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The Mountain Whitefish: a Literature Review

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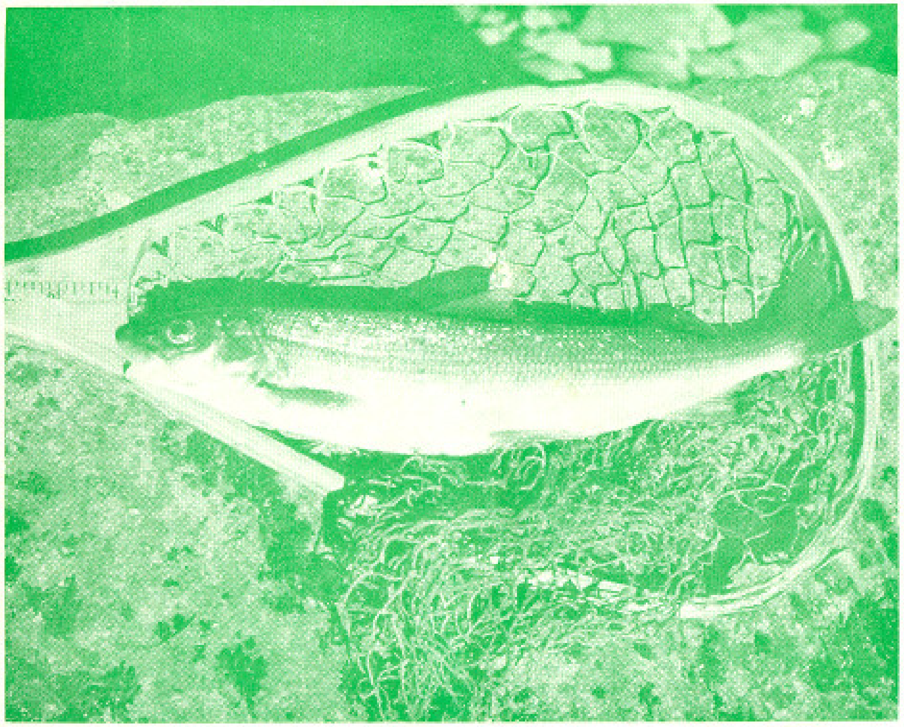

Fig. 1. Mountain Whitefish. PROSOPIUM WILLIAMSONI (Girard)

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Abstract

Mountain whitefish belong to the subfamily Coregoninae of the family Salmonidae. They inhabit coldwater lakes and streams of the western United States and Canada. They feed primarily on aquatic insect larvae, and diet varies seasonally and with age. Mountain whitefish reach a maximum size of 22 inches and 6 lbs., and a maximum age of 18 years. Age and growth depend upon productivity of the environment. Mountain whitefish spawn in streams and lakes from October through December, and females produce 5,300 to 6,900 eggs per pound of fish. Mountain whitefish may compete with associated species for food and they prey on eggs of other species. A variety of parasites infect them. Whitefish have a potential for increased sport and commercial use.

Introduction

Workers have made detailed investigations of the taxonomy, distribution, food habits, and age and growth of the mountain whitefish, **Prosopium williamsoni.** They have neglected other aspects of its life history such as reproduction, early development, interspecific relationships and behavior. In this paper I consolidated information which pertains to mountain whitefish.

Description

The mountain whitefish **(Prosopium williamsoni)** has a trout-like appearance, but the large scales, weak teeth, and small mouth of mountain whitefish distinguish the fish from trout and salmon (McAfee, 1966). It occurs in coldwater lakes and streams of the western United States and Canada, and may have the local common names of Rocky Mountain whitefish and grayling (Carl, Clemens and Lindsey, 1967).

The mountain whitefish belongs to the family Salmonidae (Carl et al, 1967 and Norden, 1961). Girard first described the species in 1856 from the Deschutes River in Oregon. The subfamily Coregoninae includes the mountain whitefish and other whitefish species and separates them from the trouts and salmons. Members of Coregoninae differ from other Salmonids by the presence of a well-ossified hypethmoid bone and a lack of teeth on the maxillae at any stage in life (Norden, 1961). The genera **Prosopium, Coregonus,** and **Stenodus** comprise the subfamily Coregoninae. **Prosopium** differs from the other two genera by having a single flap of flesh between nostrils (two in **Coregonus** and **Stenodus),** an ossified basibranchial plate superimposed over the median basibranchial bones, and parr marks on the juveniles. **Prosopium** includes six species: **cylindraceum, williamsoni, spilonotus, abyssicola, coulteri,** and **gemmiferum.** Of these

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P. cylindraceum inhabits eastern Asia and northern North America. The others all live in western North America and **P. coulteri** also occurs in Lake Superior (Norden, 1961). **P. williamsoni** was judged to be the least modified and to possess characteristics intermediate in the genus (Norden, 1970).

