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A REVIEW OF LITERATURE ON LAKE TROUT LIFE HISTORY WITH NOTES ON ALASKAN MANAGEMENT

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A REVIEW OF LITERATURE ON LAKE TROUT LIFE HISTORY WITH NOTES ON ALASKAN MANAGEMENT

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ABSTRACT

The lake trout, *Salvelinus namaycush* (Walbaum), is the largest of the chars and is distinguished from other chars by having more than 100 pyloric caeca. It is restricted to North America and chiefly inhabits oligotrophic lakes of Alaska, Canada, and the northern United States.

Food availability rather than preference usually determines the diet of lake trout. If forage fish are available, older lake trout are piscivorous while younger fish are chiefly dependent upon invertebrates. The opposum shrimp, *Mysis relicta*, is important to the diet of young lake trout in many lakes.

Spawning occurs over rocky shoals in the fall when water temperatures cool to 12° C or lower. The eggs typically hatch in 135 to 145 days. The fry move to deeper water after hatching and reside in rock crevices during their juvenile development. Growth rates and age at maturity are correlated to latitude, with northern populations growing slower and maturing later than southern populations.

Most states manage their lake trout populations for recreation. However, limited commercial lake trout fisheries exist in Canada and attempts have been made to establish similar commercial fisheries in Alaska.

TAXONOMY AND DESCRIPTION

The lake trout is the largest of the North American chars and has been classified by some ichthyologists as the only species of the genus

Cristivomer, with all remaining chars divided into the sub-genera Baione and Salvelinus. David Starr Jordan (1925) used this classification because the lake trout differs from other chars by having a crested vomer behind the chevron, which is free of the shaft. However, the current practice is to place all chars in the common genus Salvelinus.

The lake trout has the overall body form typical of the family Salmonidae. No spines are present in any fins. The anal and dorsal fins typically have from 11 to 13 rays and an adipose fin is present. The caudal fin is deeply forked. The general color pattern is composed of small, light spots on a silvery to dark gray background. The back and upper sides have faint vermiculations and the lower fins may have a light stripe along the anterior margin. The background color varies extensively depending upon the locale of the individual.

Extreme variation in spawning coloration has also been reported. Royce (1943) stated that color variation between the sexes of non-spawning lake trout was very slight. However, when sexually aroused, the males underwent a very striking color change. He stated that the chromatophores on the back contracted so that the back became very light colored while the sides were flooded with pigment, becoming lustrous, almost black. Vladykov (1954) reported that even during spawning, the colors of the sexes differed very little. Daly, et al. (1965) reported that at spawning time, males displayed a prominent black stripe along the sides. Other forms of sexual dimorphism, either permanent or seasonal, appear to be largely absent except that the snout of the male tends to be slightly longer than that of the female.

The lake trout can be distinguished from other chars by body coloration, the deeply forked caudal fin, and a larger number of pyloric caeca. Although some individual variation in number of pyloric caeca exists, Vladykov (1954) stated that lake trout averaged 138 pyloric caeca with the other chars averaging less than 50.

Popular names for the lake trout include gray trout, Great Lakes trout, mackinaw, togue and laker.

GEOGRAPHICAL DISTRIBUTION

The lake trout is restricted to the northern portion of North America with the southern boundary of its natural range approximating a line extending from the Columbia River to New York City (Royce, 1943).

Lindsey (1964) discussed the geographical distribution of lake trout at some length. He stated that within Alaska, lake trout are present north of the Brooks Range but not in lakes of the north slope lowlands. To the west, lake trout are present in the Kobuk drainage but not within 400 miles of the Bering strait. Lake trout are common in Bristol Bay drainages and in Pacific drainages south of Cook Inlet. This species is not found at lower elevations of the Yukon or Kuskokwim basins.

Lindsey further stated that although lake trout are present throughout almost all of Canada, they are not present in Newfoundland. Lake trout have been able to cross narrow sea channels and have established populations on various sea islands in the Canadian Arctic.

Lake trout apparently did not cross the Bering ice bridge into Siberia during the Pleistocene glaciation.

In recent years, the range of the lake trout has been extended by artificial stocking in such states as California, Nevada, and Colorado.

