Life History Notes on the Walleye, *Stizostedion vitreum vitreum* (Mitchill) in a Turbid Water, Utah Lake, Utah

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LIFE HISTORY NOTES ON THE WALLEYE, STIZOSTEDION VITREUM VITREUM (MITCHILL) IN A TURBID WATER, UTAH LAKE, UTAH

by

Billy B. Arnold

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Billy B. Arnold

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INTRODUCTION

Early in 1952, walleye fry were stocked for the first time in Utah Lake. Subsequent plants were made in 1954, 1955 and 1956. Altogether, over two million fry have been stocked.

By January, 1958, it was felt sufficient time had elapsed for the species to establish patterns of growth, reproduction, food habits and consequent relationships to the new environment. Thus, on January 1, 1958, a Federal Aid to Fisheries project, number DJ F-4-R-5, job T, was initiated. This project was entitled "investigations of Yellow Pikeperch and Channel Catfish of Utah Lake, Utah County." Although the closing date was December 31, 1958, data were collected until October, 1959. Funds were allocated by the Utah Fish and Game Department after December 31, 1958, for the continued study. Collection of data on the walleye was taken entirely from March, 1958, to April, 1960, and all the work included herein is from that period.

Fishery management is fast developing into a scientific discipline quite different from educated guesses that have characterized the past. Yet, we have only scratched the surface. More basic life history studies must be made if we are to manage our fishery resources intelligently. Intricate involvement in mathematical, chemical or biological problems should be included in life history studies only with discretion. Faulty collection of data renders the most brilliant analyses useless and actually does harm by misleading others in the field.

REVIEW OF LITERATURE

Publications concerning the walleye are numerous. However, most of the work has been done on populations from Iowa eastward to New York. Some studies have also been made in Tennessee and Canada.

New York state personnel are currently studying walleye populations in the Oneida Lake drainage. Their study consists primarily of age and growth, marking and recovery, sampling techniques, and creel censuses. Their latest report (April, 1960) concerning walleye reproduction, egg survival and fry movements points the way for future study although conclusions were tentative.

Eschmeyer's publication (1950) gives a complete account of all phases of the walleye life history in Michigan. His paper summarizes the findings of others and is probably the most thorough basic life history paper on the species to date.

Considerable work has also been done on the walleye by Carlander (1945-49), Hile (1954), Van Oosten (1957), Moyle (1959), Rose (1949), Lloyd Smith (1952-54), Stoudt (1939), Rawson (1957), Deason (1933), Stroud (1949) and Cleary (1949). Findings of these workers are discussed throughout this paper and need not be included here.

Local publications concerning Utah Lake are generally nontechnical, although the works of Drs. Tanner (1930-36) and Cottam (1926) are scientific. Snow's study (1931) of the algae of Utah Lake and the chemical analyses of the water by Decker and Maw (1933) are outstanding.

Various unpublished papers belonging to Dr. Tanner are valuable in gaining a knowledge of the history of Utah Lake and the valley.

Native fish and exotic introductions into Utah Lake may be found in Tanner's works (1936) and the Utah Fish and Game publication by Popov and Low (1950).

Christensen's bibliography (1956) of Utah aquatic biology summarizes local publications thoroughly.

HISTORY

General

Utah Lake occupies a small area once covered by Lake Bonneville, but it is generally conceded the former lake is not a remnant left by incomplete evaporation of the latter (Tanner, 1949). Others (Cottam, 1926) claim that the Great Salt Lake, Utah and Sevier Lakes are remnants of Lake Bonneville.

Climate of the valley is semi-arid, with an average annual rainfall of 15 inches recorded at Provo. Fifty-three percent of the total annual precipitation falls from January to May inclusive. The annual growing season of 122 days lasts from May 24th to September 24th.

Air temperatures are moderate, characteristic of mid-temperate regions. Highest temperatures (80° - 90°F.) occurs from June to October, while lowest temperatures (15° -20°F.) are recorded from December through February.

Wind direction records over a 14 year period show northwest winds prevailed eight months, north winds three, and southwest winds one month annually. Most summer months were characterized by north winds, while July was the only period when southwest winds prevailed during the 14 years.

Evaporation percentages (40 to 45 inches total annual precipitation) recorded over a six year period shows a low of 0.6 in January and 18.7 in July.

For 20 years prior to 1926, Utah Lake fluctuated annually an average of 2.7 feet, with maxima-minima being 5.1 and 1.4 feet, respectively.

Unofficial records show the highest level occurred in 1862 when the lake stood "6 to 12 feet above Compromise Level (elevation 4,488.95 feet)."[1]

Great changes in the physical, chemical, and biological characters of Utah Lake has taken place since the valley was settled by Mormon pioneers in March, 1849. Countless irrigation projects in the form of dams, canals and pumps constantly changed water levels. Industrial wastes from steel mills, sugar factories, animal by-products plants and domestic wastes in the form of raw sewage all combined to render many wildlife forms extinct in and around the lake. Erosion, both natural and man-made, has silted large areas of the lake.

Numerous legal battles have raged over water and land rights in and around Utah Lake. A final result was the establishing of "Compromise Point" (better known as Compromise Level, op. cit.) at elevation 4486.95 feet (changed in 1922 to 4488.95 feet).

Fishery

When Father Escalante came to the valley in 1776, he found the Utah trout (Salmo utah Suckley) abundant in Utah Lake. He noted that the Indians ate so many trout and suckers they were called "fish eaters" by other tribes. In 1884, Captain Fremont stated the trout were "very much inferior in size to those along the California mountains." In July, 1872, Dr. C. H. Yarrow said the trout were the most numerous species in the lake and the easiest to capture. He also believed the annual yeild had decreased one-third since commercial seining for trout began in 1847.

[1] Popular accounts give May, 1952, as highest recorded level (A. Will Jones, Provo, 1960), but the lake was only + 3.7 ft. at this time.

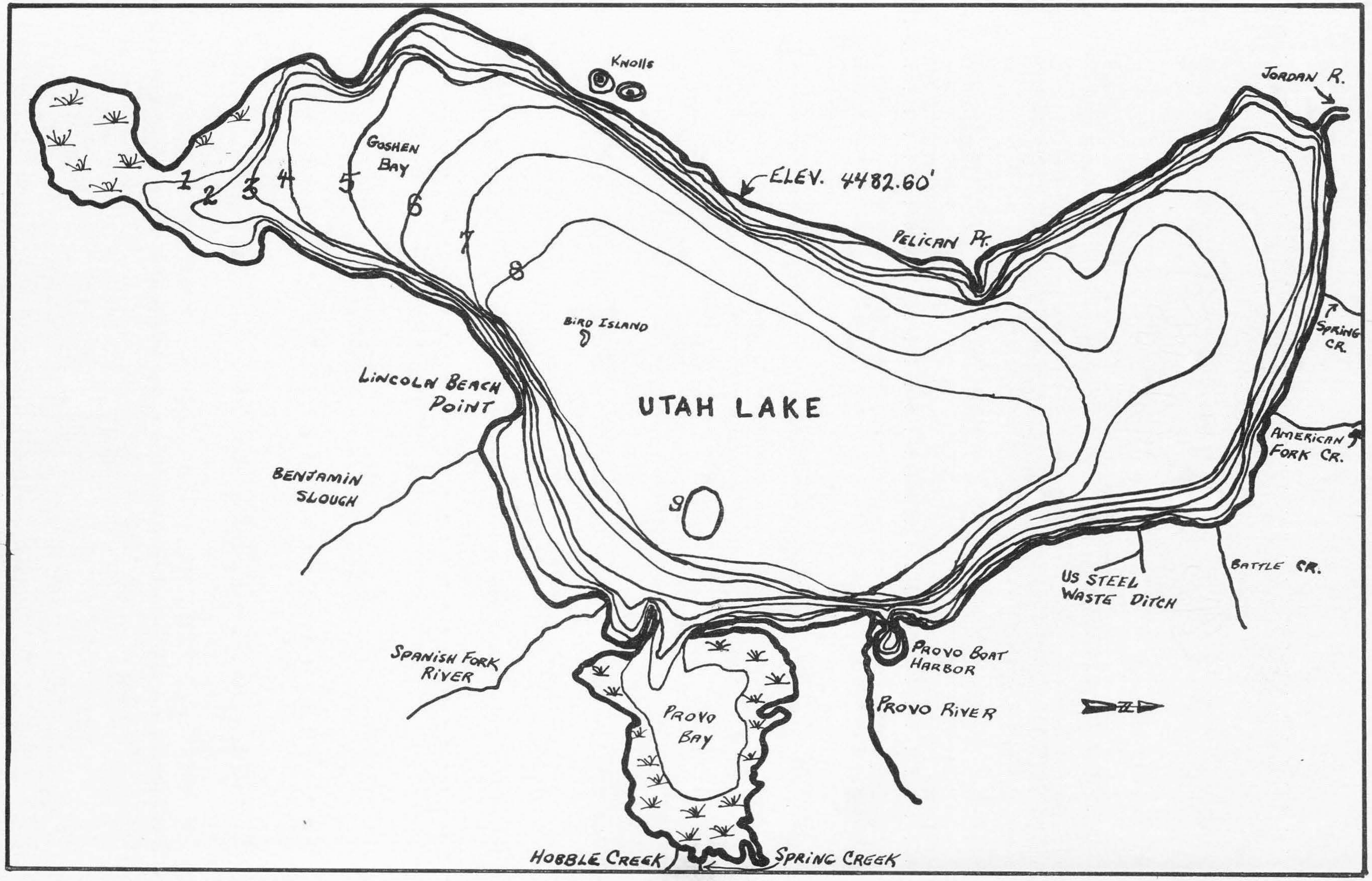

Figure 1. Contour map, October, 1959.

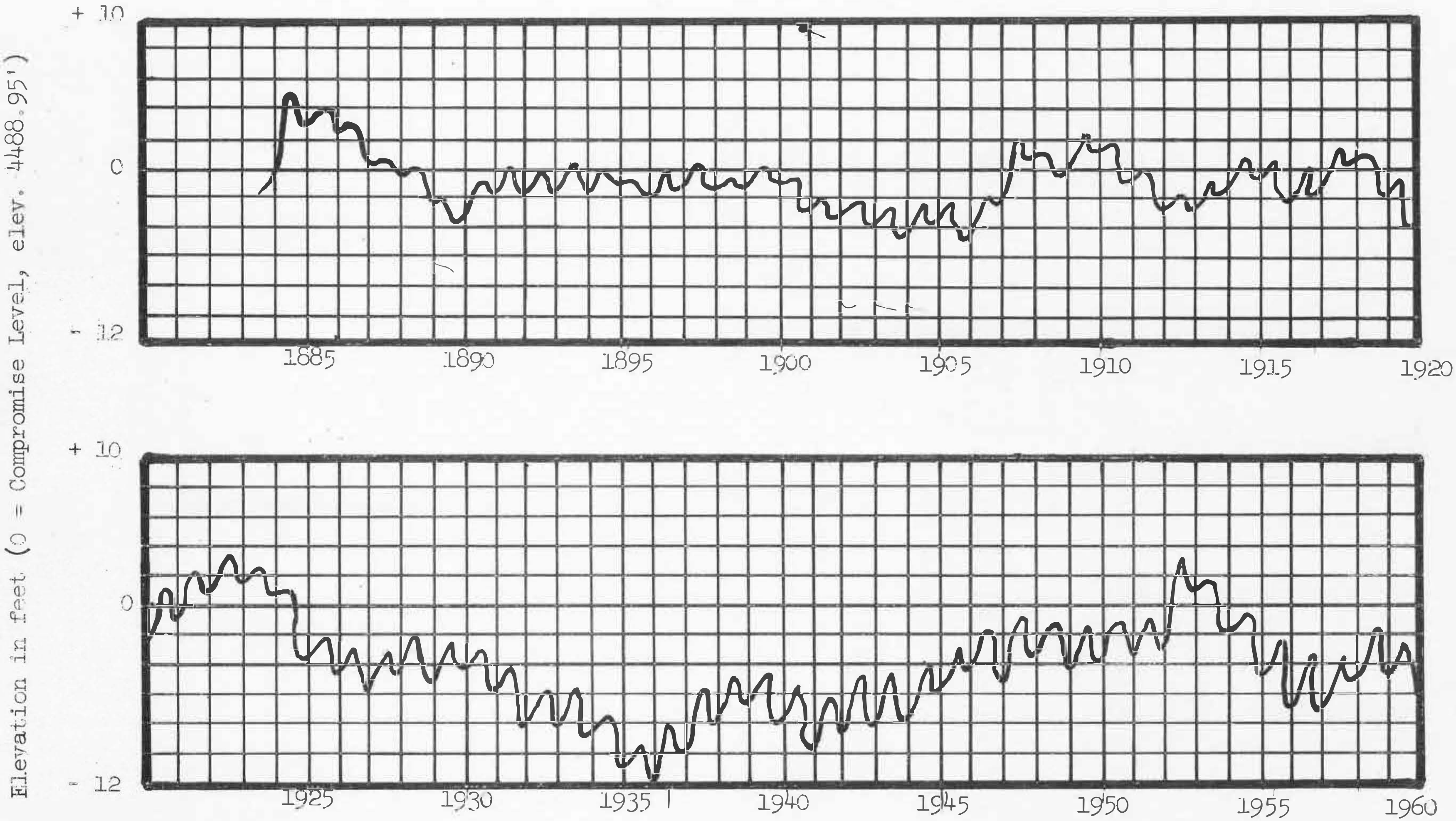

Figure 2. Fluctuation in water level of Utah Lake (from B.L.S. record # 66-418-1109 and Jordan River Pump Station).

Although regulations governing mesh size of nets were passed, wholesale seining continued until 1880.

An idea of abundance of the native trout in Utah Lake is given by Dr. Yarrow, quoting "Mr. Madsen who lived on the lake", who said, "in 1864, one haul of the seine produced between 35 and 37 hundred pounds of trout, while hauls at the present time (1872) were reduced to 500 pounds or less." By 1880, seining for trout was unprofitable in the lake.

Irrigation practices undoubtedly played a major role in the disappearance of the trout in Utah Lake. During March, April, and part of May, streams were allowed to flow into the lake. Stream spawners went up to spawn, only to have the fry diverted into ditches and onto the fields. David Starr Jordan reported spawning of the trout "in the shallow parts of the lake" in 1889. Thus, it would appear that irrigation doesn't completely account for disappearance of the trout. Just how successful spawning was in the lake, even in 1889, is questionable: turbidity has apparently always been fairly high and water levels fluctuated violently after about 1860.

Dr. Yarrow reported a maximum weight of $15\frac{1}{2}$ pounds and a length of three feet in Utah Lake trout, but the average weight was about two or three pounds and a length of 16 to 18 inches.

Dr. Vasco Tanner reported only 19 Utah cutthroat trout were known to have been taken from the lake in the 15 years prior to 1936. Two cutthroat trout were netted off West Mountain during this study; both were silvery, very slender (about 12 inches long), and with large heads in proportion to their bodies. These fish weren't keyed since no definite criteria have been found separating Salmo utah from Salmo clarki. It is possible these two cutthroats entered the lake from tributary streams, although evidence indicated they had been in the lake for some time.

Nine native species were reported in the lake or its tributaries by Tanner in 1936. Only four of these lived primarily in the lake: the Utah trout (op. cit.), Utah sucker (Catostomus fecundus), smallfin red-sided shiner (Gila balteata), and the Utah chub (Gila atraria). Three of the four are fairly abundant in the lake today: the trout has virtually disappeared. The remaining five native species found in the tributaries were the mountain whitefish (Prosopium williamsoni), mountain sucker (Pantosteus platyrhynchus), longnose dace (Rhinichthys cataractae), Utah sculpin (Cottus bairdi semiscaber), and the leatherside chub (Snyderichthys aliciae). Authorities generally agree that these species were probably native to the area when the valley was first settled by the pioneers. However, much confusion over the status of the native sucker species has developed over the years. Jordan called Utah Lake "the greatest sucker pond in the world" in 1881, and was referring to Catostomus fecundus. Cope and Yarrow reported great numbers of the June sucker (Chasmistes liorus) in 1872, although Tanner was unable to find it in the 1930's. The rosyside sucker (Catostomus ardens) was reported by the Indians to further complicate matters, but Hubbs was unable to separate C. fecundus and C. ardens among specimens examined in 1936. Today there appears to be two species of suckers in the lake: C. fecundus and C. ardens, the latter present in small numbers. This is based on fish taken in a weir in the Provo River which showed two widely separate spawning runs, where C. ardens spawned in early April while C. fecundus spawned during June. More confusion is found when Chasmistes liorus and Catostomus fecundus are compared: possible the two represent the same species with local variations causing the "split" in taxonomy.

