Bear Lake

Its Fish and Fishing

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Acknowledgment

EARL Smart, Dr. Glenn Taylor, and Dr. Kenneth Wolf were assistant project leaders part of the time during the course of this project. Donald Hales, Richard Parker, and Gar Workman also assisted in gathering data. Advice on the project was received from Donald Andriano, Forrest Hauck, and Jay Udy. Previous studies of Bear Lake were made by Drs. A. S. Hazzard, Edward L. Perry, and Stillman Wright. The fish nomenclature was checked by Dr. Robert R. Miller.

The following persons assisted in the preparation of the manuscript: Max Weaver, art; Dr. Wendell M. Keck, editing; and Mrs. Patsy Martin, typing.

Water level data were supplied by E. W. Roberts of the Utah Power and Light Company. Ellis Burnett supplied space for a field laboratory. Fish planting data were supplied by James Simpson and John Thompson.

The research was supported largely by federal aid to fisheries projects F-1-R-1,2 and F-4-R-1,2,3, for Utah, and F-10-R-1,2,3 for Idaho.

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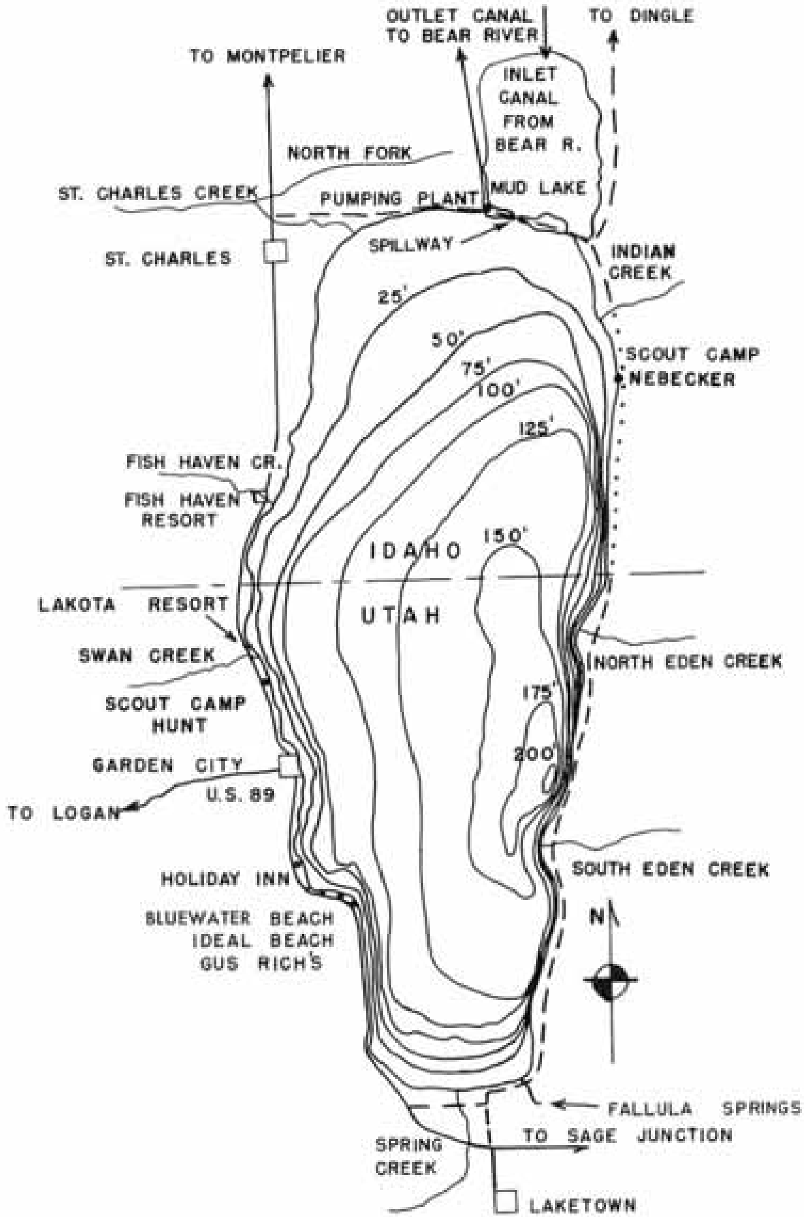
June 1957



BEAR LAKE

UTAH – IDAHO

MAXIMUM ELEVATION – 5923.6 FT. ABOVE SEA LEVEL

SCALE 1 INCH = 4 MILES

SHORELINE DISTANCE – 48 MILES

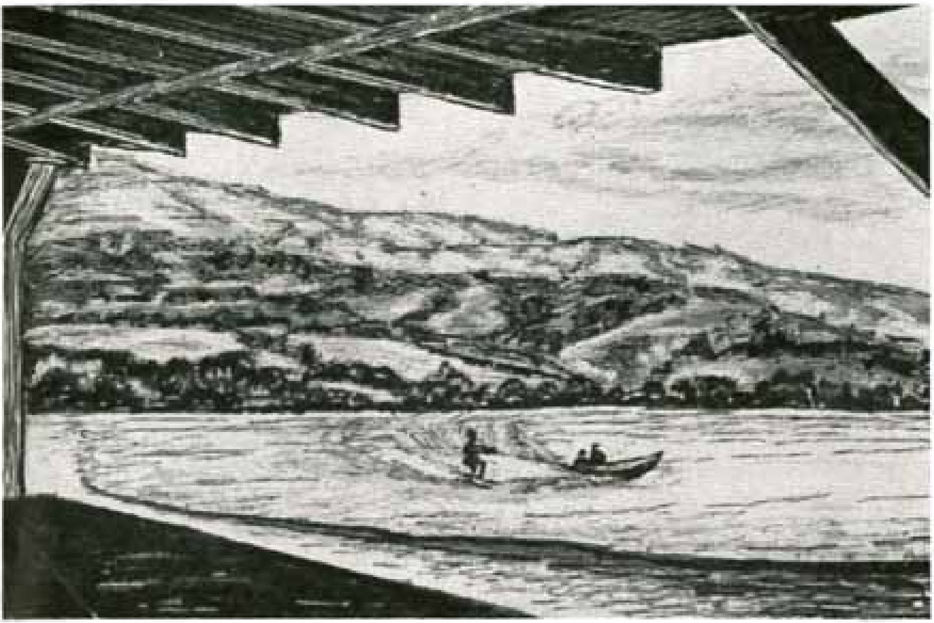
SURFACE AREA – 109 SQ. MILES

SURFACED ROADS ————————

IMPROVED ROADS — — — — — —

DIRT ROADS . . . .

Contents



PART I

Highlights of the Bear Lake Fishery

The Lake

History and Description

BEAR Lake is an old lake. The lake basin was formed during the growth of the surrounding mountains; since that time, a lake has been present whenever the climate has been wet enough, but it has probably completely dried up during very dry periods.

The present lake probably was in existence at least as long ago as the last glaciers when Lakes Bonneville and Lahontan filled much of the Great Basin. At that time Bear Lake filled the entire valley, which is about 50 miles long by 8 to 12 miles wide. The lake was deeper then, and traces of the old shorelines still can be seen. The present lake occupies only the southern end of the valley. It is just less than 20 miles long and 4 to 8 miles wide. As the lake became smaller, a large marsh formed at its northern end. Wind and waves gradually built up a natural dike, or beach bar, separating the lake from the marsh. This beach bar now forms the northern shore of the lake. Similar beach bars can be seen at the south end and at other locations around the shore.

When the lake filled the entire valley, the Bear River flowed into it. As the lake became smaller the lake and river separated and for a long time before man's interference the Bear River flowed into and out of the north end of the valley without entering Bear Lake. During that time, Bear Lake was dependent on the flow of the small streams on the local watershed. In the present climate about four-fifths of this flow is required merely to replace evaporation. During dry periods evaporation probably exceeded the inflow; the lake became smaller than it is now, with no water flowing out.

Just after 1900 Telluride Power Company began construction of dams and canals to divert the Bear River into Bear Lake. In 1912 the Utah Power and Light Company succeeded the Telluride Company and completed construction of the present canal system. At present water from Bear River is diverted into Bear Lake when not needed downstream, and later is returned to the river by pumping it out of the lake when more water is needed downstream. It is possible to lower the lake 21 feet by pumping, but fluctuation in any one year is usually only 3 to 4 feet.

Bear Lake is deepest along the east side. The greatest depth found during this study is 208 feet below the present high water level. The lake gradually shallows toward the west shore, but more than half the lake is deeper than 100 feet.

The north, northwest, and south shores are sandy beaches. Much of the rest of the shoreline is rocky. The rocks do not extend very far into the water except off the larger deltas and points; a drop in water level of 10 feet would expose most of them. Beyond the rocks, the bottom is sand to a depth of about 25 feet. From 25 to 75 feet, the sand

is gradually replaced by silt and marl, and below 75 feet the bottom is a fine gray silt marl.

Many snail shells and small clam shells lie on the shores, particularly along the north and northwest, and in the bottom material of the northern part of the lake. Neither these snails nor clams are found alive in the lake today. They were probably most numerous when the lake was at its higher levels; they are believed to have been killed off when the lake became smaller than its present size during a dry period about 5,000 years ago.

Usually the lake is quite clear except when muddy water from Bear River is entering at the north end, and when waves have stirred up the bottom materials after a storm. Its characteristic blue-green color is caused by the large amounts of carbonates in the water.

By late summer the surface water usually warms up to about 70°F. This warm layer extends down about 30 to 50 feet; below that the water cools rapidly and the water below 150 feet is usually never warmer than 42°F. In winter, if it does not freeze, the entire lake may cool to 35.5°F. The lake usually freezes over (about 4 years out of 5 according to Utah Power and Light Company records). A complete ice cover usually comes in late January or early February, and breaks up in April.

Plant Life

Only a few plants grow in Bear Lake. A few patches of cattail and bulrush grow along the northwest shore, and bulrush is fairly common along the west shore. Beds of pondweed are fairly abundant in water 5 to 25 feet deep along the northwest shore, but only an occasional bed appears along the east shore.

Fig. 1. Stormy weather makes life difficult both for plants and animals close to shore.

The swamp north of the lake has good growths of both these plants and several others. Earlier investigators had suggested that too much zinc in the water of Bear Lake had prevented the growth of plants. Results of tests made during this study have shown that there is not at present enough zinc in the water to reduce the plant growth. Lack of shelter from the waves and the fluctuating water level appear to be major factors presently limiting growth of rooted aquatic plants (fig. 1).

In addition to the larger plants, algae of several kinds grow under the water on the rocks, plant stems, and other objects wherever light can reach them. Also many small algae float in the open water. They are present in tremendous numbers—sometimes more than a million in a quart of water—but are so small that they can be seen only under a microscope. These small cells, called phytoplankton, probably contribute more plant food than all the other plants combined (fig. 2). Bear Lake is many times less productive of plant food than some other waters in the region that produce much excellent fishing; such as Henry's, Fish, and Panguitch Lakes. In these lakes plant beds are large and numerous, and phytoplankton are often abundant enough to make the water appear green

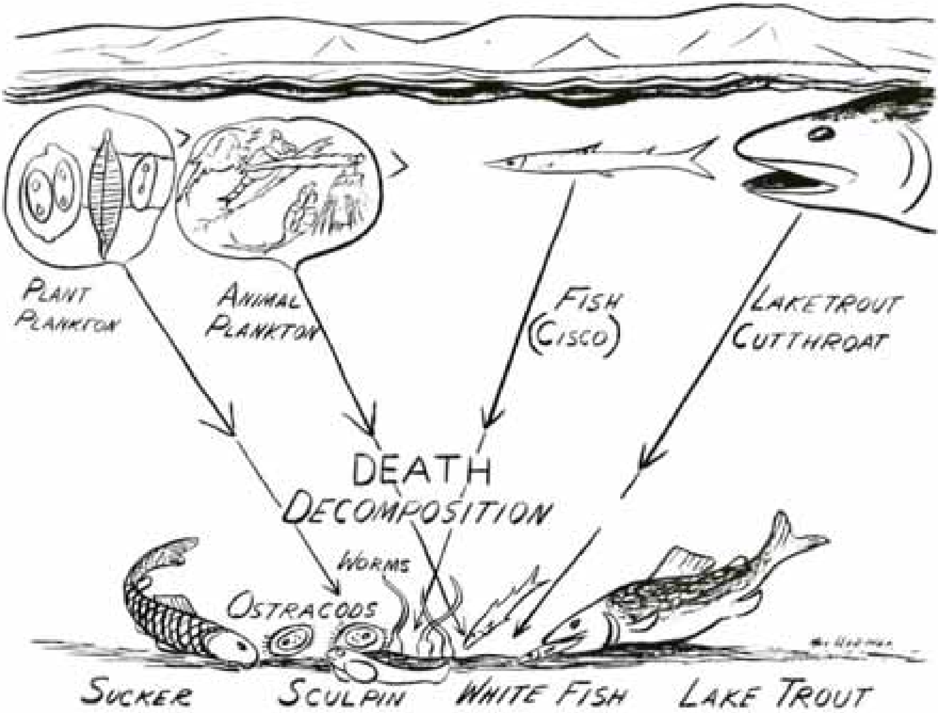


Fig. 2. There are several steps between the plant plankton, which supply the basic food, and the fish we catch.

and murky. They also are much smaller and shallower than Bear Lake. Compared to other large deep lakes such as Priest Lake and Lake Pend Oreille, Bear Lake is not extremely unproductive.

Animal Life

The submerged rocky areas along shore and the plant beds contain quite a few scuds (sometimes called shrimp or side-swimmers). There are also some aquatic insect nymphs (mayflies, dragon flies, damselflies) and quite a few midge larvae (small, bright red). When the water is high and good cover is available these forms are quite numerous; as the water goes down and the rocks and plants are exposed their numbers decrease, and when the lake reaches 10 feet below the maximum level only a few are found in the isolated patches of cover.

The sand areas have little life, except in the few plant beds growing there. In water 25 to 70 feet deep, where the sand has silt and marl mixed with it, midge larvae, aquatic worms, and numerous ostracods (a small crustacean) are found. Below about 70 feet, in the soft marl bottom, the aquatic worms become most numerous; the ostracods are fairly abundant, but few midge larvae are found (fig. 3).

In addition to these bottom living forms, several kinds of small crustaceans and rotifers are found in the open water (the zooplankton) where they live on small plants.

One fish, the cisco, feeds on the zooplankton in the open water. Most of the plankton, both plant and animal, die and sink to the bottom where they provide food for the worms, ostracods, and midge larvae. These in turn provide food for the fish. Most of the fish food in Bear Lake is produced in the open water or on the bottom in deep water.

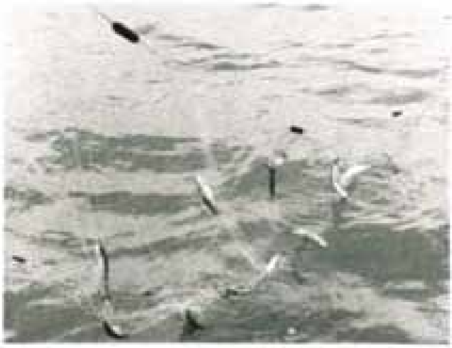


Fig. 4. The relative abundance of various fish was determined by gill netting.

The Life History and Abundance of Fish

The two most numerous fish in Bear Lake are the Bonneville cisco and the sculpin (bullhead), but no one knows certainly which of these is more abundant. Collectively these two small fish probably comprise about half the fish in Bear Lake. They have one interesting difference: the cisco moves freely throughout the lake at all depths (actually, relatively few of them are near the bottom, unless they find an area where both the temperature and the food suit them); the sculpin, conversely, is always on or near the bottom.

Next in abundance are the Utah suck-

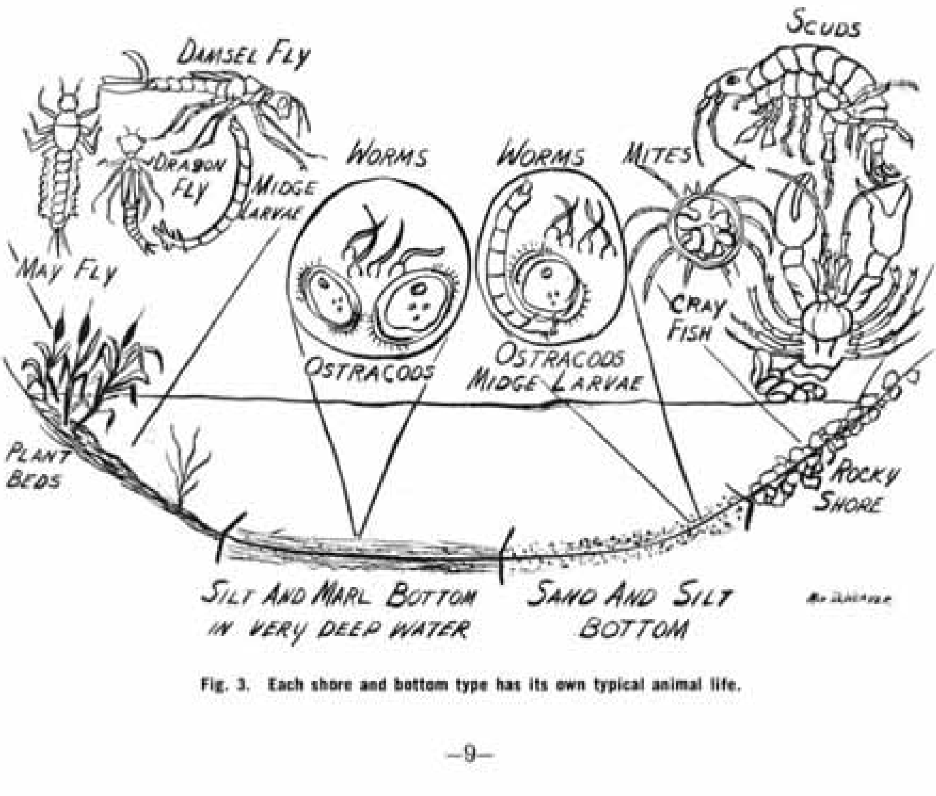


Fig. 3. Each shore and bottom type has its own typical animal life.

er and three other species of whitefish. The Utah sucker is not as numerous as either the cisco or the sculpin (possibly 20 percent), but it contributes a total poundage greater than that of either of these two fish. Collectively, the three other members of the whitefish family in Bear Lake (Bear Lake whitefish, Bonneville whitefish, and mountain whitefish) are next in abundance. It is believed that the Bonneville whitefish is the most abundant of these three whitefish. Next in order of numerical importance are the Utah chub and the carp, which probably total 4 and 3 percent, repectively, of the total. To the casual shore observer, the carp appears considerably more important than it actually is. This is because it habitually swims at or near the surface, usually within sight of shore; however, carp do occasionally move out a mile or more from shore (fig. 4).

The three important and sought after trout are the lake trout (mackinaw), the cutthroat trout (native), and the rainbow trout. All together, these three fish probably do not represent more than 3 percent of the total fish population.

Yellow perch, green sunfish, Carrington's dace, and the small fin redside shiner are present, but in small numbers.

In summer, most of the fish are widely scattered throughout the lake, and relatively few of them are close to shore. The rainbow trout stays nearer to shore than either the cutthroat or the lake trout. Generally the cutthroat trout stays

Fig. 5. Cutaway view of a gill net set under the ice. A line is passed from hole to hole until the necessary distance is covered at which time the net is pulled from the first hole to the last.

in water 75 feet deep or less in summer. The lake trout is more active in summer than in winter, and generally is at depths between 50 and 100 feet and near the bottom (fig. 5). The two fish that live in the same general habitat as the lake trout are the Bonneville whitefish and the sculpin. The Bear Lake whitefish, to a lesser degree, is also associated with the lake trout during summer months. The cisco's summer movement is apparently governed by temperature, but during the spawning season (late December and January) the cisco stays much closer to shore and to the bottom than during the rest of the year. The carp and the yellow perch apparently prefer shallow water; both of them move about considerably more in summer than in winter. They are most abundant near shore, and the carp is frequently near the surface on warm days. The Utah chub stays near shore, usually in water less than 25 feet deep during the summer months; in winter it may move into deeper water. The Utah sucker is more active in the summer than during the rest of the year, but it moves freely throughout the lake at all times—even into the deepest water.

Trout less than 10 inches long apparently have a difficult time finding sufficient food. Larger trout are generally in good condition presumably because they are able to feed on forage fish.

Apparently very few of the lake trout spawned in the lake mature and reach the creel. Most of the spawning is in the area between north and south Eden on the east side of the lake. In this area, the bottom is rock and rubble, but most of the rocks are covered by a layer of silt. This silt may suffocate many of the eggs and leave others exposed to predation, since the lake trout does not build a redd, or nest, such as the rainbow trout does. Cutthroat and rainbow trout spawn in the three largest tributaries to

Bear Lake. Of these three, St. Charles Creek is the best, followed by Swan Creek and Spring Creek. Just how much natural reproduction supports the fishery was not established, but evidence indicated that rainbow trout reproduction is low. Possibly a few more naturally spawned cutthroat trout reach the creel.

It is believed that the rainbow trout grows fastest and survives best when the lake level is at or near maximum and fluctuates least. This condition does not often occur; actually a fluctuating level somewhat below maximum is normal.

Suggestions on How, Where, and When to Fish

Biologists are really asking for trouble when they make recommendations about how a fisherman's creel may be better filled. So let us state our case clearly at the beginning of this discussion: herein we are reporting only trends in fisherman success suggested by data collected during three years of creel censusing. Part of the study reported in this bulletin reveals the reason for the relatively poor catch by some fishermen on Bear Lake; therefore, it is considered important that the practices of more successful fishermen be made known to those who intend to spend much time fishing Bear Lake.

Time of year and location on the lake seem to have important bearing on numbers and kinds of fish creeled. For example, more than 80 percent of the cutthroat trout have been taken by trolling with a lure near the bottom, or by fishing from the southeast shore with a spoon type lure in late April or May. The number of cutthroat taken from shore at other times or places has been low. A study of distribution of cutthroat, made with gill nets, indicates that this species is found offshore during most of the year but cutthroat are seldom numerous at depths exceeding 75 feet. Often the cutthroat is just beyond casting distance from the shore. Fishermen who have used bait (usually worms) have caught few cutthroat.

Catching lake trout is primarily a reward for long hours of trolling in moderately deep water, using lead core line or a quite heavy sinker. The lake trout in Bear Lake have not been taken by casting from shore except during brief periods in late spring and early fall. From the end of November until late in May this fish is seldom caught. Probably the best time of year to troll for lake trout is late summer and early fall. The best location is open to question, but gill net catches indicate a fair population along both the east and west shores of the lake. Although lake trout are sometimes found in deep water, their greatest population densities seemed to be at depths between 50 and 100 feet. The successful fishermen who were willing to give out "trade secrets" were unanimous in the opinion that any trolled lure must be very close to the bottom to be effective for lake trout. Old timers also advised caution when venturing far from shore in potentially stormy weather (fig. 6).

