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Mercer H. Patriarche

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LAKE MICHIGAN, 1978-1979¹✓

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Abstract

The Michigan Department of Natural Resources introduced the coho salmon (Oncorhynchus kisutch) into Lake Michigan in 1966 to create a sport fishery and control the overabundant alewife (Alosa pseudoharengus) population. Subsequent to that introduction, a spectacular sport fishery for salmonids has developed throughout the Great Lakes. Many problems associated with the Great Lakes salmon fishery have been solved but several unanswered questions remain relating to dispersal, natural reproduction, and hatchery diet.

To answer these questions, a concerted effort was made by the states of Indiana, Illinois, Michigan, and Wisconsin to fin clip all cohos (2.6 million fish) planted in 1978. Different fin-clip combinations were assigned to each agency. In addition, Michigan used a maxillary clip for a special diet study promulgated by that state. There were many sources for monitoring the capture of these marked fish but the principal ones were the creel censuses in each state.

The 1978 planting contributed 197,210 fish to the coho catches in Lake Michigan and its tributaries in 1978 and 1979, or 7.4% of the plant. The total coho catch in 1979 amounted to 212,850 fish, of which an estimated 9.3% were naturally spawned fish. An estimated 2,400 cohos (2.5% of the Michigan coho harvest in 1979) were furnished by plantings in other states to the Michigan catch whereas Michigan's contribution to the coho fisheries

¹✓ Contribution from Federal Aid in Fish Restoration Projects F-35-R-4 to R-6, Michigan.

in the other three jurisdictions ranged between 13 and 45 thousand fish or 50 to 75% of their catches. On the average, 3.0% of the Michigan-planted cohos were caught in their respective home areas in the two years.

Highlighting the data on movements was the pronounced concentration of fish that had been planted throughout Lake Michigan in the southern end of the lake in winter and spring. Also, cohos from Lake Erie invaded Lake Michigan in 1978, but apparently not in 1979.

There were no statistical differences in adult lengths and weights among fish raised either on the Oregon Moist Pellet or the cheaper PR-9 trout formulations. Returns to the fall creel were significantly higher for the PR-9 coho but, conversely, OMP cohos arrived at the Platte River weir in significantly greater numbers.

Introduction

The massive introduction of Pacific salmon into the Great Lakes in the mid-1960's triggered an unprecedented boom in sport fishing activity that has persisted to this day. In 1966, with the sea lamprey under control and an overabundant stock of alewives in Lake Michigan, the Michigan Department of Natural Resources introduced the coho salmon into the lake to create a sport fishery and control the alewife population.^{2/}

The first batch of eggs was generously donated by the Oregon Game and Fish Commission who took them from Columbia River coho at Bonneville Dam. They were spawned late in November 1964, the eggs were shipped to Michigan, and subsequently the fish were released in 1966 at three sites. In 1965, excellent cooperation also was received from the states of Washington and Alaska in addition to Oregon so that the 1967 plantings were derived from three sources. Chinook salmon also were introduced into Lake Michigan in 1967 for the first time, the source being the Toutle River in Washington.

The success of this stocking program was outstanding. The other states bordering Lake Michigan soon joined the program, and eventually it

^{2/} Common names of fishes used in this paper are from Special Publication No. 6 (3rd edition) of the American Fisheries Society (1970).

was extended to the other Great Lakes. Currently, nearly 3 million cohos are planted annually in Lake Michigan, together with massive plantings of chinook, lake trout, and steelhead. Many problems associated with the Great Lakes salmon fishery have been solved but several unanswered questions remain concerning salmon and their harvest such as what proportion of the plantings is taken by anglers in the various states, how much straying is done by returning adults and what is the contribution of natural reproduction to the fishery.

To answer some of these questions with respect to the coho salmon, a concerted effort was made by the states of Indiana, Illinois, Michigan, and Wisconsin to fin clip all cohos planted in Lake Michigan in 1978. Separate fin clips were assigned to each agency and subsequent harvests were monitored principally by creel censuses in 1978 and 1979. Other sources also were utilized to locate returning fish. The principal objectives were as follows:

1. Estimate the magnitude of naturally reproduced coho salmon in the Lake Michigan sport fishery.
2. Determine the contribution made by the coho plantings of each state to the respective harvests by anglers elsewhere.
3. Estimate the numbers caught and their proportions of the stocking rates at the various sites.

In addition, Michigan was particularly interested in the reduction of feeding costs. Hence, two lots of fish were raised on two different diets at the Platte River Hatchery and planted in the Platte River. Thus, a fourth major objective was to:

4. Determine if coho salmon raised on the less costly of two diets (PR-9) provided as good a return to the angler, both numerically and by weight, as cohos raised on the more expensive diet (OMP).

In an attempt to alleviate the ravaging effects of "cold-water disease," one-half of each of the diet lots also was fed a double vitamin dose.

Methods

Fin clipping

Each of the states was assigned different fin clip combinations (Table 1). Indiana, Illinois, and Wisconsin had one paired fin clip whereas Michigan had several to accommodate the various planting sites. A separate fin clip also was given to the University of Wisconsin for their experimental plants of imprinted cohos.

Indiana and Wisconsin used their personnel to clip fish whereas Illinois arranged with the proprietor of the private hatchery in Minnesota, where the fish were raised, to do the marking. Unfortunately, Illinois biologists discovered 2-3 months after planting that probably 30% of the salmon had not been fin clipped.

The Michigan fin clipping was done at the Platte River Hatchery between 10 November 1977 and 1 February 1978, by 20 women hired locally, under the guidance of hatchery biologists. The four lots of fish destined for the Platte River also had one-half of the maxillary bone removed. On the average, these women fin clipped fish at the rate of 521 per hour or 4,170 fish per day. However, when a maxillary-fin combination was involved, the mean hourly rate dropped to 292.

A total of 2,325,970 yearling cohos were fin clipped at the hatchery but mortality from cold-water disease was high and nearly 20% of the fish died before the spring plants were made. Part of this loss was restored by clipping additional fish. Cold-water disease is caused by a myxobacterium known as Cytophaga psychrophila. Seeking a way to alleviate this mortality which has been a problem before, two lots of fish assigned to the diet study were raised on food supplemented by twice the recommended Vitamin Premix packages used for each diet and two lots were fed the normal supplement in their rations.

Samples of fish were examined on two occasions for improper or missed fin clips. A total of 3,150 cohos were checked--776 on April 14 and 2,374 on April 28, 1978. These fish ranged in length between 3.3-7.0 inches (84-178 mm). Despite frequent monitoring of the clipping operation by

hatchery personnel, 3.4% of the fish bore improper clips and, overall, 1.5% were not marked. The 95% confidence limits for the latter ratio were 1.1-1.9%.

The number of coho salmon planted by each agency is shown in Table 1. All but the Indiana fish were released in the spring of 1978. Indiana planted their cohos at two sites the first week in November 1977. Michigan releases were made at 11 sites around the lake, Wisconsin used 9, and Illinois 5 (Fig. 1). Michigan's contribution to the total stocking amounted to 67.8%, with the largest single plant being in the Platte River.

Creel census

Indiana and Wisconsin conducted a complete creel census throughout the fishing season both in 1978 and 1979. Illinois operated a census in 1979 and attempted one in 1978, but funding problems arose in July and the latter had to be terminated. Having a considerably greater length of shoreline to cover, Michigan monitored its salmon fishery as follows:

1. Employed 8 creel census clerks for a 10-week period in the fall of 1978 and 7 clerks in 1979, mostly between the last week in August and the first week in November.
2. Used one clerk in the spring of 1979 to cover the early spring fishery in the southeast corner of the lake.
3. Obtained estimated catch data from a statewide mail census.
4. Utilized cooperators among the Michigan Salmon and Steelheaders' Association, Charter Boat Operator's Association, and other interested individuals largely to get information on the summer fishery.

The Michigan census clerks were assigned to planted streams plus nearby sites. Schedules for sites to be visited, counting times, work days, and hours of work (8-hour day) were drawn up in advance using a table of random numbers. However, all weekend days and Labor Day were included in the schedules. Altogether, there were 135 sites visited regularly by the interviewers each year.

Counts included boat trailers parked at access sites and, in some localities, cars parked in the vicinity of a stream access site. Fishing pressure on Lake Michigan near each port was estimated both from trailer counts and counts of out-going fishing boats at the river mouths during a one-half hour interval. During an interview, clerks were instructed to examine all salmonids for fin clips, lamprey wounds or scars, and measure most fish to the nearest 0.1 inch. No fish were weighed and occasionally scale samples were obtained from certain size groups of cohos.

Estimates of catch and fishing pressure were derived via a computer program written by R. D. Clark and J. R. Ryckman. The standard error of the estimate multiplied by two approximates the 95% confidence limit and this was used in the calculations. Critical to the estimates (which are computed separately for weekdays and weekend days plus holidays) was the estimated length of the fishing day and the number of days available for coho fishing each month. The latter particularly applied to the stream fishery. For this reason, clerks were asked to note the approximate date when the salmon first entered the streams. Estimated lengths of the fishing day ranged from 17 hours in September to 10 hours in November but varied with the type of fishing, as shown below:

Month	Type of fishing		
	Lake	Pier	Stream
August and September	6 AM- 8 PM	6 AM- 10 PM	6 AM- 11 PM
October	7 AM- 7 PM	6 AM- 8 PM	6 AM- 11 PM
November	8 AM- 6 PM	8 AM- 6 PM	8 AM- 6 PM

The daily schedule of working hours was governed by these constraints. Not included in the estimates of pressure and catch, then, was the all-night fishing activity that occurred below some of the dams, mostly in October.

