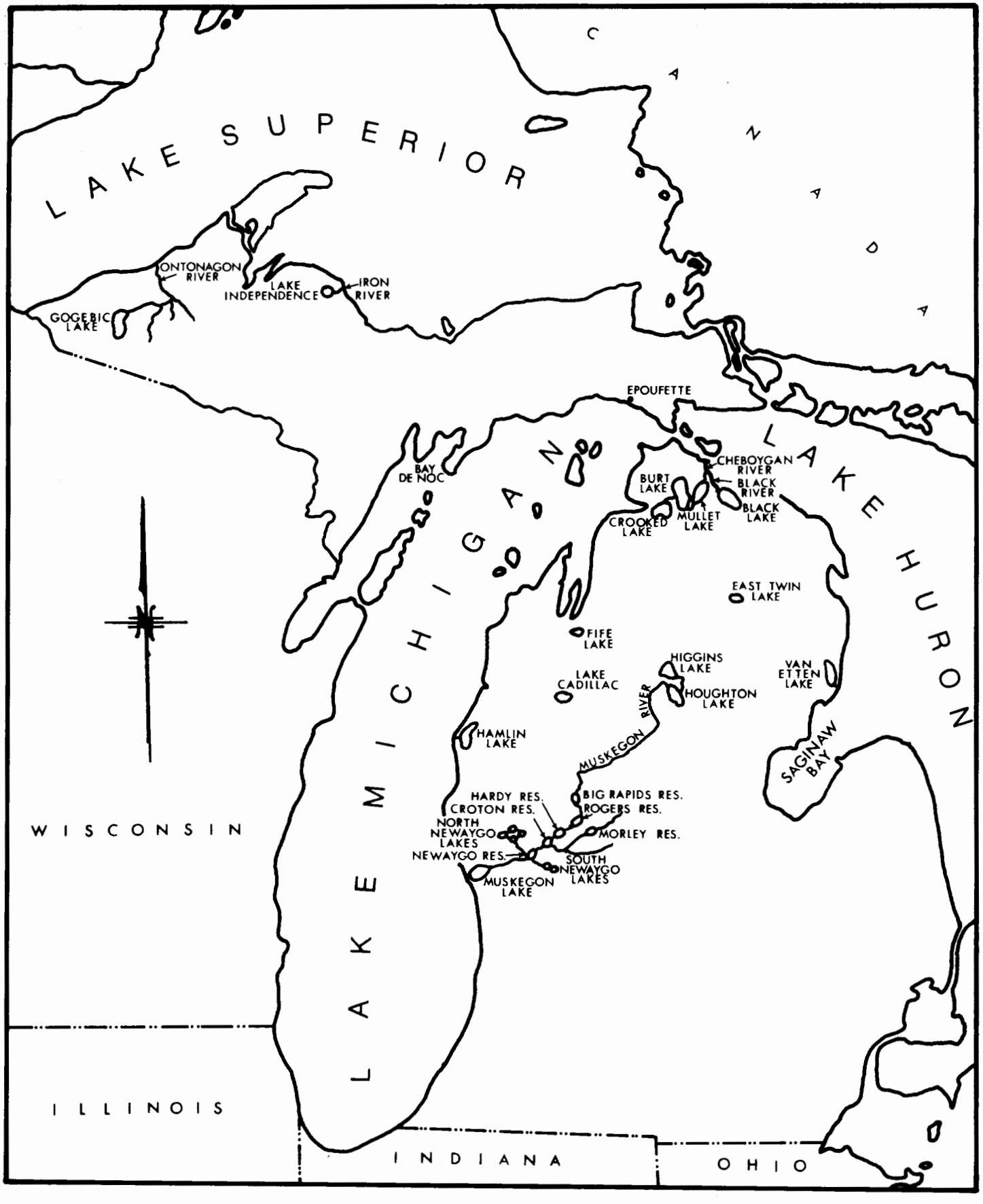

Figure 1.--Localities at which walleyes were tagged (revised from Eschmeyer and Crowe 1955).