Twenty-seven fish species have been introduced into Utah and 21 of these were introductions into Utah Lake and its tributaries (see Table 1). Only four species are presently established in the lake: the carp, channel catfish, yellow perch and black bullhead. The largemouth bass fairly erupted after the initial introduction in 1890 and Foster, of the U. S. Bureau of Fisheries, reported a "ton or more were taken per 400 foot seine haul in 1924." During the winter of 1924-25, tons of dead largemouths were washed ashore - victims of oxygen depletion.[1] Commercial fishermen believe these kills of largemouth are a result of ice breakup, and some evidence supports this theory.

Largemouth bass were so abundant at one time in the lake that a natural hatchery was established at Powell Slough and bass fingerlings were shipped to various parts of the country (Popov and Low, 1950). After 1913, the largemouth steadily declined as water conditions changed drying up their spawning grounds. Today, only limited numbers are in the lake and are found primarily around the spring areas at Lincoln Beach and Saratoga, near the Spanish Fork River, and in the Provo River near the lake.

Introduction of the carp into Utah came in 1881, but they were accidentally introduced into Utah Lake from a private rearing pond in 1889. Cottam (1926) reported a complete change of the lake flora, particularly pondweed (Potomogeton spp.), occurred within a very few years after the carp got into the lake. Early seiners reported the pondweed was so abundant in the lake it was difficult to row a boat.

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[1] Largemouth bass are reported dying almost every winter in the lake; during the recent winter (1959 - 60) another kill was reported by seiners although oxygen was plentiful under the 16 inch ice cover.

Overpopulation and consequent stunting of carp was observed by Foster in 1929. The larger carp seined today average about five pounds and are usually females.

Yellow perch, bluegill, green sunfish, black crappie, and largemouth bass were first brought to the lake from the Illinois River in 1890 by the U. S. Bureau of Fisheries. Black crappie are absent in the lake today, but an occasional bluegill or green sunfish may be found.

Great expectations for the yellow perch were expressed by Foster (op.cit.) who said, "the possibility exists that the yellow perch will make a valuable addition to Utah Lake even under its present condition (1929) and assist in reducing the numbers of carp and suckers." Actually, the yellow perch has fluctuated in numbers greatly over the years and probably has never been very abundant in the lake. Periods of low water have apparently left them without vegetation to spawn in. A noticeable decrease was noted in numbers taken in gill nets during 1959 (see Table 17). About 75 percent of all perch taken were stunted and had a least one tapeworm in their stomachs.

The channel catfish and black bullhead have been a valuable addition to the Utah Lake fishery. First recorded introduction of the channel catfish was by the Bureau of Fisheries in 1911, although the Utah County Wildlife Federation put 750 into the lake, taken from the Green River, in 1939. The black bullhead has been seined commercially and was not classified as a game fish until 1924. A study of the channel catfish was made during the same period as the one on the walleye.

Introduction of the walleye into Utah Lake came in 1952, when 600,000 fry were stocked. A total of 2,075,000 were stocked during 1952-54-55-56, and their success is the subject of the paper.

Table 1. Fish introductions into Utah Lake and its tributaries[1]

Species	Year(s)	Total No.	Success
Alosa sapidissima	1873-87-88	5,005,000	No
Oncorhynchus kisutch	1927	325,000	No
Oncorhynchus tschawytscha	1873-74-75-77-79	608,900	No
Salmo gairdneri	1897-1900	8,000	In tribs.
Salmo trutta	Prior to 1900	-	In tribs.
Salvelinus namayush	1894-1900-01	84,000	No
Salvelinus fontinalis	1894-95-97	2,900	No
Coregonus clupeaformis	1895-1921	2,100,000	No
Thymallus arcticus	1899	30,000	No
Anguilla rostrata	1872-87	80+	No
Cyprinus carpio	1889	Unknown	Yes
Ictalurus punctatus	1911-19-20-39-54	500,000+	Yes
Ictalurus melas	1871-74-93	Unknown	Yes
Perca flavescens	1890-91, 1923-31-32-33	Unknown	Yes
Micropterus dolomieui	1912	160	No
Micropterus salmoides	1890-91-95	1,800+	Yes
Pomoxis nigromaculatus	1890-95, 1931-32-33	Unknown	No
Lepomis cyanellus	1890	Unknown	In tribs.
Lepomis macrochirus	1890	Unknown	In tribs.
Stizostedion vitreum	1952-54-55-56	2,075,000	Partial
Roccus chrysops	1954	200+	Yes

[1] Based on best available records and the publication by Popov and Low, 1950.

The latest introduction was white bass in 1954, when about 270 were planted. Their success has been phenomenal thus far and considerable numbers were taken by fishermen during 1958 and 1959.

Relative abundance of species in the lake may be interpreted from Table 17, (of course, selectivity of gear must be considered. See section on "Gear Selectivity").

Angling success is undoubtedly greater in Utah Lake today than at any time since 1924, when the largemouth bass died so numerously. Channel catfishing is excellent during the early summer.

DESCRIPTION OF WATERS STUDIED

Physical

Utah Lake lies in the west central portion of Utah valley at an elevation of 4489 feet above sea level. The crescent shaped lake lies in a north-south direction with the extremes of the crescent pointing westward. Shorelines are regular except in Provo Bay, a marsh area of three to five thousand acres.

Mountains surround the lake with the Salt Lake Valley to the north allowing enough opening to possibly allow north winds that generally prevail. Lake Mountains to the west rise 3,000 feet above the lake; West Mountain on the south rises some 2,000 feet, but the Wasatch range rises from 5,000 to 7,000 feet, climaxed to the northeast by barren Mt. Timpanogas which rises 12,008 feet above sea level.

The lake is unique in that it lies in the heart of an arid region, receiving water from clear mountain streams (except the Spanish Fork River and small polluted streams), yet it is always turbid. Summer turbidity measured after normal winds during August, 1959, were a maximum of 45 ppm of SiO_2 equivalents. Shoreline turbidities are probably much greater during windy weather, but the water clears considerably during the winter. Just how long the lake has been turbid is open to speculation: it probably increased after introduction of the carp, but it was probably turbid before this.

Bottom type of about 95 percent of the lake is a mixture of calcareous clay, organic detritus and black muck. The remaining types are gravel, rubble, boulders, solid limestone rock, and sand in varying combinations (Figure 3). Small particles of clay, almost colloidal in nature, never settle out. Winds keep the bottom material so thoroughly mixed into the water that the lake is often a foaming mass of mud. The bottom is so soft that an oar can easily be pushed a foot or two into it.

Shorelines slope gently on the east, but are slightly more inclined on the west side and along West Mountain. The inclination is less than a foot to the mile along portions of the east shore. Consequently, variations of the surface area may increase and decrease greatly every year.

Evaporation and seepage are tremendous being about 300,000 acre feet during normal years.

At Compromise Level the average depth is about 12 feet, excluding the small littoral zone. During this study, the maximum depths were about 11 feet in 1958 and about 10 feet in 1959 (Figure 1). Very little irregularity in depth is found since the bottom is saucer shaped with deep springs located in Skipper Bay and around Saratoga (Figure 3). The deepest area (excluding springs) is found west of Provo Bay about one mile. Only twice has the lake been above Compromise Level since 1924, and records show it has never been over about 20 feet deep even during high water periods (Figure 2).

At present, the lake covers about 120 square miles and is roughly 20 miles long and six miles wide. The total water volume is roughly one half million acre feet as of January, 1960.

Fertile valleys east of the lake are in sharp contrast to the arid sagebrush climax along the west shore. Soils analyzed by the U.S.D.A. in Provo Bay area were generally fertile types of muck and muck-like loam, clay subsoil, fine sand, and sandy loam in varying mixtures (Harper, 1926).

Soils too alkaline for crop production were found over about one-fourth of the study area, with ionic concentrations of soluble salts up to 4.31 percent in the topsoil.

Surface water temperatures taken during this study were at a minimum of 31°F. during the winter and a maximum of 86°F. during the summer (Figure 6). Although the lake is too shallow to stratify, a sharp drop in temperature is present at a depth of two to three feet beneath the surface in summer. Earlier workers noted cooler summer temperatures than were found in this study, but direct comparisons are difficult as a result of various circumstances. Constant temperatures are found in most springs in the lake after a depth of six feet is reached. Warm springs around Saratoga were 111°F., while cold springs were 54° to 56°F. One large spring off the west end of Bird Island was 88°F. in August, 1959.

Ice usually covers the lake from December to March, with occasional breakups during windy weather and/or warm periods. The winter of 1958 - 59 was abnormally mild and ice never froze thicker than eight inches and broke out over a dozen times. The current winter (1959-60) has been the coldest in 10 years and only two complete breakups have been observed. Ice thickness around Lincoln Beach was 20 inches in February, 1960. Invariably, the southern portion of the lake is the coldest the year around and waters along the eastern shore are warmer than along the western shore.

Utah Lake lies very near the center of its drainage area of about 3,000 square miles. This area overlaps parts of five counties. It was estimated by the U.S. Geological Survey in 1904 that about 22 percent of the total inflow that year came from springs beneath the lake. Annual inflow averages about 600,000 acre feet.

Tributaries flowing into the lake proceeding along the eastern shore from Saratoga southward are: Dry, American Fork, and Battle Creeks, Provo River, Spring and Hobble Creeks, Spanish Fork River, and Benjamin (Payson) Slough. Other minor waste ditches and streams are also found on the east shore, but not a single natural tributary is found along the west shore.

By far the major tributary, the Provo River, probably flows more water than all others combined. Headwaters of the Provo are located high in the Uinta Mountains, fed by many small glacial lakes. The Spanish Fork River has about the same drainage area as the Provo (600 square miles), but the discharge is much less. Silted, muddy waters of the Spanish Fork river are the end result of streams flowing from an overgrazed and barren watershed.

Since the construction of Deer Creek dam on the Provo River in 1938, and gradual lowering of the water table, the inflow to Utah Lake has lessened in recent years. Outflow in the Jordan River, the only exit, averages about 350,000 acre feet annually - about the same as that lost by evaporation.

Chemical

There has been a great change in water chemistry of Utah Lake since settlement of the valley in 1849 (Tanner, 1931). The first chemical analyses were made in 1884, and have been made periodically every since.

Dr. F. W. Clarke of the U.S. Geologic Survey made the following remarks concerning the chemical changes between 1884 and 1904:

> "Utah Lake, in the 20 years intervening between the earliest and latest analyses has undergone a thorough transformation, and its salinity has more than quadrupled. From a freshwater of the sulphate type, it has become distinctly saline, and this change is probably a result of irrigation. Its natural supplies of water have been diverted into irrigating ditches, and at the same time salts have been leached out from the soil and washed into the lake."

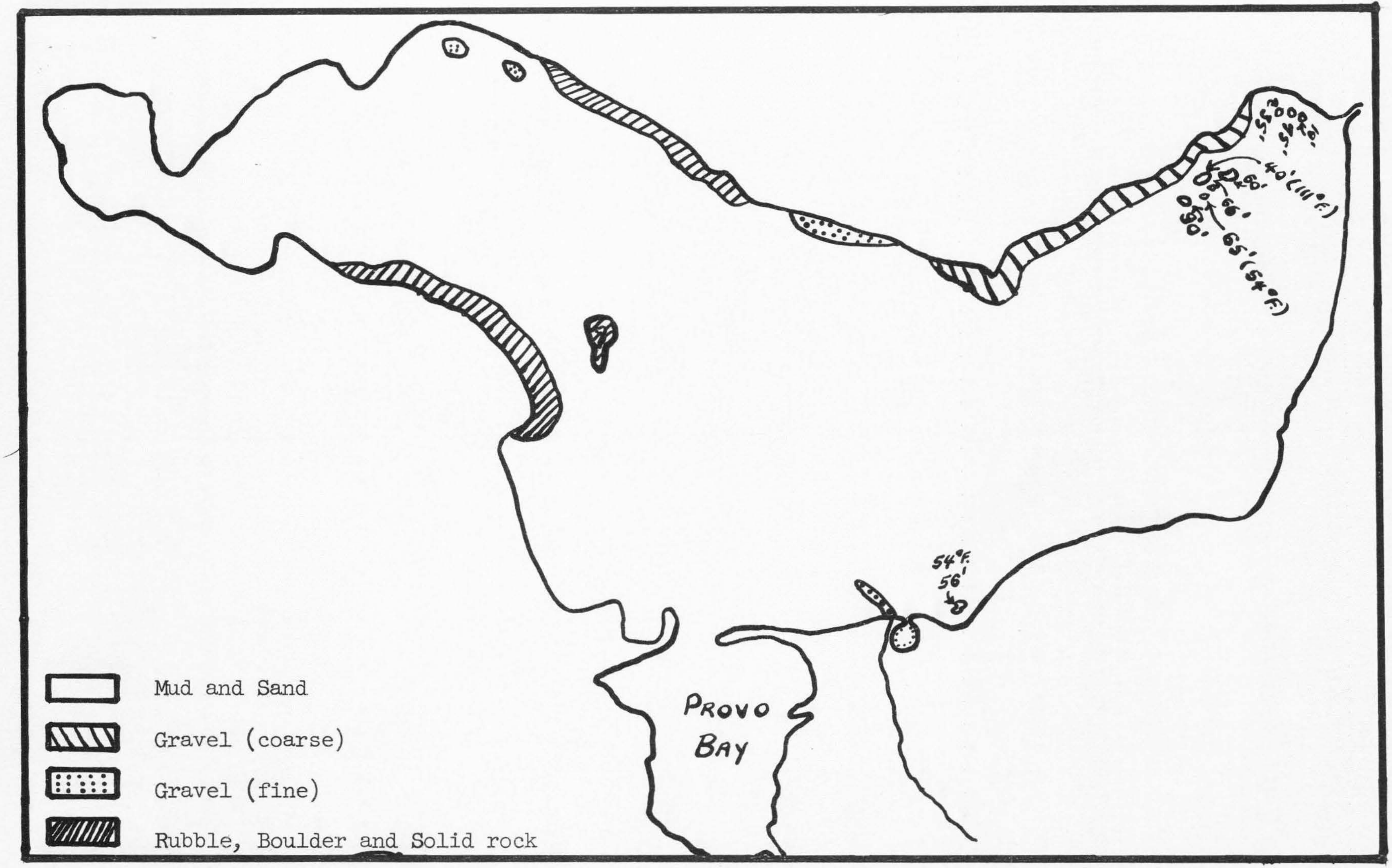

Figure 3. Bottom types, locations of springs (with depths and temperatures) found in Utah Lake.