Most lake trout complete their life cycles in cold, deep lakes. This requirement for cold water has undoubtedly restricted the migration of this species into many otherwise suitable lakes within its geographic range.

Experiments with one and two-year-old hatchery stock by Gibson and Fry (1953) demonstrated the lake trout's inability to tolerate warm water. In these experiments the lethal maximum temperature was 23.5° C. However, fish of older age classes, under natural conditions, might be able to adapt better to gradually warming temperatures.

NATURAL FOODS AND FEEDING HABITS

It is difficult to make any conclusive statements concerning the food of lake trout. Since this species principally inhabits the hypolimnion of deep, cold lakes where the concentration of food is relatively sparse, food availability may determine the diet, rather than selectivity toward any specific organism.

The diet of lake trout undergoes seasonal variation. In general, the variety of food items decreases when a lake undergoes thermal stratification in the spring. Since lake trout are found beneath the thermocline, forage fish may move into the epilomnion and be effectively separated from the lake trout by a thermal barrier. Martin (1952) reported that in the Algonquin lakes, variety of ingested food organisms was greatest in the spring due to the utilization of insects. He mentioned seeing lake trout surface feeding on March Flies during the spring. However, during the summer months the lake trout feed almost exclusively on plankton. Plankton feeding appears to be uncommon in most populations, however. Fall feeding is usually quite varied because the lake trout move into the more productive littoral zones to spawn. Since they feed throughout the spawning period, fish, crustacea and insects are all commonly utilized.

The lake trout diet is affected to a large degree by the size of the individual. In general, larger fish tend to be piscivorous, while younger individuals utilize invertebrates and very small fish. Van Oosten (1944) stated that in Lake Michigan, lake trout over 18 inches seldom consumed invertebrates, preying mainly on lake herring and ciscoes. The smaller lake trout primarily utilize invertebrates, sculpins, shiners and sticklebacks. In Lac la Ronge, Rawson (1961) found that fish made up 90 percent of food occurrences in stomachs of mature lake trout while invertebrates comprised the remaining 10 percent. Invertebrates, measured volumetrically, comprised less than 2 percent of mature lake trout diet in Lac la Ronge. Dryer, et al. (1965) reported that fish made up 96.7 to 99.9 percent of the total food volume of Great Lakes lake trout. In contrast, Miller and Kennedy (1948) reported that in Great Bear Lake, fish occurred less than half as often as other food items regardless of the size of the lake trout, and fish occurred in the stomachs of small lake trout as often as in larger individuals. They also reported that the rate of occurrence of terrestrial insects increased in the larger individuals. Several researchers have noted the high frequency of empty stomachs, ranging from 40 to 80 percent, depending upon season and locale (Miller and Kennedy, 1948; Martin, 1952; Rawson, 1961).

Numerous authors have reported the importance of the oppossum shrimp, Mysis relicta, to the diet of immature lake trout (Eschmeyer, 1956; Webster, et al., 1959; Daly, et al., 1965; Dryer, et al., 1965). Dependence upon Mysis apparently decreases after the young fish reach a length of 12 to 14 inches.

During lake surveys along the Denali Highway in central Alaska, the author has noted that in lakes containing lake trout and whitefish the majority of ingested food was fish. In such lakes, lake trout in excess of 10 pounds could commonly be captured in gill nets.

In lakes containing only lake trout, the most common food item was freshwater clams of the family Sphaeriidae. In such lakes, lake trout larger than 20 inches were rare.

Many tundra voles were also found in lake trout stomachs in the Denali area. These rodents were utilized more extensively in lakes where a forage fish was not available. As many as four voles were removed from a single lake trout stomach.

Martin (1966) compared lake trout populations from Algonquin Park lakes in which some populations had access to forage fishes while other populations were dependent upon plankton for the majority of their food. He reported that in lakes where lake trout depended upon plankton, they grew slower, matured at a smaller size and younger age, and had a shorter life span. Yields of lake trout in terms of numbers per acre were greater in plankton-dependent populations than in fish-eating populations, but yield in pounds per acre was approximately equal in both instances.

In general, the lake trout is a versatile feeder. Forage fish are preferred food items. However, during the seasons and in the locations where forage fish are scarce, lake trout are able to satisfy their food requirements by utilizing invertebrates.