The following characteristics distinguish **P. williamsoni** from other species: body troutlike; length up to about one foot, occasionally to 22 inches and 4 lbs.; mouth small with no teeth; snout long, pointed, and upturned in some individuals; gill rakers 20 to 26, short and thick; scales in 74 to 90 oblique rows; peduncle narrow, with 20 to 23 horizontal scale rows crossing a line around its narrowest part; dorsal fin with 11 to 14 rays; anal fin with 10 to 13 rays; adipose fine very large, its base more than 1½ times the eye diameter (except in very young fish); general color silvery, sometimes with a dark-bronze back; no spots on the adipose; no dark spots on the head (or, rarely, a very few); young, up to about 4 inches, with a row of about 9 large, discrete, dark brown parr marks along the lateral line, plus 1 or 2 rows of distinct smaller marks above them (Carl et al, 1967).

Distribution

The mountain whitefish has a wide distribution in the western United States and Canada. It occurs from the west slope of the Rocky Mountains to the Pacific Ocean from northern British Columbia to Utah (Jordan and Evermann, 1905). The fish does not live in the interior of the Great Basin, but occurs on the east slope of the Sierra Nevada in California and Nevada south to Upper and Lower Twin Lakes and the Walker River system (McAfee, 1966). Mountain whitefish exist on the east slope of the Rocky Mountains in the Liard, Peace, Athabaska, and Saskatchewan Rivers of Canada and in the Missouri River drainage in Montana (Brown, 1952, and Carl et al, 1967). They have a wide distribution in the Columbia and Snake River systems of the northwest United States (Godfrey, 1955; Lindsey, 1957; and Sigler, 1951), and occur in all major drainage systems of British Columbia except the Yukon.

Habitat Preference

Streams

Sigler (1951) and Gerstung, according to McAfee (1966), reported that adult mountain whitefish prefer pool and meadow areas of cool streams where water depths exceed three feet. Sigler found in Logan River, Utah, that streams which measured less than 16 feet maximum width and 4 feet maximum depth at least flow lacked whitefish. He believed that less water does not provide acceptable cover. Brown (1952) found in Montana that most of the cold valley streams contained mountain whitefish but small mountain tributaries did not, as a rule. In his work on early development of whitefish in the West Gallatin and Yellowstone Rivers, Brown noted changes in habitat preference with size. He found sac fry along the shore in two to six inches of water in small, well protected pockets created by rubble or boulders, and in all backwaters which connected to the

main streams. Fry in the Yellowstone River remained in this type of water from time of emergence in March until they reached a length of about 55 mm in late July. At that time they deserted the shallow shore waters. Brown could not locate them by seining. He located fingerling-size whitefish in October in deep pools of the main river. They averaged about 120 mm in length at that time. He aged them as young of the year. Fingerlings from the West Gallatin River had deserted the shore areas by mid June. Brown did not locate them again until early November when he collected them from deep pools. They average 94.5 mm total length at that time.

Mountain whitefish require cool water. Sigler (1951) and LaRivers (1962) believed that high water temperatures limit mountain whitefish to elevations above 4,500 feet in California, Nevada, and Utah. No one has measured their exact temperature tolerances.

The adequacy of a stream as whitefish habitat depends on the food production in the stream. Mountain whitefish occur most abundantly in streams where sufficient riffle areas provide an abundance of food. They depend primarily on aquatic insect larvae (Sigler, 1951).

Lakes

Not all authors agree on habitat preferences of mountain whitefish in lakes. Jordan and Evermann (1905) stated that they thrive in cold, oligotrophic lakes. However Godfrey (1955) found that mountain whitefish occur most abundantly in eutrophic lakes with a fairly good supply of bottom food organisms. Some diversity of findings also exists concerning depth preferences in lakes. In summer sampling with gill nets of fish populations in Babine and Lakelse Lakes, British Columbia, Godfrey caught the greatest numbers of mountain whitefish at depths of 0 to 3 meters. Below that depth zone the catches dropped off sharply. He caught no whitefish at depths greater than 25 meters in Babine Lake and 12 meters in Lakelse Lake. However Echo (1954) obtained different results in gill net sampling of Lower Thompson Lake, Montana. He took the largest numbers at lesser depths, and found that this depth distribution pattern continued throughout March-August. However he did catch greater numbers at shallower depths as summer progressed. Jordan and Evermann (1905) stated that lake-dwelling mountain whitefish usually remained in deep water until spawning season.

