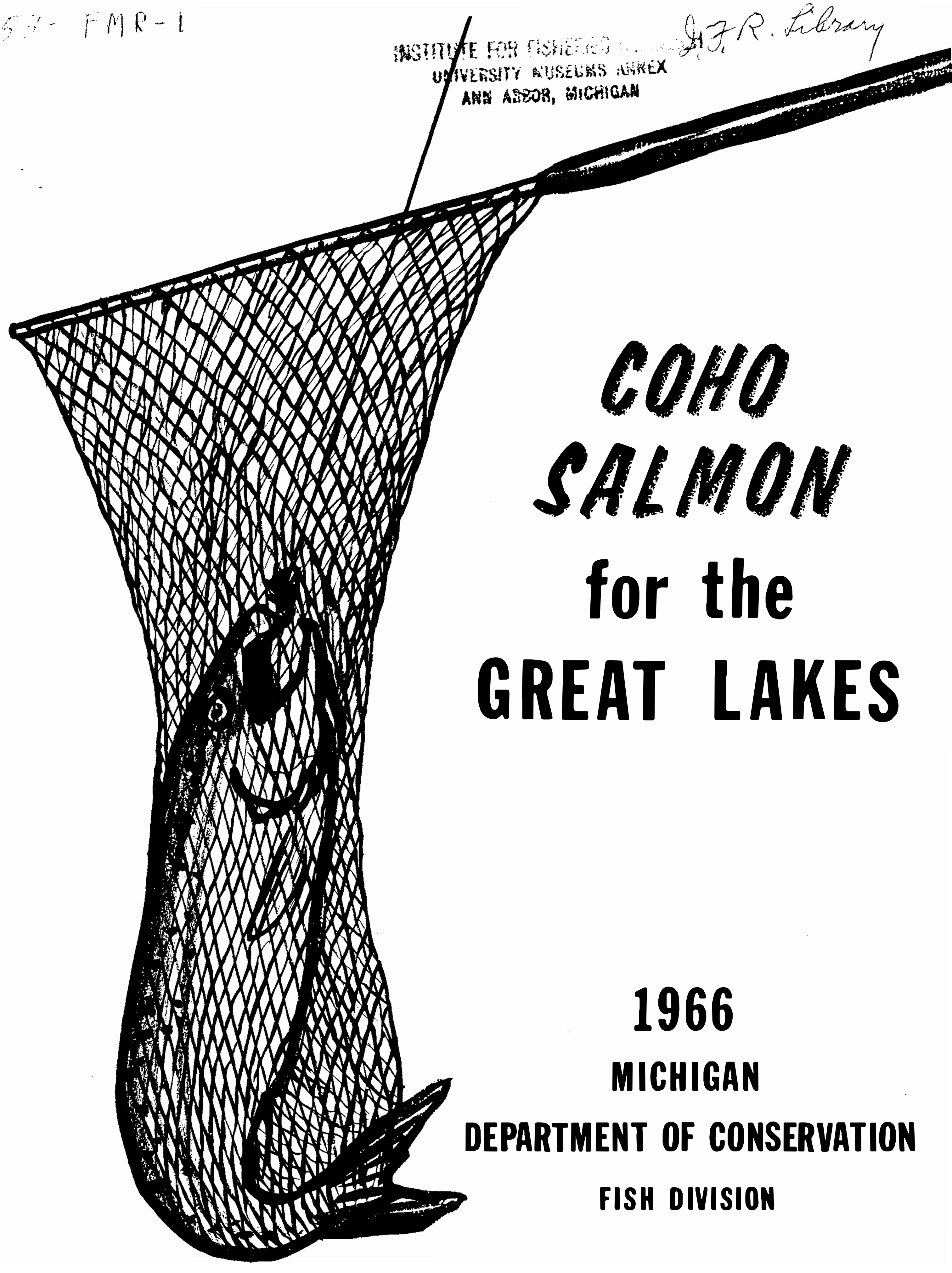


COHO SALMON for the GREAT LAKES

1966

MICHIGAN

DEPARTMENT OF CONSERVATION

FISH DIVISION

Fish Management Report No. 1 February, 1966

COHO SALMON FOR THE GREAT LAKES

by

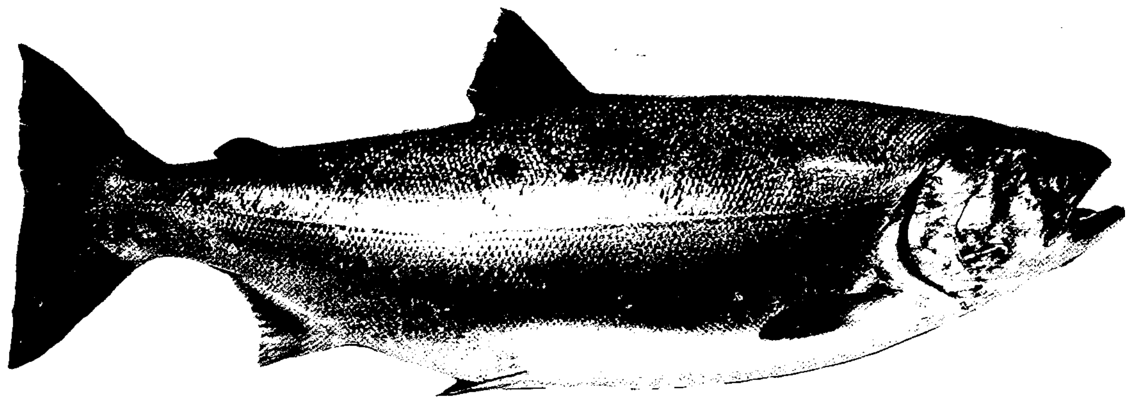
Wayne H. Tody and Howard A. Tanner

Fish Division

STATE OF MICHIGAN
GEORGE ROMNEY, GOVERNOR

DEPARTMENT OF CONSERVATION

DIRECTOR:
RALPH A. MACMULLAN



COHO (SILVER) SALMON

The coho salmon, Oncorhynchus kisutch, will soon join the ranks of Michigan sport fish. It closely resembles trout in appearance. In the Great Lakes the coho will be silver in color with few spots. Adult fish will become light red in color as they approach maturity. In the Pacific, mature coho average nine pounds and may exceed twenty pounds in weight.

Photo
Washington Dept. of Fisheries

TABLE OF CONTENTS

INTRODUCTION

In the early spring of 1966 coho salmon, Oncorhynchus kisutch, will be released by the Michigan Department of Conservation in an effort to establish this species in the Great Lakes. Additional releases of coho (also known as silver salmon) are scheduled for 1967 and 1968; thus three age-groups will be present and the full duration of the species' life cycle will be covered. The coho eggs were provided by the Oregon Fish Commission for the 1966 plants. The Washington Department of Fisheries and the Alaska Department of Fish and Game have joined with Oregon in furnishing coho eggs to Michigan for the 1967 releases. It will be necessary to obtain additional eggs from these states for plants in 1968 to complete the first phase of the coho salmon introduction.

Several years will be required to assess the outcome of the coho salmon introduction. Whether or not the coho succeeds, attempts will very likely be made to introduce certain other sport fishes in future years.

The coho is aimed at a specific fisheries management problem--namely to elevate the fisheries resource of the Great Lakes to its maximum potential for recreational fishing. The challenge in adapting the coho to the fresh-water environment of the Great Lakes is an intriguing one. Nowhere in the world has the species been permanently established outside its native range in the north Pacific coastal area. Management objectives are even more challenging. The ultimate aim is to convert an estimated annual production of 200 million pounds of low value fishes--mainly alewives--that now teem in the upper Great Lakes into an abundance of sport fishes for the recreational fishermen. Secondly, we hope to restore the depressed commercial fisheries to a productive and economically viable industry.

To accomplish these objectives, intensive management of high value fish species like the lake trout and steelhead and new species like the coho salmon is required. These species are capable of utilizing the superabundant "trash" fish as forage to produce sport or food fish of maximum interest and value.

If the coho salmon introduction succeeds, significant progress in management will have been attained. The total job, however, in "farming" the Great Lakes (the largest bodies of fresh water in the world) will involve a continuing search for additional qualified fish species, and unprecedented efforts to bring the combined group of high value sport and food fish to a level of maximum abundance.

THE MANAGEMENT SITUATION

To define the role of the coho salmon in the Great Lakes, a brief review of the past and present status of the fish populations in the upper Great Lakes (Superior, Michigan, and Huron) is necessary.

Prior to 1940 the Great Lakes held abundant populations of predatory species, predominantly lake trout and burbot, in the deeper waters; with walleyes, northern pike, and smallmouth bass along the shores and bays. These fish fed primarily on sculpin, herring, ciscoes (chubs), and lake emerald-shiners. Together these species constituted a reasonably well balanced prey-predator population.*

Invasion of the upper lakes by the sea lamprey in the mid-1930's upset this prey-predator relationship. The sea lamprey population increased rapidly. The lake trout and the burbot were virtually eliminated. The sea lamprey preyed upon the other fishes to a lesser extent. Thus, with the removal of their normal predators, the populations of chubs and other prey species expanded enormously. The loss of predatory species also set the stage for invasion of the upper lakes by other species of small fish. One particular invading species, the alewife, from Lake Ontario and the Atlantic Ocean via the Welland Canal has exploded to superabundance in lakes Michigan and Huron since 1955.

The well-known sea lamprey control program of Canada and the United States coordinated by the Great Lakes Fishery Commission has brought the sea lamprey under a relatively high degree of control in Lake Superior. The control program is well under way in Lake Michigan and is scheduled to begin on Lake Huron in 1966.

The alewife is building to an almost unbelievably dominant role in the fish populations of lakes Michigan and Huron. Recent estimates by the Bureau of Commercial Fisheries indicate that alewife may comprise 90 percent or more of the total fish population by weight in Lake Michigan. The alewife is present, but not particularly abundant as yet in Lake Superior. It is an extremely efficient competitor and appears capable of eliminating these species with which it competes for food and space. It may also eliminate or decimate all of the fish species that spawn directly in the Great Lakes by consuming their eggs or young. The spawning success of even the predatory lake trout may be seriously affected. Alewives are so abundant that swimming and boating are degraded by periodic accumulation of dead fish on the beaches and in harbor areas. Even city water supply intakes are clogged at times with hordes of alewife.

QUALIFICATIONS OF PREDATORY SPECIES

The superabundant populations of alewife in the Great Lakes would be a blessing rather than a curse if they could be utilized on a wide scale as forage for high value species.

---

* For scientific names of all species mentioned in the text, refer to Appendix.

INTRODUCTION

In the early spring of 1966 coho salmon, *Oncorhynchus kisutch*, will be released by the Michigan Department of Conservation in an effort to establish this species in the Great Lakes. Additional releases of coho (also known as silver salmon) are scheduled for 1967 and 1968; thus three age-groups will be present and the full duration of the species' life cycle will be covered. The coho eggs were provided by the Oregon Fish Commission for the 1966 plants. The Washington Department of Fisheries and the Alaska Department of Fish and Game have joined with Oregon in furnishing coho eggs to Michigan for the 1967 releases. It will be necessary to obtain additional eggs from these states for plants in 1968 to complete the first phase of the coho salmon introduction.

Several years will be required to assess the outcome of the coho salmon introduction. Whether or not the coho succeeds, attempts will very likely be made to introduce certain other sport fishes in future years.