REPRODUCTION

Lake trout are fall spawners with the spawning time varying widely in different lakes. Spawning time is generally conceded to be correlated to a cooling of water temperature to 12° C or lower over the spawning beds. Therefore, populations residing in far northern lakes tend to spawn at earlier dates than do southern populations. Miller and Kennedy (1948) noted a general movement to the spawning beds in Great Bear Lake as early as August 14. However, most populations farther south spawn in October, with some isolated populations still spawning in early December. It has not yet been determined to what extent light, fall overturn, and water temperature affect the time of spawning. Water temperature certainly is a major factor and many observers have reported the commencement of spawning activities when water temperatures ranged from 10° C to 12° C. There is some evidence to indicate that in some populations photoperiodism may be significant in determining spawning time. Rawson (1961) reported that Lac la Ronge fish appeared to spawn each year during the first week in October. He made no specific statement regarding water temperature, other than to mention that the temperature was in the range usually associated with lake trout spawning and that the fall overturn commenced a month prior to spawning. Royce (1943) believed that in New York lakes the effect of fall overturn was more important than specific water temperatures over the beds. He observed lake trout spawning at water temperature ranging from 6^{o} C to 14.5^{o} C. However, spawning never commenced prior to the fall overturn. Royce speculated that a narrow range of temperature was more important than the specific temperature over the bed and that spawning lake trout would not rise through a thermocline.

Spawning is conducted over rocky shoals or rubble bottom. Broken rock from one to six inches in diameter is preferred. No parental care is given to eggs other than a careful selection of spawning sites. Eggs are randomly broadcast over the bottom and settle into cracks and crevices between rocks. Areas which tend to accumulate heavy bottom sediments are thus rendered useless for lake trout spawning sites. Royce (1943) discovered a correlation between spawning areas and subsurface currents that tended to keep spawning areas clear of mud and debris.

Spawning depths vary widely. Royce (1943) recovered eggs from Otsego Lake, New York, in three inches of water and made no mention of any unusual lowering of water levels. Martin (1956) also mentioned spawning activities in six inches of water in Algonquin Park lakes. In contrast, Royce (1943) discovered spawning in depths of approximately 200 feet in Seneca Lake, New York. In an experimental spawn-taking project in Susitna Lake, Alaska, in which the author participated, spawning activity was concentrated at depths of from 4 to 12 feet.

Both Royce (1943) and Rawson (1961) noted that males precede the females onto the spawning beds with a maximum number of individuals present during the evening hours. The males brushed against the bottom with their fins and snouts to clean sediment from the spawning areas. Royce (1943) and Martin (1956) described the courtship and spawning behavior as follows: A male pursued a female and gently butted her sides with his snout. Occasionally, the male zig-zagged under the female, brushing his dorsal fin against her vent area. At this time the characteristic spawning colors of the male were quite visible. The males courted any female within range. The actual spawning act occurred when one or two males pressed themselves against the sides of a female. Characteristically, the mouth was held open, the dorsal fin was held erect, and associated with body quivering. Royce (1943) surmised that quivering aided the passage of sexual products toward the vent and he also noted that as many as seven males and three females were sometimes pressed together during the spawning act.

Duration of spawning activity varies widely in different lakes. In small, shallow lakes, the spawning period tends to be completed in as few as seven days (Royce, 1943; Rawson, 1961). However, spawning periods of a month or longer occur in large bodies of water, such as the Great Lakes. This variance in spawning time could possibly be accounted for by the presence of semi-isolated races containing genetic differences, within a single lake, or variations of limnological conditions in different parts of the lake. Martin (1956) believed that spawning activities could also be prolonged by bright, calm, warm weather and conversely shortened by a sudden drop in water temperature.

Information is inadequate on egg capacity of mature female lake trout. Van Oosten (1944) stated that in Lake Michigan an average spawner contained 6,000 eggs and had a ratio of 750 eggs per pound of body weight. Since the Great Lakes are intensively exploited, an unfished population with a higher ratio of older and larger spawners should have a significantly larger average number of eggs per mature fish.