Rainbow trout are most often taken by shore fishermen who are content to soak a "gob of worms." Lures, trolled or cast, catch relatively few rainbow trout, though wet flies are very effective at times during the summer. The time of year when the rate of success for this species is highest usually follows that time when a plant of legal-size rainbow trout has been made. Few rainbow trout remain from one season to the next.

The Bonneville whitefish is caught chiefly between the last week in November and the end of December. The large individuals, weighing from two to four pounds, are most frequently caught during the first half of December. Although a few Bonneville whitefish are taken with flies and spoons, more than 95 percent are caught by still fishing with worms. The other whitefishes in Bear Lake are not taken. Ice fishing was not a good producer of whitefish in 1955.

The yellow perch produces an intermittent fishery. It appears to be caught in great numbers in the fall and winter following a large spring inflow from Bear River, but this theory has not been conclusively proved. Fishing for perch in October 1952 was phenomenally successful near the pumping station at the north end of the lake. During that month and during the ensuing winter and spring, great numbers of yellow perch were caught. The contrastingly poor fishery for yellow perch in 1954 and 1955

Fig. 6. Trolling, although effective, was, at times, a bit hard on fishermen.

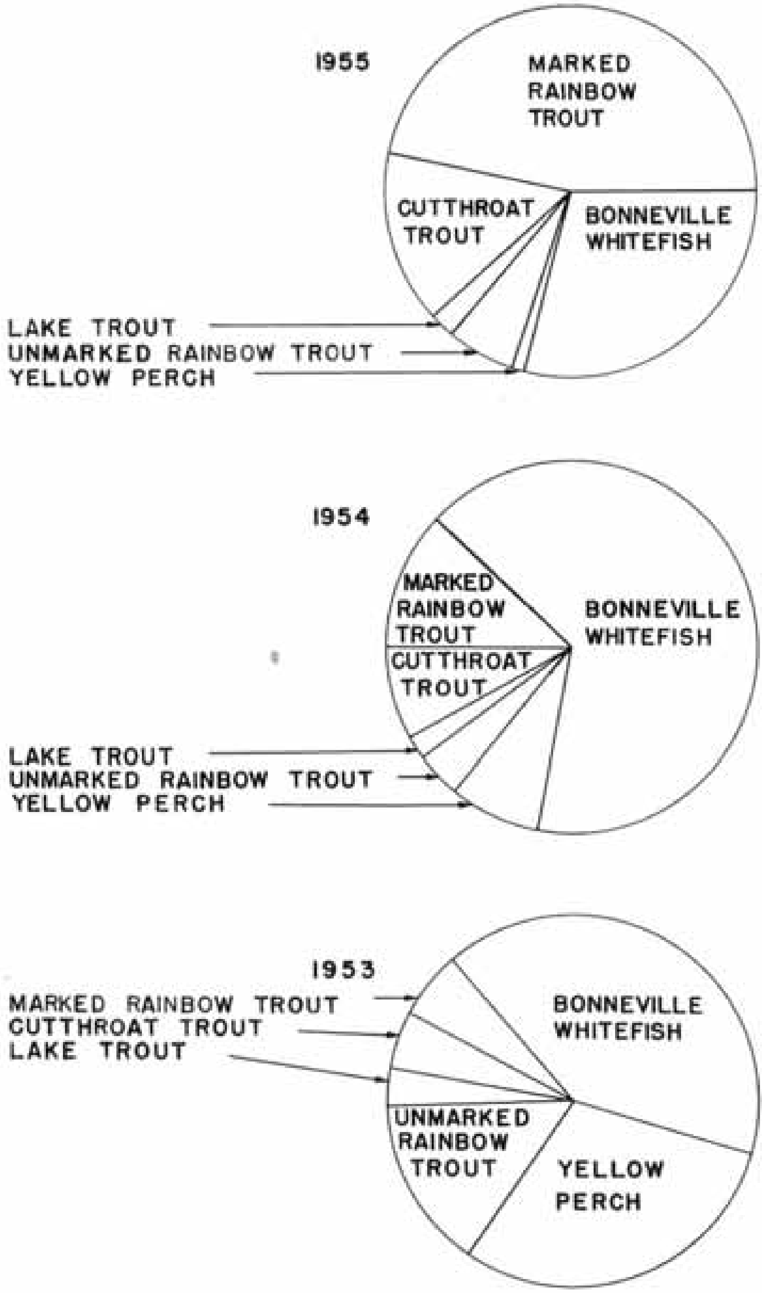


Fig. 7. Species composition of Bear Lake fishery.

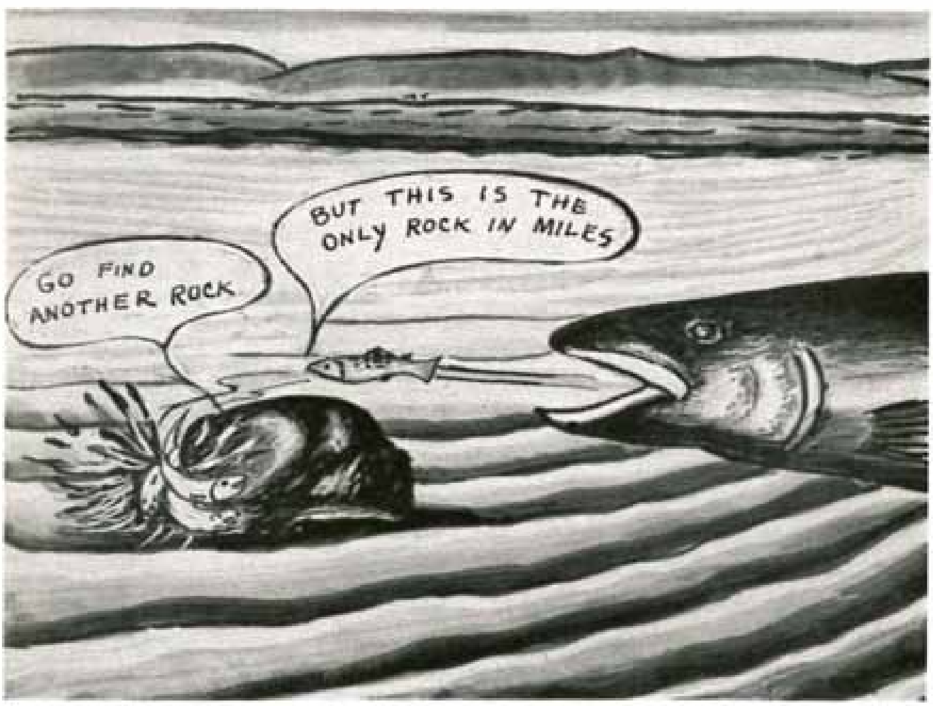
has been attributed to small inflows during those preceding years. The effect of the inflows is probably to wash great numbers of perch from Mud Lake into Bear Lake. Yellow perch were rarely taken, either by hook and line or by experimental gill net, more than a few miles from the two inlets. The size of yellow perch in Bear Lake makes them a desirable fish, but in many lakes, where they are stunted, they are considered trash fish. Still fishing with worms or pieces of fish takes most of the yellow perch.

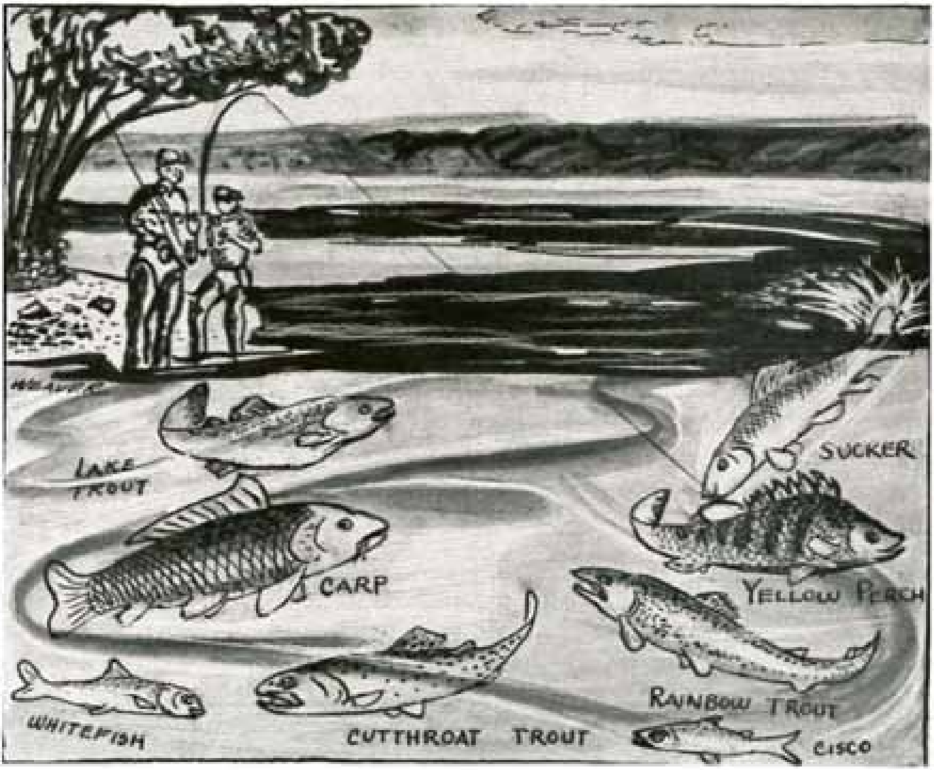
No other game fish was seen in the creels despite the fact that numbers of several other species were stocked in the 1930's. Large numbers of non-game fish such as carp, sucker, and Utah chub are taken; but since most of these are discarded it is impossible to get an accurate estimate of their numbers. Worms seem to be the best bait for non-game species, but it was obvious that many of these fish were unwilling victims of a snag hook that caught them in parts of the anatomy other than the mouth.

Shore fishermen using spinning tackle caught about 15 percent more game fish in a given period than those who used other types of gear. The advantage was much greater when only cutthroat trout and lake trout are considered. For these species, spinning tackle in the hands of shore fishermen takes about twice as many fish in a given period as any other type of tackle. Boat fishermen using regular trolling reels and lead lines took many more fish than those who attempted to troll with other types of gear.

The Creel Census

The estimated number of fishermen at Bear Lake has declined from 12,000 in





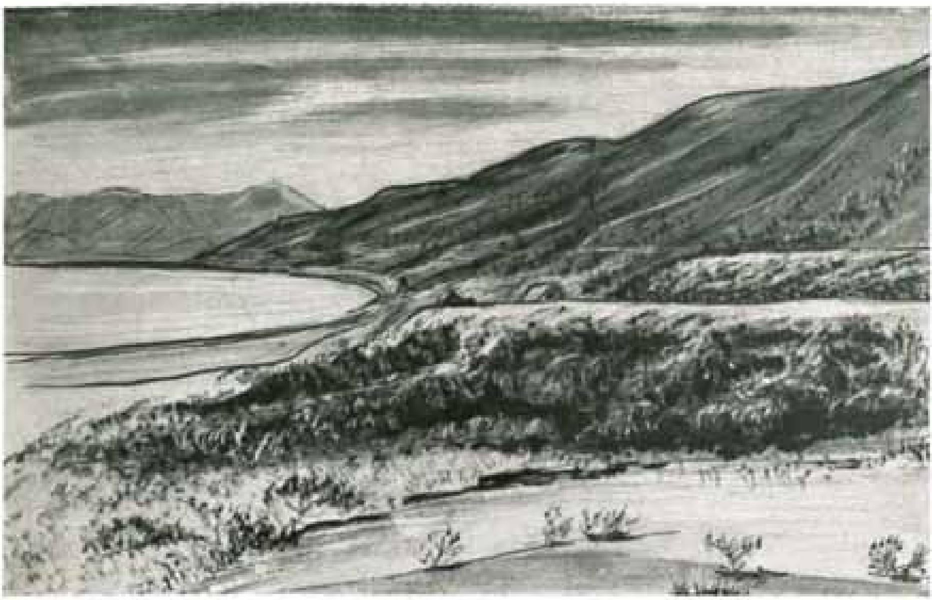
1953 to 9,000 in 1955. The cause of this decline can only be speculated on; however, it is believed that it was in part the complete disappearance of the yellow perch, and a decrease in the number of rainbow trout caught (fig. 7).

About 70 percent of the persons who fish Bear Lake are from Cache, Weber, and Rich Counties in Utah; most of the remaining 30 percent are from Bear Lake County, Idaho. An economic survey indicates an average fisherman spends $9.13 a day, which is chiefly for fishing gear, boots, boats, trailers, and camping gear. Relatively little of this money is spent locally. The total estimated amount of money spent by Bear Lake fishermen in 1953 was $109,000 or $1.50 per surface acre. This may be compared with the $82.00 per surface acre on Navajo Lake and $283.00 per surface acre on Panguitch Lake. Fishermen made catches of game fish at the rate of .33, .26, and .18 fish per hour in 1953, 1954, and 1955, respectively. During the appropriate seasons whitefish and yellow perch were caught at the rate of about ½ fish per hour, the highest rate of success for any fish. The next best catch rate was that for rainbow and cutthroat trout. Lake trout, the hardest fish to catch, required an average of 33 hours' effort for each fish.

Probably the most disappointing single feature of Bear Lake fishing is the low return of planted rainbow. Only about one out of every 20 fish planted during the period covered by this study was returned to the creel, and the highest return for any plant was about one out of every five fish. Rainbow less than 10 inches long apparently suffer a high mortality in Bear Lake within a month or two. These fish may either starve or be caught by bigger fish within a few weeks after they are planted. Fish larger than 10 inches, on the other hand, are able to fend for themselves and are the most economical to plant even though they cost more per fish. Actually the rainbow catch is no more discouraging than the cutthroat catch, which is estimated at about 1200 fish per year over the period from 1951 through 1955. This small catch resulted from the limited natural spawning plus the stocking of more than 2,000,000 cutthroat trout ranging from fry to legal size during this same 10-year period. It appears that the cutthroat trout planning program, like that of the rainbow, does not result in a large return to the creel.

The majority of lake trout caught are at least 24 inches long. There is no question that many fishermen continue to return to Bear Lake for the chance of catching one of these large and highly prized fish. The cutthroat trout is the next largest fish taken. Many of them exceed 18 inches, and some are considerably larger. The Bonneville whitefish is the next largest fish in the creel, often reaching 16 inches; it is followed by the yellow perch, which frequently may exceed 12 inches.

A tabulation of the kinds of fish caught and the frequency in the creel is presented in figure 7.



PART II

History and Previous Studies of the Bear Lake Fishery

History

BEAR Lake is popular with fishermen in northern Utah and southern Idaho for several reasons. First, it is the only large lake within a 100-mile radius that is open to fishing in winter, when most other areas are closed. Second, the large lake trout and cutthroat trout taken from Bear Lake are trophies well worth going after. Moreover, in summer Bear Lake is a beautiful place to water ski, boat, and swim, as well as fish. The vastly increased number of fishermen in recent years stimulated a renewal of interest in Bear Lake fishery research by both the Utah and Idaho Fish and Game Departments and by the Wildlife Management Department at Utah State Agricultural College.

During the first quarter of the twentieth century, a fairly substantial commercial fishery operated on Bear Lake. At first, fish were caught by set lines, seines, and large mesh gill nets. When Louis Peterson, a fisherman from Sweden, moved to Bear Lake he initiated more effective methods of catching smaller fish (particularly the cisco, a small whitefish) with small mesh gill nets in both summer and winter.

Previously, only gill nets made in the United States had been used to take Bear Lake fish. The mesh of these nets was too large to capture cisco. Mr. Peterson obtained nets of a smaller mesh size from his native country and effectively fished the cisco (Perry 1943). Commercial fishermen harvested large numbers of suckers during their spawning runs in the spring. They took many cutthroat trout and sold them in markets as far away as the state of Washington. After the advent of Peterson's methods, the Bonneville cisco became an important item both as bait for the trout fishery and as fish for human consumption.

Legislative action by Utah and Idaho in the early 1920's terminated this commercial fishing. For many years thereafter, sport fishing was confined to the general open season for trout, which was from early summer to early fall. In 1952, the lake was opened to year round fishing.

Previous Research Projects

Several scientific groups have investigated the Bear Lake fishery. The earliest, a short survey made in 1912 by George Kemmerer, J. F. Bovard, and W. R. Boorman, was part of a preliminary examination of the western trout waters by early ichthyologists. These men reported large numbers of bluenose trout (*Salmo virginalis*)[1] and Williamson's whitefish (*Coregonus williamsoni*) from Bear Lake (Kemmerer, Bovard, and Boorman 1923). The bluenose is undoubtedly the fish that was later described as the Utah cutthroat trout, and is at present believed, by us, to be extinct. Kemmerer *et al.* also reported that the bluenose could be taken only with difficulty by sport fishermen; that most catches came from nets or set lines. It is our belief that the so-called Williamson's whitefish, now known as the mountain whitefish, is rare in Bear Lake. The few that do appear drift in from Bear River.

In 1915, J. O. Snyder, assisted by Carl L. Hubbs, made collections in Bear Lake and recognized three new species of whitefish which Snyder later described (1919): the Bonneville whitefish, the Bear Lake whitefish, and the peaknose cisco.

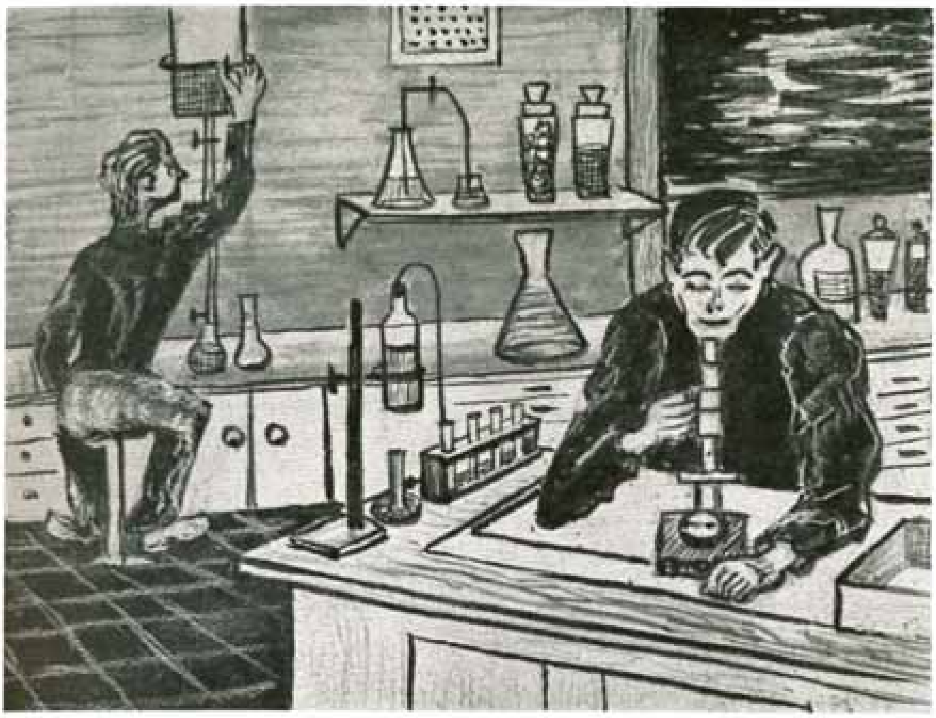
In September 1930, Tanner (1936) made gill net collections of cisco in Bear Lake. He examined 30 stomachs and reported more than 95 percent of the food consisted of *Diaptomus*.

In 1933, A. S. Hazzard made a brief fishery investigation of Bear Lake.

In 1938, Stillman Wright of the U. S. Bureau of Fisheries and L. Edward Perry, who was collecting data on the Bonneville cisco as part of his doctoral research, began study of Bear Lake. In 1939, this investigation developed into an extensive study when the Fish and Game Departments of both Utah and Idaho added their cooperation. This study continued until 1941. In the fall of 1951, the Wildlife Management Department at the Utah State Agricultural College initiated a limited program of research on fish life history and populations in Bear Lake. A Dingell-Johnson project submitted by the Utah Fish and Game Department was approved by the U. S. Fish and Wildlife Service on July 6, 1951. This was the first D-J project in the United States. One of the job outlines covered the Bear Lake research. Actual field work began September 1, 1951. In 1953, the Idaho Fish and Game Department joined the research under their federal aid program.

The federal aid field program was terminated December 31, 1955. A study of the bottom fauna continued through part of 1956. It is hoped that future research may be conducted on the phytoplankton and zooplankton populations and population dynamics of the smaller fish of Bear Lake.

[1]We believe this fish was **Salmo clarki utah.**



Limnology of Bear Lake

History and Description

BEAR Lake occupies the southern end of a high mountain valley that was formed by uplifting and faulting during the growth of the surrounding mountains. At one time, the lake filled this entire valley, which is 50 miles long by 8 to 12 miles wide. Traces of old shorelines are visible about 11, 22, and 33 feet above the present maximum lake elevation. These higher stages probably occurred at the same time Lakes Bonneville and Lahontan were at their maximum in the Great Basin (Mansfield 1927).

The present lake is oval—almost rectangular in shape—just less than 20 miles long and from 4 to 8 miles wide; its lengthwise axis lies almost directly north and south. The north and south shores of the lake are formed by large natural beach bars. The bar at the north end separates Bear Lake from Dingle Swamp, the open water portion of which is called Mud Lake (fig. 8).

Along most of the east shore a steep mountain face formed by a fault running parallel to the lake rises almost from the water's edge. The western shore rises more gradually through foothills to a high ridge, the highest point of which is Swan Peak (elevation 9114 ft.). Swan Peak is due west from the approximate center of the lake.

The bottom topography of Bear Lake

is extremely regular, and it reflects the shore characteristics. The lake is deepest along the east shore and gradually shallows toward the west. The greatest depth measured during the study was 208 feet; this was at a point about a fourth mile off the east shore and just north of South Eden delta.

When full, the lake has a surface area of just less than 110 square miles. The 48-mile shoreline is regular and has no major coves or bays.

Physical Characteristics

Water Supply

The watershed draining directly into Bear Lake covers only about 250 square miles, and contains just three tributary streams of any consequence: the south fork of St. Charles Creek, Swan Creek, and Spring Creek. Their combined maximum flow is less than 200 c.f.s. (cubic feet per second). Swan Creek heads in a large spring a mile from the lake, and Spring Creek is formed by the confluence of several smaller streams a short distance from the lake. Only St. Charles Creek comes from a long well developed canyon; it extends 12 to 15 miles back from the lake, but it divides just outside the canyon mouth so that approximately two-thirds of the flow goes through the north fork into Dingle Swamp rather than into Bear Lake.