We may explain differences in depth preferences of lake-dwelling mountain whitefish by examining productivity and food availability in lakes. Carl et al (1967) and McHugh (1940) stated that mountain whitefish feed primarily on the bottom but that the diet varies considerably with locality and in waters with poor bottom food production, the fish may feed at any level, including the surface.

Food Habits

Several workers have studied the food habits of mountain whitefish. McHugh (1940) made an extensive study of food habits of various age classes of mountain whitefish in lakes and rivers of southern British Columbia and Alberta. He found that whitefish in their first year of life feed almost entirely at the bottom, only occasionally feeding on swimming or floating organisms. Food of first-year fish consisted almost exclusively of aquatic insects. Pupae of Chironomidae and Ephemeroptera nymphs predominated. Cladocera and other free-swimming aquatics appeared occasionally and terrestrial forms rarely.

In mountain whitefish aged two years and older, McHugh found that food habits varied more and depended more upon availability and environmental conditions than in one-year fish. However, the bottom feeding habit still persisted. Larvae and pupae of Chironomidae and other aquatic Diptera occurred most commonly in the diet. Larval Ephemeroptera and Trichoptera appeared next in importance, followed by Gastropoda. Free swimming, floating, or flying organisms, such as Cladocera and terrestrial insects appeared less frequently but in quantity rarely. Food habits varied with locality, age, and season.

The most pronounced variation in food habits with locality occurred between lakes and rivers. Larval Diptera and Cladocera dominated the mountain whitefish diet in lakes. Cladocera appeared more frequently in lakes which contained a sparse bottom fauna. Also whitefish fed extensively on terrestrial insects occasionally in these lakes. The diet varied much more in streams than in lakes. Ephemeroptera and Plecoptera nymphs and Trichoptera larvae appeared as typical forms in stream-dwelling fish, which also ate a great variety of free-swimming, terrestrial or aerial organisms. Fish may have taken the latter forms anywhere between the bottom and the surface.

McHugh also discovered variations in food habits with size. Young fish fed chiefly on small individuals such as Diptera larvae and entomostraca. Small organisms occurred in smaller proportions as age of fish increased. Ephemeroptera and Plecoptera nymphs, Trichoptera larvae and terrestrial insects appeared in greatest volume in fish of intermediate age whereas larger forms such as Gastropoda appeared in largest quantities in the oldest whitefish.

McHugh also noted seasonal variations in food habits. From January to March whitefish ate aquatic insect larvae almost exclusively. From April to June additional organisms such as Cladocera, fish and terrestrial insects appeared in the diet. During July to September the diet varied most. The fish consumed aquatic insects frequently at this time but terrestrials, Cladocera, and other seasonal forms also appeared in considerable numbers. McHugh examined ripening fish in December and found little or no food in their stomachs. This suggests restricted feeding toward spawning time.

Clemens, Rawson and McHugh (1939) found that mountain whitefish ate more Cladocera than aquatic insect larvae and other forms, in lakes of the Okanagan Valley, British Columbia. They found that older fish depended primarily on water fleas and copepods for their main food supply, and ate lesser amounts of aquatic insect larvae from the lake bottom. Rawson and Elsey (1950) obtained similar findings from their study of the summer food habits of mountain whitefish in Pyramid Lake, Alberta. In Pyramid Lake Cladocera made up 29% of the diet by volume. The fish consumed lesser volumes of caddis larvae, mayfly nymphs and adults, **Gammarus,** and Chironomidae larvae and adults. Both Clemens et al (1939) and Rawson and Elsey (1950) believed that mountain whitefish ate a variety of prey species because of the poor bottom fauna of the lakes.

Godfrey (1955), Chapman and Quistorff (1938), Carl et al (1967), Jeppson (1959), Kemmerer, Bovard and Boorman (1924), Laakso (1951), Sigler (1951) all reported that the diet of mountain whitefish consists primarily of aquatic insects.

Laakso (1951) conducted one of the most extensive food habits studies on mountain whitefish. He investigated whitefish in streams in Montana where he compared food habits of fingerling and adult fish and analyzed seasonal variations in diet. He examined fingerlings of 1¼ to 2 inches average total length in June and July and found that they depended on aquatic insects for food. The fingerlings fed principally on midge larvae but also took small numbers of adult Chironomidae. Ephemeroptera nymphs, immature stoneflies and caddis larvae also appeared in important numbers in the diet. Adult whitefish also depended on aquatic insect larvae but ate larger forms such as caddis larvae and stonefly nymphs. Some variation in proportions of different aquatic insects in the diet occurred among the streams which Laakso sampled. In general Laakso found no important differences in the kinds of organisms which whitefish of various lengths ate. But smaller fish ate smaller numbers and sizes of prey.