Several studies have indicated that in more northern lakes, not all mature female lake trout spawn each fall. Kennedy (1954) found that female lake trout in Great Slave Lake could readily be divided into two groups. One group contained large eggs, approximately as large as spawned eggs, with the second group having only partially developed eggs. This second group frequently contained traces of mature eggs retained from a previous spawning. These two groups were approximately equal in numbers, indicating biennial spawning. This trend was found to be even more extreme in Great Bear Lake, with the ripe spawners in a ratio of 1:2 to fish with undeveloped gonads (Miller and Kennedy, 1948), indicating spawning every third year. This 1:2 ratio condition was noted in interior Alaska during a lake trout transplanting program. Lake trout which were injured during handling were examined and many were found with unripe gonads. However, the sample was too small to formulate a valid ratio of unripe to ripe females (Metsker, 1963).

Some researchers have noted a predominance of males in the spawning areas, but these findings may have been biased by sampling early in the spawning period before the females arrived over the beds. Notable exceptions were a Great Slave Lake study where a sample of 409 spawners consisted of 207 males and 205 females (Kennedy, 1954) and in the Waterton Lakes, Canada where Cuerrier and Schultz (1957) found females outnumbering males 123 to 113 in a sample of sexually mature fish. Valid information on the sex ratios of spawning lake trout needs further controlled studies.

Royce (1943) concluded that fertilization of eggs was quite efficient. In Otsego Lake, New York, a sample of 309 eggs collected approximately one month after spawning revealed only 5.8 percent non-fertile, 15.2 percent dead (after fertilization), and 79 percent living. Royce (1943) believed this to be maximum mortality under normal conditions because the eggs were collected in shallow water and had been exposed to heavy wave action.

Martin (1956) mounted pails and screens in numerous spawning areas in several Algonquin Park lakes to determine distribution and density of spawned eggs. In Shirley Lake, 16 to 20 sunken pails contained from 4 to 276 eggs. This indicated considerable variation in distribution of spawn. The average for all tested lakes was 50 eggs per square foot. This average compared favorably with an average of 20 to 50 eggs per square foot in New York lakes (Royce, 1951).

Although river spawning lake trout are rare, Loftus (1957) investigated several discrete river spawning populations in eastern Lake Superior. These fish matured at approximately seven years, and during the spawning season made nightly migrations into inlet streams. The peak of spawning occurred about the first of October. Repeated captures of tagged fish over several seasons indicated that fish returned to a parent stream.

HATCHING AND JUVENILE DEVELOPMENT

The incubation period for lake trout varies considerably, depending on water temperature. Royce (1951) reported average incubation time to be 140 days, in New York state lakes, with water temperature near 37° F. In the Algonquin lakes, Martin (1956) has recorded incubation periods of 105 to 147 days but water temperatures were not reported. Hacker (1956) estimated incubation time to be about 175 days in Green Lake, Wisconsin. Royce (1951) stated that excessive mortality of lake trout eggs resulted in New York hatcheries when water temperature exceeded 50° F. At 32.5° F, the eggs hatched at a slower rate, but with a low rate of mortality thus indicating that spring warming is not required for hatching and, unless frozen, eggs should remain viable at low temperatures.

Royce (1951) studied natural incubation in Otsego Lake, New York and noted spawning on December 5. He later dredged eyed eggs from these beds on February 17 and March 31, but only fry were captured in the dredge on April 27. On May 17, more advanced fry were dredged but on June 2, all fry had deserted the beds. Subsequent extensive sampling with fine-mesh gill nets at various depths failed to capture a single fry or individual of age-group-I. Several individuals of age-group-II were taken in 40 to 70 feet of water over a rocky bottom. Evidently, for several years the habitat of juvenile lake trout may be restricted to rocky areas which can afford protection from biological sampling and predators. Martin (1956) failed to capture fry in the Algonquin lakes because the movement of the fry from the spawning beds coincided with breakup of the ice.

An entirely different behavior pattern was discovered by Miller and Kennedy (1948) in Great Bear Lake. They reported that fry had hatched by June 22. The fish were observed in large numbers along the rocky shores where they lived in crevices among the rocks in only a few inches of water. The fry seemed to seek the warmest water. Living with the fry, but in a little deeper water, were individuals from age-groups I, II, and III. No individuals of age-group IV were seen. This tendency of fry to inhabit warm surface water is probably a local adaptation to stimulate growth and thus aid juvenile survival in this rigorous environment.