Fish Haven Creek, North Eden Creek, Fallula Springs, and Indian Creek are small permanent streams. Their combined maximum flow is less than 25 c.f.s. Numerous seeps and springs occur along

Fig. 8. A natural beach bar separates the north end of Bear Lake (left) from Mud Lake and Dingle Swamp.

the west shore and some along the northeast shore of the lake. Their flow is difficult to measure, but they appear to contribute a significant percentage of the total local inflow.

The flow of all streams named above is largely diverted for irrigation. In the summer the smaller creeks are at times completely diverted, and usually less than 10 c.f.s. reach the lake from each of the three larger creeks.

W. N. Gibson of the Logan office of the U. S. Geological Survey has calculated that over the years 1924-1954 the total contribution of the local watershed has averaged 66,000 acre-feet per year. He has calculated the average loss by evaporation over this same period at 55,000 acre-feet, leaving a differential of 11,000 acre-feet for outflow.

The Bear River enters the valley on the northeast side and flows out directly north. At the higher lake levels indicated by the old shorelines, Bear River was a direct tributary of Bear Lake. At the present level, Bear River is 8 miles away at the closest point; and prior to the man-made connections constructed in the early 1900's the river probably had not contributed water directly to the lake for some time. Prior to 1900, a natural outlet left the lake near the west side of the north shore and meandered through the Dingle Swamp to join the Bear River at a point 16 miles north of the lake.

In 1907 the Telluride Power Company began construction of facilities that would enable diversion of Bear River water into Dingle Swamp and Bear Lake as storage for both power and irrigation. Inlet and outlet canals were dug, and the natural outlet was closed. A dike and spillway were constructed across the outlet canal at Paris, Idaho, which would control the water level of Dingle Swamp and Mud Lake. In 1912, the Utah Power and Light Company succeeded Telluride Power Company and subsequently dug a new and larger inlet canal from a dam on the Bear River at Stewart, and also widened and deepened the outlet canal. Facilities were constructed that permitted control of the exchange of water between Bear Lake and Mud Lake.

The pumping station, near the center of the north shore of the lake, has two 6- by 12-foot gates through which water can move by gravity flow in either direction, and five 750 horsepower electric centrifugal pumps which can lift water from Bear Lake into Mud Lake when Bear Lake is too low to flow out by gravity. A spillway about ¼ mile east of the pumping station permits gravity flow in either direction depending on water levels. It is possible to discharge up to 4,000 c.f.s. from Mud Lake into Bear Lake by using both inlets, the exact maximum depending upon the differences in elevation. The pumps have been measured at approximately 400 c.f.s. each; thus, they have a combined maximum pumping capacity of about 2,000 c.f.s.

Since completion of these facilities in 1918, the system has been operated in essentially the following manner. The entire flow of Bear River is directed through the inlet canal into Mud Lake (the older Telluride canal is not used). Water is released through the control gates at the Paris dike as needed for downstream irrigation or power generation. When the river flow exceeds downstream requirements, the excess is diverted into Bear Lake through the pumping station and/or spillway. When requirements exceed the river flow, water is transferred from Bear Lake to Mud Lake, by pumping if necessary. The

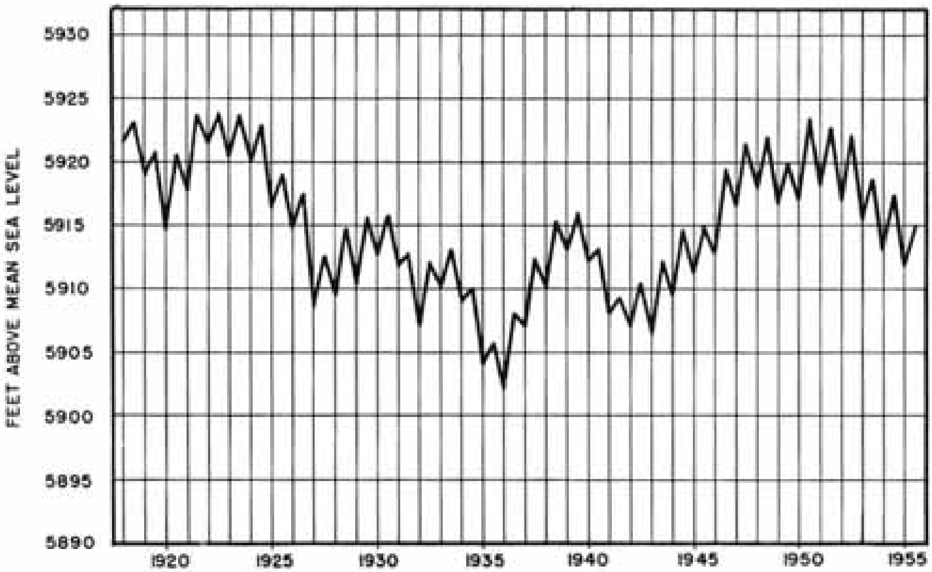


Fig. 9. Fluctuations in water level of Bear Lake, Utah-Idaho. From data of Lifton Pumping Station, Utah Power and Light Company.

maximum lake elevation is 5923.65 feet above sea level. The pumps will not operate when the lake elevation is below 5902.00 feet. This permits a possible fluctuation of 21.65 feet in lake level. The average fluctuation from 1917 to 1955 was just over 3.5 feet. The largest reduction in lake level in any one year (summer of 1926) was 8.5 feet. The largest gain from inflow was 6.5 feet, in the spring of 1946. The lake was at the maximum level in 1921-1923, and it has been at that point only once since, in 1950 (fig. 9).

The only records of fluctuation in lake level prior to man's interference are from a gauge on the lake shore just north of Fish Haven (U. S. Geol. Sur. Water Supply and Irrigation Paper 176). Readings were made during October, November, and December 1903, and from August 1904 to June 1906. The maximum fluctuation recorded during that period was 1.7 feet. The gauge readings were relative measurements only, and were not related to an absolute elevation.

Water Temperatures

Maximum surface temperatures rarely exceeded 70°F. during the period of study. A surface temperature of 73°F., recorded July 30, 1952, was the highest observed. In 1953 and 1954, the maximum surface temperature was 71°F., and in 1955, 69.4°F. In each year of the study, a thermocline formed in late June and persisted into November (figs. 10 and 11).

The even contours of the basin and the frequent and sometimes violent wind storms cause extensive mixing action. This action kept the epilimnion well mixed and practically isothermous. The border between the epilimnion and the thermocline was well defined. The thermocline, however, was very thick and its lower boundary was not definite (fig. 12). Considerable mixing within the

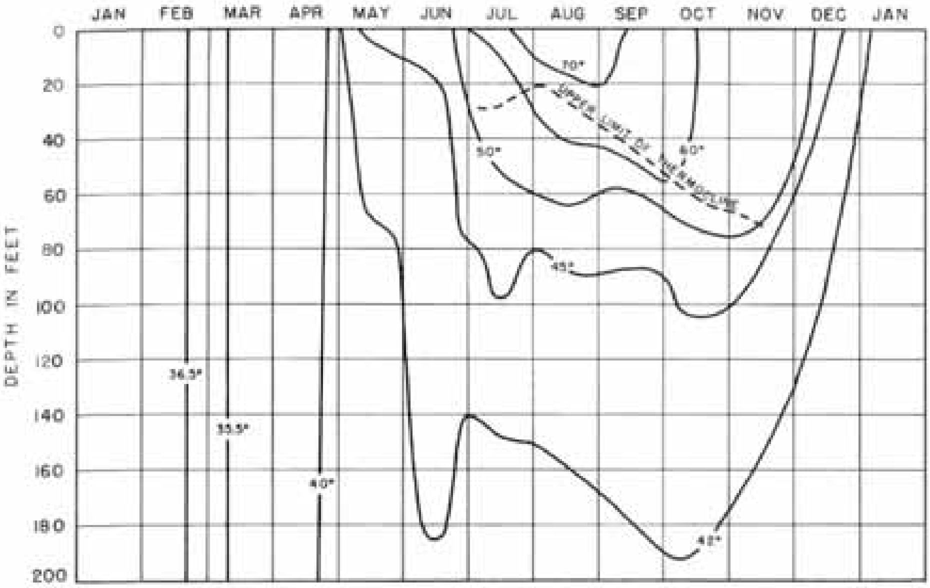


Fig. 10. Depths of isotherms (degrees F.) during 1953 on Bear Lake, Utah-Idaho.

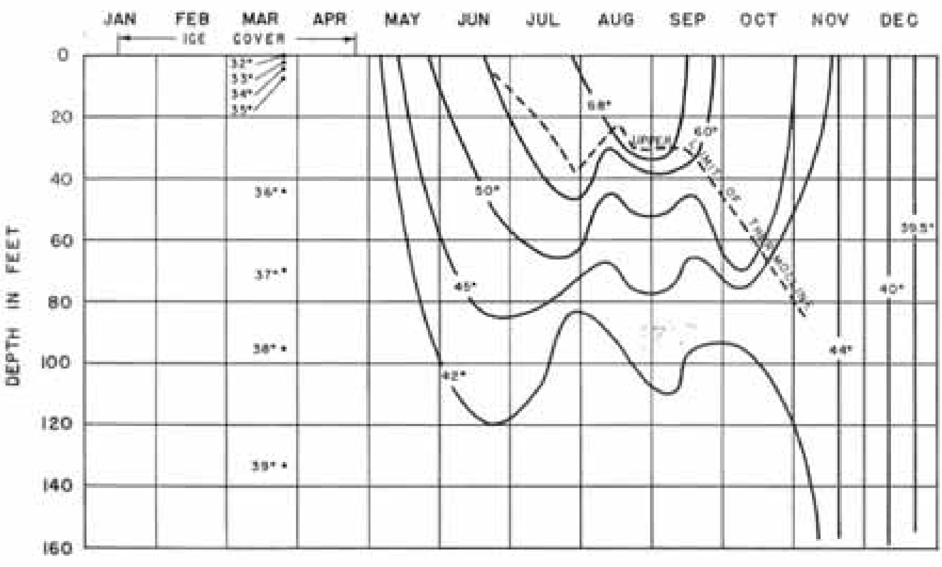


Fig. 11. Temperatures under the ice and depth of isotherms (degrees F.) during 1955 on Bear Lake, Utah-Idaho.

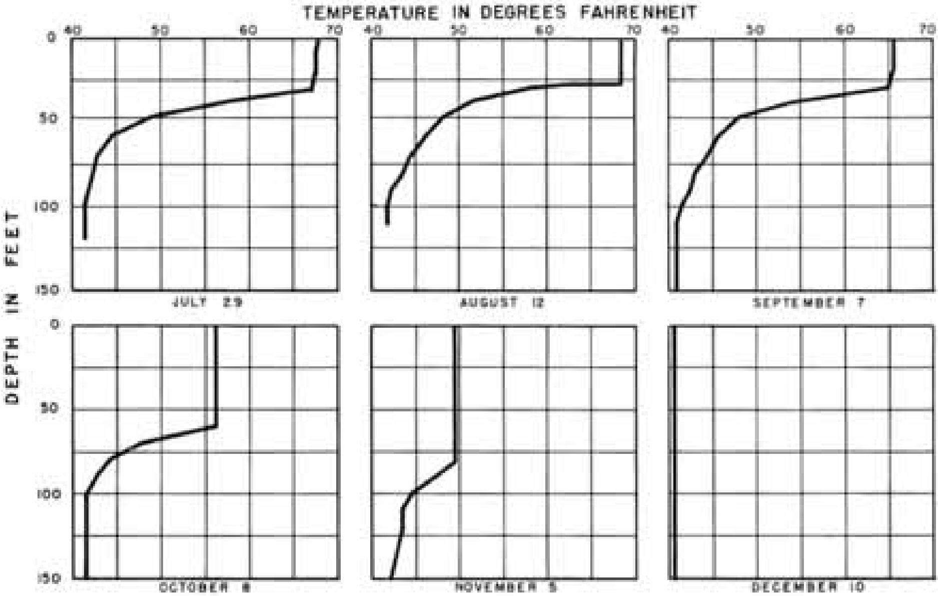


Fig. 12. Representative temperature profiles on Bear Lake, Utah-Idaho, during the latter half of 1955 showing maximum development and gradual extinction of temperature stratification.

thermocline is evidenced by the uneven isotherms (figs. 10 and 11). Replicate temperature profiles at the same location and profiles at different locations on the same day always gave very closely reproducible results. From week to week, however, the depth/temperature relations changed.

Bear Lake has had a complete ice cover in 26 of the last 33 winters. It has been frozen over once in December, 13 times in January, 11 times in February, and once in March. The breakup has come twice in February, once in March, 22 times in April, and once in May. There was no ice cover in the winters of 1952-53 and 1953-54, the only time on record when the lake failed to freeze over for two consecutive winters. In both these winters, the lake was cooled well below the point of maximum density for pure water (39.2°F.) In early March of 1953 and late February of 1954, the lake was isothermous at 35.5°F. The maximum temperature fluctuation of the water below 150 feet during the 3 years was from 35.5°F. to 42°F.

Turbidity

Turbidities in the open water ranged from 1 to 5 ppm (parts per million) silicon dioxide equivalents; the highest turbidities occurred during the spring and fall overturns. Turbidity was high near shore during and after storms, and at the north end when water was flowing in from Mud Lake.

Secchi disc readings taken in 1952 indicate the greatest visibility was 15 feet. Kemmerer *et al.* (1923) report 32.8 feet; Hazzard (1935) gives a range of 11-19 feet for a 10-day period in September; Perry (1943) lists a range of 10-30 feet over the years 1939-1941.

Kemmerer's one reading is tenuous evidence for basing comparison, but it seems probable that turbidities have increased somewhat since his visit. Increase in turbidity is presumably caused by wave action on shores of finely divided material at lower lake levels, and the effect of inflowing turbid water from Mud Lake.

Bottom Types

Aside from narrow and limited rocky areas at the shoreline, the bottom is composed of finely divided materials. A drop of 10 feet in water level below the 5923.65 feet maximum exposes all of the rock areas except on the larger deltas and points. The rocky littoral zone is estimated at less than 0.001 percent of the total bottom area.

In general, the size of the particles decreases with increasing depth. From the shore to a depth of about 25 feet the bottom is sand, except for the rocky areas previously mentioned. This sand is gradually replaced by silt and marl; below about 75 feet, the bottom material is a fine gray silt marl that is 58 percent $CaCO_3$.

Snail and clam shells are in the bottom and shore material in almost all parts of the lake, but no live specimens of either the snails or clams have been found during this or previous studies. The shells are most abundant on the north and northwest shores. Along these shores wave action piles up numerous windrows of shells, which are collected at times by local residents as a source of calcium for chickens.

A representative collection of these shells was sent to the Smithsonian Institution for identification. The institution reported that the predominant snail is *Carinifex newberryi* (Lea), which was reported as present in Utah Lake in 1884, along with other forms or species of *Carinifex* present in several waters in the West. The clam, a "fingernail clam," *Sphaerium mormonicum* Sowerby, is also a stream species and has been reported near Wellsville, Utah.

The mollusks probably were at peak abundance about 10,000 years ago during the high water stage of the lake when there were large areas of shallow water. If Bear Lake followed the course of other lakes in the region, including Lakes Bonneville and Lahontan, it probably reached a level much lower than the present stage during a dry period about 5,000 years ago (Blackwelder *et al.* 1948). Many lakes dried up completely at that time. Probably the disappearance of shallow water wiped out the mollusk population. Evidence from the composition of the present fish population indicates that the lake did not dry up completely.

Water Chemistry

Previous Investigations

Kemmerer *et al.* (1923) include complete chemical analysis for five lakes of the many they studied in the western United States: Bear Lake in Utah and Idaho, and Priest Lake, Lake Pend Oreille, and Hayden Lake in Idaho, and Lake Chelan in Washington. Bear Lake compares favorably with the other lakes in this group in amount of nutrients and essential elements present. The Bear Lake sample was taken in 1912, before diversion of Bear River water into the lake. Kemmerer *et al.* have the following to say about the analysis:

> The most interesting analysis in this set is that of Bear Lake. In the first place it contains a much larger amount of dissolved solids than any other lake (1,060.33 ppm). The magnesium con-

tent of the water is very unusual, it being many times greater than the calcium content. The fact that it contains a fairly large quantity of zinc is also of interest.

And in another section:

The presence of 0.65 parts per million of zinc is also interesting. When this is compared to the small amount of copper necessary to stop growth of algae, it seems that this quantity of zinc would have a similar effect. Since the low temperature and short summer season would also retard the growth of algae, no definite conclusions can be drawn.

From these statements a generally held opinion developed that Bear Lake was not productive because of excessive amounts of zinc in the water.

During the investigations in the early 1940's, several zinc analyses were made (table 1); these included samples of water from Swan Creek and Mud Lake as well as from Bear Lake. Two of the three Bear Lake analyses showed zinc values just over half that reported by Kemmerer. The third analysis was almost identical with Kemmerer's for the lake value, but was at variance with the other two on the amounts in Swan Creek and Mud Lake.

Current Investigation

Zinc analyses were included in the current study in the hope that the zinc question could be answered. This attempt was only partially successful. Several additional questions were raised that appear to be unanswerable on the basis of the evidence at hand.

Analyses were made by James P. Thorne, of the U. S. Department of Agriculture, Soils Laboratory, on the USAC campus. One sample was checked for Thorne by the U. S. Department of Agriculture Soils Laboratory at Ithaca, New York. In all, 35 determinations were made on 3 separate collections of water from Bear Lake and its tributaries. The largest amount of zinc found was 0.076 ppm in a sample of water flowing into Bear Lake from Mud Lake. The highest

Table 1. Results of analyses for zinc of water supplies from Bear Lake, Mud Lake, and Swan Creek

Authority	Date collected	Location and ppm zinc		
		Bear Lake	Swan Creek	Mud Lake
Kemmerer, et al. (1923)	Aug. 8, 1912	0.65	....	....
Derby Laws* (Chemist at U.S.A.C.)	May 10, 1941	0.36	0.42	0.80
State of Utah,* Division of Chemistry	Dec. 16, 1941	0.35	0.18	....
Utah Power* and Light Company	May 1, 1943	0.64	0.80	0.48
U.S.D.A. Soils Lab. at U.S.A.C.*	Jan. - June 1956	.005 - .038 (14 analyses)	.005 - .034 (9 analyses)	.001 - 0.76 (5 analyses)
U.S.D.A. Soils Lab.* at Ithaca, New York	June 6, 1956	.0050	.0057	....

*Unpublished report on file at Department of Wildlife Management, USAC, Logan, Utah figure for lake water was 0.036 ppm; the lowest, 0.005 ppm; the average of 14 determinations for Bear Lake was 0.020 ppm zinc. Logan River water, a stream of high productivity, contained 0.009 and Logan tap water, of spring source, 0.013 ppm zinc by comparison. Thorne does not consider the results to be adequate from the analyst's point of view because of the lack of reproducibility. However, even acceptance of the maximum values would still seem to remove zinc as a limiting factor.

As to the reason for the great difference in results from the other analyses, there can be only speculation. Reduction of the zinc content of Bear Lake can be explained by the dilution with Bear River water. Changes of the magnitude indicated in the zinc content of the flowing streams do not seem probable.

Evidence of a complexing element or ion was noticed in the zinc determinations, and tests were made in September 1956 for copper, lead, and cadmium as possible sources. However, none of these elements exceeded one one-hundredth part per million. For Bear Lake the values in parts per million were: copper, .005; lead, .003; cadmium, .000; for Swan Creek the values in parts per million were: copper, .009; lead, .006; cadmium, .001.

A condition that may have some limiting effect on plant production is the presence of much more magnesium than calcium (table 2). Meyer and Anderson (1952) state that excess amounts of magnesium may be toxic in solution cultures unless offset by sufficient amounts of calcium. This relation has not been investigated in Bear Lake.

The dilution of Bear Lake by the Bear River can be traced in the chemical analyses. Kemmerer *et al.* (1923) report methyl orange alkalinity equivalent to 586 ppm; Hazzard (1935) reports 430-479 ppm; Perry (1943) gives a range of 375-400 ppm; for the present study (1952-1955) the range was 294-313 ppm. Methyl orange alkalinities of the incoming streams are: Bear River 192; Swan Creek 181, and St. Charles Creek 195 ppm.

Dissolved Oxygen

All investigations have reported abundant oxygen at all depths. Kemmerer *et al.* remark that Bear Lake has more oxygen in the lower waters than at the surface in August. Perry (1943) states that dissolved oxygen was abundant at all depths, rarely going below 5 ppm. A value of 5.9 ppm at 210 feet in September 1952 was the lowest obtained during the present study.

pH

During the present study, pH values ranged from 8.4 to 8.6. Perry (1943) reports 8.4 to 8.7 and Hazzard (1935) 8.0 to 8.5.

Biology

Rooted Aquatic Plants

Emergent aquatics are scarce. A few patches of cattail (*Typha* sp.) grow along the northwest shore between Fish Haven and St. Charles Creek; some bulrush (Scirpus sp.) also appears in the same area. Bulrush is fairly common along the west shore from Fish Haven to Swan Creek, and isolated patches appear along the shore almost to the south end. The north and south shores are bare of emergents, and only a patch or two is on the entire east shore. Several old timers report that before fluctuation of the water level the cattail and bulrush extended along the north shore. Kemmerer *et al.* (1923) report from their

Table 2. Chemical analyses of water from Bear Lake, Utah-Idaho, and from two tributary streams. All figures in parts per million

Date and source	Location	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	NO_3	NH_4	PO_4	Phenol-phthalein alkalinity	Methyl orange alkalinity
Kemmerer et al. (1923)	Bear Lake	4.1	152.0	66.3	10.5	78.5	96.8	78.45	566.0	0.2	....	0.06	....	586*
Hazzard 1935	Bear Lake	....	....	....	....	....	....	....	....	....	....	....	25-37.5	430-479
Perry (1943)	Bear Lake	....	....	....	....	....	....	....	....	....	....	....	15-25	375-400
Project personnel 1952-55	Bear Lake	....	....	....	....	....	....	....	....	....	....	....	27-29	294-313
Soils Lab† 1952	Bear Lake surface water range of 3 analyses	17	78-87	23-47	6-11	53-57	71-78	13-18	352-381	....	....	....	....	....
Soils Lab 1952	Bear Lake sample from 200 ft. depth	17	81	28	6	57	78	18	352	....	....	....	....	....
Soils Lab 1952	Inflow from Mud Lake	27	95	54	12	58	75	0	467	....	....	....	....	....
Soils Lab 1952	Swan Creek	47	13	4	2	....	....	....	....	1.8	0.48	0.09	....	....