The coho is aimed at a specific fisheries management problem--namely to elevate the fisheries resource of the Great Lakes to its maximum potential for recreational fishing. The challenge in adapting the coho to the fresh-water environment of the Great Lakes is an intriguing one. Nowhere in the world has the species been permanently established outside its native range in the north Pacific coastal area. Management objectives are even more challenging. The ultimate aim is to convert an estimated annual production of 200 million pounds of low value fishes--mainly alewives--that now teem in the upper Great Lakes into an abundance of sport fishes for the recreational fishermen. Secondly, we hope to restore the depressed commercial fisheries to a productive and economically viable industry.

To accomplish these objectives, intensive management of high value fish species like the lake trout and steelhead and new species like the coho salmon is required. These species are capable of utilizing the superabundant "trash" fish as *forage* to produce sport or food fish of maximum interest and value.

If the coho salmon introduction succeeds, significant progress in management will have been attained. The total job, however, in "farming" the Great Lakes (the largest bodies of fresh water in the world) will involve a continuing search for additional qualified fish species, and unprecedented efforts to bring the combined group of high value sport and food fish to a level of maximum abundance.

THE MANAGEMENT SITUATION

To define the role of the coho salmon in the Great Lakes, a brief

In Lake Michigan abundance of most fish species has declined with the increase in alewife. One species--the steelhead, or Great Lakes rainbow trout--has been an exception. Both spring and fall runs of steelhead are building rapidly in such famous streams as the Big Manistee and Platte. The incidence of lamprey scarring on steelhead in these runs has dropped materially since 1962. The fish are in excellent condition and are growing rapidly. Adults range from 3 to over 16 pounds. It is known that adult steelhead feed heavily on alewife in Lake Michigan. In Lake Huron steelhead populations remain low probably because of continued predation by sea lampreys.

From these observations we conclude that sea lamprey control has effectively reduced losses of steelhead in lakes Superior and Michigan. Of equal importance, steelhead themselves are thriving upon the abundant alewife. Favorable factors in the ecological situation are clearly discernible. Steelhead ascend cold trout streams (well away from alewife) to spawn. The young remain in the upper river areas for an average of two years before descending to the Great Lakes at a length of 6 inches or more. At this size they are safe from alewife predation. Indeed they are large enough to begin to feed at once on the younger and smaller alewives. Here then is a key to the future management of the fishery and a possible solution to the alewife problem. Namely, to increase, through management, the upstream runs of predacious fish like steelhead which will then enter the Great Lakes at a size large enough to consume alewife. Along with the existing species we should introduce new species of equal value that can be brought to an even greater level of abundance. In addition we should, as necessary, undertake hatchery propagation to supplement natural reproduction. The goal must be to build a predator fish population of sufficient magnitude to utilize to the greatest possible degree the alewife and other low value species as forage. Maximum advantage can be derived through selection and propagation of game fish with the highest sporting qualities to support a recreational fishery. If they occur, surplus stocks can and should be harvested by the commercial fishery.

SPECIES CONSIDERED FOR MANAGEMENT

If it can be adapted to this environment, the coho salmon is an ideal fish to at least partially fulfill the present management need in the Great Lakes. Before discussing the merits of the coho in detail it is appropriate to review several other species of fish which are involved in this management approach.

The three upper Great Lakes, Michigan, Huron, and Superior, comprise a predominantly cold, clear, deep water (oligotrophic) habitat. These waters are well qualified to produce salmonid fishes. Because trout and salmon have outstanding qualities for both sport and food, their value is doubly compounded. Consequently, initial management effort has been devoted to this group.

Concerted efforts are planned to increase the abundance of both steelhead and coaster brook trout. Possibly the populations of these species can be increased 10 or even 100 fold, but it is doubtful if they can be propagated to the extent necessary to consume the available quantities of alewife. The demands for stream reproduction areas and hatchery production facilities would become a limiting factor of serious consequence for both species. Brook trout are short lived fish and vulnerable to angling. Migratory brown trout occur in the Great Lakes, but are rarely taken by anglers, a factor which severely limits their value to the sport fisherman. Lake trout feed avidly on alewife, can reproduce directly in the Great Lakes, and are being propagated and planted at the present time. They are ecologically limited to deep water (20 fathoms or more) and fishing for them is rather specialized. Thus, lake trout may be of greatest value as a commercial species or as the quarry of a limited group of anglers.

Kokanee salmon, like alewife, feed on plankton; thus they are a potential competitor, but cannot be expected to consume and convert alewife directly. It is possible that kokanee may compete successfully with alewife and replace them to some extent. The province of Ontario has introduced kokanee to lakes Huron and Ontario and are conducting studies to evaluate the potential of the species in these waters (Ontario Department of Lands and Forests, 1965; Maher, 1964).

A brief review of the remaining North American salmonids reveals that Atlantic salmon have higher stream demands and greater propagation requirements than even our stream trout. Chum and pink salmon are valuable commercial species, but do not compare favorably with the coho as a sport species.

Chinook salmon apparently have many characteristics that would qualify them for introduction to the upper Great Lakes. Chinooks have even lower stream and hatchery demands than do coho. They are much larger, have a more prolonged ocean or lake period of residence, and feed to a greater extent on a fish diet than coho. A fresh-water strain has developed in New Zealand (Burstall, 1966, personal communication). Another species of Pacific salmon, the masu (Asiatic species around the Sea of Japan) appear to be well suited for introduction. The masu salmon closely resembles the coho, and offers races adapted to an entire fresh-water life cycle. Both of these fish are being studied in detail. They were not selected as the first choice for introduction because of the greater difficulties in obtaining eggs and transplanting suitable stocks.

Potentially, the coho salmon can be established at very high levels of abundance. In its native range it supports an extremely valuable fishery for both sport and commercial interests. In British Columbia the coho salmon is estimated to be some ten-fold more abundant than steelhead (Neave, 1957). Both species are dependent on stream reproduction for the maintenance of their stocks. Neave attributes this abundance to the limited demand upon the stream by the juvenile coho prior to migration to the sea. Usually coho remain in rivers for one year before migration as contrasted to a period of two to four years for steelhead. A similar situation exists for smolts produced in hatchery culture. Although both coho and steelhead can be reared to migratory size in twelve months, coho are easier and less expensive to produce.

If the high value salmonid species do not put sufficient pressure on alewives, other fishes such as the striped bass may be introduced. Studies on the striped bass are being pursued vigorously. At this time, however, it is recommended that introduction of such species be withheld until their distribution, growth, and abundance in the Great Lakes environment can be predicted with reasonable accuracy in comparison with the salmonids.

THE COHO SALMON

A broad understanding of the qualifications of the coho salmon as a fish for introduction can best be gained through a discussion of the life history of the species and the contribution that it makes to the west coast fishery.

The original range of the coho or silver salmon is in the Pacific Ocean from Monterey Bay, California north around the Gulf of Alaska and down the Asiatic Coast of the Pacific to the Japanese Islands. Coho spawn in stream throughout this entire area. Throughout their range, they are most abundant in coastal waters (Briggs, 1953).

The coho salmon has a three year life cycle. It spawns in freshwater streams in the fall of the year, hatches the following spring, and lives as a juvenile in the parent stream for one additional year. It migrates to the sea in the spring of the second year of life at an age of 18 months; lives in the sea for an additional 18 months, i.e. two summer growing seasons, when it migrates back to the parent stream for spawning and certain death as do other Pacific salmon.

Depending upon latitude and weather conditions, the up river spawning run of coho salmon occurs during the period of September to January. Coho runs are generally composed of two age classes of fish. A part of the run is composed of two year old precocious males commonly known as "jacks" which return to the river the first fall following downstream migration. An occasional precocious fish may be a female. The bulk of the coho runs, however, are composed of adults or three year old fish. Coho salmon have a highly developed homing instinct; at least 85 percent of the adult fish in the runs return to their parent stream (Shapovalov and Taft, 1954). Transplanted coho exhibit a higher degree of straying than do coho returning to the parent stream (Ricker, 1954).

Coho runs are generally associated with periods of high rainfall. The upstream migrations occur principally during the daylight hours. Males predominate in the early portions of the run with females becoming more abundant up to the actual time of spawning. Coho ascend practically all accessible streams within their range which offer suitable spawning conditions. Seldom do they spawn more than 150 miles from the ocean even in the larger rivers. In streams where both coho and steelhead spawn, coho usually select those spawning areas lower in the watershed than steelhead. Coho will ascend small tributary streams as far as they are physically able to do so. They show remarkable persistence in swimming up riffles with stream flows as low as two cubic feet per second and in water as shallow as two inches in depth. In their dirve to reach preferred spawning gravels, coho are stopped only when confronted by impassable barriers such as log jams or dams (Briggs, 1953).

Coho salmon eggs hatch in the early spring. The fry remain in the gravel two to three weeks after hatching. After emergence the young coho take up residence in the shallow gravel areas especially along the sides of the stream where they feed avidly and grow rapidly. A high mortality of the coho fry, believed due to predation by other fish species, inevitably occurs shortly after emergence. The young coho tend to congregate in schools, but as they grow they gradually leave the schools and disperse along the stream course. Gradually they move into the stream areas of relatively slow current and deep waters in contrast to young steelhead trout which tend to remain in the swifter and more shallow stream areas (Shapovalov and Taft, 1954).

In the early spring (April) approximately one year after emergence from the gravel the young coho begin their migration to the ocean. Coho "smolt" before the normal downstream migration. Smoltation involves a physiological change characterized by an enlargement of the thyroid gland, deposition of guanine crystals in the scales causing a silvery appearance and a development of excretory salt cells in the gills (Donaldson, 1965, personal communication; Robertson, 1948). As smolts, coho migrate downstream in small schools primarily during the night or twilight hours although some may move down during the day time as well. The downstream migration is usually completed before the end of May. Young coho, upon first entering the sea, remain fairly close to shore. Very little is known regarding how soon and to what extent they begin to move out to the open sea. Migrations of the coho in the sea take place in the form of mass movements. While in the sea they wander over considerable distances, perhaps 400 miles or more from the parent stream. Stocks from different streams intermix while at sea, a behaviour which is apparently of little significance in their later segregation and homing migration to the parent streams.

Young coho in the ocean feed on crustacea and larval fish. As adults they often feed chiefly on small fish (Synkova, 1951). LeBrasseur (1966) found that euphausiids, fish, and squid were the principal food organisms taken by coho. In coastal waters where small forage fish were readily available coho fed heavily on them. The ocean herring, a fish which in appearance closely resembles alewife, is an important item in the diet of coho and is extensively used as bait for them in the ocean fishery (Reid, 1961).

Growth of coho salmon in the Pacific is extremely rapid. In the short period of 18 months they increase in size from less than an ounce to an average weight of 9 pounds. Individual coho may grow to a weight as great as 22 pounds. In comparison with the common fresh-water fishes this rate of growth is astounding. It illustrates more than any other point the tremendous production potential of the species. In fact, most of the growth takes place during the last few months of the final year of sea life.

Coho salmon provide an excellent sport fishery. The best fishing is from July to October for large fish in their last year of sea life. It is noteworthy that this period coincides well with Michigan's tourist season. In the sea fishery coho are readily taken by trolling with both natural and artificial baits. The principal sport fishery for coho is enjoyed in the sea within 20 miles of shore. Most fish are caught at the surface and rarely are they taken in more than 10 fathoms of water (Milne, 1957). Coho normally move in schools so that when one is caught it can be expected that others will also be taken in the same area.