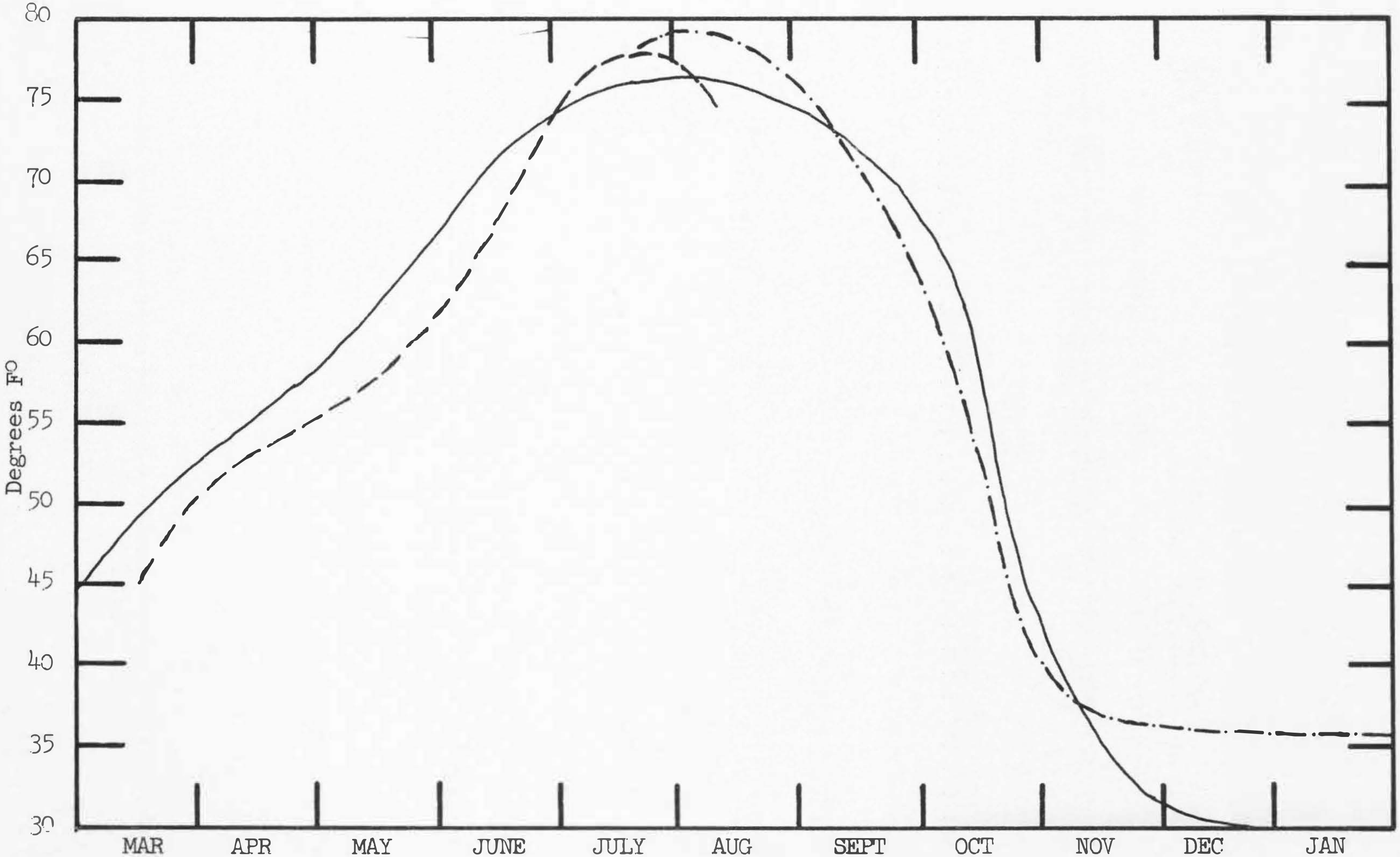

Figure 4. Mean monthly surface temperatures of Utah Lake: 1929-39[1] (solid line), 1958 (dot-dash line) and 1959 (broken line).

[1] Tanner (1960),

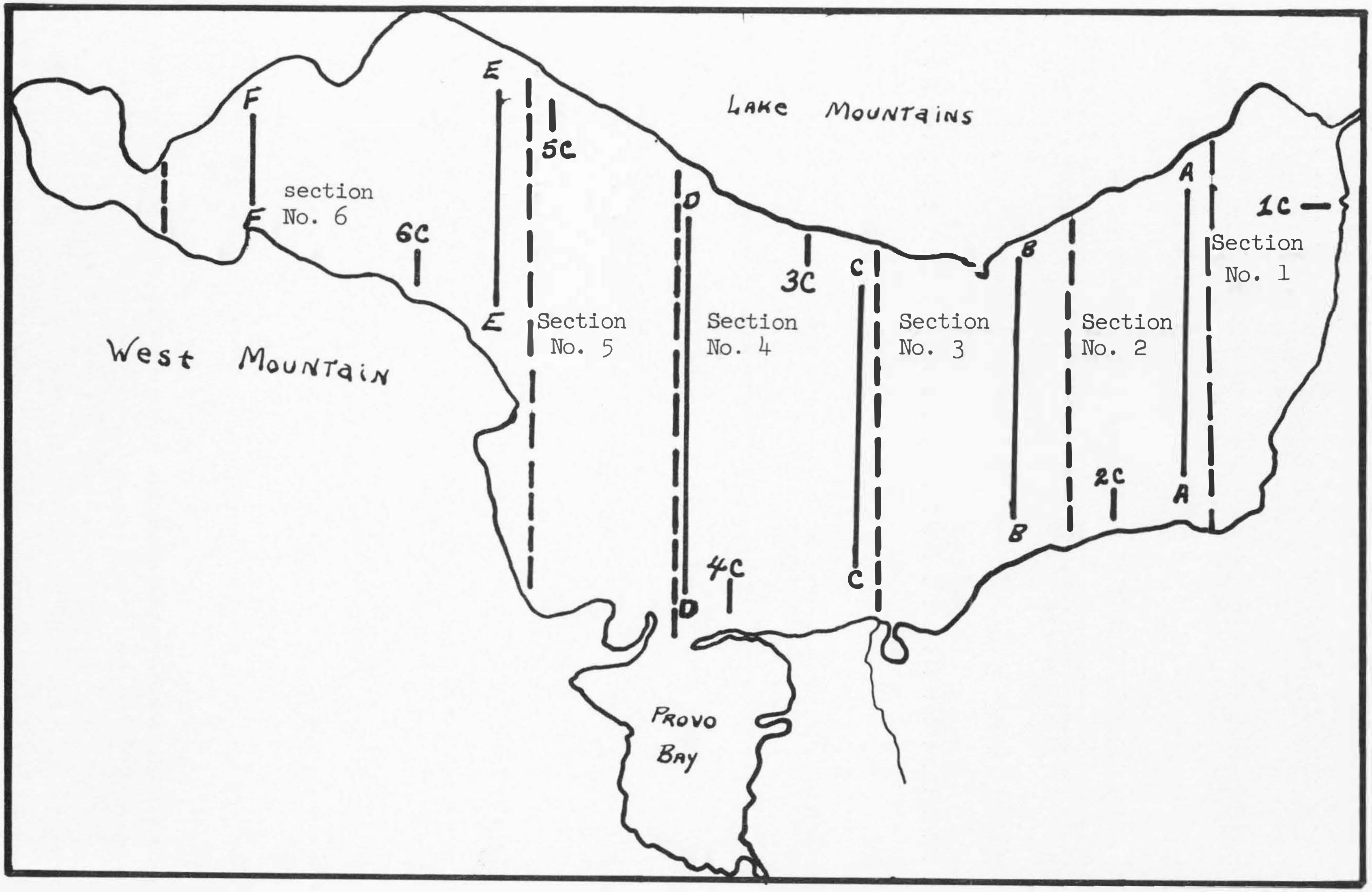

Figure 5. Control gill net stations, temperature profile areas (between broken lines) and surface temperature profiles (along solid lines).

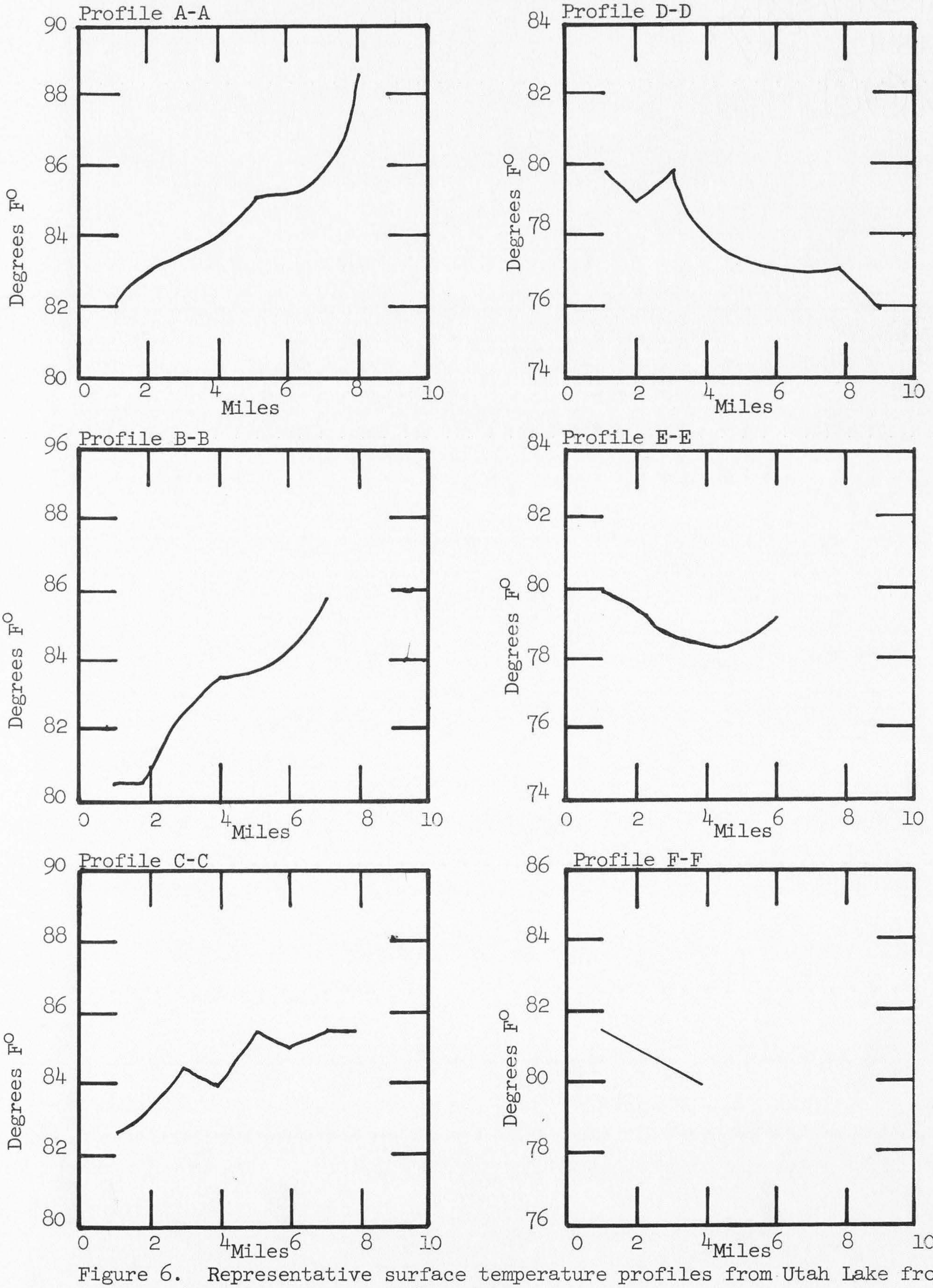

Figure 6. Representative surface temperature profiles from Utah Lake from west to east, August, 1959

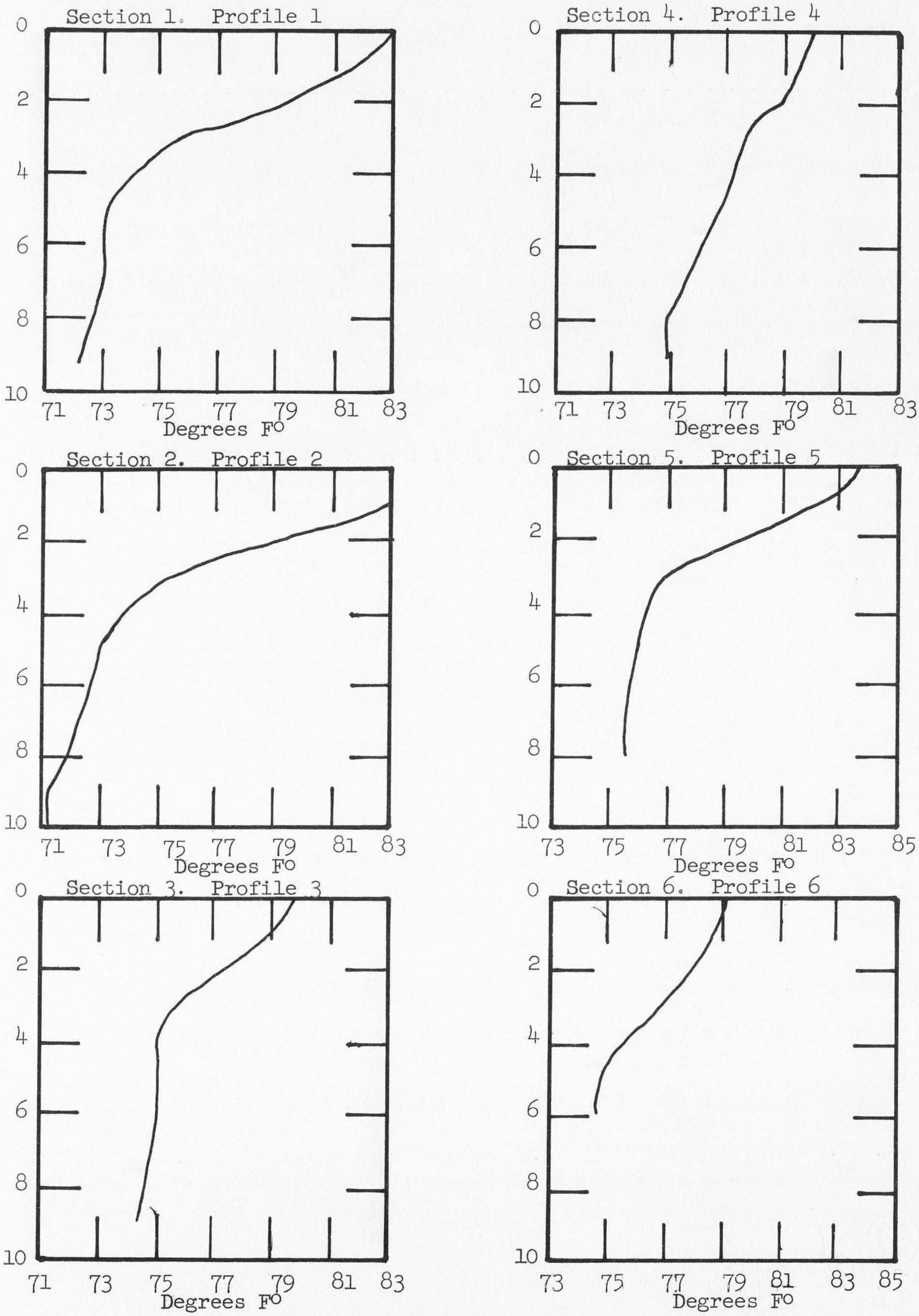

Figure 7. Representative temperature profiles of Utah Lake by one foot intervals, August, 1959 (see Figure 5 for locations).

The presence of some basic salts which are the product of strong hydroxides and weak acids, particularly calcium and magnesium, with weak carbonic acid, gives the water a pH of from 8.0 to 8.6. Free CO_2 is seldom found, although Lachlan reported up to 16 ppm from various parts of the lake. Higher CO_2 was found in some spring areas by Lachlan. Oxygen is plentiful at all depths over the entire lake, ranging from 7 to 10 ppm during the critical summer months. Winter oxygen appears to be plentiful, but only a limited number of samples have been tested at this time of year.

Tanner reported an "electronic bridge" reading showing 559 ppm of soluble salts in September, 1937, in the Jordan River.

Decker and Maw (1933) concluded that the lake wasn't increasing in dissolved solids, but rather a point of equilibrium had been reached between solids entering and leaving the lake. They also found that large thermal springs in the Saratoga area contained more dissolved solids than the seepage waters coming into the lake. Thus, they concluded that irrigation wasn't increasing dissolved solids in the lake, but irrigated land was increasing in alkalinity due to improper practices. Decker and Maw also found a water hardness up to 1783 ppm, calcium 517 ppm, bicarbonates 623 ppm, sodium 932 ppm, chlorides 1,273 ppm and sulphates up to 1,583 ppm in springs at Lincoln Beach.