Little is known about the ecology of the younger age classes of lake trout. Apparently, when large enough to avoid serious predation, the young fish begin the solitary wandering which, except for spawning periods, continues throughout life.

GROWTH, MATURITY AND LONGEVITY

The lake trout is a slow growing and slow maturing species. Present knowledge is somewhat limited on younger age classes because relatively few individuals from age-groups I through IV have been captured. However, it is known that considerable variation exists in growth rate and age of maturation. This variance is apparently closely correlated with temperatures; the more northern populations grow and mature slower. Table 1 compares lake trout growth rates from various bodies of water.

Most researchers have noted extreme variation in individual growth rates. Rawson (1961) discovered individuals of age-group II ranging from 7.7 to 13.2 inches in Lac la Ronge. Van Oosten (1944) attributed growth variation within a lake to the tendency of lake trout to travel and feed alone, resulting in some individuals being more fortunate in finding adequate food.

The world record lake trout is a 50-inch, 102 pound male taken in a commercial gill net at Lake Athabasca, Canada.

Van Oosten (1944) reported that Lake Michigan lake trout mature at age seven or slightly later with an average weight of approximately three pounds. Rawson (1961) reported similar figures for Lac la Ronge. Kennedy

Table 1. Comparative lake trout growth rates from various lakes.

Water and Reference	Year of Life 1	2	3	4	6	8	10	20	Type of Length Measurement in inches
Cayuga Lake, New York Webster et al., 1960	6.0	8.9	12.1	17.4	23.1	26.0			Fork length at collection*
Lake Michigan Van Oosten & Eschmeyer, 1956		8.8	11.0	12.2	17.0	18.5	27.2		Fork length at collection*
Lac la Ronge, Saskatchewan Rawson & Atton, 1953		9.0		13.0	17.0	20.5	23.2	36.0	Fork length at collection*
Upper Waterton Lake, Alberta Cuerrier & Schultz, 1957			9.9	12.9	16.7	21.8	32.5		Not stated
Lower Waterton Lake, Alberta Cuerrier & Schultz, 1957				16.4	20.8	25.6	32.2		Not stated
Great Bear Lake, N.W.T. Miller & Kennedy, 1948	2.5	3.9	5.3	7.1		12.6	14.6	24.6	Fork length at collection*
Cold Stream Pond, Maine DeRoche & Bond, 1955				16.6	19.2	22.7			Fork length at collection*

* May include growth from current growing season.

(1954) reported a slightly slower growth rate for Great Slave Lake. The youngest individuals in Great Slave Lake matured at age seven, with an average weight of 2.4 pounds and all fish were mature by age 11. He also reported, from the position of the outermost annulus, that seasonal growth commenced in late June and stopped in September. Throughout the remainder of the year no growth was noted and a slight decrease in size was possible during the winter.

The growth rate and maturation age of lake trout in Great Bear Lake is substantially slower (Miller and Kennedy, 1948). They reported that the youngest individuals matured at age 13 and all fish were mature by age 17. Average weight at age 7 was 14 ounces. It should be noted that age determinations from Great Slave and Great Bear Lakes may contain significant error. Miller and Kennedy (1948) reported great difficulty in interpreting age from scales of Great Bear Lake trout. Later they were assisted by Rawson and this group evaluated annuli through age 23 and with some uncertainty, through age 37. They also examined individuals which were slightly over three inches long, weighing only one ounce, and concluded that this size fish represented age-group-III.

Maximum age of lake trout is unknown. Miller and Kennedy (1948) found individuals in Great Bear Lake which they believed to be nearly 40 years old. Taub (1963) reported that a marked (fin clipped) lake trout was recovered from East Twin Lake, Connecticut 21 years after tagging.

Daly et al (1965) reported that two lake trout held at a hatchery attained ages of 24 and 28 years.

PREDATORS

With the exception of the sea lamprey in the Great Lakes, most predation upon lake trout is directed against eggs during the incubation period. Royce (1943) observed and collected individuals of numerous species that were feeding on lake trout spawn in New York lakes. He concluded that such predation was negligible since only eggs which failed to roll into rock crevices were being eaten. Lake trout are also known to feed upon their own spawn to some extent.