*Converted from date of Kemmerer **et al.** (1923 by Perry, 1943)

1912 observation: "Little vegetation exsits along the shores except at the north and northeast ends of the lake."

The major submerged aquatic is a short thin-leafed *Potamogeton* sp. Beds occur along the west shore from St. Charles Creek to Garden City, and occasional beds are present along the rest of the west shore; a few grow along the east shore. Fragments of *Potamogeton* appear in abundance after every storm, floating on the surface and thrown up on the beach. Isolated shoots of coontail (*Ceratophyllum demersum*) are present along much of the shore, but this plant is nowhere abundant. A dense bed of *Ranunculus* is present in a sheltered cove at the mouth of Swan Creek. This is the only luxuriant growth of submerged aquatics in the lake. All the plants present in Bear Lake, and several others including *Myriophyllum*, *Utricularia*, and *Polygonum*, are common to abundant in Mud Lake (Reeves 1954). The contrast between the two areas is striking (fig. 8).

Bottom Organisms

Research on the bottom organisms and their use as food is continuing. Only a general summary of this subject is presented here.

The bottom organisms vary in both quantity and composition according to the bottom type. Rocky areas under water have Gammarus, aquatic mites, some midge larvae, and crayfish. In the fall of 1952, the water level was high, and these organisms were locally quite abundant in the rocky areas. When the lake level lowered, the amount of rocky area under water decreased drastically. The bottom organisms were considerably less numerous in those rock areas that remained under water. These remaining rocks were usually half buried in sand and covered with precipitated marl. Probably wave action would reconstitute the cover in these areas if the lake remained at one level long enough.

The organisms in sandy areas include a few mites and diptera larvae. Isolated *Myriophyllum* fronds or small clumps of *Potamogeton* are present in some sandy areas. Where these plants could be examined by wading, they were found to hold abundant midge larvae and some Gammarus and mites. Mayfly nymphs were also present in clumps of submerged aquatics along the northwest shore.

Cattail and bulrush stands provided relatively little cover for bottom organisms. Some dragonfly, damselfly, and mayfly nymphs were on stalks and around roots. As the water deepens and the sand grades into a sand-silt-marl mixture, the number of midge larvae increases to a maximum density of about 500 per square yard. Aquatic *Oligochaeta* are present in this bottom type, up to 400 per square yard. A small ostracod is also present, found apparently on or just above the surface. The ostracods are difficult to sample but they appear to be extremely numerous.

In the deeper water, below about 75 feet, where the bottom is fine silt marl, midge larvae are not present, and ostracods are much less abundant. *Oligochaeta* are considerably more numerous here, and number up to 3,000 per square yard.

Plankton

A comprehensive study of the plankton was beyond the scope of the present investigation. The zooplankton were sampled on a random non-scheduled basis and some general information is available. A study of methods of sampling the phytoplankton of the lake was carried on in conjunction with the present study. Most of these sampling data will be published elsewhere. Limited information about the phytoplankton population is presented here.

Phytoplankton. On August 8, 1912, Kemmerer *et al.* (1923) made a series of vertical hauls at various depths with a closing plankton net of no. 20 silk. They report zooplankton in all hauls, but report phytoplankton in only one, that from 5 to 10 meters. In this stratum they report 7,850 cells of the blue-green algae *Coelosphaerium* per cubic meter, 7,850 cells of the diatom *Fragilaria* per cubic meter, and 15,600 cells per cubic meter of the dinoflagellate *Ceratium*, which they list as a protozoan.

Hazzard (1935) made a series of plankton net hauls during his short survey of the lake September 20 to 30, 1933. He also noted that some quantitative work was done by centrifuge, but he gives no description of the method. Hazzard lists several genera not reported by Kemmerer, but does not mention two genera listed by Kemmerer, namely, *Ceratium* and *Coelosphaerium*.

The Foerst Electric Plankton Centrifuge and membrane filter were the more important separation devices used in the present investigation of phytoplankton. Examination of the concentrate under low power (about 100x) revealed only an occasional small diatom. Under high power (about 400x) numerous small phytoplankton cells were found. The more abundant genera were *Ankistrodesmus, Oocystus, Lyngbya, Lagerheimia, Dinobryon, and Dictyosphaerium.* Diatoms were not numerous; they never exceeded 5 percent by number of the total cells. All of the cells were small (from 2 to about 50 microns in their largest dimension); only an occasional diatom was larger than 50 microns. A no. 20 silk net could not be expected to retain cells of such small size, and examination of several net samples revealed none of these smaller cells.

Of the phytoplankton forms reported (by Kemmerer and Hazzard) from net samples, only one, *Ceratium*, was found in a net sample during the present study, and this appeared only once.

During the present phytoplankton study, water samples of 3 and 6 liters were used. Kemmerer's data are equivalent to 8 cells per liter for *Coelosphaerium* and *Fragilaria* and 16 cells per liter for *Ceratium*. Hazzard reports quantitative data only for *Staurastrum*, 1 to 13 cells per liter. Counting methods in the present study involved examination with a haemacytometer of only a small fraction of the concentrate from the water samples. Organisms present at the densities reported above would have only a small probability of being seen consistently. It might be expected that they would be seen at least once during examination of more than 30 samples in a 2-year period if they were actually present at the densities reported. Of the forms other than diatoms reported by Kemmerer and Hazzard only *Microcystis* was seen in the phytoplankton samples.

In the present study, the diatoms were not identified, but because of their relatively minor importance quantitatively they were treated as a single group. It was obvious, however, that several species were present.

The genera (other than diatoms) reported by the previous investigators are quite distinctive and could not be confused with the forms found in the present study. The evidence is not conclusive, but it seems to indicate some changes in the species composition of the larger forms during the development of the lake as a reservoir, with the subsequent changes in chemical composition of the water. Since the earlier investigations did not sample the nannoplankton forms, no similar comparisons can be drawn for them. These small cells are present in tremendous numbers. *Ankistrodesmus falcatus*, the most abundant species, exceeded 2 million cells per liter in several samples. The greatest total number of cells found was just under 4.5 million per liter.

Numbers are, of course, only a rough index of productivity. The individual cells have small volumes, in the range from 12 to 250 cubic microns.

On a volume basis, the denser samples ranged from 0.4 to 1.1 x 10^9 cubic microns per liter. Verduin (1951) reports maximum values of 16 x 10^9 cubic microns per liter for Lake Erie in 1949, and 6 x 10^9 cubic microns per liter in 1950.

Phytoplankton productivity per unit volume is low in Bear Lake, but not as low as previous investigations have indicated. The total productive volume is large. The epilimnion extends to more than 50 feet by late summer, and samples indicate good production throughout this zone; some live cells are found as deep as 100 feet. Some production continues under ice cover. Samples taken through 12 inches of ice with a 6-inch snow cover gave 0.05 to 0.2 x 10^9 cubic microns per liter.

Zooplankton. Kemmerer et al. (1928), who sampled by vertical hauls with a closing net, report two copepods: *Epischura*, taken at all depths sampled, and *Canthocamptus* taken in only one 50- to 55-meter sample. The rotifer, *Polyarthra*, they report from 2 samples, 5 to 10 and 10 to 15 meters. These were the only zooplankton forms they found.

Hazzard (1935) reports only one copepod, *Epischura*, and five rotifer species: *Conochilus*, the most abundant; *Polyarthra*, second; *Anurae*, *Triathra*, and *Nothalaca*, occasional; and one cladoceran, *Daphnia*.

Perry (1943) and Stillman Wright, who was stationed in Logan as a biologist with the Fish and Wildlife Service, did considerable plankton sampling in conjunction with Perry's study of the Bonneville cisco of Bear Lake. Their sampling was done with a 10-liter plankton trap, a device considerably more accurate quantitatively than any type of unmetered net tow; however, there may be an avoidance reaction to the plankton trap by some zooplankton forms that would cause some to be missed or underestimated.

Perry mentions 12 genera of zooplankton: 3 copepods, *Canthocamptus, Cyclops, Epischura;* 3 rotifers, *Conochilus, Polyarthra, Anurea;* and 6 cladocerans, *Alona, Bosmina, Chydorus, Daphnia, Ceriodaphnia*, and *Moina*. He gives data on vertical distribution for the genera *Polygarthra, Conochilus, Epischura*, and *Anuraea*, on nine dates from June through November 1940. Four representative distributions of the two most abundant species are presented here (fig. 13). Additional data on the seasonal change in abundance of two of the more important species, *Epischura* and *Conochilus*, are presented by permission of Dr. Wright from unpublished data assembled during their investigation 1939-41 (fig. 14).

Epischura and *Conochilus* were the dominant forms in collections made during the present study. These collections do not warrant detailed quantitative treatment. Duplicate net hauls made at the same time and location varied as much as 200 percent. Maximum densities found in a vertical net haul were 11.5 *Conochilus* colonies per liter and 4 *Epischura* per liter. The maximum figures reported by Wright (fig. 14) are somewhat higher for *Epischura* and lower for *Conochilus*, but they are not drastically different for either form.

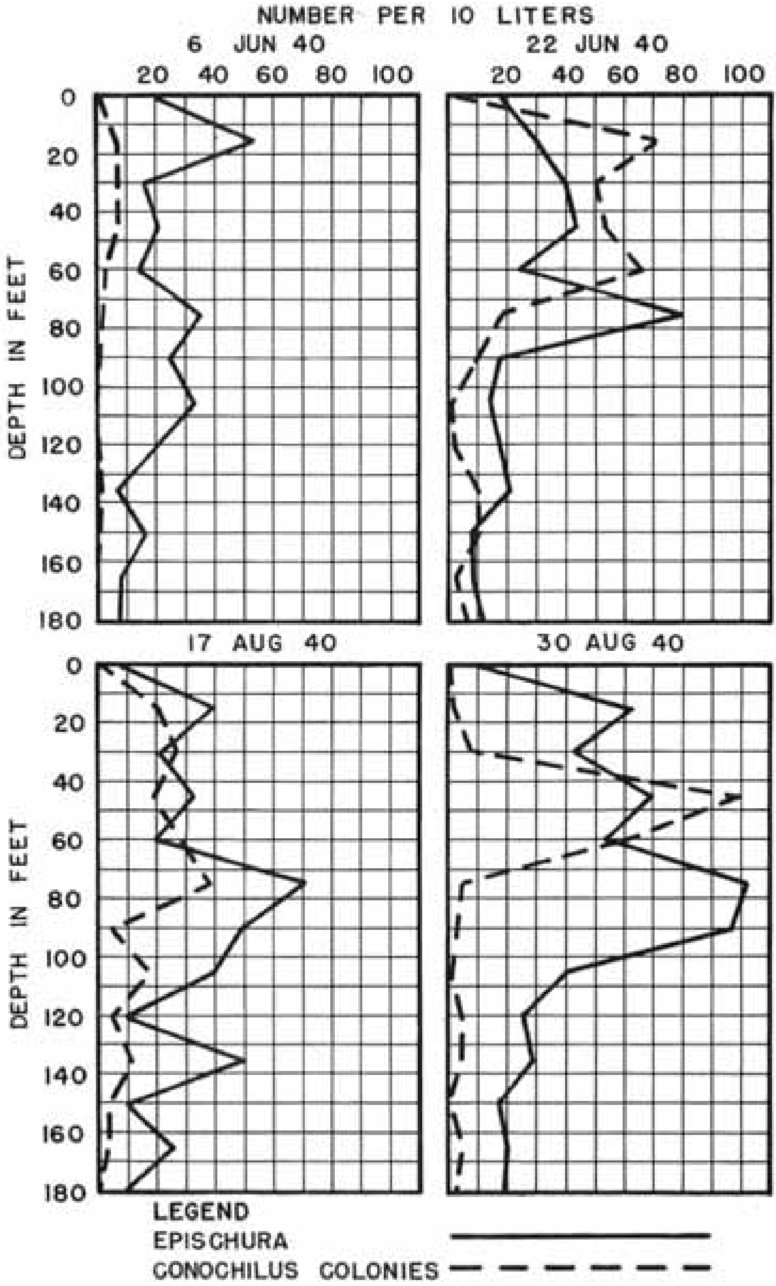


Fig. 13. Vertical distribution of the zooplankters Epischura and Conochilus (colonies) on Bear Lake, Utah-Idaho, during the summer of 1940 (from Perry, 1943).

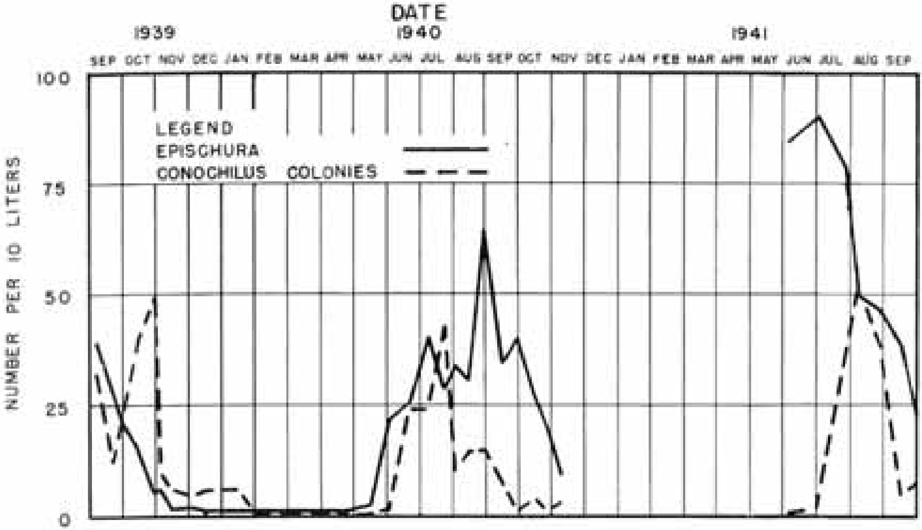


Fig. 14. Seasonal changes in abundance of the zooplankters Epischura and Conochilus (colonies). From unpublished date of Dr. Stillman Wright.

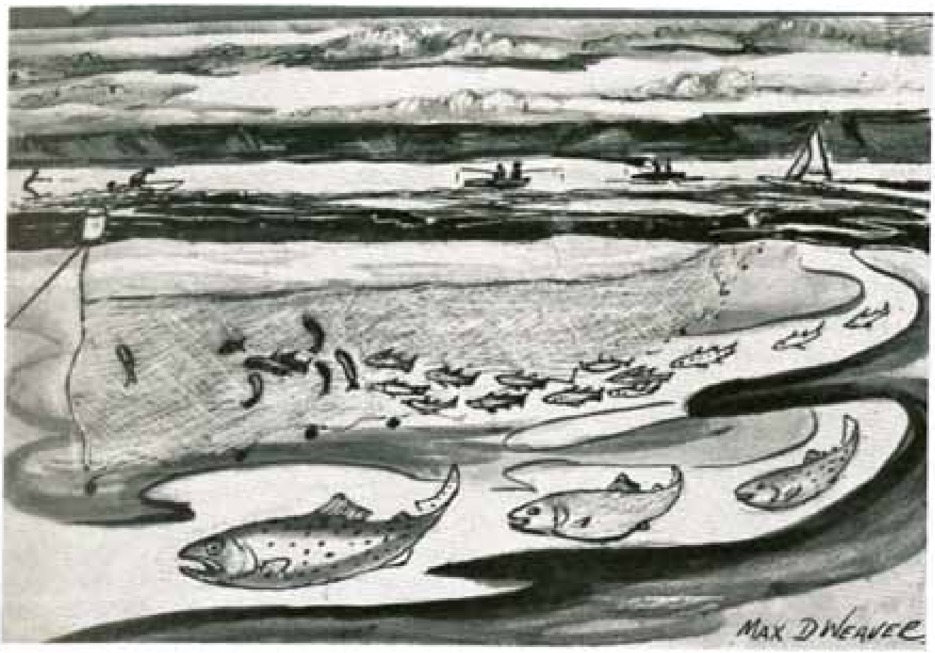
No cladocerans were taken in plankton net hauls during the present study, but they were found several times in the stomach contents of ciscoes taken in gill nets. It seems most reasonable to assume the presence of cladocerans in the zooplankton samples gathered by Perry resulted from the greater efficiency of his plankton trap rather than to a population change. All other sampling reported has been done with plankton nets, and a single occurrence of *Daphnia* reported by Hazzard (1935) is the only cladoceran reported.

Conochilus has been an important plankton in practically every collection reported by Hazzard (1935), Perry (1943), Wright, and the present study. The colonies formed by this rotifer are large and distinctive; they could hardly be overlooked or misclassified. Kemmerer *et al.* (1923) made their collections at a time of year when *Conochilus* was found to be abundant by all subsequent studies. Since Kemmerer's plankton data were collected during a single day, they do not give a substantial basis for comparison. Since Kemmerer made a series of hauls at several depths, it seems highly improbable that *Conochilus* could have been missed if it had been present in any appreciable numbers. Here again is at least suggestive evidence of a change in plankton composition associated with the conversion of Bear Lake into a reservoir.

The production of plankton in Bear Lake is low indeed when compared to that of productive bodies of water such as Henry's Lake and Island Park Reservoir in Idaho; and Strawberry Reservoir, Fish Lake, and Panguitch Lake in Utah. Production of phytoplankton in these waters is often of sufficient volume to color the water green. Where the zooplankton volume from a 50 foot haul in Bear Lake would be measured in tenths of a cubic centimeter, an equivalent haul in one of these other waters might be ten to one hundred times this volume.

These more fertile waters are without exception much smaller and shallower than Bear Lake. No larger lakes can compare in productivity per unit volume with the ones mentioned above. When compared to that in other large deep lakes the production of zooplankton in Bear Lake is low; but not drastically so. Stross (1953) gives data for *Cyclops*, the most abundant zooplankton in Lake Pend Oreille, Idaho; they show a maximum density equivalent to 16 organisms per liter for a 100-foot vertical haul, compared to 4 organisms per liter in Bear Lake for *Epischura*. Carl (1952) lists a maximum copepod density of 5.14 per liter for Cowichan Lake, British Columbia.

Whatever numerical bounds may be set on the terms "productive" or "unproductive," it must be remembered that the plankton population of Bear Lake is sufficient to support a large population of an almost exclusively zooplankton feeding fish, the Bonneville cisco.



Fish Populations

Species Present and Their Relative Abundance

THE two most numerous fish in Bear Lake are the Bonneville cisco and an undescribed sculpin. Gill nets do not sample either of these two fish effectively because only the largest of the Bonneville cisco are subject to capture, and the sculpin is a sedentary species. Cisco were taken at a relatively low rate in gill nets set on the bottom, but nets set anywhere from just off the bottom to near the surface caught the fish in numbers that equaled or exceeded those of any other fish at any depth (Perry 1943). Perry also demonstrated that Bonneville cisco are independent of the bottom. They seek depths where temperature and plankton concentrations are most acceptable. When information from all sources is considered, it appears that Bonneville cisco are more abundant than any other fish in Bear Lake, with the possible exception of the sculpin.

Sculpins were caught on the bottom in gill nets. They were also extremely abundant in collections made by poisoning shore areas, and in electro-fishing collections made in shallow water in April. Although sculpin are too small to be taken in the ¾-inch mesh of experimental gill nets, they were the most commonly caught fish in ⅜-inch mesh gill nets.

The mid-water gill net sets made during this study took only six Bonneville cisco, one Utah sucker, and one rainbow trout. The fact that mid-water sets took only one sucker and no Bonneville or

Bear Lake whitefish is accepted as evidence that these two fish and the Utah sucker are almost exclusively bottom dwellers in Bear Lake. The small cisco catch was probably the result of the wide dispersal of ciscoes in the spring and late winter when this netting was done. This theory is partially substantiated by the fact that considerable numbers of the two whitefishes and Utah suckers were caught in nets set at the same depth and temperature as midwater sets, but on the bottom. The Utah sucker, although numerically less abundant than Bonneville cisco and sculpin, contributes more to the total pounds of fish in the lake than the combined weight of the other two fish. The Bear Lake and Bonneville whitefish in aggregate are slightly fewer in number than the sucker, but from the standpoint of total pounds in the lake they are considerably less important than the sucker. It is believed that the Bear Lake whitefish is the more abundant of the two whitefishes.

The Utah chub ranks fifth on a scale of relative abundance but probably represents less than 4 percent of the total number of fish. The carp is judged to be sixth in relative abundance. To the shore observer, the carp appears considerably more important than it actually is because of its habit of concentrating at or near the surface in shallow water. On warm days, carp may, however, be found at the surface as far as a mile from shore.

The low catch of lake trout, cutthroat trout, and rainbow trout in net sets and in other types of collections makes it difficult to draw conclusions about their distribution and abundance, but it appears that all these fish stay close to the bottom and that the total population of all trout, by number, is not more than 3 percent of the fish population.

Gill nets set close to shore caught rainbow trout; and most of the rainbow trout taken by hook and line were caught by shore fishermen. These two circumstances make it appear that rainbow trout are not as scarce as the deep water gill net sets indicate. In years when rainbow trout are heavily stocked, their numbers might exceed those of the total of the two other trouts. This, however, is felt to be a temporary condition.

The yellow perch, green sunfish, kokanee, Carrington's dace, and smallfin redside shiner are present, but in small numbers.

The total population of fish in Bear Lake in 1952-53 was considerably greater than it was in 1938-42 if comparative rates of capture in similar nets are reliable indicators. The rates in the earlier study and the more recent one were 0.706 and 1.843 fish per hundred-foot gill net hour, respectively. Tests of significance yield a "t" value of 4.35 for the difference in the mean rates of capture. This exceeds the tabular value of 2.04 and indicates significance at the 95 percent confidence level. In short, the difference is probably real (fig. 15).