The following news item by Henry Lyman in THE SALTWATER SPORTSMAN, December 1965, illustrates the present role of the coho in the west coast recreational fishery:

"RECORDS FALL -- Many records were set in the sport salmon fishery at Westport, Washington, during August, with the largest total catch of any previous month; more angler trips than any other month; more coho caught than in any previous month and average size of coho the biggest ever.

"The calculated salmon catch for the month totaled 116,500 fish, far ahead of any month on record and exceeding the 100,000 mark for the first time. The coho catch of 94,700 topped any previous standard, while the chinook total of 20,800 ranked as the second highest August catch on record. Sport anglers logged 54,800 trips during the month, exceeding the 50,000 mark for the first time. Charter boat anglers accounted for more than 80 percent of the sport effort and averaged an excellent 2.29 fish per man.

"Catches of incidental food fish were quite light in view of the high fishing intensity, with salmon abundance being primarily responsible for the low catches. As in the past, black rockfish topped the incidental landings with 5,500 caught, followed by sand sole with 1,100, starry flounder with 1,000, and lingcod, some 700."

Upon approaching maturity coho salmon migrate back to the coastal area of the parental streams. Here they concentrate off shore near the stream mouth until conditions are right for the spawning runs. These concentrations of coho are famous for the excellent quality of fishing for large individual fish that they provide. Local areas may have excellent fly fishing for coho at this time. Coho are also taken by stream anglers as long as the fish retain the bright silver color characteristic of the sea fish. When they darken for spawning, they no longer feed and are seldom taken by anglers.

In addition to the sport fishery coho salmon rank as one of the principal species in the commercial fishery. They are taken by trolling and in various types of nets and traps. Troll fishermen alone took 36 million pounds in 1964 (Jensen, 1964). They are sold fresh, canned, and smoked and are recognized as choice or fancy quality in the retail trade.

In summary we can conclude that the coho is both a superb game fish and a superior food fish. Its inherent capacity for very rapid growth provides an extremely high production potential. There is little question but what the species would feed heavily on alewife if it can be adapted to the Great Lakes. Coho have a well developed pattern of homing behaviour, spawn in small streams, and are well adapted for efficient production by artificial propagation. These latter factors point to a high degree of potential abundance through management. In the upper Great Lakes it is possible that concerted management efforts can build the coho to a magnitude sufficient to convert a sizeable proportion of the existing stocks of alewife to a high value fish.

There is no chance that the coho could under any circumstances become an undesirable species such as the common carp. Any problems that may be encountered in the introduction of coho to Great Lakes waters will almost certainly be concerned with the difficulties of establishing this species to the level of abundance that the environment and demand by our people will require.

ADAPTABILITY OF THE COHO SALMON TO FRESH WATER

The coho may prove difficult to adapt to a fresh-water habitat. It is an anadromous species in that it ascends fresh-water streams to spawn, but spends most of its life in the ocean. Based on the premise that coho were not known to inhabit a strictly fresh-water environment on a permanent self-sustaining basis, they have been considered an "obligatory anadromous" species (Hoar, 1958). This term implies that coho must migrate to the marine environment for adult life, and return to fresh-water streams to reproduce in order to successfully complete their life cycle. Early attempts by fish culturists to transfer the coho to new and different environments outside of their native north Pacific range invariably failed (Foerster and Ricker, 1953). More recent efforts to transplant coho will be reviewed later in this report. The fact remains, however, that coho have not been permanently established in any waters outside their native habitat in the north Pacific Ocean area.

Despite these rather adverse facts many fisheries biologists contend that adaptation of the coho to fresh water is possible. Evidence in support of this contention is considerable and it is on this evidence that Michigan will attempt the introduction of coho into the Great Lakes. Although the possible failure of the introduction cannot be ignored, the following resume of the evidence demonstrates that the Great Lakes coho introduction has a chance to become an astounding success.

The Pacific salmon of the genus Oncorhynchus are almost certainly of fresh-water origin. Although no direct paleontological records of the salmonids have yet been found, studies of their anatomy, ecology, distribution, and physiology support the concept of a fresh-water origin (Hoar, 1958). The genus Oncorhynchus is very closely allied to the genus Salmo from which it is commonly regarded as being derived (Regan, 1920; Milne, 1948). The morphological differences between these two genera are slight. The morphological, physiological, and ecological differences among the species of Oncorhynchus are even less well defined and many of the species within the genus show a high degree of inter-fertility. Foerster (1935) was successful in obtaining a high survival of healthy hybrids from most of the crossings between species which he made. It has been suggested (Neave, 1958) that the genus Oncorhynchus was separated from Salmo and that the diversification of the present day species took place within the last 600,000 years of the pleistocene epoch. This separation during glacial times probably occurred in an isolated sea in the vicinity of the Sea of Japan. The genus Salmo does not occur in this area today although it does occur north of the Sea of Japan along the Asiatic shore and eastward along the Pacific coast of North America. Neave suggests that in geologic history the genus Salmo did reach the Japanese area and there that it became transformed into Oncorhynchus. Several relict populations of Oncorhynchus occur in the fresh-waters of Japan and Formosa. It may also be noted that O. masu, a species characteristic of the Japanese region today, is the most closely related to Salmo of all of the existing species of Oncorhynchus (Regan, 1920). The masu has resident populations in both streams and lakes. It is also anadromous, but does not range far out to sea in its marine habitat. It is probable that after this ancestral development of Oncorhynchus, members of the genus moved north and east across the Pacific following the ice ages of the pleistocene; here, relatively recently in geologic time, they evolved into the five North American species.

It is interesting that the masu did not evolve into a completely anadromous species. However, through most of its range the masu is anadromous (Berg, 1948). In light of the present attempt to introduce coho, it is noteworthy that in 1923 Oshima, a Japanese biologist, took the young of anadromous masu hatched from the eggs of spawners which had entered rivers from the marine phase of the species and transplanted them in Lake Biwa on Hondo Island in Japan. Three years later in 1926 mature males and females began to migrate for spawning from Lake Biwa to its tributaries. Thus through this simple introduction, or transplant, the anadromous masu had become a resident fish of fresh-waters (Berg, 1948).

Fujuta (1933) and Saguri (1936) offer further evidence of the tendency of some masu to remain in fresh water throughout their life cycle. Both of these authors reported that some fry obtained from anadromous masu spawners became yamame (landlocked). In some feeding experiments yamame masu have spawned successfully two or more times (Tanaka, 1963) which again indicates that the masu is very closely related to the genus Salmo.

Of the five North American species of Pacific salmon--coho, chinook, sockeye, chum, and pink--the coho most closely resembles the masu. In Asia both coho and masu populate overlapping geographical areas, although the range of the masu extends further to the south. The coho resembles the masu in general appearance, but averages somewhat larger. Both species are piscivorous. In the anadromous forms both species have a three year life cycle (occasionally longer in cold northern waters) (Berg, 1948). One landlocked form of the masu salmon, O. masou ishikawae, is more closely related to the rainbow trout (Salmo) than is the anadromous masu to coho. It is possible that taxonomically O.m. ishikawae should be classified as a separate species (this was done by Jordan, 1925) (Tsuyuki and Roberts, 1966).

In considering the six species of Oncorhynchus and their degree of deviation to adapt to a marine life cycle it is possible to divide the species into two groups. The masu, coho, and chinook have retained a period of stream life and transformation to smolts before migrating to the sea. Of these species, the Japanese masu represents a more trout-like form than the coho and chinook. The coho is dependent upon the stream environment for the first half of its life cycle and the chinook for a year or less. The remaining three species; namely, the sockeye, chum, and pink, all have forms that can migrate to the sea as fry without going through the smolt stage and can spend the major portion of the life cycle in a completely salt water environment. The kokanee, or fresh-water variety of the sockeye salmon, has probably evolved back from an anadromous marine existence to a fresh-water type (Ricker, 1940). On the other hand, the pink salmon has to a greater extent than any other species of Oncorhynchus lost its dependency on the fresh-water environment. Pink salmon that can spawn in brackish waters and need not enter an entirely fresh-water environment have been found (Rounsefell, 1958). On this basis we can rank the six species of Oncorhynchus in their evolutionary development or adaptation for a salt water environment in the following order: masu, coho, chinook, sockeye, chum, and pink.

Work by Tsuyuki and Roberts (1966) in which they compared the electropherograms of muscle myogens from the six species of Oncorhynchus with the genus Salmo, suggest a similar ranking. They arranged the species of Oncorhynchus in order of their phylogenetic relationship to the genus Salmo as follows: rainbow trout (Salmo), masu, coho, chinook, chum, sockeye, and pink. On the basis of these rankings, it is interesting to compare the degree of divergent salt water adaptation between the coho and the pink salmon. Certainly the pink salmon had evolved to a much greater degree toward a completely marine environment than has the coho. Yet, as will be pointed out later, pink salmon have been found to successfully complete their life cycle entirely in a fresh-water habitat. This evidence strongly suggests that there is no absolute physiological requirement for any species of the genus Oncorhynchus to enter the marine environment (salt water) to complete their life cycle.

Abramov (1949) summarizes the present day groups of Pacific salmon on the basis of their possible complete adaptation to a fresh-water existence as follows: "Some of them, such as the pink salmon, the summer chum, the river sockeye salmon, and the autumn chum, have to a great extent abandoned the freshwater period of life in the course of evolution. The rest, the masu, lake sockeye salmon (kokanee), coho salmon, and king (chinook) salmon have largely retained their fresh-water characteristics. By exploiting these specific qualities, we can breed fresh-water forms of salmon and populate the landlocked basins where the natural conditions are favorable for these fish."

All the evidence indicates the coho is more closely related morphologically, physiologically, and biochemically to the masu than to other species of Pacific salmon. It is reasonable to assume, therefore, that the coho could be successfully transplanted to a completely fresh-water environment with greater ease than could other Pacific salmon more distantly related to the masu. The pink salmon, by the same reasoning, should be the most difficult to adapt to fresh water. Pink salmon were released in small numbers into Lake Superior in 1959 and they have developed spawning populations that have perpetuated the species for at least two generations (MacKay, 1963). Their continued existence is not unlikely. There is no reason to believe the more easily adaptable coho (theoretically, at least) could not be transplanted to the Great Lakes with success. This view is supported by the fact that chinook salmon transplanted to New Zealand have not only developed a successful anadromous population but a resident fresh-water (yamame) population as well (Burstall, 1966, personal communication).

Retention of fresh-water characteristics by the coho salmon warrants closer inspection. If we accept the arguments for a fresh-water origin of the salmonidae (Tchernavin, 1939), we can conclude that phylogentically the coho salmon was derived from a stream dwelling trout-like fish. In their stream life juvenile coho closely resemble existing species of stream trout. Like the sockeye, but unlike the chum and the pink, they exhibit the par marks characteristic of juvenile trout. Following hatching, coho fry may move downstream in large numbers after emerging from the gravel, but they may also move upstream. Thus, they wander about like trout and become widely distributed in the river system. They do not usually leave the rivers during their first year of life; although, they may, like many trout, take up residence in lakes before migrating to the sea. In fresh water coho do not form tight schools. On the contrary, they show aggressive behaviour, selecting and defending territories and spacing themselves throughout the water avilable to them (Hoar, 1954; 1958). Migration to the sea is generally preceded by "smolting" with its significant changes in coloration and physiology. Smolt transformation in coho is comparable to that of the species of Salmo (steelhead and Atlantic salmon) in which it occurs (Hoar, 1958).