In his comparison of whitefish diets at different seasons, Laakso found that the fish ate caddis larvae most in fall and winter. Plecoptera nymphs appeared in abundance except in the fall. The diet contained significant numbers of Ephemeroptera larvae in the spring and many Diptera larvae throughout the year. Laakso compared the stomach contents of whitefish with those of trout during winter. He found that whitefish usually had full stomachs, even during the coldest part of the year. Whitefish contained over five times as much food as did trout from December to February.

Items other than aquatic insects may comprise important portions of the diet of mountain whitefish at certain seasons and localities. Jeppson (1959) stated that in Lake Pend O'reille, Idaho, whitefish prey seriously on kokanee eggs in shoal spawning areas during winter months. Laakso (1951) found fish eggs in stomachs of Gallatin River fish. Snyder (1918) stated that mountain whitefish prey on the eggs of spawning fish and sometimes fill their stomachs with eggs of their own species. Foerster

(1925) listed whitefish along with trout and suckers as the most serious marauders of the spawning beds of sockeye salmon. Munro and Clemens (1937) reported one instance of a mountain whitefish taking a sculpin.

Few workers have studied the feeding behavior of mountain whitefish. Sigler (1951) found that in the Logan River they feed primarily at night or twilight. He found that mountain whitefish normally feed on the bottom but frequently come to the surface to feet at night. He stated that they commonly feed at night in surface schools of 50 to 75 fish.

Age and Growth

Age and growth of mountain whitefish differs considerably among habitat types. McHugh (1941) listed food and temperature as two important factors which affect growth rate of mountain whitefish. Whitefish in rich, productive waters have rapid growth and low longevity whereas fish from less productive waters experience slower growth and greater longevity. McHugh compared growth of mountain whitefish in two dissimilar Canadian lakes — Bow Lake, Alberta and Cultus Lake, British Columbia. Bow Lake lies at a higher elevation, remains colder, and produces less organic matter than Cultus Lake. Size of each age class of whitefish differed significantly between the two waters (Table I). In an extreme example, eight-year-old fish from Bow Lake averaged 9.0 inches total length compared to 16.8 inches for fish from Cultus Lake. McHugh collected whitefish with a maximum age of 17 years from Bow Lake but only 8 years from Cultus Lake. Cultus Lake whitefish grew extremely rapidly during the first two years of life.

Sigler (1951) found that whitefish in the Logan River, Utah grew faster than fish in most whitefish populations. However they still grew slower than those in Cultus Lake (Table I).

Jeppson (1959) stated that mountain whitefish in Lake Pend O'reille grow somewhat faster than the average for other lakes in the United States. He estimated that fish in Lake Pend O'reille grow about 3 inches per year for the first 3 years, about 1½ inches per year during their fourth and fifth years, and about 1 inch per year thereafter. However he stated that they rarely exceed 16 inches in length or 1 lb. in weight.

In Table I I have summarized work by several authors on age and growth. All of the workers lumped both sexes together to obtain their data. Sigler (1951) stated that in the Logan River, the sexes had quite similar rates of growth. But McHugh (1941) stated that Coregonid fishes generally exhibit a sexual difference in growth by weight.

Most authors did not use weight measurements in their work, but Sigler used weights to obtain length-weight relationships for fish in the Logan River. He found that weight increased almost exactly as the cube of the length. Sigler derived the following relationship.

$$\text{Log } W = -4.75778 + 2.98023 \text{ Log } L$$

where:

L = standard length in millimeters

W — weight in grams

Sigler calculated condition factors for Logan River whitefish by using the following formula.

$$K = \frac{W \times 10^5}{L^3}$$

where:

L — standard length in millimeters

W — weight in grams

K = condition factor

He obtained an average condition factor of 1.572. Length and sex did not influence the results although Sigler did no sampling during the spawning period.

Rawson and Elsey (1950) weighed mountain whitefish from Pyramid Lake, Alberta. Weights ranged from 1 ounce for 3-year-old fish which measured 6.4 inches average total length up to 26 ounces for 10-year-old fish which measured 16.4 inches. From these data I derived an average condition factor of 0.86. The lower condition factor of Pyramid Lake fish in comparison with Logan River fish indicates a difference in habitat suitability. The difference in growth rates between the two waters also indicates this difference (Table I).

Sigler reported that apparently the natural life span of mountain whitefish rarely exceeds 9 years, but McHugh (1941) stated that they live at least 18 years. He theorized that longevity varies, with slower growing populations living longer. Other workers have rarely reported mountain whitefish over 9 years old.