After comparing various chemical analyses of Utah Lake water (Table 11), it is apparent that there is variability in its chemistry. This is probably a result of the sources of supply being so variable. The contention that sulphates are decreasing isn't shown in the various analyses. Chloride content has increased tremendously. Sodium and potassium have probably increased and fluorides, at 5 ppm, could be harmful to the fishery. Calcium

Table 2. Water chemistry[1] of Utah Lake at three locations during January, 1960 (expressed as ppm)

Compound or Element	1C	Provo Harbor[2]	6C
Total solids	805	420	1310
Fixed solids	680	320	1070
Organic and Volatile matter	125	100	240
Organic matter	20	45	30
$CaCO_3$ & $MgCO_3$ hardness	388	268	456
Chlorides as Cl	152	48	312
Sulphates as SO_4	132	25	48
Iron as Fe	0.2	0.1	0.1
Manganese as Mn	Nil	Nil	Nil
Silica as SiO_2	1.0	1.0	1.0
Nitrates and nitrites	1.7	0.4	0.3
Fluorides as Fl	5.0	3.0	5.0
H_2S	Nil	Nil	Nil
Total alkalinity	211	Not sampled	189
Sodium as Na	160	52	320
Phosphates as PO_4	5	3	3
Aluminum	0.5	0.2	0.2
Potassium	22.0	10	30
Ammonia as NH_3	.4	0.12	0.13
pH	8.5	8.0	8.5

[1] Analyzed for the Utah Fish and Game Department by Peterson Laboratories, Salt Lake City.

[2] Sample taken in the lake just west of the boat harbor.

and magnesium carbonate hardness is rather high at about 400 ppm, though it is doubtful that this is very harmful to the fishery.

Biological

The present biological status of Utah Lake is primarily a result of four significant events. In chronological order these were (1) manipulation of water levels by irrigation, (2) commercial seining of the cutthroat trout, (3) introduction of the carp, and (4) pollution, including siltation.

Since plants are good indicators of biological conditions, a discussion is included in this paper. The climax vegetation of the region is desert scrub and has probably changed very little since pioneers settled the valley (Cottam, 1926). However, aquatic plants have changed considerably in the lake area. Alkali content of the soil in marsh areas rose steadily with intensive cultivation and irrigation practices, and grassy meadows gave way to alkali-loving plants such as *Distichlis stricta*, *Salicornia rubra*, and *Allenrolfia occidentalis*. Disappearance of watercress (*Roripa nasturtium*) in areas around Powell Slough and Provo Bay suggests spring areas are fewer now than formerly (occasional patches are still found, however). Cottam reported an abundance of watercress in 1926. Abundance of pondweed prior to carp introduction has been discussed earlier.

By far the dominant plant around the lake is the bulrush. In fact, the bulrush-cattail-reed association forms a major portion of the aquatic flora, while the sedge-willow associations are common in "zone c" (Table 18).

Five plant formation types are shown in Table 18, with the marshland having the greater number of species. Marsh areas are typical of the east and northeast shores and Provo Bay. Goshen Bay has some marsh area, but it is primarily salt marsh area, particularly along the southwest shore.

Shingle beach type plants are found along the western shore south of Pelican Point. Sandy beach formations are typical around Powell Slough, Spanish Fork River and isolated portions along the entire lake shoreline. Bench land types are upland areas along West and Lake Mountains.

Heavy phytoplankton "blooms" were present along the municipal airport and Provo Bay during July and August of 1958-59.

Bird Island, whose highest elevation is one foot below Compromise Level, is an interesting case of plant invasion between periods of high and low water. Cottam (1926) reported an almost pure stand of Polygonum lapathifolium, with occasional species of Chenopodium, Panicum, and Xanthium. Today, Polygonum spp. have virtually disappeared on the island being replaced by Hordeum, Panicum, Rumex, Salix, Populus, Scirpus and Taraxacum species.

Molluscs were once abundant in the lake (Tanner, 1936). Living specimens of Pisidium, Lymnaea and Garinifex species were reported by Call in 1883. Scarcely a bottom sample may be taken today in many areas without picking up shells of the first two species. Only one living mollusc species was found during this study, that was primarily along Pelican Point. It is a large clam-like variety resembling the genus Margaritana (Needham, 1955).

Snow found 49 genera and 128 species of green and blue-green algae in and around the lake, primarily in springs, in 1931. It appears that this number has diminished since her study, but very little taxonomy was undertaken during this study. Common forms such as Oscillatoria, Nostoc, Anabaena, Hydrodictyon, Ulothrix, Cladophora, Oedogonium, Spirogyra, and Vaucheria species were found during 1958-59. Chara sp. is occasionally found in alkaline areas.

Neuhold sampled benthic fauna at 147 stations during 1955 and concluded that Diptera larvae were the only abundant insect species present in Utah Lake. He also found tubifex worms, an indicator of pollution, prevalent in many areas along the eastern shore. Other organisms found in localized areas were hemipterans (probably genus Notonecta) and freshwater shrimp.

A general quantitative study was made of the benthos during this study and generally agreed with the findings of Neuhold except fewer tubifex worms and more freshwater shrimp (Gammarus sp.) were found.

Neuhold also reported a zooplankton abundance of one milliliter per 100 milliliters of lake water.

Tanner (1930-31) reported 11 genera of Protozoa, one Porifera, one Coelenterata and one Nemathelminthes, six Rotatoria, many annelida, six Arthropoda, one Bryozoa and five Crustacea. Other genera were found but not reported.

Leeches and roundworms are common parasites of channel catfish in the lake. Tanner found numerous roundworms in plant debris near shore and in deep water mud in 1931. Tapeworms are common in yellow perch.

Waterfowl are still fairly abundant around the lake, but have diminished greatly in the past 50 years. Gulls, terns, snipes, avocets and other shore birds are numerous, but great blue herons and white pelicans have apparently decreased in the last 30 years (Tanner, 1936).

METHODS AND MATERIALS

Fish Sampling Devices Used

About 85 percent of the walleyes used in the study were taken in nylon experimental gill nets. The remainder were taken by fyke nets, trap nets, seines, electric shocker, trawl, and weir. Japanese gill nets of fine twine and $\frac{1}{2}$ inch mesh were also used.

Five nets were of the common bar mesh sizes from 3/4 inch to 1 3/4 inches, consisting of five sections of near equal lengths. Usually the length is 25 feet per section, but none of the nets used were a full 125 feet long. Original net lengths were 82, 102.2, 103, 105, 112.2, 116 and 121.2 feet, but gradually each net became shorter with use, ice and motorboat tears, etc. Two nets were of a different bar mesh: one of 3/8, 5/8, 7/8, $1\frac{1}{2}$ and $2\frac{1}{4}$ inch, and the other of 1, $1\frac{1}{4}$, $1\frac{1}{2}$, 1 3/4, and 2 inch mesh. All nets were six feet deep. Four nets were either lost or torn up during the study.

Six treated or nylon fyke nets were used with very little success. Bar mesh sizes were $\frac{1}{4}$, $\frac{1}{2}$, 3/4, 1 $1\frac{1}{2}$ and 2 inches with two throat openings of from two to six inches diameter (after adjustment). Lengths ranged from 10 to 16 feet.

Trap nets were constructed by using a seine (either 11, 16, or 50 ft.) as a leader to a fyke net. When the seine was placed at right angles to the shoreline, forming a "T" with the fyke net, fish were readily led into the net. Both the seine and fyke net were held in place by steel fence posts driven into the lake bottom (Figure 18).

Four seines were used. Three were bag seines of 11, 50 and 1200 feet, while the fourth was a "common sense" type 16 feet long. The 11 foot seine had a bag of 1/16 inch mesh, 2 X 3 feet and one foot deep; the wings were of 1/8 inch mesh. Both the 16 and 50 foot seines were of heavy cotton twine, $\frac{1}{4}$ inch mesh; the bag of the 50 foot seine was of the same material as the wings measuring about 4 X 4 feet and two feet deep. The 1200 foot seine belonged to commercial seiners and had wings of $1\frac{1}{4}$ inch bar mesh and a bag of about 3/4 inch bar mesh; the bag was approximately 6 X 6 feet and about 16 feet deep.

The electric shocker was a portable AC made by Lear Lite, San Francisco, producing 115 volts, 12.5 amperes maximum, when using one electrode equipped as a dip net (Figure 22).

A 16 foot trawl, borrowed from Utah State University was a flat gulf style of treated cotton, $1\frac{1}{2}$ inch mesh # 6 thread body and $1\frac{1}{4}$ inch mesh # 12 thread bag, with a pair of 24 X 12 inch doors and 80 foot towline.

A weir was placed into the Provo River during the 1959 spawning run. It was constructed of a 6 X 6 foot wood frame which formed the walls of the enclosure. Wings spanning the river were also constructed of grates placed obliquely to the current and supported by heavy water pipes running horizontally to the water surface, which in turn were wired to steel fence stakes driven into the river bed forming "A" frames. A "V" opening to allow fish to enter was placed on the downstream side of the enclosure and was 3 5/8 inch wide, 16 inches deep. A cover was placed over the trap and various devices were employed to induce walleyes to enter.

Data were obtained from limited number of walleyes taken by angling or dipnetting at night, although 99 percent were taken by nets, seines or in the weir. None was taken in the trawl, although the same type has been used successfully elsewhere in taking walleyes.

Sampling and Results

Fish sampling on a sound statistical basis wasn't feasible since time, personnel, money, or equipment available was inadequate. Nevertheless, it was felt that a good cross section of all size groups in the population was sampled.

Six permanent sampling stations were established on the lake and an attempt was made to set at least one gill net at each permanent station each month during the 19 month study. Every time a net was set at a permanent station, one or more nets of the same type were set elsewhere. Practically all gill nets were set on the surface since the shallowness of the lake seldom required depth settings to capture fish. Both pelagic and shore setting were made.

Taylor maximum-minimum thermometers were attached on the bottom of many experimental gill net sets and pertinent data concerning weather, time, date, depth, was always recorded.

Japanese gill nets were used to sample small fish, but very few small walleyes were taken in them. However, they were very effective in taking yellow perch and redsided shiners. They were set in the same manner and locations as experimental gill nets.

Fyke and trap nets were used around the shore, but were relatively ineffective for taking walleyes, except during the spawning period. Seining was fairly effective by commercial seiners, but neither pelagic areas nor the west shore were sampled by them during the study. Most of the young-of-the-year walleyes were taken by seines.

Electrical shocking was ineffective in the lake where depth exceeded a foot, but good results were experienced in the Provo River. The problem was finding the fish after they were narcotized in the turbid waters of the lake.

Fishing with the trawl was successful for most species - except walleyes. This is believed to be because of the relatively low numbers of walleyes present in the lake. Other workers have had good success with the trawl in taking walleyes (Forney, et al, 1959).

Weir sampling of walleyes in the Provo River was only partially successful. (This is discussed fully in the section on reproduction.)

Gear Selectivity

Many people have recognized that experimental gill nets are selective (Moyle, et al, 1959). New York biologists (1959) found that normal statistical methods aren't applicable in net catches where behavior patterns of fish differ greatly. Moyle believes all passive fishing nets are selective.

New nets never seemed to catch as many fish as older and dirtier ones. Fyke nets treated with a creosote base preservative were less effective after treatment.

Commercial seining was automatically selective because of the areas seined as well as previously mentioned factors. Yet, the best representative samples were probably taken by seines.

Considering factors of behavior, habitat and physical makeup of the fish species in Utah Lake, the following conclusions of relative numbers is drawn from Table 17: carp are probably about as numerous as Utah chubs in Utah lake, but the former ranks much higher in total poundage; carp are wary of nets, but spines in their dorsal and anal fins make escape harder than for the Utah chub. Channel catfish probably rank third in total numbers, second in total poundage; suckers are probably even less numerous than perch (than shown in Table 17), but far exceed perch in total bulk; walleyes are probably less numerous than suckers in the lake. Much of the netting was directed toward walleyes, causing the comparison in Table 17 to be somewhat misrepresentative. Black bullheads were increasing in numbers significantly in the catch from 1958 to 1959. White bass were also increasing greatly: despite the low catch per gill net hour, commercial seiners took them consistently during 1959.

A tendency for piscivorous or omnivorous fish to be more easily gill netted is obvious. Many small fish were half eaten and left in nets. Walleyes, channel catfish, yellow perch and probably bullheads were probably lured to nets and consequently higher numbers taken, thus giving a higher rate of catch than in plant eating species.

Vertical distribution of various fish species made some more vulnerable to netting than others. Catfish and walleyes at certain seasons tended to move close to the bottom and probably missed being netted while other species were taken. Carp and suckers also stayed close to the bottom, but it was usually close to shore where nets were set on the bottom.

Collecting and Analyzing Data

Standard methods as described by Sigler (1950) were used in analyzing age and growth and food habit data. Two Chatillon spring type scales of two and 15 kilogram capacity were used for weighing specimens.[1]

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[1] Two kilogram scale weighed three percent heavy while the 15 kilogram scale was found to be accurate by the Engineering Department, Brigham Young University, December 16, 1959.

Approximately 57 percent of all fish were weighed on the larger scales. Measurements of standard, fork and total lengths were made of each fish using a standard measuring board, as described by Lagler (1956) graduated in millimeters. All other pertinent data concerning date, place, sex, etc., was recorded at the time of catch. Opercles were taken from 36 fish for aging.

Scales were taken from about 400 fish for age and growth studies. Two locations were used on each fish for scale removal: immediately above the lateral line and below the first dorsal spine, and three scales from the third scale row below the lateral line beginning with the tenth scale going posteriorly. The latter scales were used as key scales (Eschmeyer, 1950) to plot the body-scale relationship curve (Figure 23).

An average of six scales was mounted on a microscope slide in a glycerin-waterglass medium and read twice using a Bausch and Lomb micro-projector at a magnification of 27 X. Oak tag strips were used to mark annuli from the projected scale image and growth calculations were made by use of a nomograph constructed from the empirical data obtained from the body scale relationship (Figure 10).

Another 103 fish were aged by experienced fishery biologists: 85 were aged by Tom Moen of the Iowa Conservation Commission and 18 were aged by Dr. Norman Benson of the U.S. Fish and Wildlife Service, Logan, Utah. Very good agreement was found between scale readings of Mr. Moen and the author, but only a 50 percent agreement with the aging by Dr. Benson. Doubtful scales were discarded.

Length-weight relationships and condition factors were based on the empirical formula,

$$\text{Log } W - -4.79031 + 3.02554 \log L.$$

When solving for "K" factors, allowance was made for weight of gonads (Table 9). It was found that fully developed testes and ovaries averaged five and 10 percent of total body weight, respectively. A percentage corresponding to date of capture was subtracted from total body weight in solving "K" factors.

Sexing fish was difficult in specimens less than six inches (SL) and where doubt existed, sex was listed as "unknown". No reliable external method of sexing was determined during the study, but recently (1959) Moen found the female walleye has two urogenital pores while the male has only one. Sexing immature walleyes by their gonads is relatively difficult (Eschmeyer, 1950), but with practice they can usually be sexed confidently.

An attempt was made to sample walleye stomachs continuously for a period of a year or more in order to detect seasonal variations in the diet. Difficulty in locating walleyes during ice cover, inclement weather and equipment trouble, made it impossible to sample every month.

Stomachs were removed from specimens immediately after being taken from nets or seines, and preserved in 10 percent formalin (after proper identification by tagging).

Identification of stomach contents was made with the aid of a binocular microscope, various other devices and publications, and preserved fish specimens from Utah Lake. Since fish made up almost the entire diet, stomach contents were rather easily identified by using scales, pharyngeal teeth, fin lengths, spine and ray counts, air bladder shape and pigmentation, general body shape, and opercles. Some difficulty in differentiating walleye and yellow perch scales was encountered, but generally it was found that walleye scales contained five or more radii while perch usually had three or four. Digestion is apparently so rapid in walleyes stomachs that often bones and scales are the only basis for identification. Unless positive identifications were made, they were listed as undetermined fish: food analyses were made from fish taken from 12 general areas over the lake during 13 months.

Chemical analyses of lake water was by standard methods as described by Lagler (1956) and Welch (1948). More difficult analyses were made by Peterson Laboratories of Salt Lake City.

Sampling of benthos were by Ekman dredge and fine screen; identifications were to genus.

Aquatic plants were collected and identified by Dr. B. F. Harrison of the Botany Department, Brigham Young University.

Water temperatures were found by using Taylor max-min and mercury pocket thermometers and Foxborough electrical resistance thermometers. Turbidity readings were made of lake water with the aid of a Hellige Turbidimeter. Soundings were made by sounding line and Bendix sonar gear. The latter gear tended to give a "false" bottom over highly turbulent spring areas where sediment boiled up.

Experimental gill netting data (Table 17) includes all sets, both permanent (control) and nonpermanent sampling stations. This was permissable since no significant differences were noted in either species or rate of catch between the two sampling stations.