Some valuable observations on the fate of coho salmon remaining in a fresh-water lake beyond the smolt stage were made by Foerster and Ricker in Cultus Lake, British Columbia, in 1953. Cultus Lake is a relatively small body of water (not over a few thousand acres) in southern British Columbia. Its outlet, Sweltzer Creek, connects through the Chilliwack River to the Fraser River and the Pacific Ocean. Sweltzer Creek supports a fairly large run of anadromous coho with the typical three year life cycle. About a quarter of the run entering Sweltzer Creek moves on through Cultus Lake and spawns in its tributaries. The lake has a fairly large population of coho salmon which do not go to sea. These fish are largely the offspring of anadromous salmon and are called "residuals" (Ricker, 1938). The residual coho in the lake are commonly caught by anglers, principally in the autumn of the second year and in the spring and early summer of the third year of life. These fish are also easily taken by seines and gill nets in the lake from the fry stage on into early summer of the third year of life. Fry and yearling coho from Cultus Lake do migrate to the sea and a very few migrate as two year olds. A large percentage of the juvenile coho entering the lake, however, do not migrate. Foerster and Ricker estimate the proportion of residual coho remaining in the lake is at least as great as the number of migratory fish and possibly four times as great.

As Cultus Lake also supports a population of residual sockeye, as well as coho, several comparisons between these species were possible. The residual coho matured at the same age as anadromous coho, i.e., males at age II, both males and females at age III. There was no suggestion that earlier maturity of males is characteristic of residuals than of anadromous coho. On the other hand, residual sockeye matured earlier than the anadromous sockeye. Both the sockeye and coho residuals grew slower than the anadromous fish, but the difference in the rate of growth was less for the coho than the sockeye. Mature males and females of both species were produced in the lake. In general, mature and maturing residual coho salmon were of smaller average size and less brightly colored than individuals of the anadromous population. A few residual coho were taken that were as large and as brightly colored as were some of the anadromous coho. These individuals ranged from 18.3 to 23.4 inches which was somewhat less than the average length of the anadromous coho. The reproductive potential of the residual coho was low due to an unexplained disappearance of both sexes in the late summer of the third year of life. The adult females examined appeared to mature normally, but the eggs were not checked for viability. Apparently neither the residual coho nor residual sockeye could maintain a population by natural reproduction in the lake if they were cut off from the recruitment of the anadromous stock. For the sockeye this lack of reproductive potential was attributed to a disappearance of female fish as they approached sexual maturity. It was of interest to note that the few mature coho found late in the third year of life were markedly larger than the average third year fish found in the lake. Apparently the high mortality of the adult coho was restricted to the smaller adults of both sexes.

Residual coho salmon also occur in Alaska. They are found quite commonly in the fresh-water lakes of the Cook Inlet-Kenai Peninsula area, often in sufficient numbers to provide an attractive sport fishery (McRea, 1965, personal communication).

It is possible that in a few Alaskan lakes coho may complete their entire life cycle in fresh water. Stefanich (1965, personal communication) reports finding a lake containing coho of all age groups that has never been stocked, and which apparently is inaccessible to anadromous fish.

Such populations have been reported several times in the past, but have never definitely been documented. On occasion kokanee salmon have been misidentified as coho. More commonly physical surveys have revealed marginal outlets which allow entry to coho fry or fingerlings. It seems possible, however, that coho in this area may be re-adapting to a fresh water life cycle. Even if a true self-sustaining fresh-water race does not now exist the development of such a stock appears to be imminent (McRea, personal communication).

The states of Alaska, Washington, and Oregon all maintain sizeable programs to stock coho salmon in inland lakes for the sport fishery. The experience of fish culturists has deomonstrated that coho are easy to handle and provide a very desirable fish for this purpose. They are well adapted to fresh-water survival and growth. Although such plants provide good fishing, they do not maintain themselves through natural reproduction (Needham, 1938).

The State of Montana conducted a coho stocking program in Georgetown Lake based upon an annual transplant of 100,000 coho salmon fingerlings obtained from Washington from 1946 through 1954. Georgetown Lake lies at an elevation of 6,000 feet in the Kalispell area and is 2,800 acres in extent. The lake is quite shallow with an average depth of 28 feet, and is considered relatively high in biological productivity. Several attempts were made to take eggs from the stocked coho. Experience proved, however, that the adults did not ripen until mid-winter, and that by May (spring break up of ice) the females had either died or absorbed the eggs. Mature coho were taken from Georgetown Lake by winter ice fishing in January of 1951 (Anonymous, 1951). The salmon were held in natural hatchery waters until the eggs ripened. Three successive year classes were handled in this manner. The hatching rate for the first group of eggs was approximately 10 percent. The progeny from this age class was held in the hatchery for three years and produced ripe eggs. The percentage of hatching from this egg take was estimated at 15 percent. Unfortunately, the experiment was terminated when the fish culturist in charge (Fred Beal) moved to another state. It was definitely established, however, that coho salmon stocked in a fresh-water inland lake could produce viable eggs. At least two generations were found to mature entirely away from the salt water environment (Whitney, 1965, personal communication).

More recently the California Department of Fish and Game has successfully maintained a strain of coho salmon in fresh water for three generations. These fish have never migrated to salt water, but have completed their full life cycles in hatchery water. The data presented in this study (West, 1965) indicate that the general egg quality is poor compared to that of naturally spawning anadromous fish. However, the results of the study indicate that coho salmon can be reared entirely in fresh-water for several generations. West concluded that through a selective breeding program a fresh-water strain of coho salmon could probably be developed for stocking in inland waters. In this work it was found that the coho eggs grow to a larger size than those from sea run fish and that the adult fish involved in the experiment lost their natural spawning instinct, but did produce eggs that could be taken manually.

Numerous plants of chinook salmon fry have been made in the Great Lakes basin, but available information reveals only one recorded plant of coho salmon. In 1933 the State of Ohio planted both coho and king (chinook) salmon fry (or fingerlings) in Lake Erie. Trautman (1935) recorded some remarks on the success of these plants. He states that PAUL'S NETTING GAZETTE published the following note in December of 1934, "Several weeks ago commercial fishermen began reporting catches of silver sides or Pacific salmon from 3 to 5 pounds in weight and that it is interesting to note the remarkable growth of these salmon from fingerling size in the spring of 1933 to a size of 5 pounds by October, 1934". Trautman also notes that the FISHERMAN MAGAZINE of January, 1935, reported that commercial fishermen in Lake Erie were catching salmon weighing from 3 to 5 pounds and that such salmon were taken almost daily. Only one salmon from the Lake Erie plants was positively identified. This fish, from the 1933 plant, was taken in July, 1935; it was a chinook salmon, 19.25 inches. None of the other salmon that were reported taken were examined by ichthyologists. It would appear from these reports that a considerable number of the introduced salmon did survive in Lake Erie waters and grew from fingerling size to a weight of 3 to 5 pounds in two years. At the time Trautman questioned these reports because the fish were not positively identified and could have been steelhead or rainbow trout. Considering the success of silver salmon planted in fresh-water lakes to provide sport fishing in the western states and the rate of growth of the residual coho salmon as reported by Foerster and Ricker in Cultus Lake the reports are creditable and are about what could be expected in Lake Erie. Nothing is known concerning the migration of these fish to other parts of the Great Lakes basin and it is apparent that no successful spawning resulted.

Chinook salmon planted in Lake Ontario by the Ontario Department of Lands and Forests in the years from 1919 to 1925 were found to have survived. Individuals of up to 30 pounds in weight were observed (MacKay, 1963). Although this plant of chinook salmon is another example of an introduction which failed to produce a naturally reproducing population, it is interesting to note that the fish were able to survive in the fresh-water environment, migrate back to the streams in which they were released, and apparently produced viable eggs and milt. Some of the individual fish were even observed to carry out the activities of spawning. It is not known whether the streams involved provided satisfactory conditions for successful reproduction. It would have been most interesting if arrangements could have been made to spawn the fish artificially. This was tried in 1927, but it was not possible to obtain both sexes at the same time to attempt a mating due to a relative scarcity of brood fish. It is known that some females deposited eggs as spent fish were found.

These observations support the following conclusions. (1) With the exception of the Japanese masu, the anadromous coho salmon has diverged to a lesser extent from its fresh-water ancestors than other species of Pacific salmon. (2) There is no obvious physiological requirement that the coho must inhabit a salt water environment to mature and produce fertile adults of either sex. (3) The difficulties in reversing the evolutionary process through selective breeding to acclimate the coho to a fresh-water existence do not appear insurmountable.

The following observations on the probable success of the coho introduction in Michigan waters of the Great Lakes can be offered at this time. (1) Coho salmon can be easily reared to smolts in Michigan fish hatcheries. (2) Growth and survival of coho salmon in the Great Lakes can be expected to be good until at least mid-summer of the last (third) year of the life cycle. (3) It can be expected that at least a portion of the adults, both male and female, will produce viable sex products. (4) It can be anticipated that adult coho salmon will home to the streams of release, but evidence that they can sustain a population through natural stream reproduction is lacking. It is possible that they may, but it appears likely that artificial propagation will be required. The chances for artificially taking eggs and milt for combined hatchery culture and selective breeding appear good if a well directed management procedure--proper size, physiological condition, time and location of release of the smolts--is followed. (5) Thus, through selective breeding it should be possible to develop a strain of coho capable of populating the upper Great Lakes. The degree of difficulty in achieving this cannot be assessed without additional experience.

It can be speculated that the Great Lakes may offer a unique environment to the coho salmon. These lakes are sufficiently large to offer a "sea" to the anadromous fish except for the dissolved mineral content. The abundance of alewife, chubs, and smelt should offer the adult fish a sufficient food supply for rapid growth. The coho may reproduce readily in fresh water. The lack of vertebrate predators in the Great Lakes as compared to the Pacific Ocean may lead to a relatively high rate of survival. Therefore, it is certainly possible that success may be achieved in establishing the coho with just the first life cycle. At this point only an actual Great Lakes introduction can provide additional information.

PLAN FOR THE INTRODUCTION

The basic plan for the introduction of coho salmon to the Great Lakes can be outlined as follows. Three successive annual plants of yearlings will be made in suitable tributary streams of lakes Michigan and Superior. Three year classes of fish are required to complete one life cycle of the coho. All of these fish must be reared from eggs imported from cooperating western states. The adult coho resulting from these plants are expected to home on their spawning migration to the site where the smolts (yearlings) were liberated. These spawning runs will be intercepted by barrier weirs and the adults trapped. Some adult spawners will be seeded to upstream spawning areas. Eggs will be taken artificially from other adults and used for continued hatchery propagation and selective breeding to maintain and improve the stocks.

The first objective of the coho introduction is to acclimate the species to the environment offered in the Great Lakes. When this objective is reached, the program can be broadened.

Discussion of Problems and Determination of Approach

The major difficulty (no known self-sustaining populations in fresh water) in adapting coho salmon to a fresh-water environment was discussed in an earlier section. Apart from this problem there are other difficulties that must be considered in planning an introductory attempt. Ricker (1954) points out the difficulty of transplanting anadromous Pacific salmon as contrasted with the quick success that has been experienced with some non-anadromous fishes. Coho salmon often migrate hundreds of miles after leaving the parent stream. To become established they must home to a suitable spawning habitat in sufficient numbers to maintain or increase their abundance. So rigid a behaviour pattern is fraught with hazards, especially in a strange environment. Coho have a rather fixed life cycle, which except for precocious males, consists of three distinct age groups. In a sense three different populations need to be established. In comparison stream trout spend their entire existence in proximity to spawning areas; the spawning population consists of several age groups; and individuals may spawn several times. The coho (and other Pacific salmon) differ in all three respects.