Lake Tahoe, California yielded the largest mountain whitefish that any worker has reported. McAfee (1966) stated that it measured 22 inches and weighed almost 6 lbs. Sigler (1951) stated that Logan River fishermen report mountain whitefish of 4 lbs. and occasionally more. However the largest whitefish Sigler examined during his study measured 17.4 inches and weighed 38 ounces. Brown (1952) examined thousands of whitefish in Montana and found that the heaviest weighed slightly over 3 lbs. McHugh (1941) stated that because of greater longevity, fish growing slowly reach maximum sizes comparable to those growing rapidly.

Reproduction

Brown (1952) found that mountain whitefish in Montana mature in their third year, although a few mature in their second year. In Utah mountain whitefish spawn at 3 or 4 years at about ½ lb. in weight (Sigler and Miller, 1963).

Fecundity correlates with length and weight. Brown made egg counts of 21 females just before spawning (egg sacs still intact), and found 1,425 to 24,143 eggs per female. A 6 ounce fish which measured 10.2 inches total length contained the smallest number, and a 3 lb., 19.5 inch fish contained the largest number. Fecundity averaged 4,401 eggs per fish or 5,343 eggs per pound of female. Sigler and Miller (1963) noted a relationship between fecundity and size and reported a range of 6,900 to 9,400 eggs per pound of female. Sigler (1951) examined five females of from 11 to 25 ounces in weight and found a range of 5,500 to 14,000 eggs per fish. Simon (1946) stated that mountain whitefish from Jackson Lake, Wyoming produced an average of 6,885 eggs per pound of female in 1938.

Sigler (1951) found that egg diameters varied from 1.94 to 2.12 mm and increased with the size of the fish. Brown (1952) found water-hardened eggs from Montana whitefish averaged 3.7 mm in diameter and had a range of 3.1 to 4.2 mm. Simon (1946) stated that mountain whitefish eggs totaled 912 eggs per fluid ounce.

Sigler (1951) found that ovaries of ripe fish made up 18.8% of the body weight. Brown (1952) found that the ovaries made up 21.8% of the body weight of one large female.

Whitefish spawn from October into December (Carl et al, 1967 and McAfee, 1966). Carl et al (1967) stated that mountain whitefish spawn in mid-November in the Okanagan Valley, British Columbia. In Montana waters Brown (1952) found differences in spawning seasons among populations in different streams. Spawning occurred later at higher elevations. In 1949 in the West Gallatin River the fish did not spawn until after October 14 when water temperatures decreased to 42 F. Brown found eggs in abundance in the gravel on October 28. Of the whitefish which he examined on October 28, some had partially spawned but none had completely spawned and others were still green. Whitefish had nearly completed spawning by November 10. All of the fish which Brown examined on November 17 had spawned completely and some showed recovery from spawning. The water temperature had decreased to 40 F by that date.

At a higher elevation on the South Fork Madison River, Brown observed a large number of unspawned ripe fish on November 14 (1950) when the water was 36 F. In the Yellowstone River Brown found that about ½ of the females had ripened and ½ remained green on October 16. On October 20 about ½ of the females had started spawning. By November 3, when the water temperature had reached 41 F, all of the females which Brown examined had completed spawning.

Mountain whitefish apparently travel only short distances to spawning areas. McAfee (1966) stated that stream populations do not seem to travel long distances to spawn. In stream-dwelling whitefish populations, Brown observed no mass movements or migrations and no unusual concentrations of fish in known spawning areas. However he stated that a small number of fish move into tributary streams from large rivers and use only the lower 300 to 500 yards of the tributary streams.

Lake-dwelling populations make pronounced runs up tributary streams to spawn (McAfee, 1966 and Simon, 1946). In Montana, large runs come into the South Fork Madison River from Hebgen Lake (Brown, 1952).

Brown observed that mountain whitefish concentrated in shallow water near the shore in Cliff Lake during the spawning season but he did not show that they spawn there. McAfee (1966) reported that Cordone (unpublished) stated that some mountain whitefish in Lake Tahoe apparently spawn in the lake.

Neither sex becomes highly colored during the spawning season. Males develop pronounced snouts (snouts appear somewhat pronounced at all times) and prominent body tubercles. Females develop smaller body tubercles (McAfee, 1966).

Mountain whitefish usually spawn in gravel and rubble in streams. McAfee (1966) stated that whitefish usually lay eggs in the gravel of riffles. Brown (1952) stated that whitefish appear to exercise little or no selection of bottom materials. He found an abundance of eggs, in various stages of development, in bottoms ranging from fine gravel to coarse rubble. He found eggs in water depths of 5 inches to 4 feet, but did not sample greater depths. He found the most eggs adjacent to strong currents. However he found some on substrata directly under rapid surface velocities and others where surface movement of water did not occur. Brown found no evidence that whitefish prepare nests as trout do. He observed no noticeable disturbance of the bottom in areas which whitefish used for spawning. He could detect spawning beds only by searching for eggs.