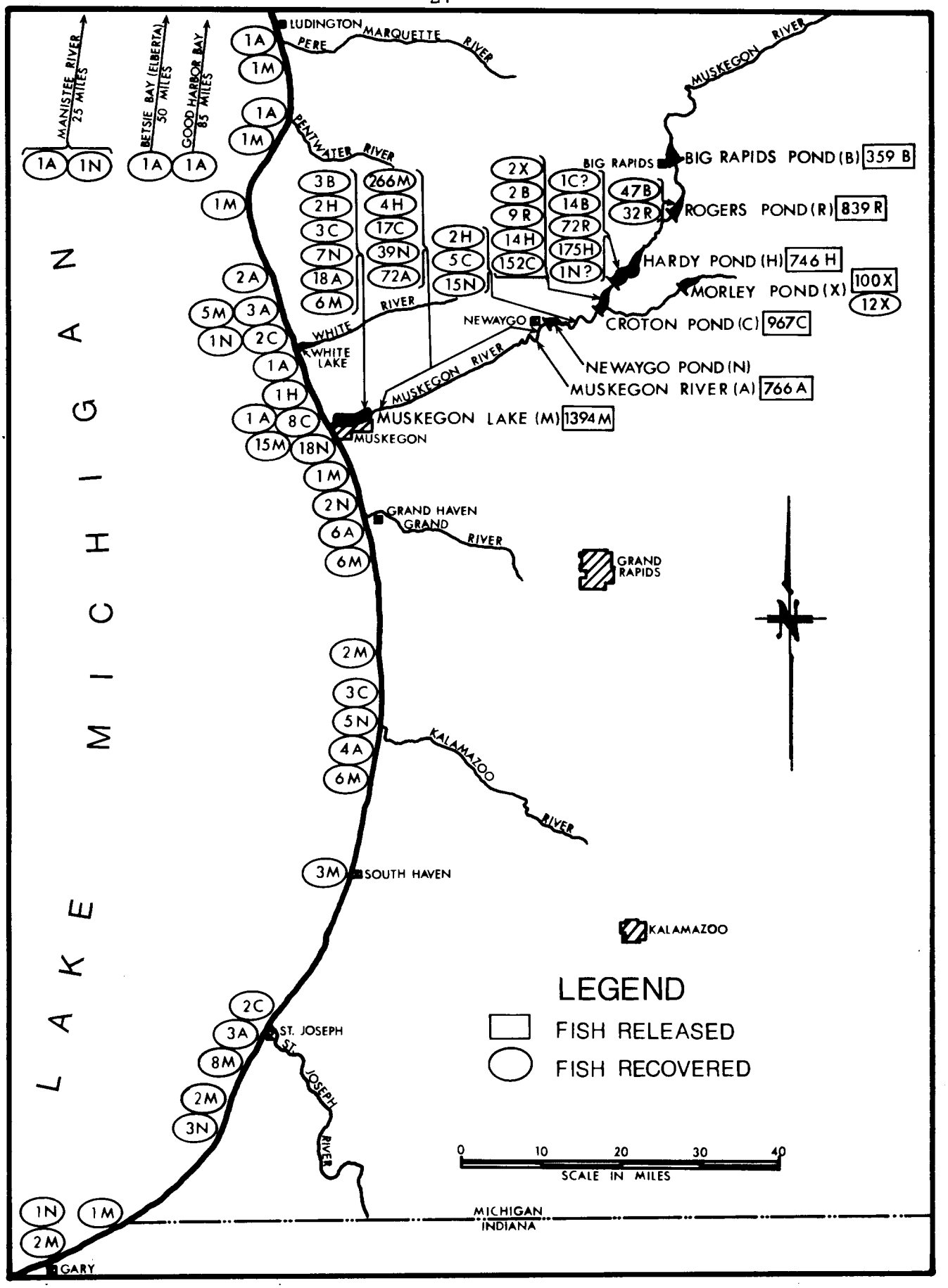

Figure 2.--Localities of release and of recovery of migrating tagged walleyes released in the Muskegon River and Muskegon Lake. Places of release are designated as follows: B--Big Rapids Pond; R--Rogers Pond; H--Hardy Pond; C--Croton Pond; X--Morley Pond; N--Newaygo Pond; A--Muskegon River below Newaygo Dam; and M--Muskegon Lake (revised from Eschmeyer and Crowe 1955).

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