To overcome some of the problems inherent in a transplant of andromous salmon, Ricker (1954) suggests two steps that may be helpful:

1. Initial plantings should be relatively large and limited to one or a few sites so that there will be an adequate expendable surplus while the selection process is weeding out genes whose effects are in poor adjustment to the new situation. Also, with large plantings, effects of predation may be lessened.

2. So far as possible, donor stocks for the new fresh-water site should be chosen from a matching marine situation.

The Oregon Fish Commission recommended (Schoning, 1964, personal communication) as a condition in supplying one million eyed coho eggs for the initial introduction that Michigan follow these management procedures:

1. Rear all fingerlings to yearling size, not less than 25 per pound, and release them in March or April.

2. Make large plants, preferably 250,000 or more per group, at each release site in not more than three streams.

3. Select streams suitable for coho spawning directly tributary to the Great Lakes.

The wisdom of the recommendations from Ricker and the Oregon Fish Commission became apparent in drafting preliminary plans designed to give the coho introduction a maximum chance for success.

Selection of Planting Stocks

The eggs for the 1966 releases were provided by the Oregon Fish Commission from coho taken at Bonneville Dam on the Columbia River. These one million eyed eggs were taken from adult fish spawned in late November of 1965. Michigan's weather conditions in November may pose a problem for these late spawning fish, but we were extremely grateful to procure the stock at the late date when arrangements were made.

For the 1967 releases we have been able to communicate with western fisheries people in some detail and have received excellent cooperation in selecting coho stocks which should be well suited to the Great Lakes habitat. Stocks from the 1965 brood year have been received from the states of Oregon, Washington, and Alaska.

The Oregon Fish Commission supplied 1,200,000 eyed eggs from the Cascade River, tributary to the Columbia River near Bonneville. These eggs were obtained from adults which spawn in mid-October, under stream and weather conditions similar to those expected in Michigan (Jeffries, 1965, personal communication).

The Washington Department of Fisheries also furnished 1,200,000 eyed eggs from the 1965 brood year. These eggs were obtained from mid-October spawners in the Toutle River, tributary to the Cowlitz and then the Columbia River some 85 miles upstream from the Pacific Ocean. This stock is subject to severe winter conditions during egg incubation each year. The river has proved an excellent donor stream for several successful coho transplants in western states (Ellis, 1965, personal communication).

The remaining coho stock for the 1967 releases is a very special lot of 70,000 eyed eggs obtained from the Alaska Department of Fish and Game. These eggs were obtained from the Swanson River southwest of Anchorage in the Kenai Peninsula. The eggs supplied Michigan were spawned out on September 27, 1965 (Kubik, 1965, personal communication). The coho salmon in this run contribute to the partially landlocked populations which occur in the lakes of the area. Alaskan biologists have not had an opportunity to undertake selective breeding to develop a true landlocked (fresh-water) stock from this run, but the high rate of residual cohos produced indicate it is one of the best stocks available for this purpose (McRea, 1965, personal communication). The resultant coho from this small lot of eggs will be used for selective breeding purposes.

It is hoped that additional stocks of coho eggs can be obtained from these sources in 1966 for the 1968 releases to complete one full compliment of three age classes for the coho introduction. It may be desirable to supplement the introduction with selected stocks in future years for a continued program of selective breeding. We are extremely grateful for the cooperation received from Oregon, Washington, and Alaska in supplying these egg stocks to Michigan entirely on a gratuitous basis to assist in our attempt at a Great Lakes introduction.

The Initial Coho Releases

Approximately 750,000 yearling coho (size 18 per pound) are available for the 1966 plants. Plans for releases in 1967 and 1968 will be similar to those outlined below for 1966 except that approximately 1,600,000 yearlings should be available for stocking in each of these later years. Coho smolts will be released in the early spring as soon as possible after severe frost and ice conditions have disappeared. Stream temperatures of from 45° to 50° F. are considered best for planting, just ahead of the generally warm spring rains. The coho can then be expected to migrate downstream rapidly with minimal losses. The actual dates of release will be about April 15 for the Lake Michigan streams and April 30 for Lake Superior.

The following three streams have been selected as the initial release sites. The stocking plan for each stream is briefly described.

1. Big Huron River

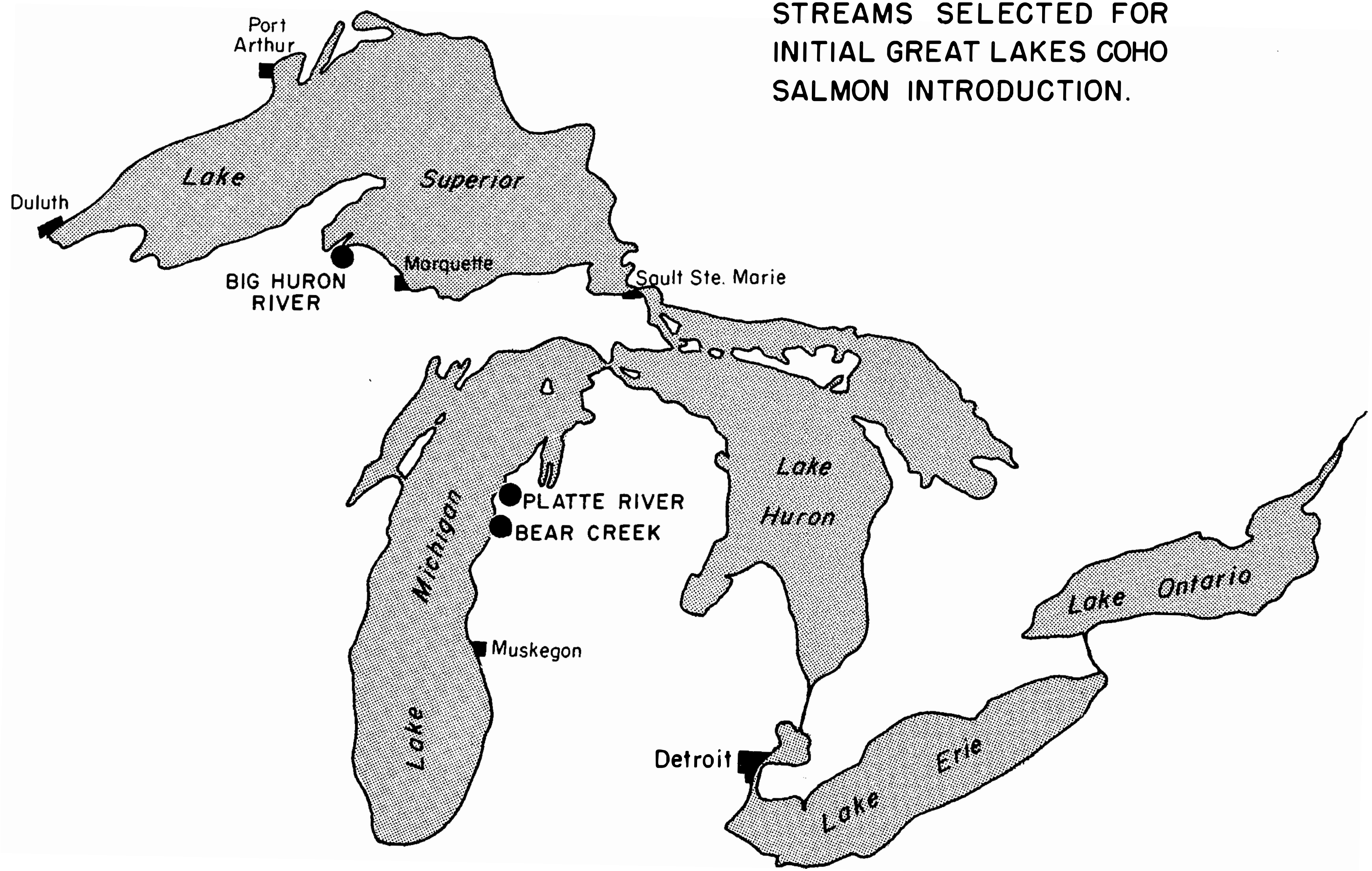
The Big Huron River is located just east of Keweenaw Bay on the central south shore of Lake Superior. It has good spawning gravels and supports both spring and fall runs of steelhead trout. The upper drainage is inaccessible due to waterfall barriers. Stream flow varies widely. The watershed is very sparsely settled, there are no dams on the river, and pollution is negligible. A United States Fish and Wildlife Service lamprey weir (electric AC-DC) is operated each spring on the lower river. There is no apparent predator problem except that the lower river contains a small population of northern pike.

The scheduled plant in the Big Huron River is 200,000 yearling coho and 50,000 fin-clipped (left pelvic) yearling steelhead. These fish are held at the Marquette State Fish Hatchery. The steelhead (hatchery rainbow trout) yearlings are being planted as a parallel management effort and are combined with the coho to buffer losses from predation.

The primary objective of the coho release in the Big Huron is to establish natural reproduction, but eggs will be taken for continued hatchery operations as necessary. The young coho will be released on gravel areas suitable for spawning.

2. Platte River

The Platte River is tributary to the north central area of Lake Michigan. It is a clear stream with a stable flow. Good spawning areas are present and the stream supports heavy runs of both fall and spring steelheads. A dense population of resident brown trout is present. Villages and cottages occur along the river, but pollution is not yet a problem. The stream flows through Platte Lake,



STREAMS SELECTED FOR INITIAL GREAT LAKES COHO SALMON INTRODUCTION.

a 2,516 acre moderately shallow lake, before entering Lake Michigan. Predation by northern pike and other fish, or the establishment of a population of residual cohos, may be problems of consequence in this area.

Some 250,000 yearling coho salmon and 50,000 yearling steelhead will be released in the Platte. These fish are held at the State Rearing Station on the stream. Some 50,000 marked (right pelvic fin clipped) coho will be released on spawning gravels above the rearing station, and the remaining 200,000 will be released directly from the rearing ponds.

3. <u>Bear Creek</u>

Bear Creek is a tributary to the Big Manistee River which flows across the north corner of Manistee Lake (1,275 acres) before entering Lake Michigan. Bear Creek has a fairly stable flow of light brown water. The Big Manistee has a similarly stable flow, but is somewhat turbid from suspended clay during periods of heavy precipitation. With the exception of Manistee Lake, pollution is not of consequence. The Manistee River and Bear Creek support good runs of steelhead. A fairly heavy population of brown trout occurs in Bear Creek; the bayous of the Big Manistee contain numerous species of fish including fairly large populations of northern pike. The Big Manistee River is blocked by a high hydro dam (Tippy) 29 miles upstream from Lake Michigan. This dam is 12 miles upstream from the mouth of Bear Creek so it should not influence the return of coho to the point of release.

The Bear Creek coho release will consist of 200,000 yearlings at the public access site two miles upstream from the State Rearing Pond Station, and 100,000 yearling coho intermixed with 50,000 (left pelvic fin clipped) yearling steelhead in Second and Third creeks a short distance further upstream. All of these fish will be liberated in stream areas with suitable gravel spawning areas. To reach the Great Lakes smolts will have to migrate an average distance of 40 miles.

<u>Observations Following Release</u>

Field personnel trained in the identification of coho salmon and the various species of trout will be assigned to follow the released fish until migration into the Great Lakes is complete. These personnel will keep a daily log of all observational notes. Particular attention will be paid to the rate of downstream migration and to any abnormal losses of the smolts from predators. Once the salmon have entered the Great Lakes personnel from the Great Lakes Unit will follow the distribution and habits of the coho until they again return to the stream environment.