The greater length of the nets and the longer immersion periods of the net sets in the earlier study may have been responsible for a lower rate of capture per unit of effort. However, examination of the data yields no evidence to confirm this suspicion. Because of the small number of gill net sets in shallow water during the earlier study, it is suspected that the carp habitat was under-sampled. The habitat of all other species was sampled at least as well in 1938-42 as it was in 1952-53. If we postulate a lower efficiency of the nets used for sampling in 1938-42 (although no evidence in this study suggests it), we would have to assume an efficiency of only 55 percent of that experienced in the recent study,

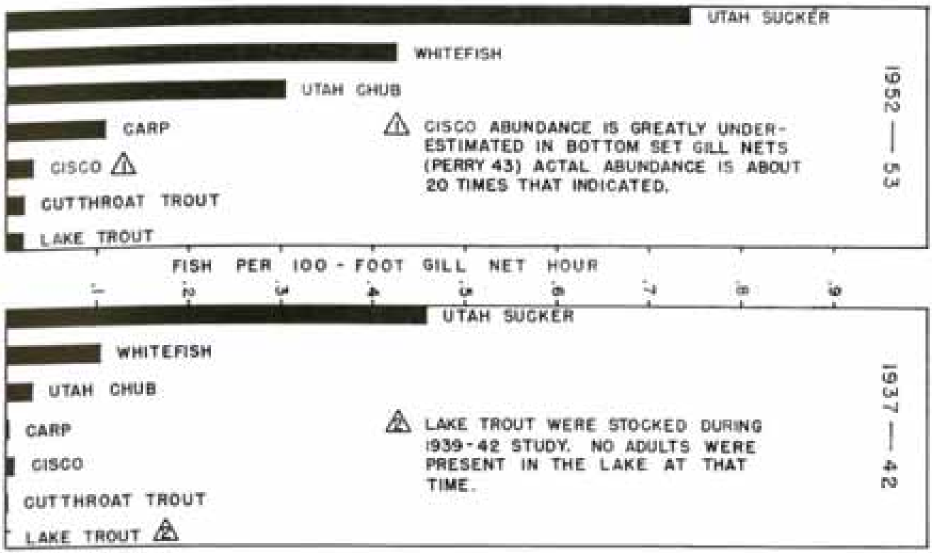


Fig. 15. Comparison of rates of capture of fish in experimental gill nets as experienced in 1938-42 and 1952-53.

before the difference in mean rates of capture would no longer be significant. It should be acknowledged that other workers have considered linen gill nets less efficient than nylon gill nets. All fish represented in both studies shared the recent increase in density, if it is, as we believe, a real difference. Cursory gill net sampling by Hazzard in 1933 also yielded a lower estimate of fish density than the more recent collections.

Distribution of Fish by Depth and Bottom Zone

The summer distribution of a species is discussed separately from that of the rest of the year. The word *summer* is used to designate the period when surface temperature of the water exceeds 60°F. In both 1953 and 1955, the water was at least this warm from mid-June until mid-October (table 3) (figs. 16 and 17).

Rainbow trout were taken only in gill nets and seines that were used in water less than 10 feet deep. Shore fishermen caught almost all rainbow trout appearing in creels.

Gill net sets indicate cutthroat trout are most abundant between shore and the 75-foot contour throughout the year. They were taken only in nets set near the bottom. However, an inshore movement of cutthroat trout occurs in spring, and a minor but definite movement offshore appears again in the fall. Degree of movement appears constant at all seasons.

The lake trout exhibit much greater activity in the warmer months than in winter. The 25- to 75-foot zone is their chosen habitat in the summer and early fall; they move out to deeper water in winter. One set, made during the summer of 1953, in 193 feet of water, took three lake trout. This exception to the general distribution pattern was corre-

Table 3. Fish captured per 100-foot net hour in experimental gill nets (bottom set) during 1952 and 1953

	Depth of sets (in feet)									
	0-25		50-75		25-50		75-100		100-200	
Season 100-ft. gill net hours	Winter 180	Summer 320	Winter 99	Summer 61	Winter 126	Summer 89	Winter 210	Summer 351	Winter 280	Summer 189
Cutthroat trout	0.04	0.006	0.01	0.05	0.01	0.03	0.01	0.006	....	0.005
Lake trout	....	....	....	0.03	....	0.06	0.005	0.01	0.004	0.005
Bonneville cisco	0.01	....	0.01	0.02	0.09	0.02	0.03	0.10	0.13	0.14
Bonneville whitefish Bear Lake whitefish	0.05	0.02	0.06	0.75	0.10	0.86	0.27	0.22	0.31	0.46
Utah sucker	0.26	0.45	0.53	1.44	0.20	0.99	0.39	0.14	0.11	0.13
Carp	0.06	0.36	0.01	....	....	....	....	....	....	....
Utah chub	0.17	0.81	0.65	0.20	....	....	0.04	....	....	....
Yellow perch	0.01	0.09	....	....	....	....	....	....	....	....

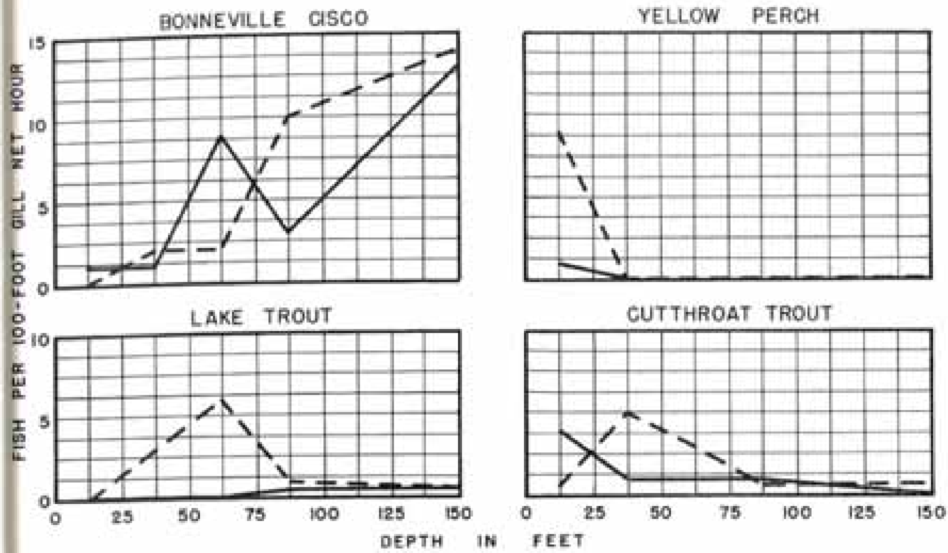


Fig. 16. Rates of capture of fish in experimental gill nets (bottom set) in several depth zones. The broken line indicates summer captures, the solid line indicates winter captures.

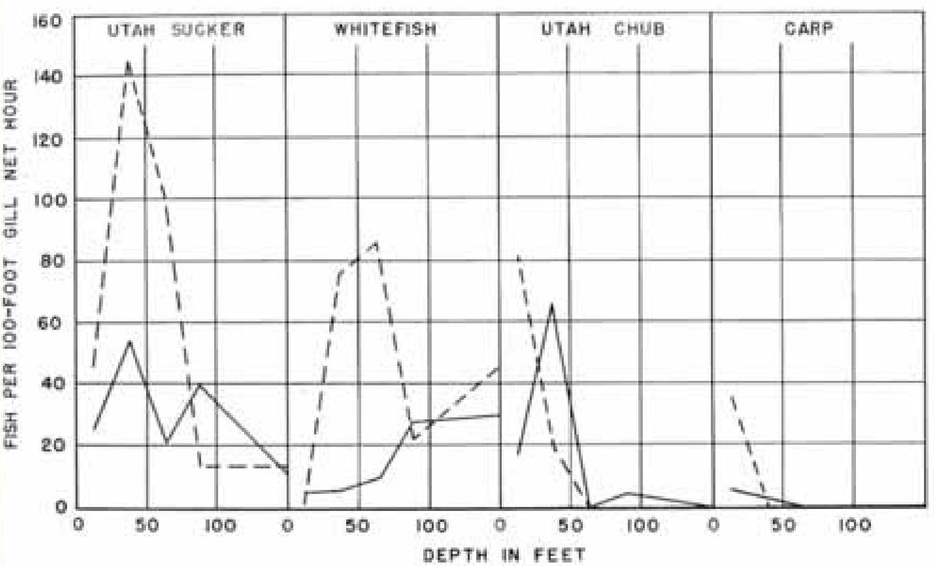


Fig. 17. Rates of capture of fish in experimental gill nets (bottom set) in several depth zones. The broken line indicates summer captures, the solid line winter captures.

lated with an unusual concentration of Bonneville whitefish for that depth.

The pattern of activity and distribution for the two whitefish is similar to that of the lake trout. It appears reasonable that the whitefish population is pursued by the lake trout. Since the Bear Lake whitefish has seldom been identified in collections taken at depths of less than 75 feet, it appears that the whitefish commonly associated with lake trout in summer must be the Bonneville whitefish. Neither of these two whitefish was taken in mid-water gill net sets.

The Bonneville cisco is more abundant in mid-water than near the bottom. This is apparently a reaction to temperature rather than to depth. Only a small portion of the cisco population is susceptible to capture on the bottom (Perry 1943). A greater number of cisco appears in bottom net sets as the depth of the water increases. No consistent difference in activity was detected between cisco collected in summer and those collected at other times of the year in bottom-set gill nets. The one exception to this last statement occurs during the spawning season, in late December and January. Generally, we did not collect fish during spawning periods.

The carp and yellow perch exhibit identical movements and depth preferences. Neither fish wanders out deeper than the 50-foot contour, and both display a greater degree of movement in summer than in the remaining seasons. Both species achieve highest densities in very shallow water, but carp occasionally travel a mile or more from shore, usually just below the surface.

Utah chub were captured most frequently in summer at depths of less than 25 feet. They move offshore to the 25- to 50-foot zone in the colder months. Activity appears little changed by seasonal temperature fluctuations.

The Utah sucker is much more active in summer than in fall, winter, or spring. The area between the 25- and 75-foot contour contains the greatest population density during all seasons; however, nets set at all depths and seasons were seldom lifted that did not contain at least one sucker. This fish is strictly a bottom dweller; only one was captured in a mid-water set.

A coincidence in season of greatest activity (summer) and zone of greatest abundance (25-75 feet) for the whitefishes, lake trout, and cutthroat trout is the most significant feature of the depth distribution data. The creel census indicates summer as the poorest time to fish in Bear Lake, yet the most sought after species were netted most frequently at this time (spawning seasons excepted). Although the 25- to 75-foot depth zone is inhabited by the most desired species in summer, it is too far out for shore fishermen. The low rate of success among summer boat fishermen is difficult to explain but may be because of the inability to locate the zone of greatest fish density.

Carrington's dace were present in limited numbers in all shallow, rubble bottom areas. Small Utah suckers appeared occasionally in shallow areas but were most abundant near creek mouths and in the vicinity of bulrush beds. Small sculpin also were present near bulrush beds and rocky areas. Fingerlings of trout and whitefish were rare in all areas poisoned or seined. Small Utah chub, smallfin redside shiners, green sunfish and small carp were common to abundant in the lower portions and at the mouths of the two muddy, sluggish streams at the south end of Bear Lake during this study, but were rare elsewhere. Small yellow perch and dace occasionally were taken where these streams enter the lake.

In Swan Creek, legal-size (7 inches total length) cutthroat trout and rainbow trout commonly were taken with the aid of an electric shocking machine. Sub-legal-size rainbow and cutthroat trout were abundant in this stream. Except during the spring months when adult suckers were quite abundant, no other fish were in Swan Creek. In lower St. Charles Creek, sub-legals of rainbow and cutthroat trout were common. Stocked legal-size rainbow trout were also common, but legal-size cutthroat trout were rare. Carp and suckers were abundant. Upper St. Charles Creek contained occasional brook and cutthroat trout and an abundance of sculpins.

Spring Creek has a spawning run of cutthroat trout during high water years, but a check during the irrigation season of 1953 revealed a flow of only 1 c.f.s. and a population of only non-game fish.

Fallula Spring is intermittent but at times contains a large population of non-game fish. Trout were rare or absent when the stream was sampled.

South Eden Creek is intermittent and is highly turbid in the periods when it does flow. Sampling by electro-shocking produced no fish.

North Eden Creek is permanent, and its upper part is free of high turbidities. It is maintained as a private fishery and and is not open to the public. An excellent population of eastern brook, rainbow, and cutthroat trout is maintained by stocking. However, cutthroat trout can escape to Bear Lake from this private fishery. There is no evidence of a spawning run from Bear Lake.

The number of tributary streams available for spawning rainbow and cutthroat trout is negligible. St. Charles and Swan Creeks are marginal for spawning and subsequent growth of the fry, because of their small productive area, but other conditions are satisfactory. These two streams supply a total of only about 20 acres of potential spawning ground; and even this area is severely reduced by irrigation diversions in July and August.

Life History Data

Cutthroat Trout

The Utah cutthroat trout is the only trout native to Bear Lake. Early introductions included Yellowstone cutthroat trout, probably other subspecies of cutthroat trout, and rainbow trout. Two circumstances – the stocking of mixed species of *Salmo* and the fact that all species of spring-spawning *Salmo* apparently hybridize freely in Bear Lake– have produced today's Bear Lake cutthroat trout. This fish really is a mixture of several subspecies of cutthroat and rainbow trout. Relatively few of the Bear Lake trout were judged to be pure cutthroat. The dominant cutthroat trout type is the hybrid described above. However, regardless of its mixed ancestry, the cutthroat ecologically is different from the stocked rainbow trout and the other wild fish identified in this study as a rainbow trout. The cutthroat grows faster and to a much greater size than the rainbow trout in Bear Lake.

Many of the wild *Salmo* sent to Dr. Robert R. Miller, associate curator of fishes, University of Michigan, Museum of Zoology, were tentatively identified as rainbow x cutthroat trout hybrids. At one time during the study, an attempt was made to determine the degree of hybridization between cutthroat trout and rainbow trout. However, this attempt was abandoned as being impractical, if not impossible, and all fish that had been labeled as either cutthroat trout or cutthroat x rainbow trout are

Table 4. Calculated total lengths of Bear Lake fish (in inches) at end of each year of life

Species	Year of collection	Number studied	Studied by*	Year of life 1	2	3	4	5	6	7	8	9	10	11	12	13
Cutthroat trout	1951-52	108	2	....	5.9	10.1	14.3	21.3	25.0	28.7						
Cutthroat trout	1953-55	39	1	1.5	6.4	10.4	14.1	17.1	19.6	20.2						
Rainbow trout	1955	33	1	4.2	8.1	10.9	14.8	14.0								
Lake trout	1952-55	44	1	8.7	13.5	17.1	19.7	21.8	23.3	24.8	26.5	27.3	28.6	29.4	30.1	31.6
Bonneville cisco	1938-41	1215	3	2.1	4.1	5.7	6.5	7.0	7.2	7.4	7.6	7.6	7.7			
Bonneville cisco	1952	55	1	2.2	4.1	5.5	6.5	7.0	7.2							
Bonneville whitefish	1951-54	245	1	3.2	5.7	7.5	9.2	10.7	12.7	14.6	16.4					
Bear Lake whitefish	1952-54	72	1	1.3	3.0	4.4	5.2	5.9	6.5	7.0	7.5					
Utah sucker	1941; 1952	189	1	1.5	5.1	8.4	10.9	13.1	14.6	16.5	17.6	19.9	22.0			
Carp	1952; 1953	109	4	2.4	5.6	8.3	11.0	13.3	15.0	16.5	17.8	18.4	19.0	20.9	21.8	26.7
Utah chub	1951-53	206	1	2.2	3.9	5.8	7.4	8.8	10.0	10.9	11.9	14.0				
Yellow perch	1952	37	2	1.9	4.7	6.9	8.6	9.7	9.8							

*1. Project personnel (Utah; Idaho)
2. Students, Utah State Agricultural College
3. Ph.D. thesis of L. Edward Perry

designated in this study as cutthroat trout. Ecologically, this designation is justified, and it is believed most of the fish that appear to be cutthroat x rainbow trout hybrids are taxonomically closer to cutthroat than to rainbow trout.

The status of cutthroat trout in Logan River is not greatly different from that of the cutthroat in Bear Lake. In Logan River, the Utah cutthroat trout has been replaced by a mixture much like that in Bear Lake; and in spite of hybridization and the frequent planting of rainbow trout in the upper waters of the Logan River, the cutthroat trout still persists and dominates that area. It is believed that in the upper Logan River and in Bear Lake the cutthroat trout would, if left alone, dominate the rainbow trout.

Growth rate of cutthroat trout in Bear Lake is considered excellent (table 4). Most cutthroat trout examined were in good condition. The limiting factors appear to be lack of suitable habitat, insufficient food for young fish, and inadequate spawning grounds.

Cutthroat trout shorter than 10 inches are rare in the creel, in the gill nets, and in collections from seining, shocking, and poisoning operations. The few that attain the length of 10 inches are then able to subsist primarily on other fish and presumably have no problem finding an adequate food supply. Stocking of approximately 4.6 million cutthroat fry during the past 15 years has not produced a large population of legal-size cutthroat trout. In addition to planting fry in Bear Lake, the Idaho Fish and Game Department has stocked large numbers of legal-size cutthroat trout. Since these fish were not marked until 1953, fish stocked earlier were not identifiable as such in the creel.

Small to moderate cutthroat trout spawning runs occur in three Bear Lake tributaries — Swan Creek, St. Charles Creek, and Spring Creek. Spawning traps have been maintained for several years in St. Charles Creek and Swan Creek. Most of the cutthroat fry stocked in recent years were hatched from spawn taken at these two traps. The diversion of most of the flow of these two streams into irrigation canals makes them ineffective as spawning sites. For this reason, the Fish and Game Departments of Utah and Idaho established spawn taking operations on these two streams. However, because of the reduced run of cutthroat trout in Swan Creek in 1953, it was suggested that the cost far outweighed the benefits; therefore, it was recommended that the trap be removed. The trap was not operated in 1954 and 1955.

In stomachs of 20 cutthroat trout, fish was the most important item as measured by both occurrence and volume. During the 1938-42 study this fact was also indicated. Bonneville cisco and sculpin were the fish most frequently found in the stomachs. One 9-pound cutthroat trout, taken in the winter, contained 17 cisco from 5 to 7 inches long. Shortly after some 6- to 9-inch lake trout were stocked in May 1954, several cutthroat trout taken contained these planted fish (9 in one stomach). None of the lake trout eaten was more than 7.5 inches long. Apparently the cutthroat has little trouble finding food once it attains a size that allows it to feed on fish.

Rainbow Trout

Fifiteen percent of the rainbow trout in the creel from 1953 through 1955 were hatchery fish. Before 1953, not all stocked rainbow trout were marked. From 1953 on, all stocked rainbow were

Table 5. Data from recoveries on 5,000 jaw-tagged rainbows planted in May 1953, October 1953, and March 1954*

Length when planted	Length when recovered	Growth increment	Month planted	No. of days to capture	Distance from release point to capture place	Place of recovery
mm.	mm.	mm.			miles	
187	222	35	May	85	1	Bear Lake
231	260	29	May	85	1	Bear Lake
211	250	39	May	92	1	Bear Lake
188	252	64	May	92	1	Bear Lake
238	256	18	May	92	1	Bear Lake
184	220	36	May	85	1	Bear Lake
195	232	37	May	85	1	Bear Lake
195	225	30	May	85	1	Swan Creek
202	240	38	May	92	1	Swan Creek
211	236	25	May	92	1	Swan Creek
212	230	18	May	85	1	Swan Creek
200	200	0	May	85	1	Swan Creek
233	250†	17	May	85	1	Swan Creek
212	256	44	May	390	1	Swan Creek
185	198	13	March	75	8	Bear Lake
233	253†	20	May	385	1	Swan Creek
200	218	18	October	153	15	Bear Lake
225	311	86	May	300	8	Bear Lake
246	330	84	May	322	8	Bear Lake
228	300	72	March	270	8	Bear Lake
187	290	103	October	390	8	Bear Lake
190	367	177	May	585	8	Bear Lake
187	200	13	March	67	5	Swan Creek

*No plants or recoveries of tagged fish were made in 1955.
†Same fish released and recovered again a year later.

fin clipped or otherwise marked. Presumably, most of the unmarked rainbow that appeared in creels in 1953 and later were hatchery rather than wild rainbow trout (table 5).

Virtually no rainbow trout were taken in deep water gill net sets, and relatively few in shallow water gill nets or by seining. A few marked rainbow trout and a larger number of unmarked ones appeared at the spawning traps in St. Charles and Swan Creeks during the spring of 1953. Moderate numbers of rainbow fingerlings were present in the lower sections of both streams. Since no rainbow trout fry have been planted in these streams since 1950, it must be assumed that natural reproduction is occurring; but it appears to contribute relatively little to the rainbow fishery of Bear Lake. A few marked rainbow trout were recorded in Swan, St. Charles, and Spring Creeks, and as far away as Round Valley.

The creel census showed less than 5 percent of all rainbow trout stocked in the lake actually return to the creel. The bulk of the return is from the current year's plant, and few or no rainbow trout that have been stocked more than three years appear in the creel. Since most of these fish are from current year's stocking, and since few rainbow trout appear in nets or other sampling devices, and since no rainbow larger than 3 pounds have been observed in the lake, it is assumed that the stocked rainbow trout and possibly wild ones also live not more than 3 years. Possibly the bulk of the hatchery fish die within their first year in Bear Lake. It is believed that most of the rainbow trout stocked when they are less than 10 inches long are unable to find food, and therefore die from starvation within their first few months in the wild. Or they may be weakened by lack of food and are easy victims of disease or large fish. Whatever the cause, returns to the creel were less than 5 percent for rainbow trout less than 10 inches long. Even the highest returns (20 to 35 percent) for 11- to 13-inch rainbow trout must be considered unsatisfactory.

When the water level elevation in the lake is near the maximum, rainbow trout seem to prosper better than when the water is dropped 3 or 4 feet. Water levels are maintained at the maximum height only occasionally, and the usual situation is that of a lowered and fluctuating water level. This condition is apparently more limiting to the rainbow trout than to either the cutthroat or the lake trout. The fluctuating water level produces a smaller, less productive littoral zone, which is frequented more by rainbow than by other trout.

Rainbow trout planted at a specific location spread to all parts of the shore. Fish from one plant made near the center of the west shore were caught directly across the lake two weeks later, a distance of 8 miles directly across or 20 miles by shore line.

Limited studies of food items in rainbow trout stomachs lead to the conclusion that insects, primarily terrestrial, are the common food. About half of 60 stomachs examined contained insects, and 20 percent contained fish, the most important item by volume. The fish most often eaten was the sculpin. Plant material and debris were common but probably contributed little food value. Other items eaten occasionally were fish, scuds, terrestrial earthworms, and fossil mollusca shells. An impression one forms from observing stomach contents is that the rainbow trout feeds either on the surface or at the bottom, but near the shore. The high incidence of such nonfood items as terrestrial plant fragments, straw, and fossil snail shells suggests that the rainbow has difficulty obtaining food in this zone. The rainbow trout's preference for shallow water may be responsible for its poor growth rate as compared to that of the cutthroat trout, which inhabits deeper water where food is more easily available.