Diet study

Two lots of cohos of nearly equal numbers were utilized for this study. One lot was raised on the Oregon Moist Pellet (OMP) formulation used on the West Coast while the other lot was raised on a cheaper trout diet (PR-9) developed at the federal fish hatchery in Spearfish, South Dakota. Furthermore, one-half of each lot received a double vitamin dosage each day. The four lots totaling 516,210 fish, with the clip combinations shown in Table 2, were planted in the Platte River.

The original intent was to use the pelvic fin clip to distinguish between the diets but the subsequent addition of the vitamin test plus an error in fin clipping led to reliance on the jaw clip to identify the "diet" returns. Assessment of the diet effect was based on size, survival, and catchability. Returns to the weirs as well as angler catches provided the sources of data.

Identification of precocious fish ("jacks")

The 1978 fall census was aimed primarily at the returning "jacks". A determination had to be made as to whether or not a small unmarked coho caught in the fall was, in fact, a naturally spawned fish by the 1976 brood or a small adult from the 1977 lake-wide planting of unmarked fish. This was resolved largely from the age-length data presented in Table 3. Cohos less than 16.0 inches long (406 mm) were deemed to be "jacks", as well as 55% of fish 16.0-17.9 inches long (406-455 mm). All larger fish were adults.

Results

Creel census

Estimates of the catch and fishing pressure on the Michigan side of Lake Michigan (and its tributaries) in 1978 and 1979 were computed from creel interviews done in the fall of 1978, spring and fall of 1979, and mail censuses in both years. The number of fishermen interviewed during each census period is shown in Table 4. Each site listing includes the fishing

done on Lake Michigan in that vicinity, tributaries, "river" lakes if present, and piers. The sites are grouped according to the territory covered by one interviewer. No clerk was available in 1979 for the Big Cedar River and this was covered intermittently by Department biologists. All fishing on the Big Sable River was done under permits issued at the Ludington State Park.

There were an estimated 578,830 fishing trips in the areas covered by the contact creel census in the fall of 1978. The following spring there were 15,690 fishing trips, followed by an estimated 314,650 in the fall of 1979. The number of fall trips was sharply reduced in 1979 from that of 1978. On the average, the mean length of a trip in 1979 was 4.4 hours, as opposed to 4.7 hours in 1978. Fishing trips in the spring averaged about 3.2 hours per trip. Table 5 contains a breakdown, by site, of the fishing pressure for coho salmon during the approximate time when the cohos were present in the fall of 1978 and 1979. Fishing pressure during the 1979 spring census is presented below:

	Trips	Hours
New Buffalo	3,970	11,240
St. Joseph	7,980	26,880
South Haven	3,740	11,390

Estimates of the coho salmon catches during the fall and spring, together with their 95% confidence limits, are presented in Table 6. These estimates cover the Michigan waters of Lake Michigan and the tributaries that were censused. It would appear that fewer coho were caught in the fall of 1979 than in 1978 (not unexpected in view of the smaller fishing pressure in 1979), but this might not be true since the confidence limits for the point estimates overlap. The limits for the 1978 estimate were 61,420-114,380 and for the 1979 fall estimate 53,640-78,840. Confidence limits for the total 1979 estimate were fairly good ($\pm 19.0\%$) but could be tightened

considerably if data for the Lyons site on the Grand River were omitted because of insufficient sampling. This site was added to the schedule late in October when it was discovered that a good fishery had developed there. Omitting the Lyons data, the estimated catch for the fall would be $58,250 \pm 10.6\%$. The $\pm 30\%$ limits for 1978 also could be materially improved if the Lake Michigan estimate at Frankfort was omitted due to inadequate sampling. The revised catch estimate would then be $76,840 \pm 21\%$. However, overlapping would not be entirely eliminated by these revisions. Included in the 1978 catch were an estimated 3,835 precocious jacks and, in 1979, 1,490 jacks plus an estimated 75 four-year-old cohos in the fall catch.

The spring and fall censuses cannot furnish total catch estimates for the year. These data must come from the mail census designed to estimate not only annual catch for Lake Michigan (Michigan waters) and its tributaries, but also the catch for other fisheries elsewhere in the state. This mail census indicated the estimated lake-wide catch of cohos in Lake Michigan and its tributaries in 1978 to be 737,760 fish (Jamsen 1979) and in 1979--524,160 fish (Jamsen, personal communication). These results are based on a sample of some 2% of the license holders. Not all respond. For example, in 1978 only 56% of the anglers in the poll returned their questionnaires. These estimates, however, appear to be considerably inflated. For example, the mail census estimate in 1978 for tributary streams of Lake Michigan was 170,480 cohos whereas the estimate from this contact census was 25,050, hence the former estimate was 6.8 times too large. In 1979, the estimated coho catch indicated by the mail census for the tributaries was 151,040, as compared to the 36,300 computed from the fall contact census--or 4.2 times as large. Therefore, on the average, the mail census estimates probably were 5.5 times too large. On this premise, catch estimates for 1978 and 1979 were adjusted to 134,140 and 95,300, respectively. Rybicki and Keller (1978) also determined the lake trout catch estimates from the mail census were on the order of five times too great in previous years.

Using another approach, in 1976 and 1977, a seasonal breakdown of the mail-census estimates was possible because of quarterly mailings

and responses in those years. Summer fishing accounted for 29.4% of the catch in Lake Michigan, on the average, as shown below:

	Percentage		
	1976	1977	Mean
Spring	14.1	14.7	14.4
Summer	24.1	34.7	29.4
Fall	61.8	50.6	56.2

The 1979 contact creel censuses in the spring and fall provided a catch estimate of 69,480 cohos for those periods (Table 6). If an estimated 28,020 cohos taken in the June-August quarter ($29.4\% \times 95,300$) are added to this 69,480, the best total estimated catch for 1979 becomes 97,500-- a difference of only 2,200 fish from the other adjusted mail-census estimate.

The estimated numbers of each state's plantings of coho in Lake Michigan that were caught lake-wide in 1979 are shown in Table 7. They ranged from 17,870 in Indiana to 90,130 in Michigan, with an overall total of 193,080. The proportion of this total catch taken in each state amounted to 9.3% for Indiana, 14.1% for Wisconsin, 30.0% for Illinois, and 46.7% for Michigan. In the fall of 1978 an estimated 4,130 jacks from the 1977 year class were caught. For each state, this amounted to the following:

Illinois	25
Indiana	80
Wisconsin	190
Michigan	3,835

The Illinois value was arbitrarily made 25. No creel census was taken but a tabulation of the Charter Boaters' catch plus that by members of Salmon Unlimited (Muench, Vidal, and Hess 1978) indicated 3,779 cohos were taken. In nearby Wisconsin waters, 0.003 percent of the catch was marked fish

from Illinois. Applying this percentage to the Illinois catch, it was estimated that 11 marked fish were caught and it was assumed all other Illinois anglers accounted for about the same number. Thus, from the plantings of the 1977 year class in 1978 (1977 in Indiana) an estimated total of 197,210 cohos of the 2.6+ million planted were taken in 1978 and 1979, or 7.4% of the plant. For each state's planting the proportion caught was 2.3% for Illinois, 3.2% for Wisconsin, 7.5% for Indiana, and 9.3% for Michigan.

One of the principal objectives of the study was to determine the contribution of natural reproduction to the fishery. The assumption was made at the outset that unmarked cohos of the 1977 year class caught would provide the basis for the estimate. However, allowance had to be made for the unmarked fish that were erroneously planted. The summary that appears in Table 8 delineates the procedure and shows the corrected estimate of the number of unmarked native coho caught in the fall of 1979 in Michigan waters. Among the cohos examined at all sites, 7.4% had no fin clip. However, 1.5% (range, 1.1-1.9%) were planted without a clip. Hence, 5.5-6.3% of the cohos caught in the fall of 1979 were native fish, the best single estimate being 3,230 fish or 5.9% of the catch of age-3 cohos. In the spring census, 8.0% (7.6-8.4%) of the catch was believed to have been native cohos, and unmarked cohos in the Michigan spring salmon tournaments amounted to 5.3% of the catch. Illinois biologists reported that 6% of their 1979 catch were unmarked. Indiana recorded 12% of their catch as being unclipped, while Wisconsin claimed that 21% of their 1979 catch were unmarked. In 1978, the adjusted catch estimate of unmarked precocious jacks was 10.8%. In Michigan waters, at least, it would be safe to say that more than 90% of the fishery depends on the hatchery product. Actually, native coho contributed 19,770 fish or 9.3% to the total catch of 212,850 cohos in Lake Michigan in 1979. This value allows for the 30% that were not marked among the Illinois plants and the 1.5% among the Michigan plants. By state, the native coho catch was 2,540--Indiana, 2,540--Illinois, 7,320--Wisconsin, and 7,370--Michigan.

Another question of interest to managers and anglers alike concerns the proportion of the various 1978 plantings that were caught in their "home" area. These data are presented in Table 9 for Michigan waters. On the

average, 3.0% of the Michigan planted cohos were caught in each of their "home" areas in the 2 years (1978 and 1979).