Observations of Coho in Great Lakes

It can be expected that coho will disperse over large areas in the Great Lakes. Dispersal probably will be influenced by temperature, water conditions, and the availability of food. Some coho may migrate from one Great Lake to another or even attempt to migrate to the sea.

Personnel and facilities will be required to follow the movements, distribution, rate of growth and food habits of the coho throughout the period of Great Lakes life. Inter-specific relationships and factors influencing mortality of the coho should be closely observed as well.

A sport fishery for coho will develop. We should assist in the development by disseminating information on areas of known concentrations, depth distribution, fishing methods, and so forth. A close surveillance of both the sport fishery and incidental take by the commercial fishery will be required to set necessary protective and harvest regulations. Initially the coho will be protected from commercial fishing by a closed season on all Michigan waters.

Return of Coho Salmon to the Streams

The first return run of coho salmon is expected to occur in the fall of 1966. This run, if it occurs, will be composed of precocious males or "jacks" which have only been in the Great Lakes for five months. The first return of adult coho is expected in the fall of 1967. To intercept these expected runs, it will be necessary to ready or construct physical facilities on each of the three streams. In 1966 all that will be required are weir and trap facilities where the jacks can be counted, measured, checked for identifying marks, and transferred upstream to the spawning areas. Before the return of mature adults in 1967, it will be necessary to provide holding or maturation ponds and facilities for the taking of eggs on each stream.

If jacks run in 1966 they will be observed closely from the time of upstream transfer on through the time of final mortality. The timing of the jack migration, their distribution and movements throughout the spawning areas, and other activities will provide valuable information upon which to predict the characteristics of the first migration of adults the year following. Special attention will be given to the development of the gonads and size as compared with fish in the native range. These observations may offer the first significant information on the success of the introduction. The occurrence of jacks in Great Lakes tributaries other than the release streams may offer significant information on what will be the homing pattern, or rate of straying, of the coho salmon in this new environment. This information will be of value in the final planning of facilities and procedures to intercept and collect the adult runs.

Establishment of Second Generation Cohos

To establish a second generation of coho salmon in the Great Lakes we must assume that adult coho with viable eggs and milt will home back to the release streams. The rearing and release procedures as outlined in the preceding sections have been designed to maximize a return run of mature adult fish.

Regardless of the size of the return runs of adults some fish will be passed to the upstream spawning areas on each of the release streams while other adults will be captured to obtain fertilized eggs for continued hatchery culture. Every effort will be made to propagate and maintain a continuing population in each stream at least at the level of the initial introduction. In addition fertilized eggs will be diverted to a selective breeding program from which stocks can be developed for broadening the coho management program to a production basis capable of stocking other suitable waters in the state. The ultimate goal will be to build a population capable of utilizing a large proportion of the available alewife in the Great Lakes as forage.

To meet these requirements it will be necessary to install facilities on each of the release streams for capturing the adult fish, holding them to maturity, and taking and processing fertilized eggs. These necessary facilities will serve a dual function in that they can be operated to capture the spring run of steelhead and allow the propagation of this species as well as coho.

It is not known exactly when the return runs of adult coho will occur or what degree of maturity (ripeness) can be expected in the adult fish at the time of capture. For these reasons it will be necessary to provide facilities in which coho can be held for periods of at least several weeks for the fish to attain sexual maturity. Burrows (1960) recommends that specially designed ponds be provided in which salmon can be held several weeks to allow successful maturation. Attempts to hold green salmon in holding ponds with vertical side walls generally result in excessive mortality of the fish. Coho jump at the walls and at water inlet structures, become injured, and suffer heavy mortalities if they are not released. The maturation ponds therefore should be designed with sloping side walls and a water supply diffused up from the bottom of the pond. Traps must be installed in the ponds to capture and segregate the maturing fish without excessive handling of the green fish. Injury to the adults must not only be minimized, but previous damages should be allowed to heal while the fish are maturing. It is extremely important that excessive handling of the adult salmon be avoided in all stages of the holding process.

Egg taking facilities will also have to be provided. These facilities will include tanks for the segregation of male and female fish, killing pens, and indoor facilities where the eggs may be safely processed until they can be transported to a permanent hatchery station. Living quarters for crews will also have to be provided.

Fish weirs, holding and maturation ponds, and egg taking facilities will be incorporated into the existing State Rearing Stations on the Platte River and Bear Creek. It will be necessary to develop new facilities on the Big Huron River where no fishery station now exists.

Regulations

Regulations that will afford adequate protection and permit reasonable utilization are difficult to prescribe without field experience. Therefore we are seeking legislation to grant the Department management authority to set necessary regulations for the coho in both the inland and Great Lakes waters of the state during the period of introduction. It will be necessary to coordinate these regulations with other states in the Great Lakes area.

Few coho smolts will exceed 7 inches in length at the time of planting. Michigan's 7 inch minimum size limit on trout should afford the downstream migrants adequate protection. In the Great Lakes angling should be allowed during the initial period of introduction. An open season will provide information on the character and quality of the sport fishery that may develop. Fairly restrictive size and creel limits will probably be necessary. During the introductory phase of the program, coho will be protected from commercial fishing. If and when coho management is placed on a production basis and it is demonstrated that certain stocks of the fish are surplus to the needs of the sport fishery and to reproduction requirements, a commercial take should be authorized.

To the maximum extent possible a sport fishery will be allowed for the jack and adult coho on the spawning runs. The principal factor in regulation of the fishery on these return runs will be to allow adequate escapement to assure continued replenishment or build up of the coho stocks. In the event that an emergency situation occurs to deplete coho on the return runs it is possible for the Department to declare a stream, or portion of a stream, closed to fishing following a period of five days public notification.

In setting regulations for the coho every effort should be made to avoid unnecessary and overly restrictive regulations and to provide a maximum and equitable harvest by the participating fisherman.

Survey and Evaluation Plans

It is essential that the coho salmon introduction be followed carefully through field observation of all phases of the operations. It is certain that direct observation will reveal necessary management steps which will materially affect the success of the program. Experience with the coho in the Great Lakes and Michigan stream environment is now totally lacking. From the first every observation will be of value. As the introduction progresses a large amount of precise factual information will be required to determine future management practices. For example, we must compare the basic economics of smolt production in streams versus hatchery production. Also, we must collect information upon which to base a total program to maximize the production and harvest of high value sport and food fish in Great Lakes waters.

Evaluation projects for the coho salmon will be closely related to similar studies of the steelhead trout, and other migratory salmonid fishes. Initially, three approaches to field observation are essential. These are: 1) a system of counting stations on selected streams to assess all aspects of the upstream migrations of adults and the downstream migration of smolts including the comparative effectiveness of management practices; 2) boats and gear to directly assess the populations of fish and the resultant fishery in the Great Lakes; and 3) a system to measure the biological and economic development of the fishery to set harvest regulations and determine future development of the program.

MANAGEMENT ON A PRODUCTION BASIS

When the objective of adapting the coho salmon to the Great Lakes area is reached, the second goal--bringing it to a high degree of abundance--will be of primary concern. Only then can we meet popular demand and establish coho in other suitable streams around the state.

Regardless of how successful the introduction attempt may be, the coho will not become an abundant fish in the Great Lakes for several years. At least two or three generations (6 to 9 years) will be required to build up a sufficient number of brood fish to produce large numbers of progeny.

An annual harvest of 20,000,000 pounds of migratory trout and salmon in the upper Great Lakes appears to be a reasonable goal. Let us examine it. An annual catch of 4,000,000 five pound salmon and trout would be required. The percentage of smolts that survive to be harvested by anglers will be small, but a return of five percent is not unreasonable. Thus a planting program of about 80,000,000 fingerlings (smolts) per year in streams tributary to the Great Lakes would be required. The projection above applies to the entire upper Great Lakes basin. Michigan owns 24,474,000 acres, or 49.5 percent, of the total area of lakes Michigan, Superior, and Huron (49,418,000 acres). Thus some 40,000,000 fingerling trout and salmon would be required to stock the Michigan waters of the upper lakes.

These young fish can be produced in two ways. First, from natural reproduction in streams, and secondly, by propagation in hatcheries. Let us review briefly the implications of each of these production sources.

Natural Reproduction in Streams

It is estimated that approximately 2,000 miles of streams tributary to lakes Michigan and Superior are presently accessible to spawning runs of steelhead trout. The magnitude of runs on these streams varies more widely than available area for spawning would indicate. Obviously natural abundance is dependent upon many variables. To adequately assess the productive capacity of these streams a complete field survey will be required. These same streams can be considered available, and perhaps suitable, for coho salmon. It is estimated that an additional 1,500 miles of similar streams could be made available for spawning if the migrating adults were provided passage upstream over dams, waterfalls, and other barriers. Equivalent data has not yet been assembled for streams tributary to Lake Huron.

Within reasonable economic bounds it is proper that this additional spawning habitat be made accessible to anadromous salmonids. Plans are being developed to accomplish this and we hope to commence pilot projects by 1967. A rough estimate indicates that more than 80 structures, trapping stations, fish ladders, lifts, and such will be required. Every effort will be made to preserve the natural beauty of many waterfalls and cascades. Also care must be taken not to pass sea lampreys and other non-desirable fishes to additional upstream spawning areas. Consequently it is planned to utilize trap and transfer facilities in many areas rather than fish ladders, even at a somewhat higher cost.

It is probable that the natural production of trout and salmon smolts can be increased by improvement of the stream habitat. Addition of gravel for spawning, installation of escape cover for the protection of juvenal fish, elimination of competing fish species by chemical fish toxicants, and other practices could well be helpful. Initially, all projects of this kind would be experimental and require careful evaluation.

In coho spawning streams in British Columbia and Oregon a production rate of 20 smolts per 100 square yards of stream area is considered good. Maximum smolt production seldom exceeds 100 smolts per 100 square yards (Chapman, Wickett, 1965, personal communication). On the basis of 20 smolts per 100 square yards a rough estimate of Michigan stream reproductive capacity can be made. If we assume that 1,500 miles of Michigan rivers (average width 30 feet) is suitable for coho and steelhead production, the total potential reproduction would be approximately 5,000,000 smolts. On the same basis all 3,500 miles of streams now accessible, or that could be made accessible, could potentially produce some 12,000,000 smolts. Quite likely these figures exceed the reproductive potential by a wide margin, because many of the stream areas would be of low quality, or already support high populations of resident trout and other fish species. In any event it is very unlikely that natural reproduction alone could ever supply sufficient trout and salmon recruitment to the Great Lakes to meet the production goal. On the other hand, a high production of wild smolts would be extremely valuable and should be given a degree of priority in management planning over straight hatchery production. It is of interest that Michigan's present steelhead populations are almost entirely dependent on natural reproduction.

Smolts can be produced in small ponds and natural lakes from which competing species of fish have been removed by drawdown or chemical treatment. Such areas are often termed natural rearing areas. They are stocked with hatchery fry or fingerlings and released as smolts on the spring migration. A barrier dam on a suitable outlet stream (preferably the pond should be drainable) is required to control residence and migration. Several thousand smolts per acre can be produced in such ponds especially if the young fish are fed artificially. In western states much of the work with natural rearing ponds is still experimental (Kruse, 1963).

Maximum use of available spawning areas would entail passing migrant adults upstream over many dams. Probably the upstream passage would be no great problem, but fairly heavy losses of the juveniles can be expected on the downstream migrations from both mechanical injuries in passing through the structures and from increased predation in the impoundment area. Most Michigan impoundments contain northern pike and other highly predacious species.