Table 3. Walleye stocking in Utah Lake and recaptures by all methods[1] during 1958 and 1959

Date	Numbers Stocked	Location	Percent of Total Stock	Return 1958	Return 1959	Percent of Stock Return
May, 1952	600,000	Middle of lake[2]	28.92	44[3]	13[4]	23.65
May, 1954	250,000	Mouth Provo R.	12.05	17	4	8.71
May 4, 1954	25,000	Lehi Mill Pond	1.21			
May 4, 1954	25,000	Sp. Fork Mill Pond	1.21			
May 17, 1955	275,000	Rocky Knolls	13.25	45	16	25.31
May 14, 1956	300,000	West Mtn. Beach	14.46	84	18[5]	42.32
May 25, 1956	600,000	Lincoln Beach	28.92			
TOTALS	2,075,000		100.00	190	51	100.00

1 Year classes 0 and I omitted since they represent natural reproduction.

2 Planted by plane.

3 Includes 10 fish in year class V, but almost completed sixth years growth.

4 Only one fish had formed seventh annulus.

5 Only 7 fish in year class III, 4 almost ready to form third annulus, and 7 either natural reproduction or aged incorrectly.

RESULTS AND DISCUSSION

Taxonomy and Range

As in many fish species, the walleye has numerous common names (Niemuth, et al, 1959). A subspecies of the yellow walleye, the blue pikeperch (*Stizostedion vitreum glaucum*, Hubbs) is found in Lake Erie. Eschmeyer (1950) prefers the name walleye to yellow pikeperch, but to prevent confusion with the blue subspecies, the latter name is preferable. For sake of brevity and since it is a member of the family Percidae rather than Esoscidae, the name walleye is used throughout this paper. Only the sauger (*Stizostedion canadense*, Smith) and blue pikeperch should be confused with the walleye. Neither of these occur in Utah; only the yellow perch would be mistaken for the walleye here. Since even small yellow perch lack canine teeth, an experienced person can distinguish the two species readily in fish less than an inch long.

Native to the Great Lakes Region, the walleye has been widely introduced elsewhere. At present, its range extends to the northeast as far as New York, and west as far as Utah. Its range extends northwest to Great Slave Lake, Canada.

Extensive descriptions of the walleye may be found in numerous textbooks and need not be included here.

Habits and Habitat

Preferred Habitat. Walleyes thrive in large lakes that are moderately fertile, but they are present in small lakes that are utrophic, oligotrophic or darkly stained dystrophic (bog) types.

Lakes having wind swept, rocky shorelines with or without incoming streams provide the necessary spawning areas. Sand is rarely used for spawning grounds. Narrow strips of gravel, rubble, or boulders only a few feet wide may be used for spawning if aerated clean water is present (Eschmeyer, 1950). Sometimes areas meeting all the apparent requirements for spawning are completely ignored: Eschmeyer found suitable areas weren't used in Lake Gogebic, Michigan. He believed that walleyes preferred to spawn along windward shores.

Turbidity may inhibit reproduction (Eschemeyer, 1950), but Van Oosten (1945) found it favorable for growth in Lake Erie where an average of 37 ppm of SiO_2 equivalents is found. Van Oosten believed fish thrived in water from 200 to 400 ppm turbidity. Deason (1933) also found walleyes more abundant in the western and most turbid end of Lake Erie.

Water depth probably isn't critical if large areas of eight to ten feet are found where temperatures seldom exceed 80°F.

A large littoral zone is undesirable and walleyes never seem to become abundant in weedy waters. Some littoral zone is preferred, however, since walleyes often are co-habitants of yellow perch and predator-prey relationships are close. Weedy areas provide the necessary spawning grounds for perch which in turn serves as food for the walleye. Sandy areas are generally unproductive and therefore undesirable.

Winter habitat is somewhat restrictive and winterkill is fairly common in shallow waters where dissolved oxygen drops below two ppm. Moyle (1959) believed when oxygen fell below five ppm in Lake Traverse, Minnesota, the walleye population suffered. He also found a positive correlation of walleye survival after winters where dissolved oxygen was five ppm or higher. Turbidity, average depth, and alkalinity in Utah Lake is very similar to that in Lake Traverse, but the former is only 20 square miles in area.

Availability seems to determine food taken by walleyes, although they are usually piscivorous after the first six months of life. Lakes having a substantial population of yellow perch, minnows, shad or various other small fish are ideal.

Growth is best in water where temperatures are between 65° - 75°F. Water between 40° - 50°F. is required for spawning.

Shelter doesn't appear to be a necessary requirement although deep and/or turbid water is desirable, at least during daylight hours. The nocturnal nature of the walleye may be because of its light sensitive eyes.

A widely dispersed food supply fits the wandering nature of the species. The home range is apparently unrestricted. Movement has been described as patternless, either in schools or singly.

Very little is known of specific water chemistry requirements of the walleye, but evidence indicates it is a tolerant species. Carlander (1947) found pulp mill wastes didn't harm walleyes in Minnesota, and Moyle (1959) reports no ill effects in water where sulphates were 483 ppm.

Generally, a CO_2 concentration below 20 ppm, a pH between six and nine, and total alkalinity between 45 and 350 ppm is acceptable to fish (Lagler, 1956). Tolerance varies greatly according to length of exposure, synergic action, and water temperatures.

Parsons (personal correspondence, 1959) reported walleye spawning in streams "strongly polluted with acid mine wastes" in Tennessee.

The walleye is an exceptional competitor. Eschmeyer reported large-mouth bass, bluegills, sunfish, minnows and other species disappeared in Lake Gogebic after stocking walleyes in 1913. In competition with mukellunge and northern pike in Lake Gogebic, the walleye made up almost 90 percent of the sport catch in 1941.

Tolerance to greatly fluctuating water levels has been found in stream spawning walleyes in Norris Reservoir, Tennessee. Miller (personal correspondence, 1959) reported an annual fluctuation of 75 to 100 feet vertically in Norris Reservoir, yet the most stable walleye population in Tennessee is found there.

Spawning success is erratic, particularly in more fertile waters (Niemuth, op. cit.).

In Utah Lake. Habitat requirements are generally suitable for the walleye in Utah Lake (op.cit.). Turbidity possibly limits reproduction, but it probably enhances movement, feeding, and consequent growth.

Lake size, food abundance, gravel areas, water temperature, and littoral zone is favorable. Water depth is slightly below that desired, particularly during crucial winter months of snow and ice cover.

Water chemistry is so varied throughout the lake that it is difficult to draw conclusions about its suitability. Chlorides are particularly high, being 312 ppm along West Mountain where walleyes were known to spawn during 1959. Potassium and fluorides are fairly high in the lake and may have harmful effects on reproduction.

A resident population of walleyes is believed to exist in the lower Provo River. Many were netted at night in deep water in the river, but rarely were they taken during the daytime. In the lake they were netted during all hours. Movement in the river seemed to be greatest from just before dark until midnight.

Feeding was believed to be more intense around Bird Island following periods of wave action. No particular pattern was observed in either feeding or migration, although walleyes disappeared from Bird Island (where the greatest numbers were consistently found throughout the study) during September, 1959. At this time, many were seined around the Spanish Fork River where they had been feeding primarily on Utah chubs and young carp.

Schooling by sexes was observed during October, 1958, when only one of 32 fish taken off Lincoln Beach was a female.

An annual migration of walleyes seemed to occur during the winter toward the warmer north end of the lake, as shown by net catches. Another movement into deeper water was observed during August, 1959. The spawning migration apparently begins in February for large numbers were seined near shore during that month in 1959. They became fairly scarce around Bird Island after March, 1959, but reappeared in June. During April and May, they were very difficult to locate in the lake. Young fish tended to show up along shore in commercial seine hauls during November, 1958-59, but this may be because they became large enough to be held in the $1\frac{1}{4}$ inch seine mesh (bar measure) at this time. Perhaps they were already inshore. Movement of walleyes increased significantly from late August to November, 1959.

As a result of turbidity, the habits of the walleye were very difficult to observe except by indirect methods.

Reproduction

Nature of the Sexes. Only spawning fish could be sexed externally with confidence and an occasional "green" female was mistaken for a male during the study.

When both sexes were together on the spawning grounds, they could usually be sexed confidently: larger size, distended abdomen, and a less wary reaction was noted in females.

The ratio of females to males on the spawning grounds in the Provo River was about 1:1.5, although the ratio checked through the weir was about 2:1. Since many males had preceded females to the spawning areas prior to weir installation, the latter ratio is understandable.

Fecundity. Gonads were weighed from time to time during the period between October, 1958, until spawning in March, 1959. It was found that nearly "ripe" ovaries made up about 10 percent of the total body weight and testes just prior to spawning averaged five percent (op.cit.). Maximum percentages found were 13.4 in one female, 7.6 in a small male. Eschmeyer (1950) found ovaries averaging 27.8 percent of body weight in walleyes in Saginaw Bay, Michigan (collected April 28), but this appears to be exceptional. Testes weight in Utah Lake walleyes agree with weights found by Eschmeyer in Michigan walleyes.

Average number of eggs produced per pound of body weight was 21,550. Larger females produced more per pound of body weight than smaller ones, and total number of eggs produced by individual fish varied greatly. A high of 185,400 eggs was estimated in a 3525 gram female while only 53,900 was estimated in one weighing 1145 grams. A low average of 13,400 eggs per pound of body weight was reported in Norris Reservoir, Tennessee, and a high average of 45,000 found in Lake Erie (C. Smith, 1941). It is generally agreed that fast growing females produce fewer eggs.

Female walleyes from Utah Lake rank below the average egg production for walleyes in the United States, both in total number produced and number per pound of body weight. Excellent weight gain was found in Utah Lake walleyes causing the estimate of egg number per pound of body weight to be low when compared to slower growing populations. Since rate of growth is believed to be inversely proportional to egg production (op.cit) a below average output was expected in the local population.

Heredity probably plays an important part in egg production; the wide range in numbers of eggs produced by the species over the United States (op. cit.) seems hard to explain on the basis of habitat differences alone.

Residual eggs were found in ovaries until late August during 1958-59. The percentage of eggs not extruded while spawning was generally low although some partially spent females were picked up returning downstream in the Provo River. Exact percentages of residual eggs were not determined in Utah Lake spawners, but Eschmeyer reported an average of 0.4 percent in fish taken from Lake Gogebic, Michigan.

Spawning Behavior in the Provo River. Males preceded females to the spawning grounds and returned to the lake later than females, although the last two fish observed in the river were females - both taken by fishermen.

It appeared there were two separate "runs" of male fish: those already present when the weir was installed and a later run during late March occurring simultaneously (but in fewer numbers) with the bulk of the female migration. The earlier run of males was believed to have returned downstream prior to the bulk of the migration.

Factors influencing the start of the spawning migration up the river were probably water temperatures and rising water levels. Average daily fluctuations of water temperature at the time of weir installation was about 12°F., or a range from 34° to 46°F. Most of the migration, especailly of females, occurred from March 25th to April 2nd when average daily temperature fluctuations were about 10°F., from about 39° to 49°F. Virtually all walleyes migrated at night, beginning shortly after dark and reaching a climax before midnight. Water temperatures during the peak of the daily migrations ranged from 40° to 43°F. which is about the same as that observed elsewhere (Rawson, et al, 1956).

Spring runoff caused a gradual rise in water level averaging about one-half inch per day from March 9th to 23rd. A slight freshet occurred on the 23rd causing the water to become turbid. The peak of the spawning run occurred shortly after and during the nights of March 25th, 26th and 27th. Water levels tended to fluctuate daily, being at a maximum during the afternoon. An abrupt rise of about eight inches occurred April 6th putting the weir out of operation. The temporary loss of the weir was considered of little importance since the migration had virtually ended by April 3rd. No walleyes were trapped after April 6th and very little spawning was observed after that time.

Very little activity was noted among the spawners during daylight hours. They could usually be observed in the deeper pools lying motionless, with an occasional fish migrating upstream. A number of fish were invariably observed immediately below the weir during the early morning. One large female was observed for 45 minutes on March 17th trying to penetrate the weir. Many times she stuck her head into the "V" opening, only to retreat again and never did fully enter the weir.

The spawning act was observed only at night between the hours of 7 p.m. and midnight in water 45° - 46°F. Fish were observed spawning only on three occasions: March 20th, 23rd, and 25th. Twice the act was observed just below the weir over a gravel bottom in fast water (1.5 ft.sec.) about three feet deep. Each act observed below the weir began with a sudden rush by a female to the water surface followed immediately by one or two males. After the initial thrust, the female would roll back and forth, her head pointed upward, then drift downstream, presumably emitting eggs for two or three seconds, then disappear to the stream bottom. Actions of males were more erratic, but all actions appeared to be an attempt to fertilize the extruded eggs. It is possible these observed spawning acts were atypical and brought on by the obstruction. The weir probably influenced spawning sites chosen by the fish which in turn might have affected the spawning act. Evidence supporting this theory was given by observing the act above the weir under more natural conditions: twice a male was observed in the spawning act with a female and both times it was less vigorous than that observed below the weir. In the latter situation, the female began the act by quickening of fin movements, writhing, and slight forward movements over shallow gravel, followed quickly by the male which kept closely apposed to the female. Actual emission of eggs was never observed because of water turbulence, lack of light, etc. These limited observations are probably inadequate to conclusively define a spawning pattern in the Provo River.

A variety of water depths were utilized. Fish were observed spawning in water from six inches to three feet deep. Eggs were found at the same depths. Many walleyes were observed in silted pools at night, but eggs were never found there. Only gravel and rubble bottoms were used, but both fast and slow waters were chosen.

Only a fraction of apparently good spawning area was used. Although spawners were observed up to the diversion dam just above state highway 114, approximately 90 percent of the spawning took place in the one-fourth mile immediately above the weir. Absence of deep pools in the upper reaches may inhibit walleye spawning there, since they seem to prefer staying in pools during daylight hours. Possibly the small number of spawners during the 1959 run accounts for much spawning area being unused. The only other species observed spawning during the walleye run were rainbow trout and rosyside suckers. The latter species had just begun their spawning when the walleyes had finished.

No territorial behavior was noted in fish on the spawning grounds. This was expected, however, since other species were virtually absent at the time and walleyes are not nest builders. No apparent pattern was established on the spawning grounds. It appeared that males migrated downstream in groups, whereas females went singly.

Nightly counts of fish on their spawning grounds led to the conclusion that the walleyes remained in deeper water and were quite inactive at water temperatures below 45°F.

Recapture at the weir of tagged, spent females indicated they spawned within one to four days after having been released upstream from the weir. Some of these recaptured females were "Green" when tagged, suggesting they ripened and spawned soon after reaching the spawning sites. Dark "river variety" fish were taken occasionally in the weir, but it wasn't determined how long walleyes must be in the river to become dark. Some individuals turned darker while spawning while others turned rather pale - particularly spent, weakened fish.

Most walleyes, especially males, became more wary of artificial light as the season progressed. Various colored filters failed to produce satisfactory results, but it was found if the beam wasn't focused directly upon an individual, observations could usually be made without frightening them. Generally, the more favorable spawning conditions were, the easier it was to observe the fish. Females were easily dipnetted below the weir with aid of a 9-volt spotlight.