Estimated fall catches for other salmonids are shown in Tables 10 and 11. Chinook greatly outnumbered all species (including coho), with the largest total coming from the Muskegon area in both years. Substantial catches also were made in the St. Joe and Manistee areas. A large number of yearling chinooks appeared in the spring which caused some confusion in distinguishing between them and small cohos. Inasmuch as all coho jacks taken in the previous fall of 1978 (and subsequently in 1979) were at least 13.0 inches (330 mm) long, all salmon observed in the spring census less than that were considered to be chinooks. Adult chinooks in the fall averaged 33-34 inches long (838-864 mm); cohos 23-24 inches in length (584-610 mm).

Fishing success for cohos in 1979 in the Michigan waters of Lake Michigan, as measured by catch per hour, varied according to the type of fishing (pier, open water, below dam). According to the data presented in Table 12, anglers on the piers had the best coho fishing in 1979, especially at Muskegon and Frankfort, as opposed to those who fished elsewhere. Likewise, among the Lake Michigan boaters, those who fished off Ludington and in Platte Bay were most successful. Coho fishing success below dams was meager, and that includes Union Street dam in Traverse City and Homestead dam on the Betsie River. However, no cohos were planted in those two streams. Actually, Loon Lake on the Platte River was the best place for coho fishing in 1979. These anglers caught cohos at the rate of 0.27 fish per hour.

Returns of marked fish

Sources for recapture data in 1979 are listed in Table 13. Of the 41,172 fish recorded, 70% of them came from the Platte River weir where all returning cohos were examined. An additional 528 marked cohos were examined in 1978.

Returns in 1978 among the precocious jacks caught by anglers in the fall (Table 14) and at power plants and weirs (Table 15) suggested a few

roamed widely. Only one out-of-state coho was caught in Michigan waters and that was an Indiana fish taken in the St. Joe River, 50 miles from the nearest Indiana planting site, which was Trail Creek at Michigan City. In Indiana, four juvenile cohos were examined in the creel census of which three were probably Indiana plants. The other juvenile was a Michigan plant from the Grand-Muskegon river area. Three Michigan cohos from the St. Joe-Black river plantings were captured by Wisconsin anglers along with one jack from a Wisconsin plant. (Wisconsin biologists also reported that 125 unmarked jacks were caught by their anglers.) While no jacks were reported in the aborted Illinois census, their fall netting surveys turned up seven Illinois fish and one from the Michigan planting in the St. Joseph-South Haven area.

Data from other sources also indicated few out-of-state jacks were recovered in Michigan waters in 1978. One from Illinois appeared at Saugatuck, four Wisconsin fish appeared at the Consumers Power Company pump storage plant at Ludington, and one at Saugatuck. Eight Indiana fish were captured either at Michigan power plants, Saugatuck, or the Little Manistee River weir. Substantial numbers of fish were examined at the Michigan weirs in 1978 by employees of the Department of Natural Resources and, as expected, the great majority of the precocious jacks returned to their home stream. On the average, 33% of the jacks at the Little Manistee weir were unmarked and presumed to be native fish. The 95% confidence limits for this estimate were 24-42%. At the upper Platte weir, 20% of the jacks were unmarked (95% CL = 13-27%).

In the spring of 1979 (March-May) there was a pronounced concentration of cohos in the southern end of the lake. Fish planted throughout the lake were captured in the southeastern corner, as shown in Table 16 for Michigan catches examined by the interviewer. Certain adjustments were made to the recovery rates, however. Among the fin-clipped cohos, the census clerk observed 74 fish which bore only an LV or RV fin clip. These fin clips were not used by themselves but rather in combination with an adipose clip (Indiana and Wisconsin) or a maxillary clip (Platte River). Also, both ventrals (pelvics) were clipped on cohos planted at the two Upper

Peninsula sites--Thompson and Big Cedar River. When samples were examined at the Platte River Hatchery prior to planting, 1 of 83 fish destined for the Platte River bore only a ventral clip; hence 1 of the 74 in that spring catch was assigned to the Platte River total and the other 73 apportioned between Indiana and Wisconsin fish. Also, about 30% of the Illinois planting were not marked. Assuming these unmarked Illinois fish would be caught in the same proportion as the marked fish, two of the unmarked cohos were assigned to Illinois. To account for unmarked Michigan fish that were planted, the proportion of unmarked cohos in the catch (9.5%) was reduced by 1.5% so that the best estimate of naturally reproduced fish in the spring creel was 8.0%.

The percentages for the various plantings that appeared in the 1979 spring catch more closely reflect the size of the 1978 plantings than the planting location (Table 16). This was tested by computing the binomial variance for the percentages and establishing 95% confidence limits for the ratios. One might expect local and nearby plants to contribute the most fish to the catch (St. Joe, Black, and Grand rivers plus Indiana plants). On the contrary, the large plantings near Manistee, Platte River, and in Wisconsin waters provided the largest proportions, lending support to the suggestion there was a widespread movement to the south. In the other spring fisheries in Indiana, Illinois, and Wisconsin (Table 17), the distribution of marked cohos was strikingly similar to the Michigan results. Exceptions were Wisconsin fish which appeared in proportionately smaller numbers in Indiana waters and the large proportion of Manistee-area plants in all catches.

This significantly high proportion of adipose-clipped fish that appeared in all other state waters seems somewhat unusual. It is possible that the fin paired with the adipose in the other state plantings was either overlooked or regenerated, but if a fin were to be overlooked it would most likely be the adipose instead. A similar situation arose for the summer catches in which large numbers of adipose-clipped cohos from the Manistee area plants were caught everywhere in significantly greater proportions than were originally planted (Table 18), except Indiana where the summer fishery was very small.

By fall the majority of the coho were seeking their home stream (Table 19). In the Indiana catch, 95% of the fish were Indiana plants but a few were captured in Wisconsin and Michigan waters as late as November. Seventy-four percent of the Illinois fall catch of marked fish was comprised of Illinois plants but a number of their cohos were taken also by Wisconsin and Michigan anglers and at the Michigan weirs. However, Muench (1980) reported that, after September 22, 90% of the Illinois fish caught were Illinois plants. Twelve Wisconsin cohos were taken in Michigan waters and 2 in Illinois, although 31% of the fall Wisconsin marked catch was made up of Wisconsin fish. In the latter case, Michigan fish may have dominated the Wisconsin catch (55%) but, again, cohos with only an adipose fin missing (Manistee area plant?) comprised 43.4% of the Wisconsin catch.

Recaptures seen at the various planted areas in the fall Michigan salmon fishery are documented in Table 20. In most streams, over 90% of the angler's catch were cohos that had returned to their home streams, the exceptions being the Black (74%), Muskegon (57%), Manistee (83%), and Platte rivers (87%). No cohos were planted at Frankfort but 98% of the catch consisted of fish from the two planting sites that bracketed this area (Platte River and Manistee area). Also, no coho were planted at Ludington but a substantial planting was made 7 miles north of there in the Big Sable River, hence the dominance of the adipose-clipped fish in the Ludington area census. South of Ludington at the Consumers Power Company pump storage plant, records compiled by Michigan State University biologists showed that 61.4% of the 114 cohos captured either in that area of Lake Michigan or in the storage lake on top of the sand dune were from Manistee area plants; 17.5% from Muskegon-Grand planting; and 14.9% from the Platte River. Cohos from two other plantings--Brewery Creek and Thompson Creek--also were taken in their nets.

Additional evidence of a strong homing tendency was provided by upstream returns at the weirs and dams (Table 21). Unlike the creel census data that were presented in Table 20, which included captures in Lake Michigan near the stream mouths, all of these cohos had migrated upstream several miles (except at Thompson). Over 96% of these fish had returned to their planted stream.

The data in Table 20 also provide information on the magnitude of fall straying. As already noted, movement by the Manistee area plant seems to have been widespread. On the other hand, plantings made at Brewery Creek in Grand Traverse Bay and the two Upper Peninsula plants were less inclined to wander. Although not many Brewery Creek cohos were taken by anglers, a late run occurred after mid-November and all fish examined at the blocking weir by the local biologist had been planted previously in that stream.

As a result of the wanderings by coho salmon, each state contributed to the other's fishery. The contribution of all other state plantings to the Michigan spring and fall fishery was an estimated 2.5% of the catch or 2,400 fish. On the other hand, Michigan's contribution to the Illinois, Indiana, and Wisconsin catches was estimated to be 45,620, 13,120, and 17,430 fish, respectively (Table 7) or 50-75% of their catches (Table 22). The latter percentages assumed that all adipose-clipped fish caught originated from the Manistee-area plants.

Diet study

The 516,210 cohos released in the Platte River were planted in nearly equal proportions (Table 2), despite the ravaging effects of cold-water disease. The attempt to alleviate this mortality by double vitamin dosages was not successful, as shown by the results below:

<u>Vitamin treatment</u>	<u>Percent mortality</u>
Double	11.9
Double	26.3
Normal	14.4
Normal	19.5

The mortality period was approximately 5 months between clipping and plant-out. On the average, 19.1% of the cohos fed the double dosage died; 17.0% of the "normals". This massive mortality prevented a planned assessment of mortality due to stress from the various combinations of clips.

Apparently this higher mortality continued after the fish were planted because relatively few of the lot raised on PR-9 plus the double vitamin package were caught, as shown below:

Treatment	Percentage of Platte River plantings in angler catches		
	Spring census	Platte River	Frankfort
OMP + regular	24.2	21.9	24.5
OMP + double dose	51.6	35.8	22.6
PR-9 + regular	15.4	34.3	49.1
PR-9 + double	8.8	8.0	3.8

Likewise, the proportion of this lot among the 25,775 returning to the hatchery weir was much smaller (2.0%) than the others (5.9%, 7.5%, and 5.1%). Consequently, in order not to prejudice the survival analysis, data for the two lots raised on the double vitamin supplement in their diet were omitted from those calculations.