Utah Sucker

The Utah sucker accounts for the greatest total weight of any fish in Bear Lake. Numerically, the Utah sucker ranks third (after the Bonneville cisco and the sculpin). This high population can be attributed to the Utah sucker's ability to feed over almost all of the bottom area of Bear Lake, including the deepest water, and to its high reproduction rate. Gill net sets showed that the Utah sucker is often in water more than 100 feet deep. It feeds freely on bottom organisms at all depths throughout the year, but it is infrequently in shallow water during late summer. That only one Utah sucker was taken in 388 hundred-foot gill net hours in off-bottom sets indicates it is a bottom dweller.

Although the Utah sucker does not have the choice of a large variety of bottom organisms, those present are ap-

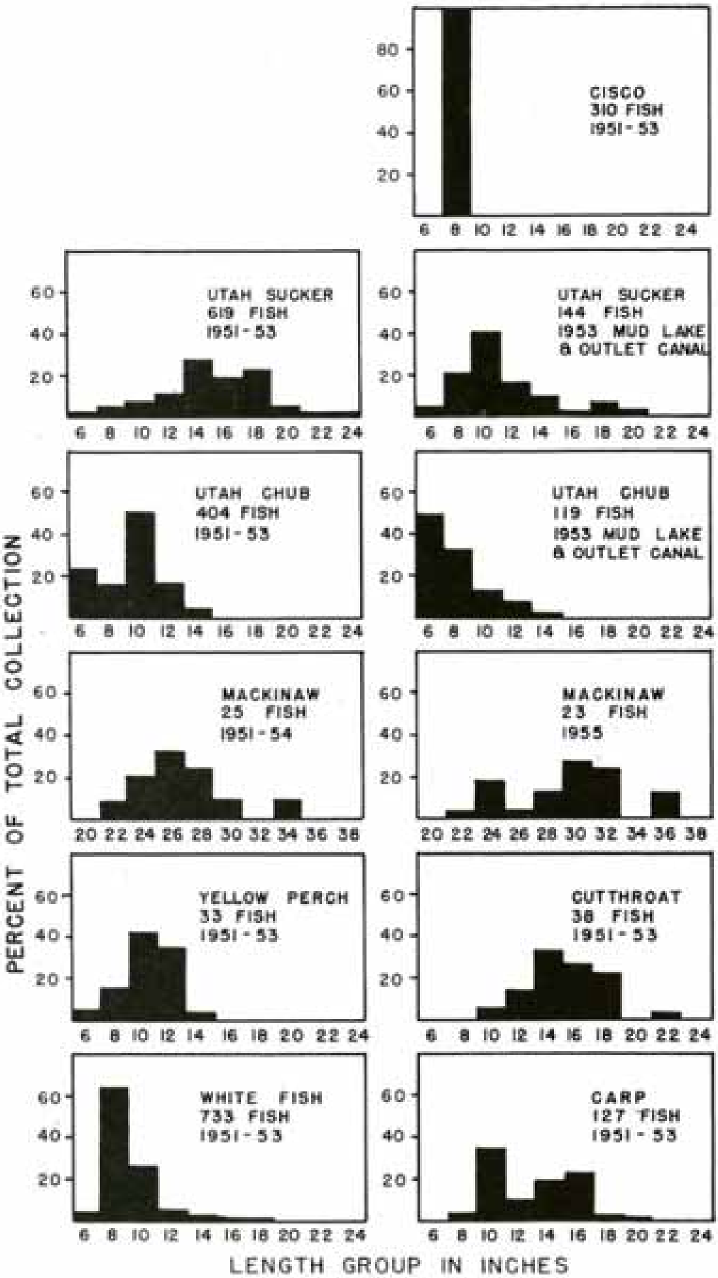


Fig. 18. Length frequencies of fish taken in bottom set gill nets.

parently adequate. Young and adult suckers alike feed on much the same food items. Large numbers of Utah suckers were taken with a drag seine both in 1954 and in 1955 at the Mud Lake inlet to Bear Lake. These fish were in water ranging in depth to 25 feet. Probably abundance of food caused this concentration.

Of the several hundred Utah suckers from this area that were examined, almost all were parasitized by *Liguala intestinalis*, a body cavity tapeworm. The larva is a plerocercoid free in the body cavity of many fish. No other Bear Lake fish thus far examined was highly parasitized by a macroparasite. Although no obvious loss of condition was apparent in these parasitized Utah suckers, the tapeworms must have some detrimental effects. Fish as small as 7 or 8 inches long often contained 3 to 4 feet of tapeworm. These fish certainly are far less attractive to fishermen, even though their food value may not be decreased. Utah suckers from other areas in Bear Lake and from tributary streams were also parasitized, but the percent of infested individuals was lower.

The Utah sucker spawns in the tributaries, in Mud Lake, and along the shoreline of the lake proper. Spawning occurs in late May and early June on the rocky shoals between North and South Eden. This same spawning area is used by lake trout, whitefish, and sculpin at other seasons. Utah chub and Bonneville whitefish were observed accompanying the spawning schools of Utah suckers, and later were found to have sucker eggs in their stomachs.

Length frequencies of catches in experimental gill nets showed that the juvenile Utah sucker is not caught in Bear Lake but is common in adjoining Mud Lake and its canal system (fig. 18). It is also abundant in the lower sections of St. Charles, Swan, and Spring Creeks.

In July 1955, St. Charles and Swan Creeks were checked with an electric shocking machine. In St. Charles Creek, as many as 50 to 60 Utah suckers were taken from pools no wider than 20 feet. Certainly many thousand Utah suckers had ascended this stream to spawn. Two groups appeared in the stream — those that had spawned and were descending, and another group that apparently would not spawn within the current year. The fish that had spawned were in considerably worse physical condition than the non-spawners. The spawned-out fish were scarred along the sides, and their color was bleached. The others were dark and unscarred. We could not determine whether the immature fish were residents of the stream; since they apparently were not there to spawn, we presumed that most of them were stream residents.

Swan Creek apparently supports a much smaller population of spawning Utah suckers, and these fish suffer a higher post-spawning mortality than those in St. Charles Creek. Swan Creek is not as deep, and its bottom is rougher and has larger boulders than St. Charles Creek; also, human interference is greater in Swan Creek.

Carp

Bear Lake is considered borderline habitat for carp. Many casual observers believe carp are abundant enough to be quite detrimental to other fish. This opinion is based on two factors: (1) most Bear Lake carp are at the surface and near shore during the warm months, and (2) they concentrate in the falls when water is flowing from Mud Lake into Bear Lake. It is almost possible to count the entire carp population of Bear

Lake on a sunny day when the lake is warmest at the surface. Evidence indicates very little reproduction of carp in Bear Lake—possibly none except at the mouth of St. Charles Creek. Most Bear Lake carp apparently are spawned in Mud Lake and in marshes along Spring Creek; then they migrate into Bear Lake. It is believed that if no carp moved from Mud Lake the population of carp in Bear Lake would be almost gone in a few years. Although the damage that carp do to the game fish population is not great, the carp certainly compete with small game fish. Unlike the sucker and other non-game fish, the young carp probably provides little or no positive benefit as a forage fish. Large numbers of carp are present near the creek mouths and around the inlets from Mud Lake. Many carp actually attempt to move into Mud Lake in the early spring, probably because the water then flowing from Mud Lake is often 5 to 10 degrees warmer than Bear Lake water.

Growth rate of the carp is poor in Bear Lake compared to that in most other carp habitats in Utah. The carp in Bear Lake lives to be as old as, or older than, it does in other Utah waters; but it grows at a much slower rate; for example, a 4-year-old carp in Bear Lake is about 11 inches long, whereas a carp of the same age in Bear River Bird Refuge normally is about 20 inches long.

Midge larvae and copepods made up the principal organisms found in the food of carp examined at the inlet in June 1954. A month later, carp were still taking many midge larvae but few copepods. The midge larvae eaten by Bear Lake carp are quite small. Gastropods, probably fossil shells, constitute about 5 percent of the total food. Plant debris was taken by many carp; much of this was seeds of *Chara* and *Potamogeton* and some live plant material. Most or all of this plant materal probably had been washed in from Mud Lake. Filamentous algae and a few diatoms had been taken but were of minor importance. About one-fifth of the intestinal content of the carp studied was sand. The taking of sand and plant debris normally indicates that the habitat is of poor to borderline quality. Presumably the carp stirs up large quantities of sand when it must feed over a large area to find the most desirable food item – midge larvae. The results of the 1955 studies of food habits did not differ greatly from those of 1954. Duck weed made its first appearance in carp stomachs in 1955. The carp in Bear Lake is almost exclusively a bottom feeder, but some "gaping" actions frequently observed at the surface appear to be a type of feeding activity.

Sculpin

Relatively little life history information about the sculpin was gathered even though this fish is considerably more important in the Bear Lake ecology and economy than the amount of study indicates. The gill nets used for the majority of the population studies were not effective in catching sculpin (fig. 19). It was not until late in the study, when fine mesh gill nets were available, that the abundance and wide distribution of the sculpin were fully realized.

Food habit studies of lake trout and other large trout show that the sculpin is always an important food item; Bonneville whitefish also feed heavily on sculpin at certain seasons. Numbers of young sculpin exceeded those of all other species counted in the poisoning collections made in the shallow waters of the lake in October or November 1953.

Adults were abundant in electric shock collections made in April 1952.

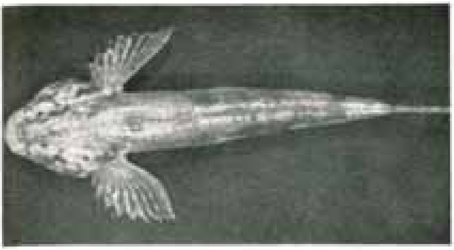


Fig. 19. The only sculpin in Bear Lake is present in all depths.

One hundred twenty sculpins, averaging 3 inches in length, were taken in 309 100-foot net hours using ⅜ and ⅝-inch mesh; more than 90 percent of the sculpins were taken in the smaller mesh. From May through October, the majority of the sculpins were in water more than 50 feet deep, and a large number were taken in water 175 feet deep. The sculpin apparently spawns in April near shore around rocks. After spawning, it migrates to deeper water despite the fact that no cover exists in the deeper areas. The species present is an undescribed form of *Cottus*, indigenous to Bear Lake.

Lake Trout

In spite of the poor fisherman success and small total catch of lake trout, this fish is a prime attraction in the Bear Lake fishery. The fact that the lake trout is taken rarely and that it attains large size apparently add to its trophy value; however, it is generally ranked somewhat below the cutthroat trout in table appeal.

Only lake trout that were inadvertently killed in the nets were examined for life history information. Additional information came from fishermen. Hence, the sample is relatively small, and the data derived from it must be interpreted with caution. Scales of the lake trout were so difficult to interpret that another method of aging was sought. Growth marks on bony structures have been used in several cases to age fish. The posterior branchiostegal rays of the lake trout had marks that appeared to be year marks and aging was done by counting these marks. The marks were quite distinct and regular, and the number of marks usually increased in proportion to length of the fish. Complete verification of the validity of this aging method was not possible with the limited data available.

The growth rate of lake trout in Bear Lake appears to equal or surpass that in several habitats where the species is native (table 4). All specimens examined from Bear Lake were in excellent condition. Spawning areas typical of those used by lake trout in other waters are extremely limited in Bear Lake. Boulder and rubble areas extend below the zone of water fluctuation and wave action in only 3 places: North and South Eden deltas and Rich's Point. Even in these areas the rocks are usually partially buried in sand and are always coated with precipitated marl. In 1954 and 1955, a concentration of lake trout appeared on the rubble area off South Eden delta during October and November, and lake trout taken later from the vicinity were spent; hence, it is assumed that lake trout were spawning there.

Apparently few, if any, of the eggs spawned in the lake produce fish that survive to maturity. Only one lake trout smaller than 20 inches long was taken by all methods during the study. With few exceptions, the age of the lake trout examined coincided with years in which lake trout had been planted. Since all lake trout stocked from 1952 to 1955 were marked, more information will be available when these year classes return to the creel.

The chief obstacles to a self-sustaining lake trout fishery seem to be a lack of suitable spawning area and lack of nursery grounds for the fry.

Only occasional stomachs were examined and, as expected, fish were the only item found.

Yellow Perch

The yellow perch, considered an undesirable fish when small, grows to acceptable size in Bear Lake (table 4). The perch fishery exists only at the north end of the lake in areas adjacent to the inlets from Mud Lake. Occasional migrants have been taken in gill nets along the west shore as far south as Swan Creek, but they are rarely taken on hook and line there.

Reproduction probably occurs in Mud Lake, where the shallow water warms early in the spring, and where vegetation is more abundant than in Bear Lake. In early May 1952, large numbers of egg masses were found along the north shore of Bear Lake near the Mud Lake inlet. Most of these had been washed ashore by strong winds. An attempt to hatch some of them failed. Probably these eggs had been carried into Bear Lake by the great volume of water that flowed through the Mud Lake inlet earlier that spring.

Bonneville Cisco

During a fishery survey of Bear Lake from 1938 to 1941, Perry (1943) collected extensive life history information on the Bonneville cisco. For this reason the present study collected only limited information, which, incidentally, appears to confirm Perry's findings.

Data on nearly 8,000 Bonneville cisco collected by Perry, with the aid of gill nets, indicated they seek temperatures below 59° F. as the water warms up in summer. At other seasons of the year they are distributed throughout all depths of the lake. Perry found they seek

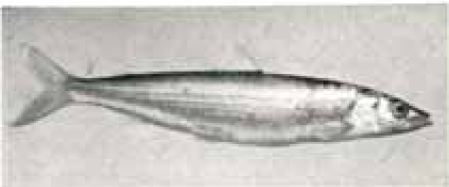


Fig. 20. The Bonneville cisco is found only in Bear Lake.

the upper regions of the hypolimnion rather than its colder and deeper water. He, however, suggested that it might be a reaction to light, a search for food, or both, rather than just the change in water temperature. The cisco reaches maturity during the second or third year of life. The male fish precedes the female to spawning grounds during late January and early February when the temperature of the water is 36° F. to 38° F.

Age and growth studies indicate that there is a little difference in the growth rate of the sexes. Perry attributed this to differential mortality and errors of interpretation. The Bonneville cisco seldom reaches a length of more than 7 inches, or a weight of more than 2 ounces. The greatest growth occurs during the first 2 years, and after that the growth rate is low.

Even though the Bonneville cisco presumably feeds every month of the year, the principal growth is in June and July. These fish have a relatively simple diet. The predominant food item at all times of the year except spring is *Epischura.* During the spring months *Bosmina, Cyclops,* and *Chydorus* are taken. Both adult and immature insects are of little importance. Changes in food habits at different depths were not observed by Perry.

Bonneville Whitefish

The original descriptions of Bear Lake coregonids were made by Snyder (1919).

Three species of whitefish in addition to the Bonneville cisco are in Bear Lake: the Bonneville, the Bear Lake, and the

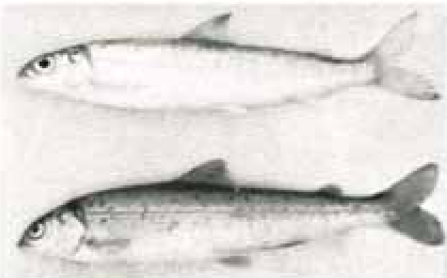


Fig. 21. The upper fish is Coregonus spilonotus, the lower is C. williamsoni from the adjacent Bear River drainage. The heavier body, more rounded fins, and darker coloration of C. williamsoni are apparent. Each specimen is mature.

Rocky Mountain whitefish (fig. 21). Because the Rocky Mountain whitefish is considered a rare migrant from Bear River, it is not discussed in this report.

The only species appearing in creels from Bear Lake is the Bonneville whitefish. In some years, more than half of the total harvest is composed of this fish. Aspects of the fishery for Bonneville whitefish are discussed in detail in the section on creel census.

The usual spawning time of the Bonneville whitefish is early December. Fish judged to be ripe were taken from mid-November until early January. The usual spawning areas appeared to be rocky shallows; but in low water periods, when the rocks are exposed, it is presumed that Bonneville whitefish spawn over sandy points. Small females, about 8 inches long, contained from 600 to 900 eggs. One 9-inch female contained 1200 eggs. No large ripe females were obtained for egg counts.

Gill netting on spawning areas usually resulted in capture of large numbers of spawners between 8 and 9 inches long. The hook and line fishery took many spawners exceeding a foot in length, a size that seldom appeared in the gill nets. Whether this discrepancy represents gear selectivity or segregation by size of the spawners is not known. Slight but consistent differences in appearance between spawning groups may suggest races within the species. Brief morphometric studies of this species, using measurements of body parts, indicate a variety of intergrades. Some individuals dwelling near stream mouths were almost indistinguishable from Rocky Mountain whitefish, which were also present in the vicinity. This suggests that many of the differences between typical Bonneville whitefish and typical Rocky Mountain whitefish may be due to environmental conditions as well as genetic makeup.

Scale studies lead to the conclusion that the Bonneville whitefish grows at rates similar to those at which the Rocky Mountain whitefish grows in the nearby but unconnected Logan River (Sigler, 1953). A spawning size of 8 inches is attained in the fourth year. The 10- to 12-inch group, most common in the creel, are either 5 or 6 years old.

Midge larvae and pupae were present in 52 percent of the stomachs of 65 adult Bonneville whitefish. The next most common item was a combination of gravel, sticks, fossil shells, and other detritus. These were found in 34 percent of the stomachs examined. Miscellaneous aquatic and terrestrial insects, excluding midges, occurred in 10 percent of the stomachs, and fish were in

12 percent. Twenty-one percent of the stomachs contained small numbers of at least one of the following: copepods, ostracods, whitefish eggs, aquatic oligochaeta, or unidentified material presumed to be aquatic oligochaeta. It is evident that, if the stomachs examined were representative, the Bonneville whitefish is a far-ranging opportunist. The midge larvae and aquatic oligochaeta live in deep water, while the remainder of the insects are in shallow water or are terrestrial forms.

Young Bonneville whitefish were common in ⅜- and ⅝-inch gill nets that were set at depths varying from 40 to 100 feet. Few young whitefish were taken by any method in shallower water. This tendency to inhabit deep water probably explains the comparatively greater success of this species in Bear Lake than that enjoyed by the trout species.

Bear Lake Whitefish

The Bear Lake whitefish was not recorded in creels during the study. All individuals taken in gill nets were from water usually exceeding 75 feet in depth. The chief features that distinguish this species from the Bonneville whitefish are its larger scales and unique "roman nose." The Bear Lake whitefish is a dwarf species seldom exceeding 9 inches in length. The largest individual taken in gill nets during the study was just short of 11 inches. This same individual was either 10, 11, or 12 years old.

Normally, spawning occurs in water from 50 to 100 feet deep during January and February; however, ripe females were taken in late March. This observation is consistent with belief that the spawning period for this species is much less definite than that of the Bonneville whitefish. Lake temperatures, at the time Bear Lake whitefish spawn, are generally 35-39°F. The temperature at which the Bonneville whitefish spawns is nearer 45°F. Egg counts for 8-inch Bear Lake whitefish averaged 2000 per female.

Ostracods were in 80 percent of 33 Bear Lake whitefish stomachs studied, but aquatic oligochaeta were recognized in only one of these stomachs. Unidentified animal material ,presumed to be digested aquatic oligochaeta, occurred in 30 percent of the stomachs. Eighteen percent of the stomachs contained midge larvae. An occasional Bear Lake whitefish chose to eat fish, copepods, or insects other than midge larvae, but these items were unimportant. These observations, admittedly limited in scope, suggest a complete dependence on the soft marl bottom in deep water as a source of food. That is the habitat of the ostracods and aquatic oligochaeta.

Utah Chub

The status of the Utah chub may be compared to that of the trout species in Bear Lake. Although the Utah chub cannot be considered a successful species, because of its relatively low total numbers, individual Utah chub grow to a larger size than that recorded for Utah chub in any other lake in Utah. The growth rate as determined from scale studies is considerably more rapid than that displayed by Utah chub in lakes in Utah where extremely large populations of this species are present (table 4).

Reproduction and early growth probably occur in Mud Lake. Young adult fish migrating to Bear Lake from Mud Lake appear to be the main source of recruitment for the Utah chub population in Bear Lake. The largest populations of chub were found near the connections with Mud Lake. No spawning activities or sexually ripe individuals were seen in Bear Lake.

Food habits were investigated only cursorily. Plant material and midge larvae were the items most common in 10 stomachs examined. Sucker eggs were the dominant item in 3 Utah chub stomachs taken from individuals in a large school of chub accompanying spawning suckers.

Creel Census

Rates of Fishing Success, Total Harvest, and Return of Marked Trout

THE estimated rates of fisherman success for game fish during 1953, 1954, and 1955, were 0.33, 0.26, and 0.18 fish per hour, respectively. The rates of success for individual species and marked groups usually were computed only for that part of the year or for the method of fishing that produced 75 percent or more of the kind of fish under consideration.

Although not always strictly comparable with each other, some of the extremes in rates of success are interesting. In 1953 and 1954 during the peak of the spawning period in November and December, whitefish were caught at the rate of 0.53 fish per hour. Yellow perch were taken at this same rate during the first quarter of 1953. This rate of success was the best for any protracted period on Bear Lake. Other high rates of capture were as follows: rainbow trout (summer 1955) 0.36 fish per hour; cutthroat trout, by boat fishermen (all months of 1955) 0.056 fish per hour; and lake trout, by boat fishermen (late summer and early fall 1953) 0.03 fish per hour. The poorest rates of capture for species except the rainbow trout often remained close to zero for periods as long as three months during seasons when fishermen were least successful. The rainbow trout is not nearly as seasonal as other game fish, and the success of fishermen depends directly on the recency of a plant of large fish. Fishing success of 0.25 or more fish per hour may continue for as long as six months after a heavy plant of large rainbow trout, but it declines rapidly thereafter. The estimated rate of capture for all trout in 1955 was 0.125 per hour.