Mountain whitefish begin spawning activities just after dark (Brown, 1952). Brown observed them congregating in shallow water just before dark during the spawning season. He watched 30 fish spawn in a 100 ft^2 area just after dark on November 2, 1951. All of the fish had ripened and males predominated in numbers. The fish spawned in groups of 2 to 5. They concentrated most densely just to the side of the main current in water about one foot deep .The fish held their positions against the current and at intervals the individuals within a small area moved close together so that their bodies made contact, and as they did they almost came to rest on the bottom. They remained so for 2 to 4 seconds and then moved apart, sometimes separating and moving up or down stream. Individuals from one group would join others and repeat the process. No rapid or violent body movements occurred. Brown collected eggs on a screen below the spawning groups.

Development

Mountain whitefish eggs require low temperatures for optimum development. They hatch in about 5 months at 35 F and in about 1 month at 48 F (Sigler and Miller, 1963, and Simon, 1946). Brown (1952) observed embryonic development of whitefish in the West Gallatin River, Montana, where whitefish spawned from October 14 to November 10. Brown found the first eyed embryos on December 4, and noted that embryos had become uniform in development by January 20. He observed the first hatching individuals on March 4. Practically all fry hatched March 4 to 28 when water temperatures ranged from 40 to 42 F. On April 14 water temperatures reached 48 F and whitefish sac fry averaged 15.8 mm total length. On May 21 the fry averaged 27.7 mm. Brown next measured the young whitefish on November 2 when they averaged 94.5 mm.

In the Yellowstone River, young averaged 55 mm total length in late July and 120.3 mm on October 22. Brown did not measure early development of Yellowstone River whitefish.

Development under artificial conditions may take place more rapidly than under natural circumstances. Artificially-reared embryos from fish from the South Fork Madison River and held at 52 F hatched 36 days after fertilization (Brown, 1952), and living embryos eyed in 22 days. The majority hatched in 36 days and fry had absorbed all yolk 9 days after hatching. At a Lake Tahoe hatchery, one-half of a batch of mountain whitefish eggs hatched in 110 days at an average water temperature of 38 F (McAfee, 1966).

Associated Species

Mountain whitefish associate with a variety of coldwater species throughout their range. Principal associated forms include various species of whitefish, trout, chars, suckers, cyprinids, and cottids. Mountain whitefish also associate with northern pike **(Esox lucius)**, burbot **(Lota lota)**, yellow perch **(Perca flavescens)**, and stonecat **(Noturus flavus)** (Sigler, 1951; Currier and Schultz, 1957; Jordan and Evermann, 1905; Laakso, 1951; and McAfee, 1966).

Interspecific Competition

Mountain whitefish and juveniles and adults of most trout species have similar food habits in that aquatic insects make up major portions of the diet of both (Godfrey, 1955; Laakso, 1951; McAfee, 1966; McHugh, 1940; and Rawson and Elsey, 1950). Therefore whitefish and trout may compete for food. McAfee (1966) believed that whitefish might seriously compete with trout in places like Little Truckee River, California, where chemical treatment of a section showed that it contained a larger poundage of whitefish than trout. Sigler (1951) considered mountain whitefish important in Utah because "they compete with other important game fish for food and space."

Whitefish may also compete for food with the peamouth chub **(Mylocheilus caurinus)**, northern squawfish **(Ptychocheilus oregonensis)**, and yellow perch **(Perca flavescens)**, various suckers **(Catostomus sp.)**, and juvenile sockeye salmon **(Oncorhynchus nerka)**. Uses of foods by these species vary seasonally or with availability of food forms.

Laakso (1951) examined stomachs of whitefish and brown trout from the same location in Montana on November 23, 1947. He found equal proportions of caddis lavae, stonefly nymphs and whitefish eggs in the stomachs of each. Stomachs of both contained whitefish eggs as the most abundant form. However, on November 29, stoneflies made up 39% of the food volume in brown trout stomachs and only about 15% of the food volume in whitefish stomachs.

Laakso (1951) compared stomach contents of rainbow trout and mountain whitefish and found significant differences. At one time and location, algae comprised about 23% of the contents of rainbow stomachs but

whitefish stomachs contained no algae. At another time and location, rainbow trout stomachs contained a variety of surface food, which included adult mayflies and midges, leaf hoppers, beetles and ants. Whitefish stomachs contained none of these.