There were virtually no differences in either length or weight among the surviving adults taken at the upper Platte weir in the fall of 1979 (Table 23). Overall mean weight for OMP fish was 4.40 pounds (2.0 kg) vs. 4.36 pounds (1.98 kg) for PR-9 fish. Likewise, there were only minor differences between sexes. Furthermore, the mean lengths of cohos captured by anglers was very close (no fish were weighed). An analysis of variance showed no significant difference among these angler-caught fish ($F = 0.72$). Ignoring the vitamin supplements, cohos raised on PR-9 averaged 23.7 inches (602 mm) when caught whereas OMP-fed cohos averaged 23.5 inches (595 mm).

In the fall of 1978, there also were no differences of consequence among the 238 precocious jacks that returned to the weir. Fish raised on each diet averaged 14.9 inches (365 mm) in length. The mean weight of OMP cohos was 1.15 pounds (522 g); for the PR-9 cohos--1.19 pounds

(540 g). Thus, with respect to growth, the dry diet (PR-9) was just as effective as the more expensive OMP diet.

Catchability and survival were tested by chi-square. A sample of 223 cohos caught in the Platte River and Lake Michigan in the vicinity of the river were used for the test on the number of fish caught from the two lots in question (Table 24). The expected numbers were based on the proportions planted in 1978. A much higher proportion of PR-9 fish were caught than one would expect. A similar test of 36 Platte River cohos taken in the spring of 1979 between South Haven and New Buffalo, however, did not show any real differences in catchability between the two lots.

On the other hand, a significantly greater number of OMP cohos appeared at the weir, according to the chi-square test applied to 340 returnees. One could conclude from this that OMP fish seemed to have the advantage of a higher survival rate (or a greater homing instinct) whereas PR-9 cohos were more catchable than the others. It appears that the cheaper diet (PR-9) could readily be adopted for Michigan cohos, in view of the similarities in growth and a higher (or at least equal) catchability than that of the OMP fish. With a price differential of \$0.12 per pound in 1979, annual savings in rearing costs would be substantial.

Previous, but inconclusive, testing of these two diets by both Michigan and Wisconsin provided somewhat different results than those reported here. In 1973, two lots of fish were planted in the Little Manistee River and returning adults at the weir on that stream were examined for growth and numerical differences. There was no creel census. In an unpublished memorandum in 1975, Rybicki reported also that OMP cohos returned to the weir in greater numbers than PR-9 cohos, but that PR-9 fish showed significantly greater growth--as opposed to no difference in this 1979 study. PR-9 fish averaged 6.4 pounds (2.9 kg), as compared to 5.6 pounds (2.5 kg) for OMP cohos. Two strains of fish were used, however, and planting times were a month apart. Daly reported to the Lake Michigan Committee of the Great Lakes Fishery Commission in 1970 and 1971 that cohos raised on the OMP diet in Wisconsin grew faster and had better returns

to the parent stream than did those raised on the PR-9 diet. However, there was no difference in numbers caught by anglers.

Discussion

Despite the strong homing tendency shown by most cohos in the fall of 1979, straying and widespread movement of coho salmon in the Great Lakes have been reported periodically since the species was first introduced into Lake Michigan in 1966. Reports of the Lake Michigan Committee to the Great Lakes Fishery Commission in 1967-1970 contained references to catches in Illinois and Indiana waters before those states commenced their plantings. Borgeson (1970), Taube (1971), Parsons (1973), and Rybicki (1973) alluded to the straying propensity of the coho, and Peck (1970) described the extensive straying of coho into Lake Superior tributaries. Also, in the 1970 Michigan report edited by Borgeson, it was reported that in 1967, three coho salmon were observed in Lake Huron (Saginaw Bay and Georgian Bay), two in Lake St. Clair, and two in Lake Erie. However, no quantitative estimates of these movements were possible, although Borgeson suggested that perhaps as many as 10,000 cohos had strayed into unplanted tributaries of Lake Michigan in 1967.

Fin-clipped salmon periodically have been stocked for one reason or another since 1968, but at no time were all cohos fin clipped in one year by all states bordering Lake Michigan. Wisconsin has fin clipped at least a portion of their plantings each year since 1969, Illinois marked all cohos planted in 1969 and 1973. Michigan fin clipped portions of the 1969 fish planted in Whitefish River, Brewery Creek, and Thompson Creek. The proportion of returns of these Michigan-marked fish among fish observed in subsequent years approximated the percentage originally marked, indicating a tendency for homing to the planting site.

Pfender and Poff (unpublished MS) reviewed the success of 13 discrete Wisconsin stocking efforts done between 1969-1976. They concluded that coho moved mostly south of the stocking location, with a tendency for returning fish stocked in the southern portion of the lake to be caught early

in the season whereas those stocked in the northern portion of the lake were caught later in the fall. Sixty-two percent of the Wisconsin fall returns in the north occurred predominantly in the grid where stocked.

Quite unexpectedly, a large contingent of adult cohos from Lake Erie invaded Lake Michigan in 1978. At least 118 marked adults either were taken by anglers in Michigan waters or seen at the weirs and examined for fin clips. Fourteen were known to be captured by Wisconsin anglers, five of which were from Ohio plantings and nine from New York. Among the Michigan recoveries, 85 had been planted in Ohio waters (Chagrin and Huron rivers) and 33 had been stocked by New York in the eastern end of the lake. Another 44 adults bore assorted marks not attributable to any earlier planting and were presumed to be erroneously identified. Most of the latter were purported to be maxillary clips.

The Ohio fish came from two plantings totalling 377,460 cohos planted in November 1976, and bore either a right pectoral fin clip (Huron River) or left pectoral clip (Chagrin River). New York planted 50,000 fingerlings with an adipose clip in the fall of 1976 (plus 340,000 without a clip). The following spring New York added 49,800 cohos from the same brood plus 99,500 without a fin clip. Some of these marked fish were captured in trap nets set by Michigan biologists near Belle Isle in the Detroit River in the fall of 1978. Two marked cohos from Lake Michigan also were caught at Belle Isle both in 1978 and in 1979.

Inasmuch as the only marked cohos planted in the Great Lakes in the fall of 1976 or spring of 1977 were those in Lake Erie, there was no question but that a sizable number found their way into Lake Michigan in 1978. Two percent of the 1978 Michigan coho catch in Lake Michigan originated in Lake Erie waters, as well as 2% of the cohos caught in the 1978 spring tournaments and 3% of the adults handled at the weirs.

Having discovered this situation in 1978, it was feared that the 1979 returns in Lake Michigan would be complicated because Ohio also planted 285,000 yearlings in the fall of 1977 with the same pectoral fin clip used on the Grand and St. Joseph rivers. Furthermore, New York stocked 50,000 adipose-clipped cohos in the fall of 1977, 51,000 with a right pelvic

clip in the spring of 1978, plus 93,000 unmarked cohos. Fortunately, and inexplicably, there was no intrusion of Lake Erie cohos in 1979. Evidence for this comes from the lack of returns at the two permanent Michigan weirs. Whereas 81 marked adults with the pectoral and adipose Lake Erie fin clips appeared in 1978, only 3 adult cohos with a right pectoral fin clip arrived at the Little Manistee weir in 1979, and one with a left pectoral fin clip at the Platte weir. These were presumed to be Lake Michigan cohos.

Recognizing that this interlake movement could be a two-way affair, Lake Erie biologists were asked to be on the lookout for Lake Michigan cohos in 1979. There was no evidence that this occurred, judging by the responses to an inquiry made at the end of the year.

The mean total lengths at capture in October for cohos bearing the various Michigan marking combinations are shown in Table 25, together with the mean length of unmarked (native) cohos. The greatest discrepancy between unmarked and marked fish occurred with the double pelvic clip assigned to fish planted in northern Lake Michigan (Thompson Creek and Big Cedar River). A 't' test using a pooled estimate of the variance indicated no significant difference between these lengths. It appears that growth was affected by neither the fin clips nor the maxillary clips.

There was a significant decline ($r = 0.95$) in coho growth between 1967 and 1979, as shown in Figure 2, wherein the mean lengths and weights of cohos were plotted for those measured at the Platte River weir in autumn. The regression equations are:

$$\text{Total length (inches)} = 59.50 - 0.45 (\text{year})$$

$$\text{Total weight (pounds)} = 37.65 - 0.42 (\text{year})$$

During the two years of this project alone, the mean lengths and weights of coho salmon taken in Michigan weirs dropped 2 inches (50 mm) and 1.4 pounds (0.6 kg), with a similar decline in fish caught by anglers. By 1979, also, female Lake Michigan coho in the fall were smaller, on the average, than their counterparts in tributaries of the Pacific Ocean. The mean length of Platte River cohos was 22.9 inches (582 mm) whereas published data from

eight populations in California, Oregon, Washington, British Columbia, and Alaska reveal a range in length of 24.8 inches (630 mm) to 29.4 inches (746 mm).

This decline apparently was reversed in 1980. Numerous accounts of salmon caught in 1980 indicate cohos ranging from 7-10 pounds were taken in large numbers. Also, data from the spring tournaments revealed the cohos were larger than in recent years.