Table 4. Dates, sizes, water temperatures, numbers, and condition of spawning walleyes (arranged by two day intervals) in the Provo River in 1959

	Average Total Length		Water Temp.	Number		Conditions[1] Males		Females			No. Marked	
Dates	M	F	Max-Min (°F)	M	F	R	G	R	G	S	Fin Clip	Tag
Mar 13-14	451	507	48-30	8	5	8		2	1	2	4	9
15-16	410	496	57-30	5	3	5		2	1			8
17-18	443	582	50-37	2	1	2				1		2
20-21	465	461	47-37	1	3	1		1	1	1		3
23-24	417	541	49-40	3	13	3		7	6	1		17
25-26	439	479	49-39	34	66	34		31	33	2	54	25
27-28	450	489	45-40	25	51	23	2	22	26	3	33	35
29-30	456	479	45-39	18	41	17	1	14	26	1	36	23
Apr. 1-2	444	476	53-40	11	18	10	1	7	11		11	18
3-5	458	480	53-41	8	21	8		7	14		19	10
TOTALS	4430	4990		115	222	111	4	93	119	11	157	150
AVERAGES[2]	445	486	49.6-37.3									

[1] R = Ripe, G= Green, S = Spent

[2] Average Lengths weighted

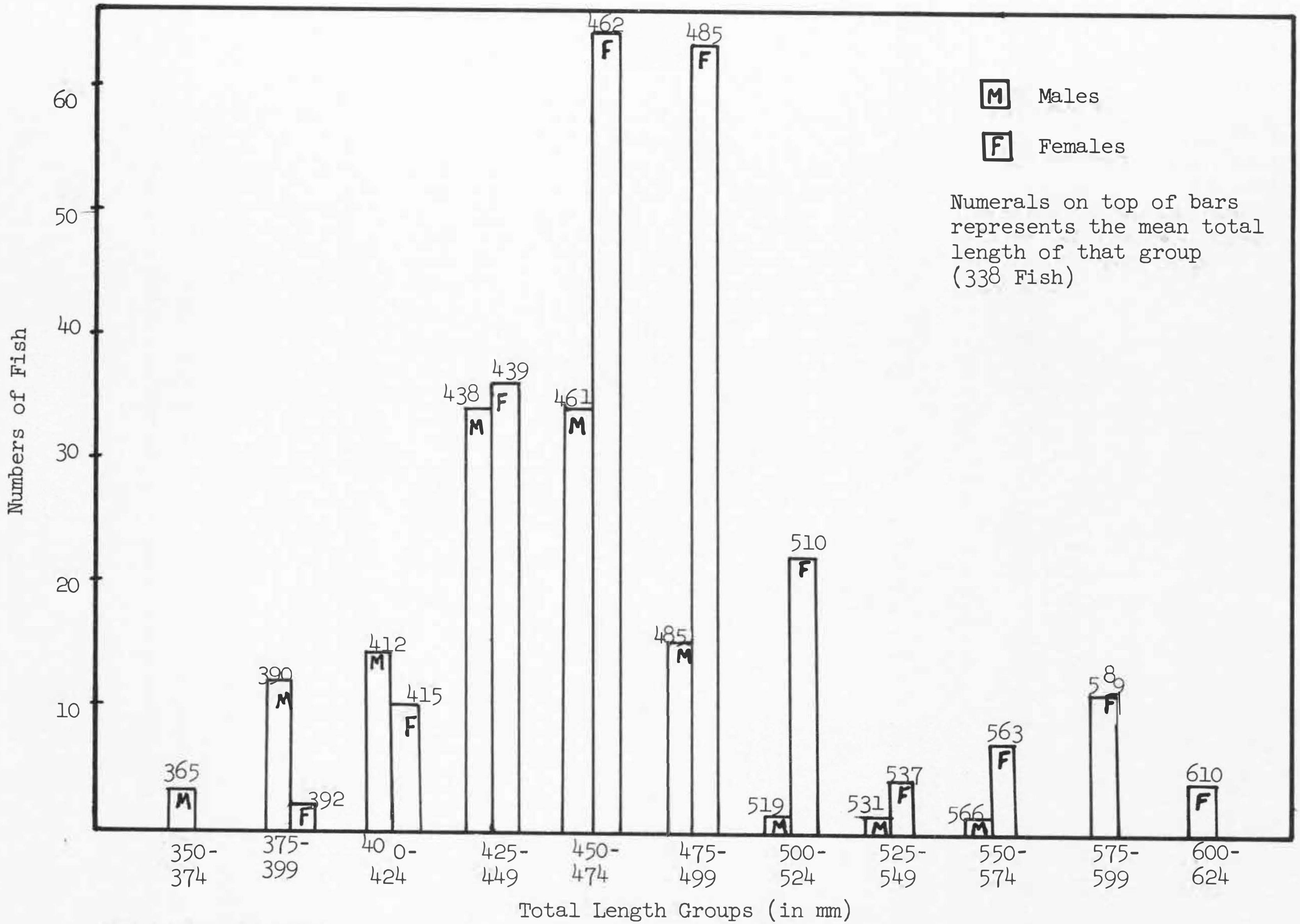

Figure 8. Sex Ratio, sizes and numbers of spawning walleyes in the Provo River, 1959.

Trapped fish were easily startled by quick movements which made tagging operations difficult. Some fish hit the grates so hard they stunned themselves. This reaction wasn't observed in trout, sucker, or carp also captured in the weir.

Only a few females were spent when tagged. Most of these probably spawned after entering the trap since eggs were often found on screen-wire placed in the weir.

It required about 25 seconds for one technician to tag, sex, and measure each fish and return it to the water. This was accomplished without an anesthetic. Fish weren't released immediately upstream, but were held to recuperate from the shock of tagging and handling. Heavy females were quite delicate and were handled carefully. Tagging loss was negligible: only 12 dead fish were retrieved from the wings of the trap and some of these were probably natural mortality.

A total of 307 fish were marked and released upstream. Another 20 were fin clipped and released downstream shortly after the weir was installed. These latter fish were returning males mentioned earlier. Of the 327 marked fish, 150 were tagged and 177 fin clipped (upper lobe of caudal). Average total lengths of males was 445 and 486 mm in females (see Table 4). Size range was 360-566 mm in males and 387-618 mm in females (see Figure 8). Sizes in both sexes were rather uniform throughout the season with some irregularity noted in earlier spawning females. A conservative estimate of 1900 fish made up the spawning run in the Provo River during 1959.

Eschmeyer (1950) reports walleye spawning from late March to May over the United States and Canada. Thus, it appears that 1959 and 1960 were early spawning years for Utah Lake walleyes.

Spawning Behavior in Utah Lake. Although most of the attention was focused on the Provo River, there were indications that spawning occurred in the lake. Ripe fish of both sexes were taken in gill nets one mile north of permanent sampling station # 6 (see Figure 5) during early April when water temperatures were between 46° and 54°F. Ripe males were easily netted around Bird Island, but no females were taken there during the spawning season.

Trap and fyke nets set along the west shore and in all major tributaries failed to take walleyes during March and April. Fyke nets were placed in the tributaries in such a manner that both upstream and downstream migrants would be taken. Spent fish of both sexes were captured off West Mountain beach April 17th.

Periodic checks around the lake shoreline at night didn't reveal spawning walleyes. Turbid waters, coupled with generally bad weather and wave action prevented much observation. Water temperatures ranged from 49° to 53°F. during the nightly checks from March 23rd to April 4th. Observations were also made at night at Bird Island, with negative results.

Walleyes became hard to find along West Mountain after April 4th in areas where good net catches were made previously.

Evaluation of Spawning Areas. Gravel and rubble areas with pools and riffles appeared to be ideal for walleye spawning in the Provo River. Water temperatures and dissolved oxygen were favorable in both the river and lake. The upper reaches of the Provo River possibly lacked suitable resting pools, but spawning was observed in this riffle area (maximum depth two feet).

Spawning area wasn't lacking in Utah Lake either. Large areas of gravel, rubble, solid rock and boulders were found, particularly along

West Mountain, Rocky Knolls, and Bird Island (see Figure 3). Bird Island provides a gravel reef extending about 500 yards to the southeast and is completely surrounded by rubble and rock substrate.

Eschmeyer noted that walleyes seemed to prefer rocky, wave swept shorelines along a 10 mile portion of Lake Gogebic. The prevailing winds on Utah Lake are northwesterly (op.cit.) and may account for the apparent spawning along West Mountain while Rocky Knolls and the west shore were ignored. However, this doesn't explain why Lincoln Beach or Bird Island apparently weren't utilized for spawning.

Water chemistry of the lake doesn't appear to be a limiting factor, although salinity is pretty high - particularly off West Mountain. Recently (1959) it was found that walleye eggs would hatch successfully at an oxygen level as low as 0.9 ppm at 10°C., while fry hatches at 2.0 ppm appeared to be as healthy and vigorous as those hatched at much higher levels (Anon., 1955).

Shoreline areas are very turbid during the walleye spawning season (op.cit.). Other workers believed turbidity limits reproduction[1], but Van Oosten found walleyes increasing in numbers in Lake Erie despite turbidity. The scum-like turbidity found in Utah Lake is probably much different than that found in Lake Erie, however. Scidmore (op.cit.) noted good growth, but erratic walleye spawning success in southern Minnesota lakes similar (except in size) to Utah Lake. Walleye eggs were never found in Utah Lake.

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[1] W. J. Scidmore, Minnesota State Conservation Department, personal correspondence.

Spawning Success. It appears that spawning success, thus far, has been negligible. This isn't meant to imply that spawning didn't occur or that eggs didn't hatch out, but rather that offspring six inches or longer didn't show up in the catch. This cannot be attributed to selectivity of gear since such a wide variety of sampling devices were employed over the entire lake.

In the Provo River where spawning occurred during 1959, it appeared that broadcasting of eggs by the females in fast water left much chance for error in bringing gametes together. Even under ideal conditions the walleye, being so prolific, loses a very high percentage of eggs to infertility, predators, or other causes (Eschmeyer, 1950).

Periodic sampling in the Provo with a hatchery screen used like a Surber Sampler failed to turn up many eggs in areas where spawning acts were known to have occurred, although a few eggs were always found. A quantitative estimate of eggs was virtually impossible, but numbers of eggs on the spawning grounds were far below those expected. An estimate of egg loss was made in a section of the Provo river where heavy spawning occurred before the water was diverted for irrigation on April 15th, 1959. The area covered about 6500 sq. ft. and an average of 2.3 eggs per sq. ft. was estimated, for a total loss of 15,000 eggs. Water taken out for irrigation caused the river level to drop 19 inches in six days. It appeared most of the eggs had hatched prior to diversion, but this may not be the case in subsequent years when walleyes spawn later than in 1959.

Eggs artificially incubated in fruit jars in the river became eyed in 18 days and hatched in 22 at a mean water temperature of 47°F. Only a fraction of the eggs hatched successfully, and many became fungused and silted badly. This was possibly a result of inexperience in fertilizing and handling the spawn, although methods outlined by Davis (1956) were followed.

The specific gravity of walleye eggs is slightly greater than water, causing them to go with the water current, and possibly accounting for the failure to find more eggs on the spawning grounds. Yet, this doesn't account for their sparsity in relatively quiet pools in the river where spawning occurred. Those eggs that were found were mostly hyaline, turgid and apparently viable.

Effects of predation on the spawn wasn't known.[1] Gulls, herons, and mergansers appeared soon after spawning began in the river, but this effect on spawning success was probably slight. Carp, bullhead, catfish and yellow perch are known to prey upon walleye eggs (Rose, 1947) yet no evidence was found of this in the Provo River. In an experiment, both yellow perch and carp were kept in an aquarium for two months without food prior to walleye spawning in the river. Fresh walleye eggs were placed into the aquarium with the fish and observed. Carp immediately began picking the eggs up, but spat them out. Yellow perch were never observed eating them and finally the eggs were removed after becoming fungused. Some predation by rosyside suckers may have occurred since they used the same spawning areas after the walleye finished.

Numerous attempts to seine walleye fry in the river were unsuccessful. Mesh size of the 11 foot seine was believed to be small enough (op.cit.) to take newly hatched walleyes, for numerous small dace, suckers, redsided shiners, and yellow perch were taken. It is possible that the bulk of the

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[1] One fisherman reported "larger numbers" of walleye eggs in the stomachs of two rainbow trout (hatchery fish) taken in the Provo River in March, 1960.

walleye hatch was missed since no attempt was made to seine them until after April 5th, but it is unlikely that the sampling would have been completely negative had fry been present. Also, viable eggs were found as late as April 17th.

Eschmeyer believed walleye fry moved, or were carried by currents, into pelagic waters shortly after hatching and often became associated with yellow perch.[1] This might explain the failure to find many fry in the lake, but doesn't completely explain why they weren't found in the river.

Evidence of spawning success in the lake was found on June 15, 1959, when two walleye fry (34 and 36 mm-SL) were seined in a school of yellow perch off West Mountain where spawning was believed to have occurred. Although 11 hauls were made in the area with the 50 foot seine, no other walleyes were taken. The area was rocky with isolated stands of bulrush (where the two walleye fry were seined), and about seven miles from the Provo river and four miles from the nearest tributary.

Very little is known about the movement of young walleyes in the lake, since so very few were taken during the study (see "Habits and Habitat").

Food wasn't believed to be critical for newly hatched walleyes in the lake. Plankton, yellow perch fry, chironomid larva and freshwater shrimp are plentiful over much of the lake.

Failure of walleyes to spawn successfully in the lake thus far may be chance. They are erratic spawners (op.cit.) particularly in turbid, fertile waters. Perhaps it is too early to draw any conclusions, since

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[1] This has been confirmed by Dr. William T. Helm, Utah State University, and the recent (1960) New York studies on Oneida Lake walleyes.

only two years have passed (1958-59) when any appreciable spawning could have occurred (see next section on maturity). In view of the relatively low number believed to be present in the lake, negative results might be expected. Competition with yellow perch (Carlander, 1947) may also be a limiting factor.

Age at Maturity. Forty two male walleyes in the Provo River during the 1958 spawning run were aged. Another 28 were aged from the 1959 run. No definite conclusions could be made from the 1958 run, since data wasn't taken during the entire spawning season. However, almost all of the 42 fish aged were three year old males (two annuli).

The 1959 run was mostly composed of three and four year old fish. Since the 1959 annulus wasn't yet formed (March), these fish fell in the II and III year class for age and growth purposes. Only two males were seven years old (six annuli), while five females were this old. Of the remaining 21 fish aged from the 1959 run, 14 were females; six females were two year olds and eight were six year olds. The remaining seven males were only two years old. The 28 fish sampled in 1959 weren't random samples: all size ranges were taken on purpose.[1]

Comparing these findings to the size ranges shown in Figure 8, and Table 4, it appears that about 56 percent of all spawners (338 total) were either three or four years old. Supposedly these represented the 1954 and 1955 stocked fish. About 10 percent (mostly males) were probably two year olds.

Since the 1958 run appeared to be mostly three year old males, it is

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[1] Length frequencies of walleyes dipnetted during the 1960 spawning run was very similar to those of the 1959 run.

possible this reflected a scarcity of mature females that year. But, since males migrate to the spawning grounds earlier than females, time of sample taking could have biased results. These fish were taken over a three week period during March and April, 1958. A few large females were reportedly taken by electrical gear on the spawning grounds in the Provo river during 1958.

It is possible that walleyes have a "homing instinct" as found in salmon (Stoudt, 1939). About 250,000 fry were planted in the mouth of the Provo River in 1954, and many of the fish in the 1958-59 runs were from this year class. Much more study would be required to warrant conclusions, however. Smith (1951) also observed the "homing" phenomenon in tagged walleyes, but his evidence was inconclusive.

Generally, it appeared that most males were matured by age four and most females by age five in Utah Lake (year classes III and IV). This doesn't discount the fact that many matured at age three in both sexes. Some two year olds were mature.

The walleye normally doesn't spawn every year (Eschmeyer, 1950) but Rawson (1956) found evidence of consecutive spawning in some individuals. Two large walleyes (one male, one female) tagged in 1959, were taken by fishermen in the Provo river in 1960. Both fish had spawned in 1959 and 1960. Rawson also observed discrete spawning populations in rivers six miles apart, although the two populations mingled freely during most of the year.

A wide range of maturity ages from three years (Tennessee) to eight years (Canada) has been reported in walleyes. Where the maturity is early, the life span is usually shorter. Late maturity in walleyes is usually positively correlated to cold waters and vice-versa.

Since very few seven year old fish (six annuli) were taken during the 1959 spawning run in the Provo River, it is possible that 1952 stocked fish were disappearing in the lake.

Food Habits

General Observations. Four species of forage fish comprised 63.5 percent of all identified food found in 159 stomachs. These were (in order of occurrence) smallfin redsided shiners, *Gila balteata* (Richardson); yellow perch, *Perca flavescens* (Mitchill); Utah chub, *Gila atraria* (Girard); and European carp, *Cyprinus carpio* Linneaus, as classified by Eddy, (1957). Only other food found was unidentified fish, one sucker (*Catostomus fecundus*), and two white bass, *Roccus chrysops* (Rafinesque).

Size range (in total lengths) of predators with food in their stomachs was 139 mm to 642 mm. The bulk of the walleyes were between 400 and 500 mm, while 13 measured 250 mm or less. Only four, all females, were over 600 mm total length.