Coho salmon and steelhead trout are about equally tolerant to pollution (Jeffries, 1965, personal communication). It is unlikely, therefore, that coho will spawn in rivers that are not now suitable for steelhead because of pollution. However, runs may be maintained in rivers unsuitable for natural reproduction through plants of hatchery smolts. In this manner coho and steelhead runs might be established and provide attractive fishing in several rivers of southern Michigan close to dense centers of the State's population.

Coho salmon die after spawning. The mortality occurs in late fall, but it could prove objectionable in resort and other populated areas.

Hatchery Culture

In the preceding section of this report it was estimated that 40,000,000 fingerling trout and salmon (mostly yearling smolts) would be required to stock Michigan waters of the upper Great Lakes. Natural reproduction in streams might produce 5,000,000 wild fingerlings, and under intensive management of the streams production might approach 12,000,000 fingerlings. The remaining fingerlings required, roughly 30,000,000 would of necessity have to be produced in fish hatcheries.

One of the most important points in selecting the trout and salmon as a group of fish to manage in the Great Lakes is the ease of culture in hatcheries. In the United States trout have been artificially propagated for about 100 years. Techniques required to produce fish of any given size are better known than for other groups of fish.

Coho salmon are especially suitable for hatchery culture. Despite limited experience we were able to rear approximately 750,000 smolts from the first lot of 1,000,000 eyed eggs obtained from the State of Oregon in 1965. In a sense the coho is a domesticated animal which can be "farmed" in suitable natural waters. As necessary and to the extent that it is economically feasible, we should be prepared to maintain abundant coho populations in the Great Lakes by hatchery propagation.

Let us look more closely at how ideally suited the coho salmon is for artificial propagation. Coho salmon have a highly developed homing behaviour. Mature adults will return, after many months in the sea, to the area of the parent stream where the young smolts began the downstream migration. This ability for almost exact homing is based on the olfactory nerve system (sense of smell) and an amazing retention and recall of the stream characteristics experienced on the downstream migration. Coho salmon share this (or a similar ability) with many other anadromous species of fish. If the adult spawning run is intercepted with barrier weirs, adult coho will readily enter fish chutes that divert them to holding ponds. Here they can be sorted and handled easily to check for identifying marks and suitable breeders can be selected. Maturing coho salmon undergo an irreversible physiological change ending in death at the end of the spawning cycle. Consequently, the breeders are killed and eggs are removed surgically in a complete and simple manner. Fertilization is external and is accomplished simply by extruding milt from selected males.

Coho salmon eggs are large and highly vascularized. They are relatively easy to handle. In the eyed stage they can be shipped safely for long distances. Fry and fingerlings can be fed on either a dry pelletized or meat diet. Proper nutrition and disease control is, of course, important. In the past few years new diets have been developed on the west coast. One of these--the Oregon Moist Pellet Diet--has apparently revolutionized salmon culture. Smolts reared on this diet have shown a much higher rate of survival in the wild environment than was previously possible (Jeffries, personal communication). In Michigan we are purchasing this feed from Oregon manufacturers for all stocks of coho now being produced. Disease control and other hatchery practices are similar to those of trout and thus relatively well known. Michigan coho are receiving supplemental iodine in hatchery water supplies as a precautionary measure to compensate for a known deficiency for this trace element.

In a continuing program of artificial propagation of coho much can be accomplished through a selective breeding program. Through selective breeding the seasonal period of spawning can be adjusted; fecundity, rate of growth, appearance, migration habits, and other characteristics of the fish can be improved upon. A well directed program of selection, mating and culling is required over a span of many generations (Donaldson, 1963).

If we assume a five percent rate of return to the fishery from hatchery produced fingerlings, it is possible to estimate roughly the cost of supporting a coho fishery with a hatchery program. With an efficient hatchery system it is estimated that yearling coho could be reared at a cost of 7 cents each. With one fish returned to the fishery out of twenty planted, each fish taken would represent a hatchery value of $1.40. At an average weight of five pounds these fish would have a value of $3.00 to the commercial fisherman (60 cents per pound in the round), or some $20.00 to the recreational fisherman. Undoubtedly, with actual experience the estimates can be refined, but certainly the potential value of individual adult fish is great enough to warrant hatchery production.

Stream Fishing Areas

In 1965 Michigan fisheries biologists classified and inventoried all trout streams in the state. The final inventory included 462 miles of stream classified as "steelhead" waters. In these rivers the dominant fishing interest is for runs of steelhead from the Great Lakes. An extended trout fishing season is provided on these waters in either the spring or fall, often in both seasons, to allow a maximum allowable recreational opportunity in harvesting the large migrant steelhead and brown trout.

An intensive management program to build abundant populations of steelhead, coho salmon and other species of migratory salmonids will require provision of additional stream fishing areas. It is estimated that a total of 950 miles of river, large enough to fish, in the Lake Superior and Lake Michigan watersheds are now accessible to runs of migratory fish. If the runs are passed upstream to suitable habitat above dams, waterfalls and other barriers, an additional 800 miles of fishable stream or a total of 1,750 miles could be made available. This total will be extended once data has been collected for streams tributary to Lake Huron.

These data exclude small tributary or "feeder" streams from the fishable area. However, many of the streams included are too small to allow high quality fishing for the large migrant salmonids. On these small streams illegal spearing, dip netting, and snagging present problems. It is apparent that the relatively few large rivers and the downstream main channel areas on others are now, and will remain, the prime fishing areas.

Many of the fishable rivers would benefit from stream maintenance and improvement projects to afford better fishing conditions. Most of the lands along these streams are privately owned. An extensive land acquisition or a long term public lease program will be necessary to assure anglers free access and fishing rights in future years. In some areas land acquisition and zoning will be required to protect the streams from excessive enrichment and pollution.

Not many of the downstream areas provide high quality fishing for resident stream trout. Summer water temperatures are too high to provide a suitable habitat. The use of these rivers for intensive spring, fall, and winter fishing for the runs of Great Lake salmonids will maximize recreational opportunity.

CONSIDERATIONS FOR FUTURE MANAGEMENT

In this attempt to manage coho salmon in the Great Lakes area an all out effort will be made to assure success. It remains a possibility, however, that the effort may fail, or that coho will never measure up to our highest expectations. Such an event would be disappointing, but in no way would it lessen the need to utilize the enormous populations of alewife and other low value fish species in the Great Lakes to support an attractive recreational fishery. Even while the attempt to introduce coho salmon is in progress, a parallel program to build populations of steelhead trout is being conducted, and other active management programs are concerned with the lake trout and coaster brook trout. It is likely that within a year plans for an attempted introduction of chinook salmon will be announced. Further in the future introductions of masu salmon, striped bass, and other valuable game fish may be called for to meet the management objectives. Whichever species prove most feasible to manage, a long continuation of efforts to build them to a high level of abundance to utilize the low value species will predictably dwarf the original introduction attempts in demands for time, labor, and money.

Anadromous Fish

The coho salmon, chinook salmon, masu salmon, steelhead trout, coaster brook trout, and striped bass have one common characteristic. All of these species ascend streams to spawn, then descend to the sea or a large lake for adult life. For lack of a better term such migratory species will probably be termed "anadromous" in the Great Lakes environment. Scientifically the term anadromous implies adult residence in the ocean or marine environment, and a necessity to ascend fresh-water streams to spawn. Truly anadromous species therefore must be capable of osmoregulation in both salt and fresh water. All of the species listed above have truly anadromous forms as do the sea lamprey, smelt, brown trout, and alewife which are now found in the Great Lakes. As the life cycle of all these fish is essentially the same in either the Great Lakes or the ocean environment perhaps the term will not cause an excessive degree of confusion, except as it may be applied to species capable only of a fresh-water existence.

The Anadromous Fish Act

The United States Congress in 1965 enacted a new fisheries program entitled the Anadromous Fish Act, Public Law 89-304. This act concerns the anadromous fisheries resources of the Nation, but it specifically includes a program for conserving, enhancing and developing the fish in the Great Lakes that ascend streams to spawn. This act promises to be of major significance in affording a financial base, and an early acceleration of activities to develop the Great Lakes and associated stream fisheries.

The Act enables the United States Fish and Wildlife Service to enter into cooperative projects with any eligible states on a grant-in-aid, 50:50 cost share basis for management of both sport and commercial species. Authorization is provided to appropriate not more than $25,000,000 prior to July 1, 1970, to carry out the purposes of the Act. Not more than $1,000,000 may be obligated in any one fiscal year in any one state.

The following activities can qualify for federal cost sharing under the Anadromous Fish Act:

1. Essential investigations, engineering and biological surveys, and research.

2. Stream clearance projects to facilitate migration.

3. Stream habitat improvement (spawning, protection, etc.).

4. Construct, operate, and maintain fish hatcheries.

5. Acquisition and lease of lands.

The provisions of this Act appear sufficiently broad to cover nearly all essential activities encompassed in the program outlined in this report. Maximum advantage should be taken of this Act to finance all qualified projects. On the Great Lakes, development of sport fisheries must receive the highest priority. Let us summarize the need, opportunity, and approach to the development of this sport fishery.

The Great Lakes area is the heart of the industrial Midwest. Forty percent of the Nation's population reside here. The three Lake states--Michigan, Wisconsin, and Minnesota--sell over 3,000,000 sport fishing licenses annually. Only one state, California, has more licensed anglers than any one of these three states. Yet sport fishing license sales have been in a slow decline in Michigan for the past decade. We attribute this decline to a saturation level of fishing pressure on the inland waters coupled with an increase in such competitive use of these waters as fast pleasure boats, waterskiing, and skin diving.

The demand for outdoor recreational opportunity continues to expand. To serve the recreational needs of the nearby heavily populated industrial areas, tourism has grown to a billion dollar industry in Michigan. With this need for extensive high quality recreational opportunity, it is certainly worthwhile to turn to the sport fishing potential on the Great Lakes for a major expansion of the recreational industry.

The Great Lakes comprise by far the largest body of fresh water in the world. These lakes should be a mecca for sport fishermen, but they are not. They have potential, but it is undeveloped. Even the traditional commercial fishery is at the point of economic collapse. Today Michigan probably has less than 100 full time commercial fishermen. Their average wage is substandard.

Through a program which combines the introduction of new sport fish, stream habitat development, extension of the spawning range by fishways, and an expanded program of hatchery culture, we can be reasonably certain that populations of valuable anadromous sport fish can be increased many fold. The supply of forage available in the alewife and other forage fish populations, now so spectacularly abundant in the Great Lakes, provides an almost unlimited potential for the development of a sport fishery. The impact of this fishery will be felt throughout central North America. Marinas and harbors of refuge for pleasure boats are now being built on these waters, but we lack the basic ingredient--an enticing sport fishery--needed to provide the main attraction to stimulate recreational use. The economic rewards, as well as recreational opportunity, are extremely promising.

Associated Programs

International, federal, and inter-agency programs that make vital contributions to the development of a recreational fishery are now in operation on the Great Lakes. As agents for the Great Lakes Fishery Commission, the Bureau of Commercial Fisheries and the Fisheries Research Board of Canada are conducting the sea lamprey control program. This essential activity must continue to assure suitability of the Great Lakes as a habitat for salmonid fishes. Expenditures for this program approach $1,000,000 per year. The Bureau of Sport Fisheries and Wildlife is rearing about 3½ million lake trout annually with eggs from the Michigan Department of Conservation brood stock. The states of Wisconsin and Minnesota and the Province of Ontario also rear considerable numbers of lake trout. Through these joint efforts it is expected that this valuable sport and food fish will be reestablished in the Great Lakes. Surveillance of the lake trout restoration program is being pursued by the Bureau of Commercial Fisheries and the state agencies. Activities are coordinated under the auspices of the Great Lakes Fishery Commission. The Bureau of Sport Fisheries and Wildlife each year provides Michigan with fish for planting. It is recommended that this effort be encouraged to help meet the fish planting requirements in inland waters and the Great Lakes.