Coho growth in Lake Michigan appears to be closely attuned to the abundance of alewives. The steady decline in growth prior to 1980 suggests that the forage base (chiefly alewives) was being eroded away, not only by cohos but other salmonids as well. An initial reduction in growth following the first plantings in 1966 was to be expected since forage was plentiful and predators were few. Brown (1972) described the relative abundance of alewives between 1960-1970, but predicted a rise in their abundance into the early 1970's, following the massive die-off in 1967. Hatch (1979) calculated annual biomass estimates (minimal because they relate only to fish available to bottom trawls) for 1973-1979. If plotted, the estimates would produce a concave curve that sinks to a low for 1976-1977 of 51,800-56,500 metric tons, then rises abruptly to the 91,000 metric tons computed for 1978 and 1979, but still somewhat short of the 118,000-123,000 metric tons estimated for 1973-1975. Alewives again were abundant in 1980, and the coho growth rate has apparently improved significantly.

Acknowledgments

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Table 1. --Numbers of coho salmon planted in 1978 at various sites on Lake Michigan, together with their assigned fin clips and proportions of the total planting.

Site	Number	Percent of total	Percent of Michigan total	Marks
Indiana ^a	104,850	3.9	---	Right pelvic-adipose
Illinois	252,380	9.5	---	Left pectoral-adipose
Wisconsin ^b	499,300	18.8	---	Left pelvic-adipose
Michigan	1,801,960	67.8	---	
St. Joseph River	192,590	9.1	13.5	Left pectoral
Black River	50,280			
Grand River	112,200	8.2	12.1	Right pectoral
Muskegon River	106,620			
Big Sable River	200,650	22.7	33.5	Adipose
Little Manistee River	302,980			
Portage Lake	100,600			
Platte River	516,200	19.4	28.7	Pelvics and maxillaries
Brewery Creek	81,000	3.2	4.5	Right pectoral-adipose
Thompson Creek	92,560	5.2	7.7	Both pelvics
Big Cedar River	46,280			
Total planting	2,658,490			

^a Planted November 1-4, 1977.

^b Included are plantings of 30,000 cohos for a University of Wisconsin imprinting study. One-third of these were dosed with morphaline and bore an additional left maxillary clip; the other 20,000 were imprinted with rose oil and bore an additional right maxillary clip.

Table 2. --Mean length, number, and clip for four lots of coho salmon planted in the Platte River, 1978.

Diet and vitamin dosage	Marking combination ^a	Number planted	Percent of plant	Mean length	
				milli- meters	inches
OMP + regular	RVLM	129,850	25.1	127	5.0
OMP + double	LVLM	118,400	22.9	132	5.2
PR-9 + regular	LVRM	132,270	25.7	140	5.5
PR-9 + double	RVRM	135,690	26.3	135	5.3

^a V = pelvic fin; M = maxillary; R and L = right and left, respectively.

Table 3.--Age-length distribution of Lake Michigan coho salmon in the fall, 1978 and 1979.

<u>Size group</u>		<u>Year of life</u>	
<u>millimeters</u>	<u>inches</u>	<u>2</u>	<u>3</u>
330-405	13-15	17	0
406-430	16	4	3
431-455	17	1	1
456-506	18-19	0	8
> 506	>20	0	all

Table 4. --Number of fishermen interviewed at various Michigan sites by creel census clerks in 1978 and 1979.

Site	1978	1979
<u>Fall</u>		
St. Joseph area	890	1,513
South Haven area	555	857
Grand River	1,226	1,709
Muskegon area	1,245	1,114
White Lake	76	156
Ludington area ^a ✓	203	483
Manistee area	650	686
Portage Lake	52	55
Frankfort	125	505
Platte River	703	881
Grand Traverse Bay	1,782	935
Manistique	161	152
Thompson	502	514
Big Cedar River	148	279
Menominee	26	--
Totals	8,394	9,839
<u>Spring</u>		
South Haven	--	381
St. Joseph	--	762
New Buffalo	--	470
Totals		1,613

^a ✓ In addition to fishing activity at Ludington and Scottville, a permit salmon fishery was operated September 15-October 31 at Ludington State Park on the Big Sable River. See Table 5 for number of anglers.

Table 5.--Estimated fishing pressure (number of trips and hours) during the approximate dates when coho salmon were present in the fall of 1978 and 1979. All values rounded to the nearest 10 hours.

Site	1978		1979	
	Trips	Hours	Trips	Hours
Lake Michigan (St. Joseph)	8,530	51,370	10,130	64,590
St. Joe piers	7,330	29,900	14,970	48,510
St. Joe River	6,000	39,090	7,130	44,090
Berrien Springs area	42,910	221,850	27,090	154,310
Lake Michigan (South Haven)	9,990	48,100	3,990	24,980
South Haven piers	7,170	24,260	6,840	23,480
Black River	7,480	25,400	6,610	27,450
Lake Michigan (Grand Haven)	27,980	159,790	11,500	57,990
Grand Haven piers	6,370	19,100	13,290	39,240
Grand River (6th Street dam)	13,640	39,520	15,050	47,940
Grand River (Grand Rapids-Lyons)	2,240	9,410	4,740	15,730
Rogue River	1,720	5,740	870	4,240
Flat River	1,300	2,890	1,420	4,420
Lake Michigan (Muskegon)	92,730	500,290	9,710	47,370
Muskegon piers	1,720	4,450	2,640	7,430
Muskegon Lake	19,710	87,740	18,480	79,350
Muskegon River	28,530	112,050	16,530	67,490
Croton Dam area	24,250	89,660	4,780	23,000
White Lake	6,740	55,990	8,080	32,570
Big Sable River	17,580	36,780	16,570	33,140
Lake Michigan (Ludington)	16,100	95,460	4,530	26,240
Ludington piers	2,400	7,280	1,550	5,120
Pere Marquette River and Lake	17,040	76,930	8,830	40,980
Lake Michigan (Manistee)	28,190	153,620	8,690	49,850
Manistee piers	4,930	22,340	2,660	11,300
Manistee Lake	28,640	169,430	14,340	75,780
Manistee River	8,530	22,190	5,440	31,500
Tippy Dam area	14,900	61,590	5,640	30,060
Lake Michigan (Portage Lake)	2,170	10,920	310	1,660
Portage Lake and piers	1,600	7,350	1,620	8,320
Lake Michigan (Frankfort)	23,600	142,380	5,590	28,470
Frankfort piers	9,960	40,900	8,920	34,930
Betsie River and Lake	3,970	19,370	2,120	11,800

(continued, next page)

Table 5. --continued.

Site	1978		1979	
	Trips	Hours	Trips	Hours
Lake Michigan (Platte)	13,340	77,250	9,110	47,490
Platte River (including lakes)	8,900	34,100	4,490	24,990
Grand Traverse Bay	31,560	111,320	14,850	49,560
Boardman River (mouth to dam)	16,460	47,780	7,510	30,140
Lake Michigan (Thompson)	6,150	24,370	2,960	12,550
Manistique River	3,880	11,810	1,570	5,470
Big Cedar River	1,200	3,010	3,500	10,090
Menominee River	1,390	4,800		
Totals	578,830	2,707,580	314,650	1,383,620

Table 6. --Catch estimates of coho salmon taken in Michigan waters of Lake Michigan and tributaries, plus their associated 95% confidence limits in the fall of 1978 and 1979, and spring of 1979. Values rounded to the nearest 10 fish.

Area ^a ✓	1978		1979		1979	
	Fall		Fall		Spring	
	Number	95% confi- dence limits	Number	95% confi- dence limits	Number	95% confi- dence limits
St. Joseph	4,760	4,810	15,800	4,280	960	580
South Haven	2,230	2,110	1,260	700	700	730
New Buffalo	--	--	--	--	1,580	1,030
Grand River	11,870	4,740	14,020	10,970	--	--
Muskegon	17,930	11,500	2,360	1,370	--	--
White Lake	1,250	980	790	890	--	--
Big Sable River	3,070	--	7,950	--	--	--
Ludington	6,490	5,240	3,240	1,460	--	--
Manistee	7,670	4,480	2,390	1,240	--	--
Portage Lake	270	490	200	720	--	--
Frankfort	14,520	20,920	5,550	2,170	--	--
Platte River	12,670	5,460	9,690	2,670	--	--
Grand Traverse Bay	1,740	1,050	880	690	--	--
Manistique	180	230	20	30	--	--
Thompson	2,630	1,410	1,920	670	--	--
Big Cedar River	620	410	170	150	--	--
Totals	87,900	26,480	66,240	12,600	3,240	1,390

^a ✓ Includes Lake Michigan and tributaries.

Table 7. --Contribution of each state's plantings of the 1977 year class^a to the Lake Michigan catch in 1979.

Planting source	Estimated number caught				Totals
	Indiana	Illinois	Wisconsin	Michigan	
Indiana	2,240	2,110	2,590	790	7,730
Illinois	500	4,470	760	110	5,840
Wisconsin	2,010	5,680	6,420	1,500	15,610
Michigan	13,120	45,620	17,430	87,730	163,900
St. Joe-Black rivers	1,070	3,930	1,280	20,050	26,330
Grand-Muskegon rivers	1,130	4,230	1,790	15,460	22,610
Manistee area	7,160	25,250	10,910	28,930	72,250
Platte River	2,610	8,220	1,900	19,950	32,680
Brewery Creek	730	2,360	930	1,100	5,120
Thompson-Big Cedar R.	420	1,630	620	2,240	4,910
Totals (four states)	17,870	57,880	27,200	90,130	193,080

^a From the 1976 brood stock.