Godfrey (1955) reported that dolly varden usually eat fish and therefore compete little with whitefish. Godfrey also stated that the diets of fine-scaled and white suckers, which consist mainly of insect larvae, small mollusks, and plankton crustaceans, closely resemble the diet of mountain whitefish.

Foerster(1925) stated that sockeye salmon yearlings feed largely on aquatic insect larvae.

McHugh (1940) believed that in highly productive waters only insignificant competition between whitefish and other species would result. However, in waters which have a limited food supply, serious competition might occur.

Birch (1957) defines competition as the demand, typically at the same time, of more than one organism for a resource in excess of immediate supply. Competition may not occur even though two organisms eat the same foods at the same time. Conversely, Johannes and Larkin (1961) showed that competition for food may occur even where two organisms apparently do not eat the same foods. Present food availability and diet may result from past competition. Nilsson (1967) also supported this concept.

Whitefish and other species could conceivably interact in a manner that favors sympatric fishes. For example, feeding behavior of whitefish may dislodge invertebrates which then enter the drift and become available to trout.

Predation on Other Species

Mountain whitefish may consume eggs of other species. Sigler (1951) stated that mountain whitefish may prey on the eggs of trout and other coldwater fish, and Foerster (1925) found eggs of sockeye salmon in stomachs of mountain whitefish. Foerster thought that under certain conditions mountain whitefish might adversely affect the yield of a salmon river. Chapman and Quistorff (1938) did not believe that whitefish prey on young salmonid fishes in the Columbia River. Brown (1952), and Laakso (1951) showed that mountain whitefish eat their own eggs.

Predators and Parasites

Currier and Schultz (1957) found that lake trout **(Salvelinus namaycush)** in Waterton Lakes, Alberta feed on mountain whitefish. According to McAfee (1966) Cordone (unpublished) stated that lake trout prey on mountain whitefish in Lake Tahoe and other waters. He believed that brown, cutthroat and rainbow trout do likewise. Other sympatric piscivorous species probably prey on mountain whitefish.

A variety of parasites infect mountain whitefish. Bangham and Adams (1954) examined 253 mountain whitefish from 19 locations in British

Columbia, and found that parasites infected 213 or 84%. Bangham and Adams took as many as 8 species of parasites from hosts in single locations. Parasites infected 57% of the whitefish sampled from streams in the Columbia River drainage. Bangham and Adams found 19 parasitic forms in whitefish from the Columbia River, and identified the principal ones as **Bulbodacnitis globosa, Discocotyle salmonis, Diphyllobothrium sp., Pomphorhynchus bulbocolli** and **Hepaticola bakeri.** Parasites infected 99% of the whitefish sampled from the Fraser River drainage. Bangham and Adams identified 20 parasitic forms there. They found that 73% of the whitefish from the Skeena River drainage had parasites. Seven parasites occurred in these fish. Four parasitic forms infected 100% of the fish from the Peace River drainage, and three forms infected 100% of the whitefish from the Liard River drainage. Bangham and Adams also examined 23 mountain whitefish from the upper Snake River in the United States and found that all had parasites. In whitefish from the Snake River they identified nine species of parasites, all of which occurred in whitefish in British Columbia.

Sigler (1951) stated that stomach nematodes parasitized whitefish in two collections which he took from the Logan River, Utah in 1948 and 1949. He said that the fish showed no loss of condition. Sigler also recorded two infestations of external parasites, one copepod and one unidentified.

Duff (1932) reported that mountain whitefish suffered the highest mortality of any species during a period of high infestation of furunculosis in Elk River, British Columbia. The furunculosis appeared as hemorrhagic circular areas between the pelvic fins or on other parts of the ventral surface.

Importance

Mountain whitefish have the potential to become an important game and commercial species in western North America. They comprise a major portion of the fish biomass in many coldwater lakes and streams which occur within their range (Sigler, 1951; Jeppson, 1959; McAfee, 1966; and Rawson and Elsey, 1950). McAfee (1966) and McHugh (1940) stated that mountain whitefish have a delicious taste, and noted that some people prefer mountain whitefish over other freshwater species for eating.

Sigler (1951) stated that mountain whitefish have not become commercially important in either the United States or Canada. No one has made an extensive attempt to use the fish commercially in the United States. Efforts in Canada failed because of economic reasons. Sigler believed that the rather limited distribution of the mountain whitefish and its relatively small numbers in any particular population have prevented commercial interests from developing the fishery. Jeppson (1959) stated that the commercial fishery in Lake Pend O'reille, Idaho consisted primarily of mountain whitefish prior to the 1940's. During the 1940's kokanee began replacing them in the commercial catch. McAfee (1966) stated that a commercial fishery on mountain whitefish formerly existed in Lake Tahoe in conjunction with harvests of Lahontan cutthroat trout. Indians of western Canada take them in gill nets for food (McHugh, 1940).