Redsided shiners made up 39.7 percent, Utah chub 19.6 percent, yellow perch 23.4 percent, and carp 17.4 percent of the total number of identified forage fish.

Only two walleyes under 139 mm were examined. The largest, 43 mm (TL) had two unidentifed fish in its stomach, while the other, 36 mm (TL) contained insects which appeared to be mayfly nymphs. Both fish were seined in a school of small yellow perch along West Mountain beach, June 15, 1959.

Although redsided shiners made up the bulk of the diet in all three categories, they were more seasonal than the other three principal species. The upward trend of feeding on shiners and simultaneous downward trend of feeding on the other three species (Figure 9) probably represents availability as the season progressed.

It is believed the percent of empty stomachs found (Table 6) is biased since a few walleyes taken in gill nets had apparently regurgitated food. Small fish found in walleyes mouths in these instances were partially digested.

Specific Feeding Trends. Although a valid statistical sample was not taken, definite trends were noted. For example, carp were usually found in fish taken close to shore. They were more conspicuous in walleyes taken in the Goshen Bay area. Around Bird Island, redsided shiners, yellow perch, and Utah chubs made up almost 100 percent of the walleye diet. Redsided shiners comprised a major portion of the food of walleyes taken in the Skipper Bay area, while both yellow perch and redsided shiners made up the diet in the Provo river. A small population of bluegill is found in the Provo river, but none were found in walleye stomachs. Walleyes taken in pelagic areas of the lake appeared to feed about equally on three species: Utah chubs, yellow perch and redsided shiners. Gill net catches revealed the greatest number of yellow perch was along the northwest section of the lake, particularly during winter. Seldom was a walleye found in this area, however, except during periods of ice cover in the winter (op. cit.).

Smaller fish (under 300 mm-TL) seemed to prefer redsided shiners. Middle-sized fish (300-500 mm-TL) showed no significant preference other than seasonal, which probably reflects availability rather than preference. Fish over 500 mm (TL) seemed to prefer the other three forage species to the redsided shiner.

Periodic running of nets revealed that walleyes fed at all hours, day and night. This is contrary to findings of others (Niemuth, 1959), but Eschmeyer (1950) believes roily waters encourages them to feed during daylight hours. Feeding after windy weather has been observed by a number of workers (Eschmeyer, 1950). Fish netted during daylight hours usually contained more food than those taken at night. However, this may be a result of the longer intervals between net checks at night, which allowed for more digestion in the latter situation.

As has been observed in other studies, walleyes in Utah Lake curtailed feeding activities during hot weather, particularly August, when deeper water temperatures went above 75°F. At this time, they would usually be found in the deeper water. The most active feeding month appeared to be October, when water temperatures ranged from 55° to 65°F.

Absence of crustaceans, insects, and molluscs from the walleye diet probably reflects the sparseness of these organisms in the lake, although midge larvae (Chironomidae), scuds (Gammarus sp.) and backswimmers (Notonectidae) are locally abundant (op. cit.).

Others have concluded that yellow perch are a preferred food of the walleye (Eschmeyer, 1950). This also seems to be true in Utah Lake. During 17 months netting of fish in the lake, only about 17 percent as many yellow perch were taken as either carp or Utah chubs. Yet the yellow perch outranked both species in the walleye diet (Table 5). Many carp and Utah chubs weren't available as food because of their larger size, but evidence pointed to a large population of both species in the lake. A downward trend in numbers of yellow perch in the lake was noted from 1958 through 1959.

Availability probably plays an important part in the diet of Utah Lake walleyes. Nevertheless, redsided shiners and yellow perch appeared to be preferred by fish over 200 mm (TL).

Thirty-two (17.4 percent) of the identified fish were either eaten

Table 5. Food of walleyes from Utah Lake, Utah, taken July 16, 1958 to July 8, 1959.[1] (Based on percent of occurrence, number and volume)

Category Animal	Occurrence	Number	Volume
Fish	100.0	100.0	100.0
Undetermined	35.1	31.9	11.6
Determined	64.9	68.1	88.4
Game Fish	0.9	0.7	2.0
Roccus chrysops	0.9	0.7	2.0
Forage Fish	64.0	67.4	86.4
Gila balteata	19.6	27.0	23.1
Perca flavescens	16.7	15.6	10.3
Gila atraria	14.8	12.8	27.5
Cyprinus carpio	12.4	11.7	25.2
Catostomus fecundus	0.5	0.3	0.4

[1] A total of 194 stomachs were examined, but only 159 contained food.

Table 6. Stomachs collected per month from Utah Lake walleyes showing percent containing food[1], total volume of food, and total lengths (mean and range) of predator and prey

Date of Collection	Number Stomachs	Percent w/food	Total Vol. (cc)	Total Length (mm)			
				Predator		Prey[2]	
				Mean	Range	Mean	Range
July 1958	32	84.4	102.3	411.3	300-469	74.7	35-115
August	15	60.0	49.6	402.1	175-464	77.0	50-120
September	18	94.4	71.7	421.6	221-526	80.4	60-100
October	53	98.1	192.9	412.8	227-507	80.2	40-115
November	10	70.0	104.8	361.9	178-534	84.5	50-115
December	24	70.9	83.3	435.9	139-615	79.8	35-105
January 1959	5	80.0	24.9	495.0	435-630	77.2	50-90
February	19	68.5	80.4	422.9	224-607	75.1	55-100
March	6	66.7	4.1	304.8	207-483	76.7	60-85
April	1	100.0	50.4	642.0	642	111.3	75-135
May	2	100.0	60.0	438.0	397-479	100.0	70-165
June	8	75.0	10.5	415.5	278-467	54.0	27-100
July	1	0.0	0.0	-	-	-	-
TOTALS	194		834.9		139-630		27-165
AVERAGES[3]		81.9		391.5		77.1	

[1] Thirty-five of 194 stomachs were empty

[2] Estimated lenghts intact

[3] Weighted

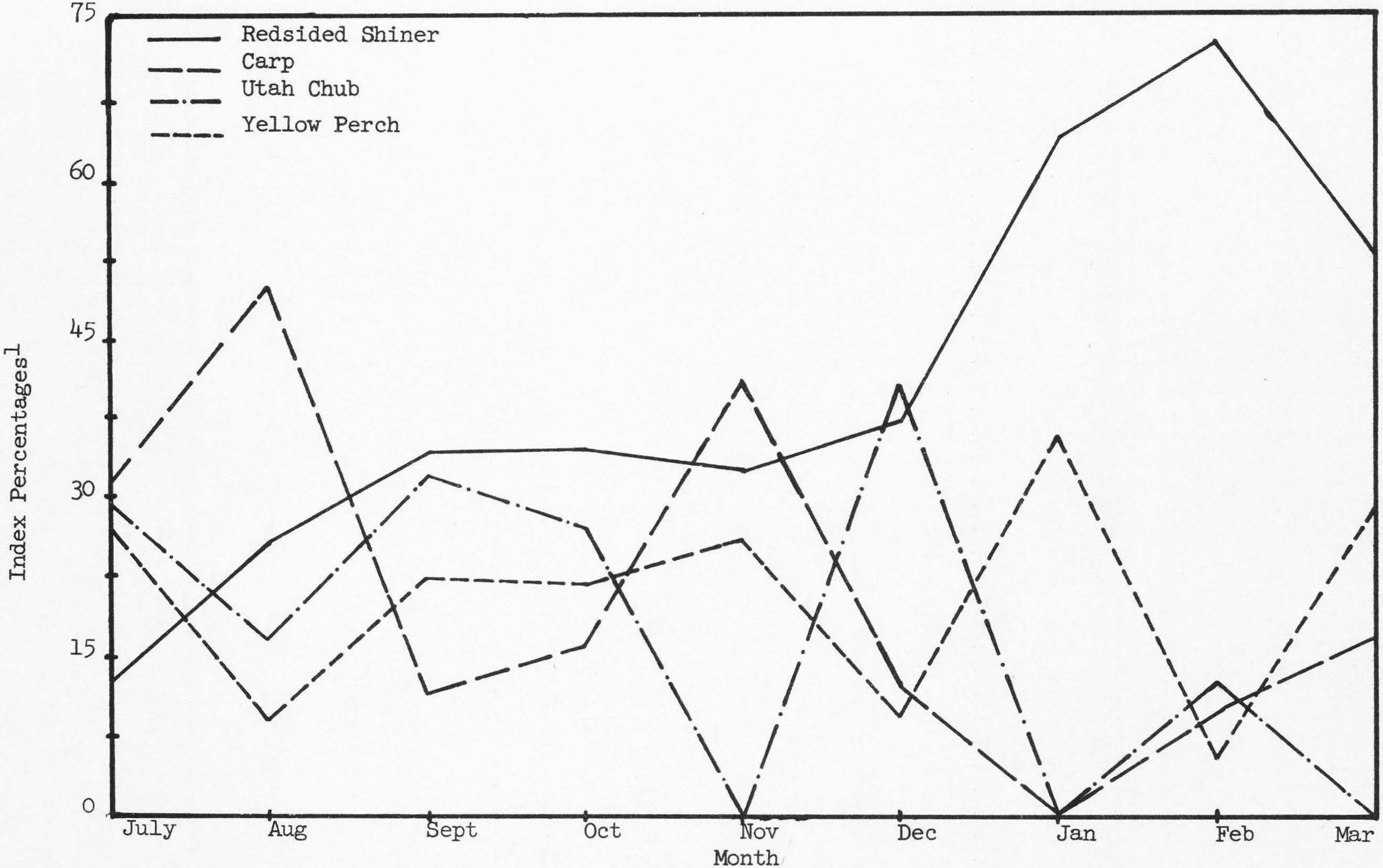

Figure 9. Occurrence, volume and number of four forage fish species found in the diet of 159 Utah Lake walleyes (1958-59).

[1] Mean of occurrence, volume and number percentages.

tail first or turned inside the stomach after being swallowed.

Age and Growth

Body-Scale Relationship. Two growth curves representing the body-scale relationships were plotted from empirical data (Figures 10 and 23). One curve was found by plotting scale radii from 329 walleyes arranged by 15 mm length groups. This was essentially a straight line relationship and was used in all age and growth calculations presented here.

A fourth degree curve was found for 39 fish where key scales were taken, but it was believed the 329 fish best represented growth of the population.

It was found that walleyes less than 30 mm (SL) lacked scales while those over 34 mm (SL) had them. Thus, the intercept on the Y-axis at approximately 15 mm may be slightly misleading. A base of 35 mm rather than zero was used in nomograph construction for growth calculations. Other workers have been equally divided in their findings of body-scale relationships in walleye populations. Cleary (1949) found a straight line relationships in 215 fish taken from Clear Lake, Iowa, while Carlander (1943) reported a curve described by a third degree polynomial in walleyes from Lake of the Woods, Minnesota.

Age Composition and Strength of Year Classes. The dominant year class during 1958 was three-year olds which made up almost 29 percent of walleyes taken during the study. Eighty-one percent of all three-year olds were males, but about half of these were males taken during the spawning run in the Provo river during March and April, 1958.[1]

[1] Actually these fish were in their third year of life (op.cit.) with only two annuli on their scales.

Presumably these three-year olds represented the 1956 plant when 900,000 fry were stocked. The first natural reproduction probably didn't occur to any extent until 1957 and very little then (see "Reproduction"). Thus, it is logical to assume that only fish from year classes 0, I and II came from both stocked fish and natural reproduction. Lack of evidence of much spawning success (op.cit.) leads to the conclusion that almost all of the walleyes taken during the study were stocked fish.

The 1956 plant was 43 percent of the entire number stocked in the lake and were dominant in the 1959 catch, but was much less pronounced than during 1958.

Generally, year class abundance followed in direct proportion to the numbers stocked during the four years (Table 3), but it appeared that fish stocked in 1952 and 1955 were more successful than those planted in 1954. This may be explained on the basis of location of plants: during 1954 all walleye plants were made in tributaries to the lake while other plants were in the lake proper. Whether chances are better for survival of walleye fry in the lake than in the tributaries is debatable, however. Selectivity of sampling gear isn't believed to be a major factor, since 1954 stocked fish would normally be expected to show up in experimental gill nets more often than most other year classes during 1958-59. Predation by largemouth bass and yellow perch may have taken a heavy toll of the 1954 fry plant in the Provo River.

Males dominated the catch, contributing almost 63 percent of all fish one year or older. This is biased, however, since only males were sampled during the 1958 spawning run in the Provo River. The catch in the lake was about 54 percent males and gear selectivity could account for this. Females usually outlive males (Carlander, 1943), but no conclusions were drawn of the young Utah Lake population. Fewer 1952 year class fish were taken during 1959 than 1958, but 1959 was a very poor water year and may have caused abnormal mortality.

In the order of abundance, the 1956 year class ranked first (31.8 percent), then 1955 (17.4 percent), 1952 (15.7 percent), 1954 (15.7 percent), 1957 (11.0 percent), and 1958 (8.0 percent). This was based on 329 individuals aged confidently. Another 64 fish couldn't be aged with confidence and weren't included in age and growth studies.

Aging by Opercles Versus Scales. Both opercles were taken from 34 fish. They were cleaned by boiling in water and read objectively by holding them between the naked eye and a light source. Agreement between only 16 fish and their corresponding scales was found. Sixteen of the remaining 18 differed by one year in each case. It appeared that the first annulus was absent or very faint on many opercles.

Validity of the annulus as a true year mark on walleye scales has been established by several workers. Most persons agree that walleye scales are unusually difficult to read in some populations (personal correspondence with Dr. K. D. Carlander, et al, 1959). Others have found that fast growing walleye populations are typically easier to age than are slow growing ones by the scale method. In this study, about 60 percent could be aged with confidence by the author, but only about 20 percent was discarded after final readings were made by all persons involved (op. cit.)

Although 103 fish were aged by other biologists, disagreement was found in only 19 individuals. The latter were mostly older fish and seldom was the difference greater than one year. Older males were invariably more difficult to age than older females.

Time of annulus formation appeared to be between late March and early

April, which is somewhat earlier than that found in other walleye populations.

Growth by Sexes. Utah Lake walleyes grow exceptionally fast, both in length and weight. This is typical of newly stocked species in favorable habitat. Only a few waters report faster growth in the United States and Canada (Table 10). The fastest growth yet recorded occurs in Tennessee waters where Stroud (1947) reported a growth of 16.4 inches (TL) in two years in Norris Reservoir. Extremely good growth has also been observed in Dale Hollow and Center Hill reservoirs in Tennessee (personal correspondence, J. S. Parsons, U. S. Fish and Wildlife Service, 1959).

Little difference in growth rate was observed between the sexes for the first two years in Utah Lake. After that, growth was markedly faster in females (Figure 12). The first and second years were the fastest growing years in both sexes, with a marked decrease during the third year of life. Annual increments were about the same in both sexes after the second year.

Scidmore (op.cit.) reported good growth in southern Minnesota lakes which are roughly comparable to Utah Lake both chemically and physically. Turbid waters of western Lake Erie are also apparently favorable for fast walleye growth (Van Oosten, 1945).

Lee's phenomenon of apparent growth rate change wasn't believed to be significant in the 329 walleyes studied (Table 7). Although some year classes showed varying growth, it wasn't consistent. The third year of life of year VI fish may represent a good growth year, but low sample numbers may account for inconsistencies in calculated growths shown in Table 7. Older males were hard to age (op.cit.), the tendency being to "under-age", which may account for the higher average growth increment found during year IV than year III among that sex. However, this increase may be explained on the basis of availability of food. The Utah chub was utilized by larger fish which suggests, perhaps, that fish younger than age III were usually unable to eat them. This explanation probably doesn't apply to the faster growing females.

Variability in growth was the rule rather than the exception. Many two year olds were larger than three year olds of the same sex. Inequality of growth might be expected if large numbers of both stocked and naturally spawned fish were present. No evidence indicates a niche of habitat superior to another, foodwise, in the lake with the exception of red-sided shiners which are locally abundant.

One male only 110 mm (SL) had 3 definite annuli. Fortunately, this was atypical.