Table 8.--Estimated number of unmarked cohos (1977 year class) caught in the Michigan fall fishery in and around Lake Michigan in 1979. Estimates rounded to the nearest 5 fish.

Area	Num- ber ob- served ^a	Per- cent in creel	Per- cent un- marked planters	Ad- justed per- cent in creel	±95% confi- dence limits	1977 year class		Range of estimates
						Esti- mated total catch	Number of native cohos	
All sites	128	7.4	1.5	5.9	1.1-1.9	54,725	3,230	3,010-3,445
St. Joseph	17	6.3	1.9	4.4	0.1-3.7	14,920	655	390- 925
South Haven	2	5.0	1.9	3.1	0.1-3.7	1,230	40	15- 60
Grand River	26	12.6	1.9	10.7	0.8-3.0	13,210	1,415	1,270-1,560
Muskegon- White Lake	8	19.0	1.9	17.1	0.8-3.0	2,475	425	400- 450
Ludington	8	9.2	1.4 ^b	7.8	0.6-2.2	2,920	230	205- 250
Manistee	3	6.0	1.4	4.6	0.6-2.2	2,165	100	80- 115
Frankfort	13	12.3	0.9 ^c	11.2	0.4-1.6	5,455	610	585- 650
Platte River	30	6.0	0.9	5.1	0.4-1.6	9,625	490	425- 540
Thompson	19	8.9	0.9	8.0	1.9-1.9	1,475	120	---
Big Cedar River	2	25.0	0.9	24.1	1.9-1.9	170	40	---
Grand Traverse Bay	0	--	--	--	---	880	--	---
Portage Lake	0	--	--	--	---	200	--	---

^a Adult cohos of the 1977 year (1976 brood).

^b Only cohos planted near Ludington were in the Big Sable River with Ad clip.

^c No cohos planted at Frankfort. Data from nearby Platte River planting.

Table 9. --Proportion of the 1978 Michigan coho plantings captured by anglers in the vicinity of the planting site in 1978 and 1979.

Site	Number planted	Estimated catch	Percent
St. Joseph-South Haven	242,870	15,120 ^a	6.2
Grand-Muskegon rivers	218,820	12,800 ^b	5.8
Manistee area	604,230	12,890 ^c	2.1
Platte River	516,200	8,060	1.6
Brewery Creek	81,000	790	1.0
Thompson-Big Cedar River	138,840	1,500	1.1
Average			3.0

^a Includes spring catch at New Buffalo.

^b Includes White Lake.

^c Includes Big Sable River and Ludington area.

Table 10.--Estimated numbers of salmonids other than coho salmon taken during the fall creel census of 1978 in Michigan waters of Lake Michigan and tributaries with 95% confidence limits in parentheses. All values rounded to the nearest 10 fish.^a✓

Location	Chinook salmon	Steel-head	Lake trout	Brown trout
St. Joseph	33,340 (21,480)	7,410 (6,400)	2,360 (1,420)	1,940 (4,080)
South Haven	4,220 (1,815)	2,470 (1,290)	5,070 (2,350)	360 (290)
Grand River	23,620 (10,340)	2,160 (1,380)	2,450 (2,750)	540 (840)
Muskegon	139,830 (51,740)	14,030 (5,670)	3,980 (3,680)	1,220 (940)
White Lake	5,450 (2,800)	2,550 (2,950)	880 (1,300)	
Big Sable River	11,780			
Ludington	14,730 (11,300)	460 (340)	370 (630)	20 (30)
Manistee	55,850 (22,350)	2,140 (2,960)	570 (1,180)	170 (330)
Portage Lake	490 (510)	120 (140)		
Frankfort	17,400 (15,760)	5,120 (3,990)	560 (730)	30 (60)
Platte River	4,320 (2,850)	3,610 (980)	170 (160)	260 (190)
Grand Traverse Bay	6,350 (3,140)	3,690 (1,800)	7,150 (10,010)	10
Manistique	610 (350)	480 (260)	390 (850)	20 (30)
Thompson	60 (90)	400 (300)		
Big Cedar River	760 (560)	20 (40)		
Menominee	270 (430)	300 (420)		10
Totals	319,480 (64,430)	45,270 (10,710)	23,950 (10,960)	4,600 (4,290)

^a✓ Not shown are 2 Atlantic salmon, 1 pink salmon, 1 brook trout, 1 round whitefish, and 1 lake whitefish observed in the catches.

Table 11. --Estimated numbers of salmonids other than coho salmon taken during the fall creel census of 1979 in Michigan waters of Lake Michigan and tributaries with 95% confidence limits in parentheses. All values rounded to the nearest 10 fish. ^{a/}

Location	Chinook salmon	Steel-head	Lake trout	Brown trout
St. Joseph	23,310 (5,300)	2,770 (1,290)	4,910 (1,920)	280 (220)
South Haven	3,170 (1,250)	1,090 (550)	3,610 (2,270)	110 (150)
Grand River	18,870 (3,680)	1,700 (860)	1,150 (560)	580 (510)
Muskegon	36,380 (10,550)	840 (710)	220 (190)	720 (920)
White Lake	5,440 (4,310)	180 (400)	150 (300)	
Big Sable River	12,530			
Ludington	15,660 (6,660)	20 (30)		
Manistee	23,870 (8,310)	2,460 (3,090)	90 (160)	
Portage Lake	140 (170)			
Frankfort	5,460 (3,200)	1,200 (1,070)	560 (550)	790 (1,000)
Platte River	2,180 (930)	1,320 (730)	5 (10)	150 (150)
Grand Traverse Bay	2,800 (1,760)	680 (400)	420 (180)	
Manistique	660 (350)	230 (210)	5 (10)	
Thompson	30 (40)	920 (500)		20 (50)
Big Cedar River	460 (330)	30 (60)		30 (60)
Totals	150,960 (17,350)	13,440 (3,880)	11,120 (3,100)	2,680 (1,490)

^{a/} Not shown are 3 brook trout, 4 pink salmon, 5 lake whitefish, and 151 menominees observed in the catches.

Table 12. --Catch-per-hour values for the 1979 coho fishery at three types of fishing areas on Michigan waters of Lake Michigan.

Location	Fishing areas		
	Pier	Lake Michigan	Below dam
St. Joseph	0.050	0.008	0.080
South Haven	0.050	0.006	0.000
Grand River	0.080	0.010	0.060
Muskegon	0.130	0.020	0.000
Ludington	0.110	0.098	--
Manistee	0.030	0.030	0.010
Frankfort	0.130	0.030	--
Platte River	--	0.097	--
Mean	0.083	0.037	0.030

Table 13.--Numbers of marked coho reported by various sources in 1979.

Source	Number
Creel censuses	
Michigan	2,541
Wisconsin	1,441
Illinois	1,593
Indiana	1,473
Weirs	
Platte River	28,975
Thompson Creek	309
Little Manistee River	662
Berrien Springs (St. Joe River)	1,889
Power plants	
Ludington Pump Storage	134
Cook	74
Campbell	9
Miscellaneous	
Volunteer Boaters' Census	933
Netting surveys ^a	29
Egg buyers	258
Individuals	14
Tournaments (Michigan and Wisconsin)	838
Total	41,172

^a Michigan Department of Natural Resources and U.S. Fish and Wildlife Service.

Table 14. --Number of marked coho jacks recovered in the fall at Michigan creel census sites on Lake Michigan in 1978. ^a Underlined numbers indicate those that returned to their home stream.

Planting site	Recovery sites							
	St. Joseph River	Muskegon River	Manistee River	Grand Traverse Bay	Thompson Creek	Cedar River	Platte River	Frankfort pier
Indiana	2							
St. Joseph-Black rivers	<u>7</u>							
Grand-Muskegon rivers	6	<u>5</u>			1			
Manistee area	1	1	<u>3</u>					
Platte River	2	3		2			<u>10</u>	2
Thompson Creek Big Cedar River						<u>5</u>		
Totals	17	9	3	2	1	5	10	2

^a Indiana reported one Michigan coho and three local cohos; Wisconsin anglers caught at least three Michigan fish and one local fish.

Table 15. --Number of marked coho jacks observed by non-anglers at various sites on Lake Michigan, 1978. ^a Underlined values are those recovered close to a planting site.

Planting site	Recovery sites						
	Cook Power Plant ^b	<u>Ludington</u> ^c Spring Fall	Campbell Power Plant ^d	Lake Manistee weir	Platte weirs	Detroit River ^e	
Indiana	3		1	3			
Wisconsin		4					
St. Joseph-Black rivers			1				
Grand-Muskegon rivers	1	2	<u>5</u>		7		
Manistee area	2	<u>44</u>	<u>7</u>	<u>153</u>	8		
Platte River	1	1		3	<u>222</u>	2	
Brewery Creek		1		3	2		
Thompson Creek- Big Cedar River			1		2		
Totals	7	44	16	7	162	241	2

^a In addition, catches by the RV Cisco (USFWS) included:
 Saugatuck--1 each from Indiana, Illinois, and Wisconsin + 4 unmarked jacks.
 New Buffalo--4 unmarked jacks.
 Port Washington, Wis.--1 Grand River plant and 1 unmarked jack.
 Racine, Wis.--2 unmarked jacks.

^b Near Bridgman. Data from Univ. Mich. staff.

^c Pump storage plant. Data from Mich. State Univ. staff.

^d Between Holland and Grand Haven. Data from Univ. Mich. staff.