As a sporting fish, the mountain whitefish has more potential. It readily takes artificial flies or bait and puts up a good fight when the angler hooks it (Carl et al, 1967; Dill and Shapovalov, 1939; Laakso, 1951; McAfee, 1966; and McHugh, 1940). Mountain whitefish provide considerable sports fishing in lakes and rivers of Alberta and British Columbia (McHugh, 1940). Whitefish fishing may produce best results during winter because of their active winter feeding habits (Laakso, 1951; and McAfee, 1966). In Lake Pend O'reille anglers harvest the greatest numbers of mountain whitefish during winter when they find poor kokanee fishing (Jeppson, 1959). In Montana anglers seek them in winter when state law prohibits fishing for trout (Brown, 1952).

But most anglers still do not appreciate the mountain whitefish. Sigler (1951) noted that the fish does not appeal to Utah fishermen from the standpoint of either sport or table use. Brown (1952) and McAfee (1966) also reported that Montana and California fishermen respectively have a generally low regard for the fish. Dill and Shapovalov (1939) attributed lack of popularity of whitefish to its superficial similarity to suckers, and to the indiscriminate use of the word "whitefish" for several large minnows, particularly the squawfish **(Ptychocheilus grandis)**. However the mountain whitefish has increased in popularity in recent years. Gaffney (1960), in an attempt to popularize whitefish in Montana, outlined methods of capture, discussed palatability, and provided recipes and smoking techniques.

Management

McAfee (1966) believed that, in their native waters, mountain whitefish make up an interesting and desirable part of the fauna even though they may limit trout production somewhat. He stated that such waters usually contain fairly good trout populations and that, from a practical standpoint, trout fishing would probably not improve greatly if fisheries managers removed the whitefish. McAfee did not believe that managers should presently attempt to extend the range of the mountain whitefish because anglers regard the species as inferior and a competitor with existing game fish. Therefore he believed that managers should aim at encouraging greater utilization of an underharvested, unappreciated, and in some places, abundant resource.

Utah officials discouraged the use of mountain whitefish by giving them the same legal status as trout (Sigler, 1951). Therefore anglers preferred to fill their limits with trout rather than with the less popular whitefish. Montana lengthened the season and allowed icefishing for whitefish to increase the harvest. This management program succeeded because mountain whitefish feed much more actively than trout in winter months (Laakso, 1951). Montana found that the administrative problems involved in this type of management did not hamper the program as much as they believed it would. Wyoming has also used educational campaigns and special regulations on seasons and bag limits to stimulate angling for whitefish (McAfee, 1966).

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Table 1. Ages and lengths of mountain whitefish from various waters. Sigler's (1959) conversion factors used to convert the measurements of Clemens et al (1939) from millimeters standard length to inches total length and Rawson and Elsey's (1950) measurements from inches fork length to inches total length.

Reference	Water	0	1	2	3	4	5	6	7	8	9	10	11	12 ...	17
McHugh (1940)	Bow Lake, Alberta	2.0	3.6	4.8	5.4	7.3	6.5	7.3	8.6	9.0	10.1	-	12.6	14.7	17.2
McHugh (1941)	Cultus Lake, B.C.	-	5.1	10.0	12.0	11.7	14.0	15.6	16.2	16.8	-	-	-	-	-
Sigler (1951)	Logan River, Utah	-	4.6	8.1	10.2	11.6	12.8	14.1	15.4	16.4	17.4	-	-	-	-
Meacham (1950)	Upper Twin Lake, California	-	-	7.3	7.7	8.2	9.1	-	-	-	-	-	-	-	-
Clemens, Rawson and McHugh (1939)	Lakes of Okanagan Valley, B.C.	-	5.3	8.8	11.7	12.9	13.5	-	-	-	-	-	-	-	-
Rawson and Elsey (1950)	Pyramid Lake, Alberta	-	2.6	4.2	6.4	8.2	9.9	11.3	12.8	13.8	14.8	16.4	-	-	-
Godfrey (1955)	Lakelse Lake, B.C.	3.8	5.3	7.3	8.8	10.1	11.7	12.6	14.0	13.8	14.1	-	-	-	-
Godfrey (1955)	Babine Lake, B.C.	-	6.9	8.5	10.3	15.3	11.7	13.1	14.2	14.5	15.2	-	-	-	-
Godfrey (1955)	Morrison Lake, B.C.	-	7.4	8.9	9.5	-	-	-	13.2	-	-	-	-	-	-