Some predation is sustained by juveniles during their first four years while they are still too small to leave the protection of the rocky bottom. Ling cod, (Lota lota) and pike, (Esox lucius) apparently prey to some extent on juvenile lake trout. However, during much of the year, temperature barriers may effectively seal off the immature lake trout from carnivorous species, other than older lake trout.

In the Great Lakes, older lake trout are preyed on extensively by sea lamprey. The lamprey attaches itself to the sides of the fish and ingests body fluids of the host. In recent years, this predator has been blamed for the rapid decline of the commercial lake trout fishery in the Great Lakes.

DEPTH DISTRIBUTION, MOVEMENTS AND MIGRATIONS

The maximum depth that lake trout can tolerate is unknown. Van Oosten (1944) reported that lake trout have been netted in the Great Lakes in 750 feet of water and Miller and Kennedy (1948) reported no decrease in the density of lake trout at 400-foot depths in Great Bear Lake. Rawson (1961) found that in Lac la Ronge, lake trout were caught in nearly equal numbers at all depths during the spring but when the lake became thermally stratified, the lake trout were compressed below the 10° C isotherm. Cuerrier and Schultz (1957) found that lake trout netted at a depth of 100 meters in the Waterton Lakes, Alberta, were markedly different from fish netted in shallower water. They believed a "deep water type" of lake trout, which has adapted to living at greater depths, exists in these lakes. Galligan (1962) found during the summer months in Cayuga Lake, New York, that lake trout of all sizes were found predominantly between depths 40 and 100 feet, with the greatest density of fish between 80 and 100 feet. Increased surface temperatures caused lake trout to move deeper. Galligan found no correlation between depth and size of fish, while Martin (1952) reported that in Algonquin Park lakes smaller lake trout were distributed deeper than larger fish.

Galligan (1962) also found that lake trout in Cayuga Lake moved into shallower water for about two weeks in July, apparently to feed on spawning alewives (*Alosa pseudoharengus*). At this time maximum numbers of lake trout were found in water exceeding 16° C. This behavior is apparently very unusual as most researchers seldom found lake trout above a 12° C isotherm.

The literature varies widely regarding the movement of lake trout in various lakes. Eschmeyer (1964) reported that in Lake Superior one tagged individual was recovered 300 miles from the tagging site and another lake trout moved 190 miles in 19 days. He reported similar data from Lake Michigan and also noted that large fish tended to move farther than small fish. However, numerous studies with tagged lake trout have revealed that most fish tend to remain in one general area. Longer migrations can generally be correlated with a greater time interval between tagging and recapture. Buettner (1961) reported that in Lake Superior none of the 309 tagged lake trout recovered within three months had traveled more than 75 miles and that 306 were recovered within 25 miles. The mean distance traveled was nine miles and after two years' liberty the mean distance traveled had increased to only 40 miles. Keleher (1963) found that in Great Slave Lake, Canada, 65 percent of 221 recoveries of tagged lake trout occurred within 10 miles of the tagging site despite a mean time between tagging and recapture of 471 days. Pycha et al (1965) compared lake trout movement and surface water currents in Lake Superior and concluded that water currents caused a directional movement of lake trout in that lake. In smaller, shallower lakes, a directional movement may be induced by the lake trout seeking deep, cool water basins during summer months (Rawson and Atton, 1953; McCrimmon, 1958). Miller and Kennedy (1948) assumed that movement of lake trout in Great Bear Lake was quite restricted after they computed the frequency of infestation of the tape worm, Triaenophorus crassus, at various locations in the lake. At one location, 25 fish were examined and 16, or 64 percent were infected. At a site eight miles away, eight fish were checked and none were infected. On the basis of this and similar studies they concluded that lake trout populations in Great Bear Lake did not intermingle; rather, they spent entire lives in their natal bays.

Eschmeyer, et al (1953) concluded that mature lake trout in Lake Superior displayed a homing tendency to the same general area each spawning season. McCrimmon (1958) found no evidence of homing behavior in lake Simcoe, Ontario.

UTILIZATION AND MANAGEMENT

For many years, lake trout supported extensive commercial fisheries in the Great Lakes and small commercial fisheries in some Canadian lakes.