^e Detroit River. Data from trap-net survey at Belle Isle by Michigan Department of Natural Resources.

Table 16. --Number and percentage (95% confidence limit in parentheses) of marked and unmarked cohos examined at four Michigan creel census sites in southwestern Lake Michigan on March 18-May 19, 1979. The planting sites and the proportion of the total plant made at each site are included.

Planting site	Proportion of total plant at site	Number examined	Percentage of total catch
Indiana	3.9	54	7.2 ^a (6.9)
Illinois	9.5	13	1.9 ^a (7.5)
Wisconsin	18.8	135	18.1 ^a (6.6)
Michigan (all)	67.8	472	63.3 (4.5)
St. Joe-Black rivers	9.1	44	5.9 (7.2)
Grand-Muskegon rivers	8.2	61	8.2 (6.9)
Manistee area	22.7	231	31.0 (6.0)
Platte River	19.4	95	12.7 (6.9)
Brewery Creek	2.2	23	3.1 (7.2)
Thompson-Big Cedar	5.2	18	2.4 (7.2)
No clip	--	71	9.5 ^b (6.9)
Total	--	745	

^a Adjusted values (see text, p. 16).

^b Best estimate is 8.0% because 1.5% of the planted fish were not marked.

Table 17. --Numbers of marked coho salmon examined in the 1979 spring fishery (March-May) in Indiana, Illinois, and Wisconsin waters, planting location and ratio, and the percentage of each planting in the catches. The 95% confidence limits of the catch ratios are shown in parentheses.

Planting site	Proportion of total lake plant	Indiana		Illinois		Wisconsin ^a	
		Num- ber	Per- cent	Num- ber	Per- cent	Num- ber	Per- cent
Indiana	3.9		6.6 (5.7)	18	3.7 (8.9)	9	9.6 (19.6)
Illinois	9.5	46	3.8 (5.7)	22	4.5 (8.9)	2	2.2 (20.8)
Wisconsin	18.8	130	10.9 (5.3)	64	13.2 (8.5)	15	16.1 (19.0)
Michigan (all)	67.8	942	78.7 (2.8)	381	78.6 (4.0)	67	72.0 (11.0)
St. Joe-Black	9.1	82	6.9 (5.6)	44	9.1 (8.7)	9	9.7 (19.6)
Grand-Muskegon	8.2	81	6.8 (5.7)	47	9.7 (8.7)	10	10.7 (19.6)
Manistee area	22.7	508	42.4 (4.5)	192	39.6 (6.9)	36	38.7 (16.2)
Platte River	19.4	190	15.9 (5.3)	59	12.2 (8.5)	6	6.5 (20.1)
Brewery Creek	3.2	53	4.4 (5.7)	27	5.6 (8.9)	4	4.3 (20.3)
Thompson- Big Cedar	5.2	28	2.3 (5.7)	12	2.5 (8.9)	2	2.2 (20.8)
Totals (four states)		1,197	100.0	485	100.0	93	100.0

^a May fishery only at Milwaukee, Racine, and Kenosha.

Table 18.--Numbers of marked cohos examined in the 1979 summer fishery (June-August) in the various state waters of Lake Michigan, planting location and ratio, and the percentage of each planting in the catches. The 95% confidence limits of the catch ratios are shown in parentheses.

Planting site	Proportion of total lake plant	Illinois		Wisconsin ^a		Wisconsin ^b		Michigan ^c	
		Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent
Indiana	3.9	35	3.5 (6.3)	26	4.7 (8.2)	38	5.3 (7.2)	0	--
Illinois	9.5	25	2.5 (6.3)	15	2.7 (8.5)	15	2.1 (7.5)	0	--
Wisconsin	18.8	76	7.6 (6.0)	92 ^d	16.6 (7.7)	179 ^d	24.8 (6.3)	2	1.6 (17.8)
Michigan (all)	67.8	862	86.4 (2.8)	422	76.0 (4.0)	490	67.9 (4.0)	120	98.4 (2.0)
St. Joe-Black	9.1	48	4.8 (6.0)	38	6.8 (8.2)	50	6.9 (7.2)	23	18.8 (16.2)
Grand-Muskegon	8.2	59	5.9 (6.0)	48	8.7 (8.2)	58	8.0 (7.2)	8	6.6 (17.5)
Manistee area	22.7	530	37.7 (4.5)	268	48.3 (6.0)	282	39.1 (5.7)	45	36.9 (14.4)
Platte River	19.4	155	15.6 (5.7)	23 ^e	4.1 (8.2)	50 ^e	6.9 (7.2)	41	33.6 (14.7)
Brewery Creek	3.2	42	4.2 (6.0)	30	5.4 (8.2)	27	3.7 (7.2)	3	2.5 (18.0)
Thompson- Big Cedar	5.2	28	2.8 (6.3)	15	2.7 (8.5)	23	3.2 (7.2)	0	--
Totals (four states)		998	100.0	555	100.0	722	100.0	122	100.0

^a Milwaukee, Racine, and Kenosha.

^b Port Washington, Sheboygan, and Manitowoc.

^c Reported by volunteers.

^d Includes LV clip and all triple clips.

^e Single pelvic and maxillary clip only marks not included.

Table 19. --Numbers of marked cohos examined in the 1979 fall fishery (September-November) in the Indiana, Illinois, and Wisconsin waters listed according to the planting site.

Planting site	Indiana		Illinois		Wisconsin	
	Num- ber	Per- cent	Num- ber	Per- cent	Num- ber	Per- cent
Indiana	35	94.6			32	8.3
Illinois			32	74.4	22	5.7
Wisconsin			2	4.7	119	30.9
Michigan (all)	2	5.4	9	20.9	212	55.1
St. Joe-Black			6	14.0	18	4.7
Grand-Muskegon					11	2.9
Manistee area	2	5.4	3	6.9	167	43.4
Platte River					4	1.0
Brewery Creek					11	2.9
Thompson-Big Cedar					1	0.2
Totals (four states)	37	100.0	43	100.0	385	100.0

Table 20. --Number and percent of total (in parentheses) of marked cohos observed in the 1979 fall catch at the various Michigan census sites on Lake Michigan.

Recovery site	Planting site									Totals
	Indi- ana	Illi- nois	Wiscon- sin	St.Joe- Black	Grand- Muskegon	Man- istee area	Platte River	Brew- ery Creek	Thomp- son- Big Cedar	
St. Joseph River	3 (1.2)		8 (3.1)	239 (94.1)	4 (1.6)					254
Black River		1 (2.6)	2 (5.3)	28 (73.7)	3 (7.9)	4 (10.5)				38
Grand River					173 (92.5)	8 (4.3)	3 (1.6)	3 (1.6)		187
Muskegon area ^a					20 (57.1)	12 (34.3)	3 (8.6)			35
Manistee area ^b						33 (82.5)	6 (15.0)		1 (2.5)	40
Ludington			1 (1.3)	1 (1.3)	2 (2.5)	72 (91.1)	3 (3.8)			79
Big Sable River					1 (0.5)	189 (99.5)				190
Frankfort				1 (1.0)		37 (39.9)	54 (58.1)		1 (1.0)	93
Platte River	1 (0.2)		1 (0.2)	2 (0.4)		50 (10.6)	406 (86.5)		10 (2.1)	470
Grand Traverse Bay						1 (3.3)	2 (6.7)	27 (90.0)		30
Thompson							3 (1.6)	2 (1.1)	180 (97.3)	185
Big Cedar River									6 (100.0)	6
Total										1,607

^a Includes 18 from White Lake.

^b Includes 3 from Portage Lake.

Table 21. --Total number and percent (in parentheses) of marked cohos from various planting sites observed at upstream dams and weirs in the fall 1979, in five Michigan tributaries to Lake Michigan.

Recovery site ^{a/}	Planting site									Totals
	Indi- ana	Illi- nois	Wiscon- sin	St.Joe- Black	Grand- Muskegon	Man- istee area	Platte River	Brew- ery Creek	Thomp- son- Big Cedar	
St. Joseph	1		1	1,757 (96.5)	37 (2.0)	20 (1.1)	4 (0.2)	1		1,821
Grand				1	139 (98.6)		1			141
Little Manistee	2 (0.3)		5 (0.8)		3 (0.5)	596 (97.2)	4 (0.7)		3 (0.5)	613
Platte	5	7	70 (0.3)		113 (0.4)	495 (1.8)	25,775 (96.1)	297 (1.1)	74 (0.3)	26,836
Thompson									282 (100.0)	282

^{a/} St. Joseph River--Berrien Springs fish ladder.
 Grand River--6th Street dam and Lyons dam (angler catches).
 Little Manistee River--weir.
 Platte River--upper Platte weir.
 Thompson Creek--blocking weir.

Table 22. --Percentages of the total 1979 catch of cohos in each state supplied by out-of-state plantings.

Source	Recipient state and total catch			
	Michigan	Indiana	Illinois	Wisconsin
Michigan		64.3	75.5	50.5
Indiana	0.8		3.5	7.5
Illinois	0.1	2.4		2.2
Wisconsin	1.6	9.8	9.4	
Total out-of-state percentages	2.5	76.5	88.4	60.2
Total catch	97,500	20,410	90,360	34,520

Table 23. --Average lengths of four lots of Platte River coho salmon captured in 1979 by anglers in the Platte River, and the mean lengths and weights of these lots appearing at the upper weir.