Certain experienced fishermen on Bear Lake consistently caught fish. Others used methods obviously less efficient. The most obvious source of widely varying rates of success during any one pe-

Table 6. Estimated total catches of Bear Lake fishery for 1953-54-55

Year	Species or group	Mark	Catch	95% confidence limits
1953	All game fish		18,500*	
	Cutthroat trout	None	1,000*	
	Lake trout	None	500*	
	Rainbow trout	None	2,865*	
	Rainbow trout	Adipose only	260†	
	Rainbow trout	Ad. & left pelvic	405*	
	Rainbow trout	Ad.& right pelvic	306*	
	Rainbow trout	Tagged	110*	
	Rainbow trout	Total	4,000*	
	Yellow perch	None	5,500*	
	Bonneville whitefish	None	7,500*	
1954	All game fish		12,450±	8,000
	Cutthroat trout	None	950*	
	Lake trout	None	200*	
	Rainbow trout	None	500*	
	Rainbow trout	Adipose only	85*	
	Rainbow trout	Ad. & left pelvic	455*	
	Rainbow trout	Ad. & right pelvic	40*	
	Rainbow trout	Ad. & left pectoral	480*	
	Rainbow trout	Ad. & right pectoral	30*	
	Rainbow trout	Ad. & dosal	150*	
	Rainbow trout	Ad. & both pelvics	50*	
	Rainbow trout	Tagged	40*	
	Rainbow trout	Total	1,830*	
	Yellow perch	None	900*	
	Bonneville whitefish	None	7,400±	4,060
1955	All game fish		5,800±	3,700
	Cutthroat trout	None	900±	765
	Lake trout	None	115±	80
	Rainbow trout	None	350±	190
	Rainbow trout	Adipose only	0	
	Rainbow trout	Ad. & left pelvic	35±	20
	Rainbow trout	Ad. & right pelvic	0	
	Rainbow trout	Ad. & left pectoral	260±	145
	Rainbow trout	Ad. & right pectoral	30±	14
	Rainbow trout	Ad. & dorsal	35±	30
	Rainbow trout	Ad. & both pelvics	20±	9
	Rainbow trout	Ad. & anal	2,400±	1,320
	Rainbow trout	Total	3,130±	1,700
	Yellow perch	None	25±	20
	Bonneville whitefish	None	1,700±	920

*Limits not computed but, based on 1955 variances, they are assumed to be less than 100 percent of total catch indicated.
†640 estimated to have been caught in 1952 creel census, Utah only.

riod of the year was the fact that trolling from a boat and still fishing from the shore are both effective methods of fishing but do not catch the same species of fish.

Total harvests for all species were computed for each year. Fiducial limits at the 95 percent confidence level were computed for 1954 and 1955 (table 6). The most obvious conclusion that yearly trends might lead one to make is that it is difficult to predict which species will contribute most to the total harvest.

There appears to be a correlation between water level and size of harvest of whitefish. Three years' data hardly give sufficient proof for this hypothesis. If it is true that more whitefish are taken during years of high water than when the lake is 6 or more feet below basin capacity, the relation is probably based on greater availability of whitefish to shore fishermen rather than on a larger population.

Reasons for fluctuations in the perch harvest probably are related directly to the amount of spring inflow. Fluctuations in numbers of rainbow trout har-

Table 7. Estimated percent of Bear Lake rainbow returned to creel. (Recorded by individual plants)

Mark	Number planted	Date planted	Average size and range at time of planting (in inches)	Percent returned				Total
				'52	'53	'54	'55	
Adipose only	2,800	June 1952	9 (8-11)	22.9*	9.3	3.1	0	35.3
Adipose & left pelvic	16,900	June-July 1953	7 (4-12)		2.4	2.7	0.2	5.3
Adipose & right pelvic	21,000	June 1953	5 (4-6)		1.7	0.2	0	2.0
Tagged fish	3,700	May-Oct. 1953	8 (7-10)		2.9	1.0	0	3.9
Adipose & left pectoral	20,200	June 1954	8 (7-10)			2.4	1.2	3.5
Adipose & right pectoral	16,000	July 1954	5 (4-6)			0.2	0.2	0.4
Adipose & both pelvics	8,000	March 1954	7 (6-8)			0.6	0.2	0.8
Adipose & dorsal	25,000	Oct.-Nov. 1954	7 (6-8)			0.6	0.4	1.0
Adipose & anal	12,000	July-Aug. 1955	9.5 (8.5-14)				20.2	20.2
Total	125,600							

4.7% of all marked fish planted returned during project.

*This figure was derived by assuming a fishing pressure for the Idaho half of the lake during the first year when the creel census did not include that part. It is probably an overestimate.

vested result from fluctuations in the volume of legal-size or larger plantings. The steady decline of the lake trout fishery is probably caused by lack of natural recruitment and depletion of stocked fish. The relative stability of the cutthroat trout fishery appears to indicate a small but constant recruitment rate. The harvest of trout per acre on Bear Lake during 1955 averaged 0.06. The low rate of harvest on Bear Lake is not due entirely to a low productivity. Until fishing pressure on Bear Lake reaches a point comparable to that on other large lakes, the real productivity of the lake will be in doubt. It is entirely possible that a fourfold increase in fishing pressure would not noticeably depress the rate of success.

The percent of planted rainbow trout returned to the creel is perhaps the most important part of the findings (table 7). No marked lake trout or cutthroat trout were returned to the creel. The lack of marked lake trout in creels was to be expected since they had not been planted in large numbers until 1954. The ten thouand 8-inch cutthroat trout planted in July 1954 had not yet appeared in the fishery at the end of the study. If we consider the harvest from 1946 through 1955 to have been 1200

Table 8. Cutthroat trout planted in Bear Lake, 1939-1954

Planting	Number	Length (inches)	Fin clip
1939, Oct.	464,790	1½	None
1939, Oct.	115,860	2½	None
1940, Aug.	288,768	1	None
1940, Sept.	129,920	1½	None
1941, June	80,102	5	None
1941, Aug.	434,500	1½	None
1941, Sept.	20,000	2	None
1941, Oct.	7,000	1½	None
1942, Feb.	50,000	2	None
1942, Sept.	430,450	1	None
1943, June	30,200	1	None
1943, July	17,700	1	None
1943, Aug.	7,100	1	None
1943, Aug.	19,320	1	None
1944	597,000	3	None
1945	361,000	3	None
1946	683,000	3	None
1947	700,000	3	None
1948	575,000	3	None
1948	4,400	3-8*	None
1949	700	3-8*	None
1950	58,000	3	None
1950	29,000	3-8*	None
1951	20,000	3-8*	None
1952	26,000	3-8*	None
1953	65,000	3	None
1953	4,000	3-8*	Adipose and left pelvic
1953, Mar.	1,000	2-4	Adipose only
1953, July	1,000	8	Adipose and left pelvic
1954, July	10,000	5	Adipose and left pectoral

*Majority 5 inches or less.

cutthroat trout per year, as was true for 1953 and 1954, the total harvest for the 9-year period would be 10,800 fish. During that period, about 2,100,000 cutthroat trout, ranging in size from fry to legal-size, were planted in Bear Lake. A return to the creel of one-half of 1 percent of all cutthroat trout planted may be computed from these figures if it is assumed that there is no other source of recruitment. The mildest statement that can be made about the cutthroat planting program is that it appears to be uneconomic (tables 8, 9, 10).

The return of marked rainbow trout averaging less than 8 inches is without exception less than 1 percent. No marked rainbow trout shorter than 4 inches were planted during the study. Groups averaging 8 or 9 inches long con-

Table 9. Lake trout planted in Bear Lake from 1940 through 1955

Planting	Number	Length (inches)	Fin clip	Year class
1940 (June)	19,824	6	None	1939
1940 (July)	229,120	3	None	1940
1940 (Aug.)	166,900	3	None	1940
1941 (Apr.)	19,200	5	None	1940
1941 (June)	21,000	5	None	1940
1947	3,500	3-7	None	1946
1948	4,770	6-10	None	1947
1949	1,488	7-11	None	1948
1952 (Summer)	1,500	7	Adipose only	1952
1953 (Summer)	800	7	Adipose only	1953
1954 (May)	8,900	7.5	Adipose and left pelvic	1953
1955	15,000	7.1(6-11)	Adipose and anal	1954
1955	16,000	6.0(4-8)	Adipose and anal	1954
1955	3,500	10	Adipose and right pelvic	1954

Table 10. Thousands of salmonids planted in Bear Lake — 1933-1938*

Year	Kokanee				Brook trout				Lake trout			
	1"	2"	3"	4"	1"	2"	3"	4"	1"	2"	3"	4"
1933		43.3			214		44.2	80.4				
1934		18.2				87.8						
1935	244											
1936	124											
1937		98	51.2	45	50				79.6			
1938	65	240	47		50						10	

*In 1933 and 1934 there were 61,491 landlocked salmon of 2-inch length.

tributed less than 5 percent of their planted numbers to the creel. Two hand-picked groups of rainbow trout having many 11- to 12-inch individuals returned 35 percent and 20 percent of their numbers to the creel. The group contributing 35 percent was planted in 1952 by Utah when the census was being conducted on a limited scale on the Utah side of the lake only. The 35 percent return was only a rough estimate and is subject to doubt. The 20 percent return came from a plant of 12,000 rainbow trout made in 1955, a season when numerous interviews were taken. Confidence limits for this harvest at the 95 percent level equal 11 to 39 percent of the total plant. Even the upper figure represents a poor return when compared to the 60 to 80 percent returns from small bodies of

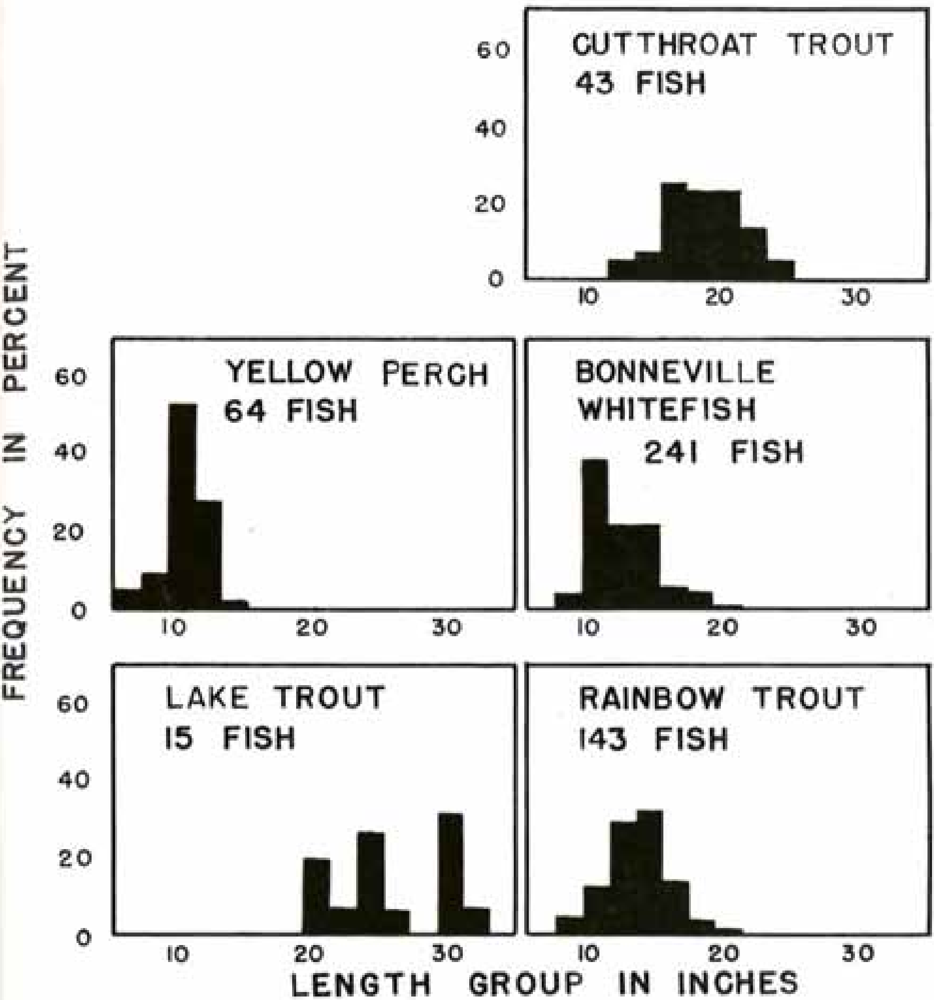


Fig. 22. Length frequencies of fish in the creel during 1952-53.

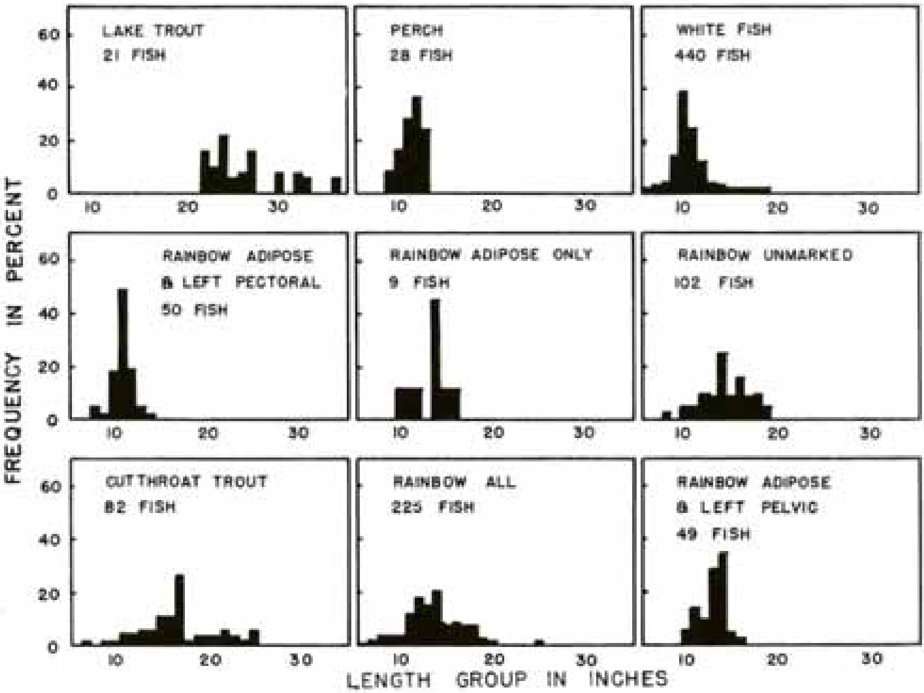


Fig. 23. Length frequencies of fish in the creel during 1954.

water that have a heavy fishing pressure (Regenthal, 1952).

The unmarked rainbow trout in the Bear Lake creel probably came from plants totaling about 44,000 legal-size fish planted in 1951 and 1952. A partial creel census conducted on the Utah side gives basis for a rough estimate of 5000 trout per year for 1951 and 1952. Experience from the combined creel census was used to make an estimate of the Idaho catch as compared to the known Utah catch for those years. When the estimate of unmarked rainbow trout caught in 1951 and 1952 is added to the estimated harvests of 1953-55, an estimated total of about 9,000 stocked unmarked rainbows was caught during this period. This represents a return to the creel of 20 percent of the original plant. Since the most optimistic figures were used in estimates whenever there was any doubt, this is a maximum figure.

Size of Fish in Creel

The one feature that brings fishermen back to Bear Lake time after unsuccessful time is the knowledge that the few large lake trout and cutthroat trout taken are in excellent condition. The majority of the lake trout taken exceeded 24 inches in length, one approaching 36 inches in length was recorded. The most frequent size of cutthroat trout is from 17 to 19 inches, but several individuals have exceeded 24 inches. Rainbow trout are often rather thin, and individuals known to have been in the lake for three years did not exceed 15 inches in length. The yellow perch, in years when they entered the fishery, averaged 11 inches. In the fall of 1952, several perch weighing more than 2 pounds were caught in one day where the outlet canal enters the pumping station at Lifton. The average length of whitefish in 1954 was 10 inches, in 1955 it was 12 inches. Whitefish weighing 4 pounds have been reported, but the interviewers recorded few fish that exceeded 2 pounds (figs. 22, 23, 24).

Numbers, Residence, and Expenditures of Fishermen

The estimated numbers of fishermen on Bear Lake declined each year of the creel census. In 1953, it was estimated that 12,000 fisherman days were spent on the lake; in 1954, the estimate was 10,000, and in 1955 9,000. Although these differences are not statistically significant, they appear to be real. The decrease in total number of fishermen in 1954 compared with that for 1953 is thought to be associated with a decline in the quality of fishing caused by a drop in numbers of rainbow trout and yellow perch in the lake. The lower number of fishermen in 1955 may have resulted from these causes plus a long period of ice cover that was not present in 1953 or 1954.

The most intensive fishing pressure occurred during May and December of the years of creel census. It is estimated that less than 20 percent of the total amount of fishing pressure occurred in the period between June 1 and the end of September. This period of low fishing pressure is thought to result from the poor summer fishing in Bear Lake compared to that of other nearby lakes having open seasons at the same time. Fishing pressures on Bear Lake never ex-

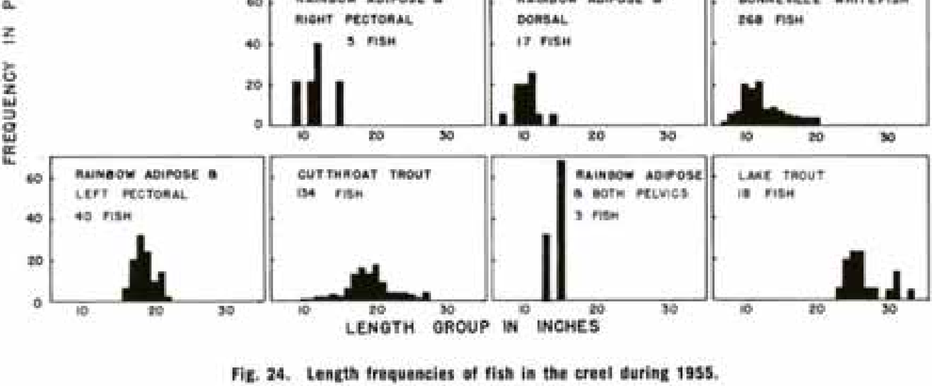


Fig. 24. Length frequencies of fish in the creel during 1955.

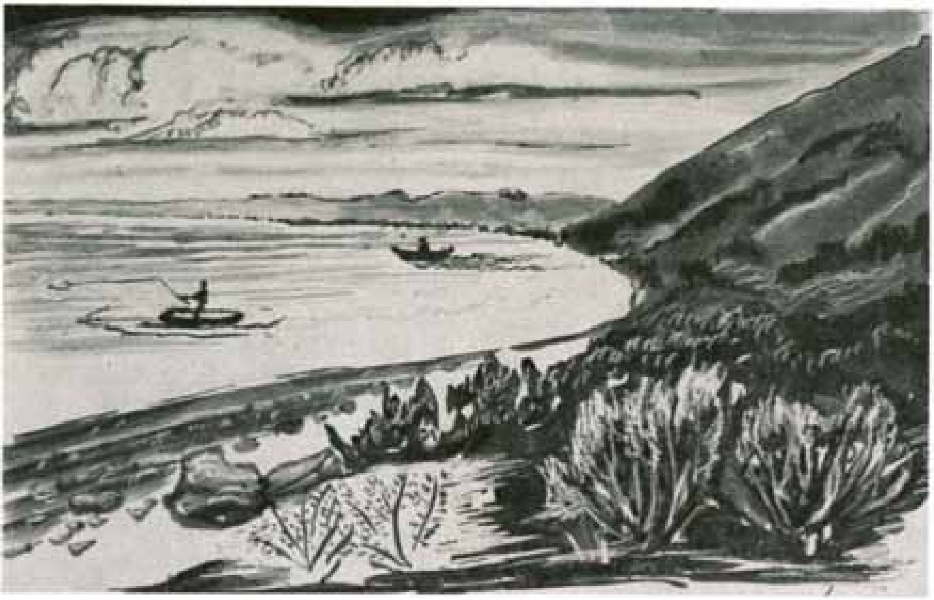
ceeded 0.17 fishermen per surface acre per year during any year of census.

The creel census data indicate that about 70 percent of Bear Lake fishermen live in Utah, and almost all the remainder come from Idaho. Most of the Utah residents live in Cache, Weber, and Rich Counties; almost all Idaho residents are from Bear Lake County. Fishermen from states other than Idaho and Utah are rare.

A record of individual fisherman expenditures was made in 1953. The fishermen interviewed were asked how much money they had spent on several items since the last time they had gone fishing. The average of the amounts spent was considered a fair estimate of the average expenditure per fishing trip for the items asked about. No attempt was made to set confidence limits to the values.

The estimated average expenditure per fishing day was $9.09. This was divided among the following items common to fishermen: fishing gear, $4.63; boots, boats, trailers, camping gear, and similar items, 50 cents; license, 33 cents; meals and lodging, 65 cents; travel, $2.63; and such miscellaneous items as cigarettes, film, and liquor, 35 cents. It is apparent that few of these expeditures were made near the lake and that fishermen contribute relatively little to the general economy of the immediate area. The two largest expenditures, those for travel and fishing gear, are probably made by most fishermen in Logan, Ogden, and Montpelier.

The estimated total expenditure by fishermen on Bear Lake for 1953 was $109,000, or $1.50 per surface acre. This can be compared to the 1952 estimates of $82.00 and $283.00 per surface acre for Navajo and Panguitch Lakes in southern Utah. These lakes have an excellent fishery during the tourist season, whereas Bear Lake usually has its poorest fishery in the warm months. Fishermen at Lake Pend Oreille made non-capital expenditures amounting to $400,000 (Stross 1953) which may be compared to a total expenditure on Bear Lake, minus capital expenditures, of about $12,000.



Management

REGULATIONS on Bear Lake as to time, gear, and creel must continue to be liberal. All evidence points to the fact that only a small percent of the population of any species is harvested. A rather large part of the fish actually die of predation, disease, old age, or other causes. Closures of areas should be kept to a minimum, and at no time should the philosophy of closing the lake for a period to "let the little fish grow up" be allowed to stand. The rate of success for the Bear Lake fishery probably will continue to be low. One point must be kept in mind; this relatively low rate of success is not atypical for many infertile lakes of its size in either the United States or Canada. Considerable evidence indicates that average depth and length of shoreline have a strong influence on productivity (Rawson, 1955). The average depth of Bear Lake (100 feet) is much greater than that of most of the productive western lakes, and its shoreline distance (48 miles) is exceptionally short for its water area of more than 100 square miles.

The lake trout, because of its large size and uniqueness, continues to be the prime attraction for Bear Lake fishermen. The lake trout probably contributes about half as many pounds to the creel as the cutthroat trout. Stocking of lake trout should be continued as long as it can be done within economic limits, although lake trout are becoming hard to get. Present information has not established what size is most economical to stock; however, it appears that lake trout should be at least 7 inches long, and preferably 10 inches. Probably information gathered from the marked lake trout stocked during this study will supply a basis for making future stocking policies.

Lake trout, or any small fish, should be well scattered, preferably from a plane or boat.

The return of rainbows, even those stocked when they are legal-size or larger, is disappointing. Fishing pressure has been primarily in late fall and in late spring. It is believed that the most economical returns come from plantings of 10-inch or larger rainbow stocked in June. These fish increase the summer fishery, which is now the poorest of the year; they also help the fall fishery. It appears uneconomical, even under these circumstances, to stock large numbers of rainbow unless either the fishing pressure or success and the resulting higher take are increased several fold.