Since the middle of the 19th century, the Great Lakes have annually produced millions of pounds of commercially caught lake trout. However, in recent years the fisheries have collapsed due to a drastic reduction of the lake trout stocks of these lakes. This collapse has been attributed to the accidental introduction of the sea lamprey. The first effects were felt in Lake Huron and, subsequently, the Lake Michigan and Lake Superior fisheries collapsed. In Lake Michigan, from 1927 to 1944 the commercial lake trout catch averaged 5,651,000 pounds. During 1945 the first effects of lamprey predation became evident and the annual catch decreased sharply. By 1949, the catch had dropped to 342,000 pounds, a reduction of 94.7 percent in five years (Hile et al, 1951). By 1954 the annual catch of lake trout in Lake Michigan totaled less than 1,000 pounds (Power, 1960). Lake Superior has undergone a similar reduction in lake trout catch. An extensive eradication program was undertaken to reduce the lamprey population in Lake Superior. The results to date are not conclusive but are highly encouraging.

A limited commercial fishery is now established in Great Slave Lake (Kennedy, 1954). Lake trout in Lac la Ronge are taken incidental to the whitefish fishery, but the annual catch is quite small (Rawson, 1961). Commercial whitefish-lake trout fisheries have been attempted in the Bristol Bay region of Alaska.

In addition to its value as a commercial species, lake trout are utilized extensively in sport fisheries. Most northern states now manage their lake trout populations solely for recreation. Demand by sportsmen for lake trout is increasing rapidly, due to its trophy size.

Fishing for lake trout through the ice is particularly popular. At Trout Lake in Minnesota winter anglers were found to be twice as effective and harvest five times as many lake trout as the summer angler. (Shumacher, 1961).

Spring and summer lake trout fisheries typically show peak catches in the spring when surface waters are still cool. As the surface waters warm, lake trout move deeper and catches decline. In areas where lake trout are intensively fished, anglers use special weighted or monel lines to troll lures at extreme depths. This method can significantly increase the sports catch of lake trout during the summer months. However, in Alaska most anglers are either not aware of the need, or do not care to invest in the heavy tackle required to consistently catch lake trout during the warm weather months. Consequently, Alaskan lake trout fisheries show a modest harvest during the spring and late fall with sharply reduced angling effort and catches during July and August.

Most management programs are aimed at regulating the harvest of self-sustaining natural populations. The majority of lake trout studies have been conducted chiefly to enable governmental agencies to formulate harvest regulations which will allow the largest yield possible while maintaining adequate spawning stock.

In specific instances planting programs have been initiated. These planting programs may be divided into:

(1) Introduction of lake trout to establish self-sustaining populations where suitable habitat already exists. Typical examples are Tahoe Lake, California and Harding Lake, Alaska.

(2) Rebuilding of depleted wild stocks. The outstanding example of this type of program is the planting program conducted in Lake Michigan to rejuvinate the lake trout stock decimated by the sea lamprey (Fry and Budd, 1958; Eschmeyer, 1964; Daly et al, 1965; Pycha et al, 1965).

(3) Planting in lakes where natural egg survival is low. An ideal example is Cayuga Lake, New York where natural spawning has not been adequate to maintain a successful fishery for at least the last half-century (Webster et al, 1959). In Cayuga Lake the lake trout population size can be adjusted by changes in the stocking rate. This lake is unusual in that it is probably the only major "put and take" lake trout fishery in existence.

Lake trout for stocking are obtained either from spawn from wild stock or from hatchery brood stock. Most states faced with a future of constant lake trout plants now maintain their own brood stocks. Most stocking is done with yearlings because experimental planting has shown that fish 16 to 18 months old yield the highest survival consistent with rearing costs (Eschmeyer, 1964; Pycha et al, 1965).

In a few cases attempts have been made to increase lake trout reproductive success or survival by habitat improvement. The opposum shrimp *Mysis* has been introduced into numerous lakes such as Tahoe Lake, California (Linn and Frantz, 1965) and Grindstone Lake, Minnesota (Schumacher, 1966). Artificial rubble spawning beds have been placed in Green Lake, Wisconsin (Hacker, 1956) and Lake Massawippi, Quebec (Prevost, 1956).

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