Treatment	Creel		Weir			
	Length		Length		Weight	
	centi- meters	inches	centi- meters	inches	kilo- grams	pounds
OMP + regular	58.7	23.1	59.0	23.6	2.04	4.5
OMP + double	60.0	23.6	58.3	23.3	1.93	4.3
PR-9 + regular	60.2	23.7	58.7	23.4	1.97	4.3
PR-9 + double	59.5	23.4	58.5	23.4	1.99	4.4
Number of fish	(367)		(682)			

Table 24.--Chi-square tests on survival and catchability of coho salmon raised on two diets, observed in the fall of 1979 at the weir and in the creel on the Platte River, as well as in the 1979 spring creel census in Michigan waters of Lake Michigan.

Data source	Diet ^a ✓	Expected number	Observed number	Chi-square
Fall creel	PR-9	113	136	9.1 ^b ✓
	OMP	110	87	
Spring creel	PR-9	18	14	1.3
	OMP	18	22	
Weir	PR-9	172	148	6.5 ^b ✓
	OMP	168	192	

✓^a Rations for each lot were supplemented only with regular vitamin package.

✓^b Significant at the 99% level.

Table 25. --Mean total lengths of marked coho salmon planted in Michigan waters in 1978, and captured in their home stream in October 1979.

Mark	Number of fish	Length	
		Centimeters	Inches
None	65	60.0	23.6
Both pelvics	91	57.2	22.5
Adipose	23	57.6	22.7
Right pectoral	124	58.1	22.9
Right pectoral, adipose	11	58.4	23.0
Right pelvic, left maxillary	35	58.9	23.2
Right pelvic, right maxillary	17	59.5	23.4
Left pelvic, left maxillary	45	60.0	23.6
Left pelvic, right maxillary	59	60.5	23.8
Left pectoral	174	60.7	23.9

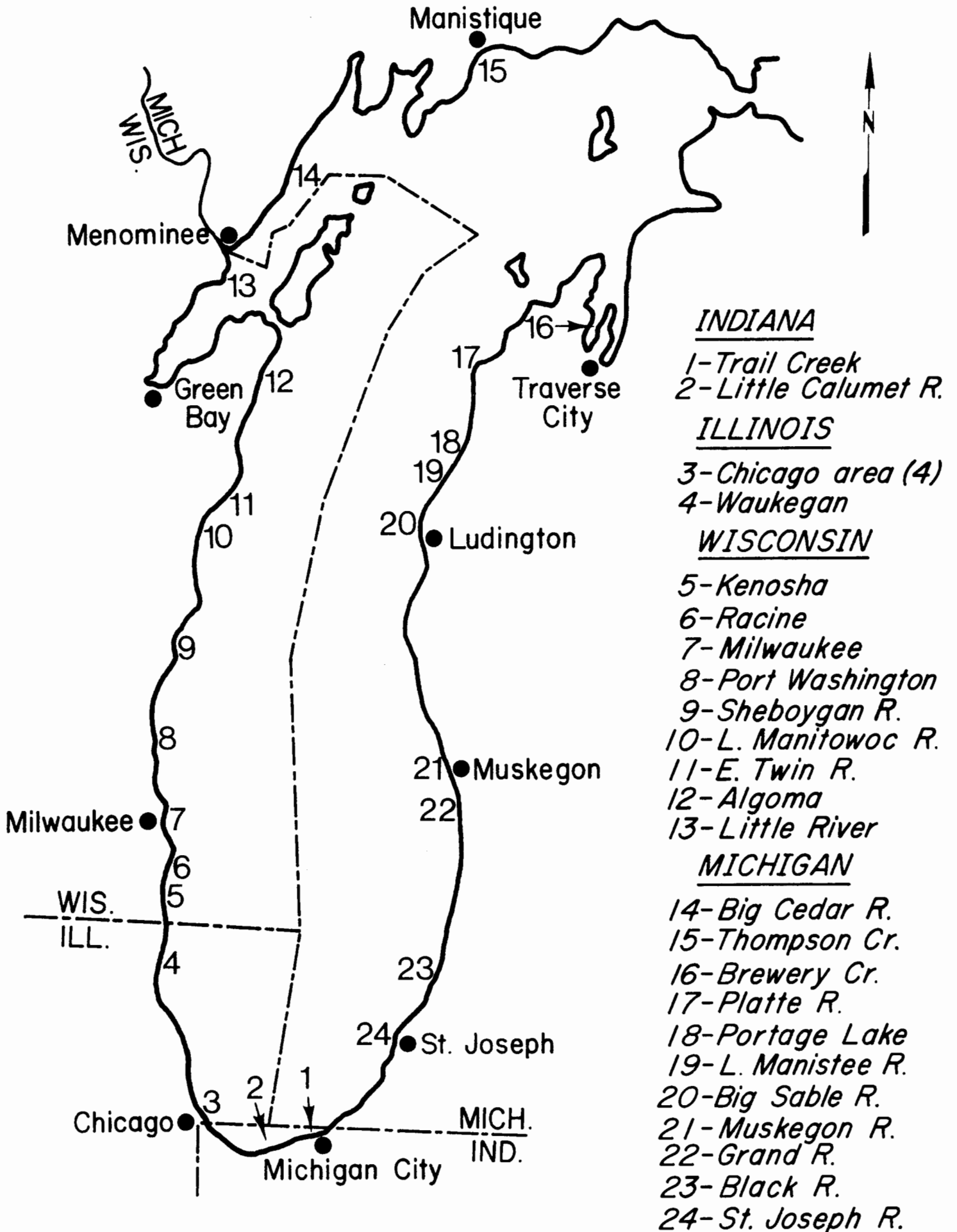


Figure 1.--Sites where coho salmon were planted in Lake Michigan, 1978.

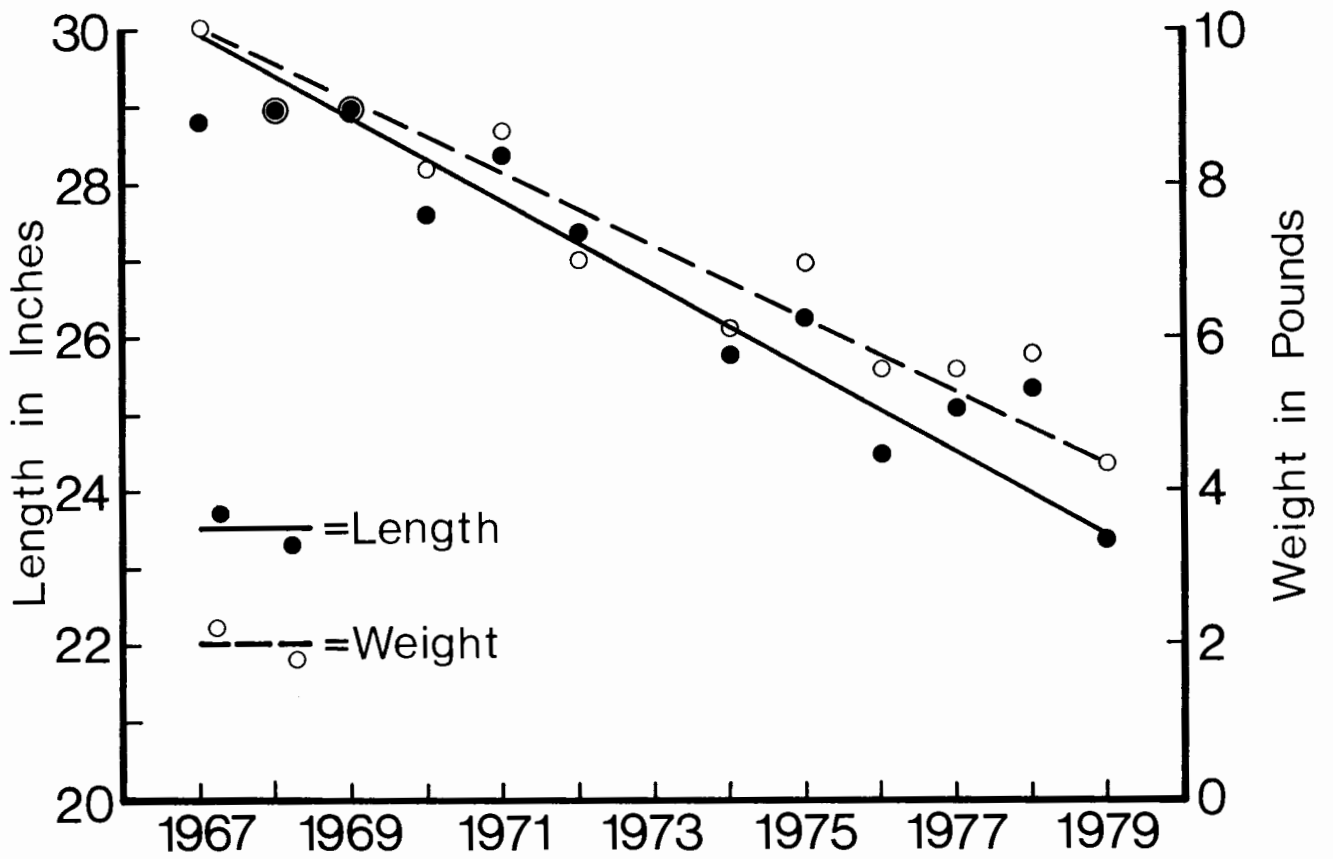


Figure 2. --Mean lengths and weights of coho salmon at Platte River Hatchery weir, fall 1967-1979.

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Report approved by W. C. Latta

Typed by M. S. McClure