It has been pointed out that, in spite of repeated stockings during the past 35 years, native fish still dominate Bear Lake. This is particularly true of the cutthroat trout, which grow to a size of 6 to 10 pounds and provide most of the larger size fish in the creel, except for the relatively few lake trout. Since cutthroat trout live for several years in Bear Lake, as opposed to rainbow trout, many of which do not, they are much more likely to grow to larger size and are more likely to be exposed to several years of fishing pressure. An additional benefit is that the difference in the size of the cutthroat trout between stocking and capture is often several fold. However, when the cost of cutthroat planting since 1946 is compared to the value of the estimated harvested since 1948 (same rate as present), it is apparent that planting cutthroat is expensive even when their large size is considered. It should be reiterated here that even if the density of the cutthroat trout population were materially increased, shore fishermen would probably not experience a notable increase in success. The present cutthroat trout population (1951-1955) has only been slightly exploited.

A few kokanee were in Bear Lake in 1954 and 1955. They were originally introduced in a series of plantings made between 1933 and 1938. Results of these early plantings are not encouraging. Apparently, the kokanee rarely grow to larger than 8 inches in Bear Lake, and relatively few have survived to reproduce. However ,if the kokanee should become established and grow to a size acceptable to fishermen it would be a fish that does not compete for critical food and, from a table and sporting standpoint, it is desirable. A large planting of kokanee fingerlings each year might produce a substantial fishery.

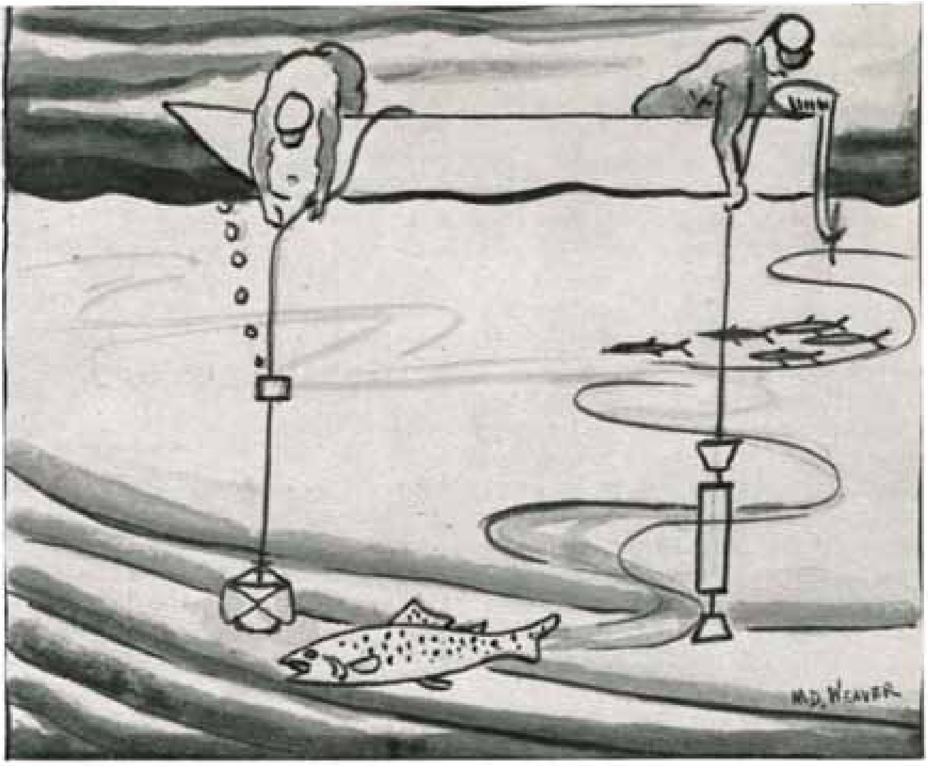
Yellow perch in Bear Lake reach a size quite acceptable to fishermen. The perch fishery is confined almost entirely to the area near the pumping station. When conditions are right, the perch spawns in the early spring on the aquatic vegetation in Mud Lake; if the water movement is sufficient to carry these young fish into Bear Lake, a substantial fishery is produced that may last for one or two years. Little can be done to improve the perch fishery; rather, it is merely something to be used when it is available.

The Bonneville is the only one of the four whitefish taken with any degree of regularity on hook and line in Bear Lake. None of the other whitefish can be harvested effectively except with a gill net. The two smaller whitefish, particularly the Bonneville cisco, are used extensively as food by the larger trout and presumably, to some extent, by the Bonneville whitefish. The Bear Lake whitefish rarely grows longer than 10 inches, and does not move close enough to shore to be within reach of fishermen (it seldom appears in water less than

75 feet deep). It seems to have less inclination than the Bonneville whitefish to take a hook. The Bonneville cisco is absent from the sport fishery, possibly because of its small mouth. The Bonneville whitefish is so abundant that there is no evidence that the fishery depletes its population at all. This fish should be used more freely than it has been, and fishermen should be encouraged, possibly through education, to use it more. Both the food value and palatability of smoked whitefish are high.

The Utah sucker, the carp, and the Utah chub do not contribute to the sport fishery. Since there is no commercial fishery, their only benefit to the sport fishing is whatever their young contribute to the diet of game fish. This contribution certainly is not important, and limited evidence suggests that their value is, at best, neutral. Possible predation on game fish eggs bears further investigation. A substantial number of the young of these three fish drift in from Mud Lake in years when the spawning condition for them is optimum, and when there is an adequate flow to carry them into Bear Lake. It is possible that a period of several years of high water and optimum conditions could create a condition in which one or all of these fish would actually have a seriously detrimental effect on sport fishing. If this should ever occur, then it would appear desirable to use commercial methods to reduce the population. At present the problem is not critical.

From time to time, habitat improvements have been suggested for Bear Lake. One of these includes a series of 100 or more enclosed aspen pole cribs filled with brush and native hay. These cribs would increase the nutritive value of the water in their immediate vicinity by producing limited additional zooplankton which, in turn, would attract small fish; and these, in turn, attract larger fish to the area. In the midwest and eastern United States these devices have been used successfully to concentrate legal-size fish. Since cover for invetebrates and small fish is so sparse in Bear Lake these shelters merit serious consideration. It has also been suggested that if large rubble areas were to be created on the east side of Bear Lake, between North and South Eden, lake trout might reproduce more successfully than they do at present since most of that area is covered by silt. This type of improvement would protect eggs and small fish, but it would be extremely expensive.



Materials and Methods

Populations

RELATIVE abundance, distribution, and length frequencies of the fish studied were determined primarily from collections made in 1952 and 1953 with bottom-set gill nets. These nets were 125 feet long by 5 feet deep, and were made of nylon. They had five 25-foot panels; each panel a different size of nylon mesh. The mesh sizes, by bar measure were ¾, 1, 1¼, 1½, and 2 inches. Sets that were analyzed for rate of catch per unit of netting effort were made for overnight periods averaging 16 hours. Sampling was done during all seasons.

Records of gill net collections made in 1938-42 were made available by Dr. Stillman Wright of the U. S. Fish and Wildlife Service. The type of net used by the U. S. Fish and Wildlife Service was comparable to ours but was made of linen instead of nylon. Brief comparisons of the efficiency of nylon and linen sets made by the writers did not show any great difference.

The unit of netting effort on which catch rates are based is the 100-foot-net hour. Use of such a unit requires the assumption that one unit of net length set for two units of time is equally as effective as the converse. No evidence to the contrary was discovered in the catch records.

Opinions on relative abundance of species in gill net collections are based on rates of capture. However, without knowledge of species movements it is impossible to separate the evidence of abundance from degree of movement. In other words, greater activity creates the impression of greater abundance because this activity increases the catch.

In presenting figures on relative abundance, it is assumed that populations of individual species are static. This is the same as saying the total mortality and total recruitment equal each other during the period of collecting. Presentation of length-frequency information, obtained from collections made over an extended period, assumes the foregoing plus equal mortality and recruitment for individual size groups. Such assumptions are undoubtedly partially inaccurate, but it is improbable that any great population changes did occur without being noticed in net collections.

Spot checks with the same nets were taken in 1954, 1955, and 1956 to determine the degree of consistency existing among sets made under comparable conditions. These later collections led to the same opinions about relative abundance and distribution as did the earlier data.

Gill netting with the nets suspended above the botom was done to gain some idea of the density of species moving in this stratum. Approximately 200 hundred-foot net hours of effort were spent at several positions between surface and bottom. Briefly, the method used consisted of suspending nets having neutral buoyancy on lines hung from two large, firmly positioned floats (fig. 25).

In addition to the data on mid-water sets made with experimental nets during the recent inevstigation, data were available on the mid-water distribution of ciscoes as determined by Perry (1943) from nets having ¾-inch mesh. Additional results of 188 hundred-foot net hours of effort at several mid-water positions with 2-inch mesh in 1938-42 were also considered when analyzing the distribution of Bear Lake fish.

To obtain an estimate of the population of small fish in deep waters, 309 hundred-foot net hours of sampling were done in 1954 with nets having equal panels of ¾-inch and ½-inch Japanese nylon mesh. The threads of these nets were considerably finer than those in any domestic mesh.

To determine the characteristics of the fish population of shallow areas close to shore, several other collecting methods were used. Spot poisoning with rotenone in three typical shore cover types and mouths of two creeks was the chief

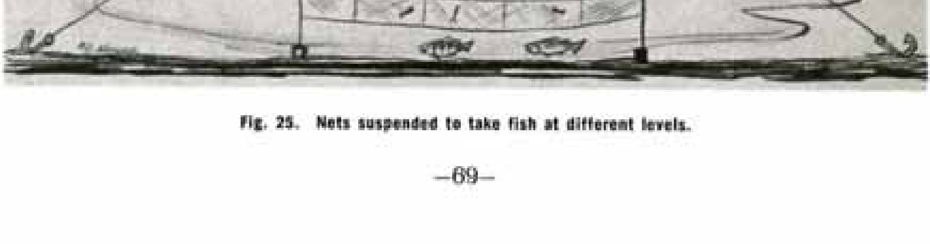


Fig. 25. Nets suspended to take fish at different levels.

source of data for populations of small fish. Seines were used mostly to catch Utah chub and carp to obtain life history material, but seining also contributed to the knowledge of the fish populations. Two lake shore collections were made by electro-fishing with 5 kilowatts of direct current at 240 volts. Several daylight gill net sets of short duration were made in less than 5 feet of water. These sets are considered atypical and are not included with the primary data.

The results of 26,578 hook-hours of set line fishing in 1939-40-41 and 5000 hook-hours in 1952-53 are presented under the creel census discussion.

Fish populations in tributary streams were sampled by electro-fishing with 5 kilowatts of direct current at 240 volts. Statements on relative abundance are based on observations at twenty 1/10-mile stations examined during the period 1951-1954.

Life History

Life history data were collected whenever possible, but such collections were incidental to carrying out the main objectives. Life histories presented in this study are not complete, and some are based on small samples. Efforts with the first trawl were unproductive, presumably because of its small mouth. The second trawl was similar to one used in the Great Lakes fishery investigation, and was considered successful, but we used it only a few times. Its heavy iron frame made the net so cumbersome that it could be landed only on a sloping shore. It is believed the use of a smaller light weight frame would make this equipment more useable. These data are preented as interim information until more complete information is gained. An exception to this is the abundant body of data on the Bonneville cisco available in the graduate thesis by L. Edward Perry (1943).

Investigations of the food habits of bottom feeding fish and of bottom fauna are now under way.

Scales were used to determine age and growth rates for all fish except lake trout and carp. The posterior branchiostegal ray and opercular bone, respectively, were used for these species. Data were obtained from fish collected by all methods mentioned and by hook and line (fishermen creels). Empirical body-scale relations are, for all practical purposes, linear.

Food habits of carp were determined from contents of seine collections. Whitefish stomachs were obtained from gill net collections. Statements about trout food habits are based on examination of stomach contents of fish taken by hook and line.

Creel Census Methods

The creel census may best be described as a concurrent fisherman count and interview program designed to yield information on total fishing pressure, return of marked fish to the creel, fisherman success, species composition of the creel, and life history data. In addition to the foregoing categories of information, data were collected on best fishing methods, best times of the year to fish for the various species, and the economic importance of the Bear Lake fishery.

Fishing pressure, in numbers of fishermen present, was determined by counting on a stratified, random schedule. Counts were made on each of two weekdays and one weekend day per week. Weekdays on which counts were to be made were chosen randomly every two weeks; the first weekend day only was randomly selected and the remainnately. Counts were made once during ing ones for the year were taken alter- quarter-day periods randomized independently of the days in a manner that insured that four times of day would be sampled in any four days. The length of the possible fishing day was based on the daylight period rather than the legal day, since previous experience with the fishery indicated that the heaviest pressure occurs at times of the year when the weather is too cold to encourage early or late fishing.

Actual counts were made while driving along the road that parallels the entire shore line. All fishermen were visible from this road. Boat fishermen could be counted as individuals because boats seldom ventured more than a few hundred yards off shore.

Interviews were made on count days and on additional days when necessary. In the years that the census was conducted, the following approximate numbers of interviews were taken: 1953, 300; 1954, 700; and 1955, 1200.

During the 1953 census, detailed information was collected about fisherman expenditures and types of tackle used. This was not done in the last two years because of the relatively small number of interviews that could be made when such detailed questionnaires were used. During 1954 and 1955, most of the information was gathered by direct observation by the biologist rather than by questioning the fishermen. In fact, the only questions asked were the hour when the interviewee started to fish and state of his legel residence. Method of fishing, creel composition, size of fish, number of marked fish, time and location of interview, and bait used were all recorded as observations of the interviewer. It is believed that this practice produced data that were much more reliable than data gathered by direct question or mailed questionnaire. This is because a small but statistically reliable sample by a competent biologist is better than large amounts of unsubstantiated data from laymen.

The final product of analysis of each category of data collected in the field is an average. All averages are subject to error, and may be suspected of not representing the true average for the entire group, which was only sampled. The most important averages, therefore, were subjected to statistical analysis to determine maximum and minimum values between which the real average would occur 95 percent of the time. The averages considered most important were the average number of fish caught per hour, the average number of the more numerous species and groups of marked fish caught per hour, and the average numbers of fishermen present on count days. The foregoing averages were determined separately for each season of the year and for categories of fishermen (boat and shore) in which inspection of the data indicated a fishery of unique attributes when compared to the remainder of the data. This procedure was necessary to prevent serious errors from entering the final estimates. The errors most likely to be introduced were those caused by differences in the proportion between number of interviews and total number of fishermen present and those caused by applying statistics for periods other than those during which certain species of fish were caught.

The total harvest of any group of fish was computed by application of the following formula:

> Average number of fishermen counted x fish caught per hour x the total number of daylight

hours available in the period considered.

The procedures for setting limits to the mean and weighting means and variances of strata or divisions within the data are from chapter 17, Snedecor (1948). A brief description of the procedures as applied to the creel census data is appropriate here. Neuhold and Lu (1957) discuss a similar approach, but they treat the variance more intensively. The sum of squared deviations from the mean rate of success differs from the usual sum of squares in that each deviation squared is weighted by the number of hours fished by the fisherman having each rate of success. The variance is then computed by dividing by the number of hours rather than by the number of degrees of freedom. Degrees of freedom are the number of interviews. Variance of the mean and standard error of the mean are computed in the normal manner using the real number of degrees of freedom to compute the variance. The variance of the mean product of the average fisherman count multiplied by the average rate of success (fish caught by all fishermen during an average daylight hour) is simply the sum of the squares of the coefficients of variation (of the means) of the two factors. The standard error of the mean product is, as usual, the square root of the variance of the mean product.

The distribution of individual catch rates and numbers of fishermen present both departed noticeably from the normal. This skewness did not offer any difficulties to setting limits to the means of groups, for means of samples from almost any type of distribution are themselves distributed normally.

The exact t value to use in the final harvest estimates was not determined easily since the degrees of freedom were not pooled. It is felt this is not a serious consideration in creel census work since the difference between extreme values of t for individual strata of the data is seldom great. The exact confidence level at which limits are given is not known, but it appears impossible for it to be more than 1 or 2 percent on either side of the 95 percent level.

The body of data as examined at the end of each year seemed to indicate that by improving the sample in any single category a marked improvement might be made in determining the limits of the final estimate; but the category that showed the greatest variance changed from year to year. The only conclusion concerning an improvement in the estimate that can be drawn at the end of the study is that to be sure of a definite narrowing of the confidence limits one should increase the number of samples (counts and interviews) taken during times when fishing pressure is obviously greater than usual. Such times must be determined by immediate experience, for they cannot be predicted. If the variance remained the same from year to year, it could be shown that doubling the size of each sample would result in an increase in accuracy of the estimate of the total harvest of fish by about 30 percent.

Limnological Methods

Physical

Temperatures were read from a Foxboro electrical resistance thermometer using a graduated cable and from Bathythermograph recordings.

Turbidities were determined with a Hellige turbidimeter.

A few transparency readings were made with a Secchi Disc. Soundings were made with the graduated thermometer cable and with graduated lines. Soundings were located by triangulation with a sextant. The contours were later checked and adjusted from transects made with a recording fathometer.

Chemical

Chemical determinations by project personnel utilized methods described in Welch (1935) with the unmodified Winkler method for oxygen. Water samples were taken with 1- and 3-liter Kemmerer water samplers.

Biological

Bottom samples were taken with a 6-inch Ekman dredge and washed through a number 30 screen. Zooplankton collections were made with a small Wisconsin plankton net of no. 20 silk as described by Welch (1935). Quantitative counts were made on 1 milliliter samples obtained with a piston pipette.

Phytoplankton water samples were collected with a 3-liter Kemmerer water sampler, and concentrated with a Foerst plankton centrifuge (15,000 revolutions per minute) and by membrane filter. Samples of the concentrate were counted in a haemacytometer.

Analytical Procedures Used in Zinc Analyses

Department of Agriculture, Soils Laboratory, Utah State Agricultural College

Three different sets of samples have been analyzed during this time. The first method used involved the Zincon color development. Zincon is a tradename chemical sold by the LaMotte Chemical Company. Excellent reproduction of the standard curve was obtained with Zincon. The problem, of course, was removing interference—in other words, isolating the sample to be run. This was first done by using dithizone in rather concentrated solution, as suggested for analysis of plant material by Parks, **et al.** in Industrial and Engineering Chemistry, Analytical Edition, August 1943, pp. 527-533. The original sample was extracted with dithizone at pH 8.5. Zinc was separated from this carbon tetrachloride phase from other heavy metals by shaking with 50 ml. of .02 normal HC1 for exactly two minutes. After extraction, the HC1 was removed by evaporation and zinc determined, using the Zincon reagent.

Since values obtained by this method were not of the same order as those reported earlier for both the Lake water and adjacent streams, another method was used. It is described in "Standard Methods for Examination of Water, Sewage, and Industrial Wastes," tenth edition, 1955. Published by the American Public Health Association, Inc., 1790 Broadway, New York 19, N. Y. The mono-color method is described on pages 215 to 217. In general, values obtained with this method are somewhat lower than those obtained with the previous method. Fairly good duplication of the standard curve was obtained here, too, although it was not as good as with the Zincon reagent. Standards were run in two different ways; by adding zinc to redistilled water and running standards through the same process as was used on the samples, and secondly, by direct development of color on given quantities of standard zinc solution. Three different zinc standard solutions were prepared; two of them from elemental zinc and a third from zinc sulfate. The standards all agreed.

Field samples were collected in both soft glass, pyrex glass, and polyethelene bottles. They were brought to the laboratory without the addition of HC1, and also with the addition of HC1 at a rate of approximately 10 ml. of concentrated HC1 per liter of water. No great differences were found between the amounts of zinc obtained from the acidulated and the non-acidulated samples.

Recoveries of added zinc to the water samples have been good. Amounts of zinc varying from .01 to .03 mg. have been added to samples to test recovery.

Department of Agriculture, Plant, Soil and Nutrition Laboratory, Ithaca, New York

The determination was made on three liters of each water sample. After evaporation to dryness, muffling at 500° C. for two hours, the samples received hydrofluoric-perchloric acid treatment in platinum dishes.

An alkaline dithizone extraction at pH 8.5 followed by an acid extraction (.02 N HC1) was used to separate zinc. The actual determination of zinc was done by measuring the concentration of zinc dithizonate in carbon tetrachloride (colorimetrically) using sodium diethyldithiocarbamate as a complex former with zinc to reduce somewhat the color intensity given by dithizone.

During the alkaline dithizone extraction at pH 8.5, the Bear Lake sample gave an orange to red-orange color and was rich in a complexing element since four extractions were necessary to remove the element. The complexing element is unknown at this time.

Check List of Fish in Bear Lake*

Common name	Scientific name
Native fish present in Bear Lake:	
Cutthroat trout (native)	**Salmo clarki**† Richardson
Bonneville cisco (peaknose)	**Coregonus gemifer** Snyder
Rocky Mountain whitefish	**Coregonus williamsoni** Girard
Bonneville whitefish	**Coregonus spilonotus** Snyder
Bear Lake whitefish	**Coregonus abyssicola** Snyder
Utah sucker	**Catostomus arden** Jordan & Gilbert
Smallfin redside shiner	**Richardsonius balteatus hydrophlox** Cope
Utah chub	**Gila atraria** Girard
Carrington's dace	**Rhinichthys osculus carringtoni** Cope
Sculpin	**Cottus species** (undescribed)
Native fish presumably extinct:	
Utah cutthroat trout	**Salmo clarki utah** Suckley
Introduced fish present in Bear Lake:	
Kokanee	**Oncorhynchus nerka kennerlyi** Suckley
Yellowstone cutthroat	**Salmo clarki lewisi**‡ Girard
Rainbow trout	**Salmo gairdneri irideus** Gibbons
Brown trout	**Salmo trutta fairo** Linnaeus
Lake trout (mackinaw)	**Salvelinus namaycush** Walbaum
Carp	**Cyprinus carpio** Linnaeus
Yellow perch	**Perca flavescens** Mitchell
Green sunfish	**Lepomis cyanellus** Rafinesque
Fish introduced or reportedly introduced but not recorded during present investigation:	
Chum salmon	**Oncorhynchus keta** Walbaum
Silver salmon	**Oncorhynchus kisutch** Walbaum
Landlocked salmon	**Salmo salar** Girard
Eastern brook trout	**Salvelinus fontinalis**§ Mitchell
Largemouth bass	**Micropterus salmoides** Lacepede

*Stocking information furnished by U. S. Fish and Wildlife Service, Utah Fish and Game Department, and Idaho Fish and Game Department.

†Subspecies not distinguished in field studies.

‡Planted and possibly present but not recognized to subspecies.

§Present in tributaries.

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