Direct Financial Requirements

Implementation of the program will require adequate financial support. It would be most unrealistic to divert funds from the existing management program on inland waters. Thus, the Anadromous Fish Act is of tremendous importance because it can provide funds for this particular program. Obviously, state funds must be available to meet the 50:50 matching provision of the Act. The people of Michigan, who own 49.5 percent of the upper Great Lakes, should assume the leading role. We recommend that Michigan meet at least the minimum financial obligation required to initiate the program, and federal monies will be used to accelerate and broaden it.

It is recommended that to provide minimum necessary support for the Great Lakes Salmon-Steelhead Development Program the sum of $1,000,000 be appropriated for fiscal 1966-67. Such an appropriation would allow initial implementation of the program. When funds become available under the Act, the program will be accelerated and broadened. High priority capital outlay (development) projects amounting to $15,000,000 have been outlined in separate reports. To meet these obligations and utilize federal monies to the maximum degree, an annual appropriation of about $2,000,000 will be required starting with fiscal 1967-68.

REFERENCES CITED

Abramov, V. V. 1949. Adaptive features of the young Pacific salmon belonging to the genus Oncorhynchus. Pacific Salmon. Selected Articles from Soviet Periodicals (Translated by PST staff, 1961). Tech. Ser., U.S. Dept. of Commerce, Wash., D.C.

Anonymous. 1951. Landlocked silver salmon for Montana waters. Prog. Fish.-Cult., Vol. 13, No. 4.

Berg, Leo S. 1948. Freshwater fishes of the U.S.S.R. and adjacent countries. Acad. of Sci. of the U.S.S.R., Vol. I. (Translated by Omry Ronen, 1962). Tech. Ser., U.S. Dept. of Commerce, Wash., D.C.

Briggs, John C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Dept. Fish & Game, Fish. Bull. No. 94.

Burrows, R. E. 1960. Holding ponds for adult salmon. U.S. Fish & Wild. Ser., Spec. Sci. Rept., Fish. No. 357.

Burstall, Pat J. 1966. Personal communication. Dept. of Internal Affairs, Wellington, New Zealand.

Chapman, Donald W. 1965. Personal communication. Univ. Idaho, Moscow.

Donaldson, Lauren R. 1963. Can the stocks of anadromous fish be improved in quantity, and quality by selective breeding?. Rept. of 2nd Gov. Conf. on Pac. Salmon, Washington, p. 102-104.

__________________. 1965. Personal communication. Univ. Washington, Seattle.

Ellis, C. H. 1965. Personal communication. Dept. of Fisheries, Olympia, Washington.

Foerster, R. E. 1935. Inter-specific cross-breeding of Pacific salmon. Trans. Roy. Soc. Can. Series III, 29, Sec. V: 21-33.

Foerster, R. E. and W. E. Ricker. 1953. The coho salmon of Cultus Lake and Sweltzer Creek. J. Fish. Res. Bd. Can., 10: 293-319.

Fujita, Shiro. 1933. On the habitat of masu salmon. J. Rakusui-Kai, 28: 30-32 (in Japanese).

Hoar, W. S. 1954. The behaviour of juvenile Pacific salmon, with particular reference to the sockeye (Oncorhynchus nerka). J. Fish. Res. Bd. Can., 11: 69-97.

Hoar, W. S. 1958. The evolution of migratory behavior among juvenile salmon of the genus Oncorhynchus. J. Fish. Res. Bd. Can., 15: 391-428.

Jeffries, Ernie. 1965. Personal communication. Oregon Fish Comm., Portland.

Jensen, Paul T. 1964. Salmon status reports, 1964. 16th & 17th Annual Reports of the Pacific Marine Fisheries Commission for the years 1963-64.

Jordan, D. S. 1925. Fishes. Appleton and Co., New York, 773 p.

Kruse, Thomas E. 1963. Investigations of supplemental rearing ponds for silver salmon conducted by the Oregon Fish Commission. Rept. of 2nd Gov. Conf. on Pac. Salmon, Seattle, Washington.

Kubik, Stanley W. 1965. Personal communication. Alaska Dept. of Fish and Game, Anchorage.

LeBrasseur, R. J. 1966. Stomach contents of salmon and steelhead trout in the northeastern Pacific Ocean. J. Fish. Res. Bd. Can., 23: 85-100.

MacKay, W. E. 1963. Fishes of Ontario. The Bryant Press Ltd., Toronto, Canada, 300 p.

Maher, F. P. 1964. On the feasibility of introducing kokanee the land-locked sockeye salmon. Section Rept. (Fish.) No. 55, Ontario Dept. Lands & Forests.

McRea, Alex H. 1965. Personal communication. Alaska Dept. of Fish and Game, Juneau.

Milne, D. J. 1948. The growth, morphology and relationship of the species of Pacific salmon and the steelhead trout. MS. Ph.D. thesis, McGill Univ., Montreal, Canada.

__________. 1957. Recent British Columbia spring and coho salmon tagging experiments, and a comparison with those conducted from 1925 to 1930. Fish. Res. Bd. Can., Bull. 113.

Neave, Ferris. 1957. Stream ecology and production of anadromous fish. Studies from the Stations of the Fish. Res. Bd. of Can., No. 511, p. 43-48.

__________. 1958. The origin and speciation of Oncorhynchus. Studies from the Stations of the Fish. Res. Bd. of Can., No. 551, p. 25-39.

Needham, P. R. 1938. Trout streams. Comstock Publ. Co., Ithaca, New York.

Ontario Dept. of Lands and Forests. 1965. Plant million kokanee swim-up fry this spring--the landlocked sockeye salmon story. Ont. Dept. of Lands & Forests News Release, Vol. 18, No. 11, p. 2-8.

Regan, C. Tate. 1920. The geographical distribution of salmon and trout. Salmon and Trout Mag., 22: 25-35.

Reid, Gerald M. 1961. Stomach content analysis of troll-caught king and coho salmon, southeastern Alaska, 1957-58. U.S. Fish. and Wild. Ser., Spe. Sci. Rept. No. 379.

Ricker, W. E. 1938. "Residual" and kokanee salmon in Cultus Lake. J. Fish. Res. Bd. Can., 4: 192-218.

___________. 1940. On the origin of kokanee, a fresh-water type of sockeye salmon. Trans. Roy. Soc. Can. Series III, 34, Sec. V: 121-35.

___________. 1954. Pacific salmon for Atlantic waters?. Canadian Fish. Cult., No. 16, p. 1-8.

Robertson, O. H. 1948. The occurrence of increased activity of the thyroid gland in rainbow trout at the time of transformation from par to silvery smolt. Physiological Zoology, Vol. XXI, No. 3, p. 281-295.

Rounsefell, G. A. 1958. Anadromy in north American salmonidae. Fish. Bull., U.S. Fish. & Wild. Ser., 131: 171-185.

Saguri, Misao. 1936. Ecology of masu salmon. J. Fish. Cult. Ass. of Japan, 6 (2): 35-40 (in Japanese).

Schoning, Robert W. 1964. Personal communication. Oregon Fish Comm., Portland.

Shapovalov, Leo and Alan C. Taft. 1954. The life histories of the steelhead rainbow (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch). Calif. Dept. Fish. & Game, Fish. Bull. No. 98.

Stefanich, Frank. 1965. Personal communication. Alaska Dept. of Fish and Game, Anchorage.

Synkova, A. I. 1951. Food of Pacific salmon in Kamchatka waters. Pacific Salmon. Selected Articles from Soviet Periodicals (Translated by PST staff, 1961). Tech. Ser., U.S. Dept. of Commerce, Wash., D.C.

Tanaka, S. 1963. Salmon of the North Pacific Ocean. Part IX. A review of the biological information on masu salmon (Oncorhynchus masu). Tokai Reg. Fish. Res. Lab., Fish. Agency, Tokyo. International N. Pac. Fish. Comm. Doc. 616.

Tchernavin, V. 1939. The origin of salmon. Salmon and Trout Mag., 95: 1-21.

Trautman, M. B. 1935a. The attempted introduction of Pacific salmon in Lake Erie waters. Mich. Dept. Cons., Inst. Fish. Res. Rept. No. 298, 4 p.

______________. 1935b. The recent capture of a king salmon (Oncorhynchus tshawytscha) in Lake Erie. Mich. Dept. Cons., Inst. Fish. Res. Rept. No. 297, 2 p.

Tsuyuki, H. and E. Roberts. 1966. Inter-species relationships within the genus Oncorhynchus based on biochemical systematics. J. Fish. Res. Bd. of Can., 23: 101-107.

West, Delbert A. 1965. Freshwater silver salmon, Oncorhynchus kisutch (Walbaum). Calif. Dept. Fish. & Game, 51: 210-212.

Whitney, Arthur. 1965. Personal communication. Montana Dept. of Fish and Game, Helena.

Wickett, W. P. 1965. Personal communication. Fish. Res. Bd. of Can., Nanaimo, British Columbia.

APPENDIX

Names of fishes cited in the text[1]

Common name	Scientific name
Sea lamprey	*Petromyzon marinus* Linnaeus
Alewife	*Alosa pseudoharengus* (Wilson)
Pacific (ocean) herring	*Clupea harengus* Valenciennes
Lake trout	*Salvelinus namaycush* (Walbaum)
Brook trout	*Salvelinus fontinalis* (Mitchell)
Atlantic salmon	*Salmo salar* Linnaeus
Brown trout	*Salmo trutta* Linnaeus
Rainbow or Steelhead trout	*Salmo gairdneri* Richardson
Masu salmon	*Oncorhynchus masu* (Brevoort)[2]
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)
Sockeye or Kokanee salmon	*Oncorhynchus nerka* (Walbaum)
Chum salmon	*Oncorhynchus keta* (Walbaum)
Pink salmon	*Oncorhynchus gorbuscha* (Walbaum)
Lake herring	*Coregonus artedii* (LeSuer)
Ciscoes (chubs)	*Coregonus* sp. (LeSuer)
Smelt	*Osmerus mordax* (Mitchell)
Northern pike	*Esox lucius* Linnaeus
Carp	*Cyprinus carpio* Linnaeus
(Lake) Emerald shiner	*Notropis atherinoides* Rafinesque

[1]cf. American Fisheries Society, 1960. A list of common and scientific names of fishes from the United States and Canada. 2nd Ed. Spec. Publ. No. 2, Am. Fisheries Soc., 102 p.

[2]Cited from Berg, 1948. See REFERENCES CITED.

Common name	Scientific name
Burbot	_Lota lota_ (Linnaeus)
Striped bass	_Roccus saxatilis_ (Walbaum)
Smallmouth bass	_Micropterus dolomieui_ Lacepede
Walleye	_Stizostedion vitreum vitreum_ (Mitchell)
Black rockfish	_Sebastodes melanops_ (Girard)
Lingcod	_Ophiodon elongatus_ Girard
Sculpin	_Cottus_ sp.
Starry flounder	_Platichthys stellatus_ (Pallas)
Sand sole	_Pseltichthys melanostictus_ Girard