A relatively long growing season, as compared to that of other waters at the same approximate latitude, is noted in Utah Lake. Although growth by month was not estimated, it appears growth followed the feeding pattern of the walleye population. Early spring and summer growth was fast, particularly in smaller fish, with a marked decrease during August and early September. Heavy feeding begins in September and continues through October with another growth increase lagging into November. Feeding was never curtailed entirely during the winter of 1958-59, but growth after December 1st was slight.

<u>Length-Weight Relationships</u>

Exceptional weight gain was found among all year classes. Table 9 gives average and calculated weights of sexes combined (before gonad weights were deducted). Condition factors are based on actual weights minus developing gonad weight. Cleary (1949) found an average "K" of 1.494 based on 143 fish from Clear Lake, Iowa. Other "K" averages (Cleary, 1949) include 1.446 in Trout Lake, Wisconsin, and 1.470 in Lake of the Woods, Minnesota. A "K" of 1.51 was found in Norris Reservoir, Tennessee, by Stroud (1949), but an average of 1.38 was noted by him in young-of-the-year walleyes. Thus, it appears the average "K" factor of 1.855, sexes combined, found in Utah Lake walleyes is unusual. Unpublished data may show comparable results from Tennessee (Parsons, op.cit.).

Average "K" factors were higher in males than females which might appear erroneous, but is plausible since females grow faster lengthwise than males. Also, this could be reversed were the factors computed on total weight with gonads intact. All possibility of error in calculating condition factors were checked: scales were calibrated, gonad weight and sample size considered. As in length, variability in weight was the rule, but much more noticeable in older fish. All "K" factors were calculated according to the established formula,

$$K = \frac{W\ 10^5}{L^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where W = weight in grams
and L = standard length in millimeters

Length-weight relationships were based on the general expression (Hile, 1941),

$$W = CL^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where both C and n are constants

The above formula was expressed mathematically by solving empirical data (op.cit.) by logarithms and the least squares method, yielding the formula,

$$\text{Log } W = -4.79031 + 3.02554 \log L$$

This describes a cubic parabola upon which Figure 11 is based.

The excellent weight gain is probably a result of many factors. New environment, low walleye population, turbidity of water, lack of competition, and ample forage fish populations probably all influenced growth.

Mesenteric fat made up 7.83 percent of the body weight in eight individuals (four of each sex) taken during January and February, 1959. Size nor sex seemed to influence the percentage, but none of the eight weighed less than 480 grams.

The conversion factor from standard to total length (1.1995) is somewhat higher than those reported by Carlander (1943) and Cleary (1949), who reported factors from 1.159 to 1.198. When converting from standard to fork length, the factor 1.1330 was used in this study. Again this is somewhat higher than in other studies, but less pronounced than in standard to total length conversions.

Ecology

General. Walleyes are competitors of largemouth bass, yellow perch and white bass in Utah Lake. All four species feed heavily on fish, but the small numbers of walleyes present probably have little effect on the population of either species of bass. Largemouth bass weren't found in any walleye stomachs and very few white bass were found.

Since a fairly large population of young-of-the-year largemouth bass were found in the lower Provo River and a resident population of walleyes were believed to be in the river at the same time, it is likely that a "buffer" species such as redsided shiners or yellow perch accounts for the lack of largemouth bass being found in walleyes taken from the Provo River. No doubt walleyes would feed on the small bass should their numbers become greater.

Lack of abundance of small white bass, in comparison to other species, may account for their failure to show up consistently in the diet of walleyes. Yet they didn't show up in proportion to their numbers believed to be present in the lake which is probably a result of their body shape, schooling habits, and fast growth. A walleye-white bass associes is desirable in a lake such as Utah Lake, where a small littoral zone of about three percent is present (Niemuth, 1959).

The decline of the largemouth is probably a result of factors other than walleye competition (op. cit.).

Mortality of larger walleyes in the lake is believed to be primarily from old age.

Low water conditions (and resultant high water temperatures) may have influenced the leathargic behavior noted in many walleyes seined and gill netted during the summer of 1959. Mortality as a result of angling, disease, or parasites was probably slight. Some natural mortality was observed in post spawners, but the loss was believed to be negligible.

Potential predators of young walleyes are present in the lake, but the apparent lack of reproductive success of the walleye population gave no basis for sound conclusions. No evidence indicated that predators inhibited walleye spawning success.

Although walleyes are known to harbor tapeworms, leeches and flukes (Niemuth, 1959), only a very few tapeworms and no leeches or flukes were found in the species in Utah Lake. A few tapeworms were found, but probably were transferred to walleyes by eating yellow perch. An

Table 7. Average calculated standard lengths in mm attained by 275[1] Utah Lake walleyes

Age Group	Sex	Number of Specimens	SL at Capture (Ave. in mm)	Ave. Calculated SL in mm at each annulus 1	2	3	4	5	6
I	M	17	237	168					
	F	17	248	167					
II	M	77	327	168	293				
	F	18	334	170	306				
III	M	33	357	161	277	322			
	F	19	374	171	292	342			
IV	M	11	386	172	302	314	360		
	F	22	403	171	283	339	383		
V	M	5	408	175	292	329	362	397	
	F	9	437	183	305	343	401	437	
VI	M	29	435	176	291	344	381	386	399
	F	18	478	175	310	365	407	441	465
Totals & Averages[2]									
	Males	172		169	290	330	374	389	399
	Females	103		172	298	347	395	440	465
Growth Increments									
	Males			169	121	40	44	15	10
	Females			172	126	49	48	45	25
Growth (Sexes Combined)[2]									
	in mm			171	294	339	385	422	432
	in inches			6.7	11.6	13.4	15.2	16.6	17.0

[1] Actually 329 fish were aged, but 54 were less than one year old (March, 1958 to October, 1959).

[2] Weighted

Table 8. Factors for the conversion of standard, fork, and total lengths of walleyes[1] from Utah Lake

Conversion	Factor
T.L. to S.L. (No change of Units)	0.8337
T.L. (inches) to S.L. (mm)	21.1760
S.L. to T.L. (No change of Units)	1.1995
S.L. (mm) to T.L. (inches)	0.0472
F.L. to S.L. (No change of Units)	0.8850
F.L. (inches) to S.L. (mm)	22.4779
S.L. to F.L. (no change of Units)	1.1330
S.L. (mm) to F.L. (inches)	0.0445
T.L. to F.L. (No change of Units)	0.9421
F.L. to T.L. (No change of Units)	1.0615

[1] S.L. = Standard Length; F.L. = Fork Length; T.L. = Total Length. The factors involve 351 fish ranging in standard length from 110 to 575 mm.

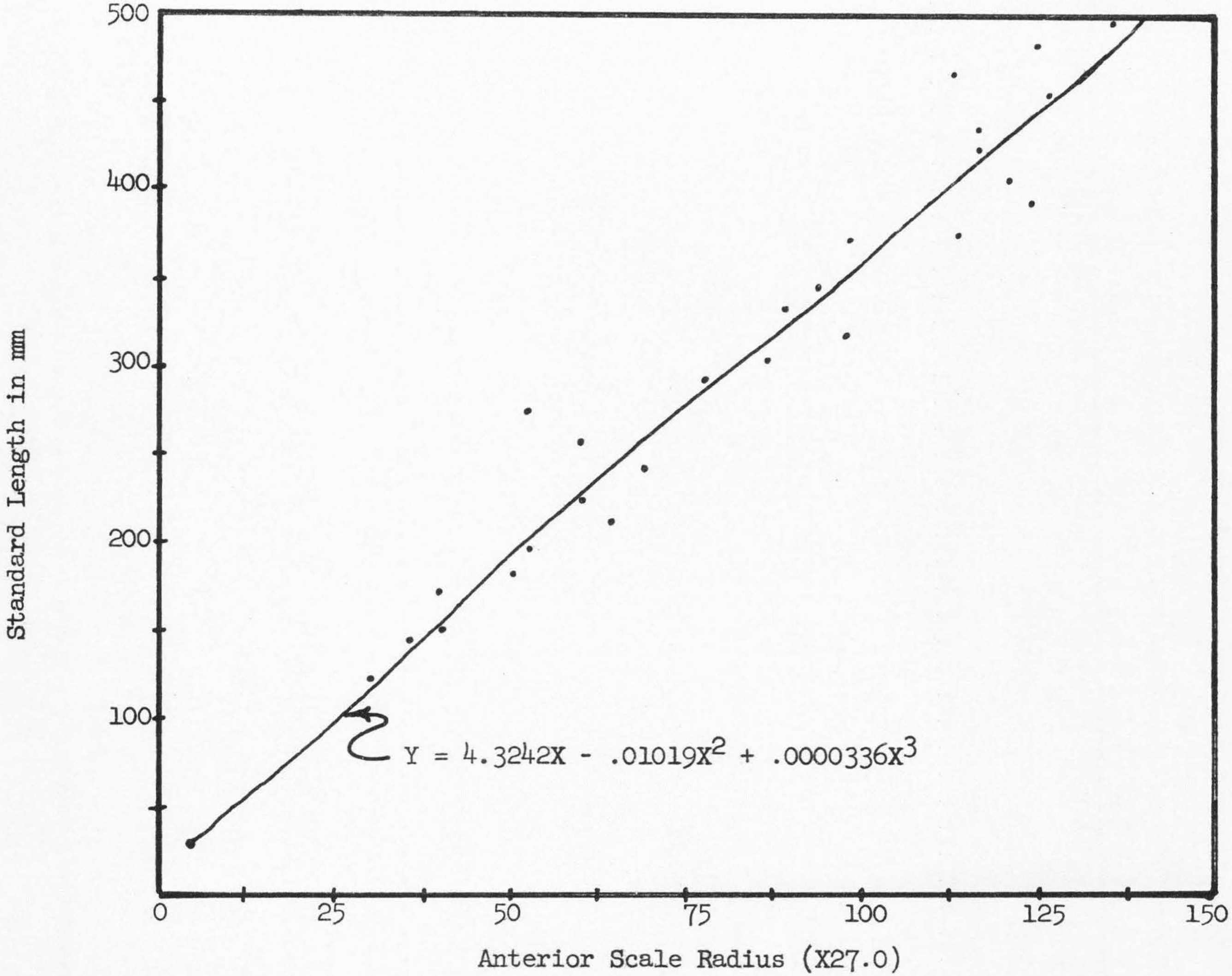

Figure 10. Body-scale relationship of 329 Utah Lake walleyes (arranged by 15 mm length groups).

Table 9. Length-Weight relationship and coefficient of condition (K) of 330 Utah Lake walleyes collected from March, 1958 to September 16, 1959.

Avg. Standard Length in mm	Number of Fish	Weight in Grams			Average K[1]	
		Average	Range	Calculated[2]	Male	Female
129	3	42	29-49	39	-	-
160	5	73	49-102	76	-	-
192	17	142	116-175	131	1.93	1.97
223	19	207	160-247	206	1.89	1.88
250	8	278	243-340	292	1.80	1.82
286	12	402	340-524	438	1.74	1.69
315	30	555	437-669	587	1.77	1.75
340	62	691	548-849	739	1.77	1.75
374	74	916	631-1237	986	1.75	1.76
398	46	1264	970-1727	1191	1.99	1.83
430	23	1612	1436-1985	1504	2.09	1.83
461	16	1881	1310-2110	1857	1.89	1.87
486	8	2373	2183-2722	2179	2.02	1.98
532	7	2840	2231-3419	2864	-	1.80
TOTAL	330		Grand Averages[3]		1.88	1.83

[1] Estimated after weight of developing gonads subtracted from total weight of each fish.

[2] Based on the empirical formula: $\text{Log } W = -4.79031 + 3.02554 \log L$.

[3] Weighted

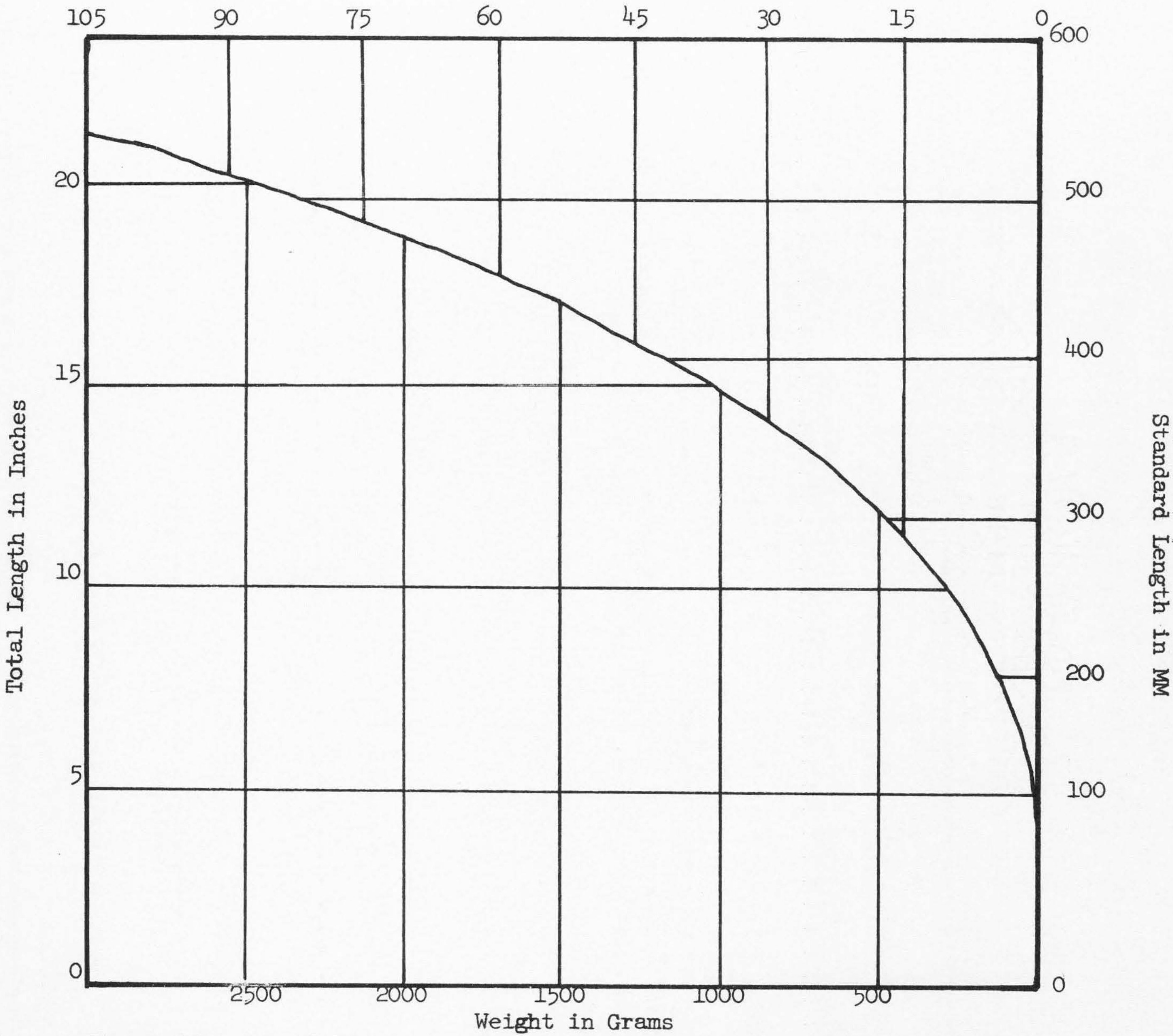

Figure 11. Length-Weight relationship of 330 walleyes from Utah Lake.

Table 10. Growth of walleyes in Utah Lake compared to other waters

Water and Reference	Number of Fish	Avg. Total Lengths (inches) at End of Year					
		1	2	3	4	5	6
Prairie Provinces, Canada (Bajkov, 1930)	-	7.4	10.5	13.2	15.0	16.3	17.7
Ontario Watershed, N.Y. (Greeley, 1949)	59	9.3	13.0	17.0	17.9	19.7	20.3
Norris Reservoir, Tenn. (Stroud, 1949)	1,146	10.3	16.4	18.7	19.9	20.8	21.0
Average[1], 16 Lakes and Watersheds (U.S. & Canada)	16,201+	6.1	10.0	13.0	15.1	16.9	18.4
Southern Green Bay, Wisc. (Niemuth, 1959)	-	8.7	13.2	16.2	19.1	20.7	-
Utah Lake, Utah	275	8.0	13.9	16.1	18.2	19.9	20.4

[1] Unweighted averages, from Eschmeyer (1950)

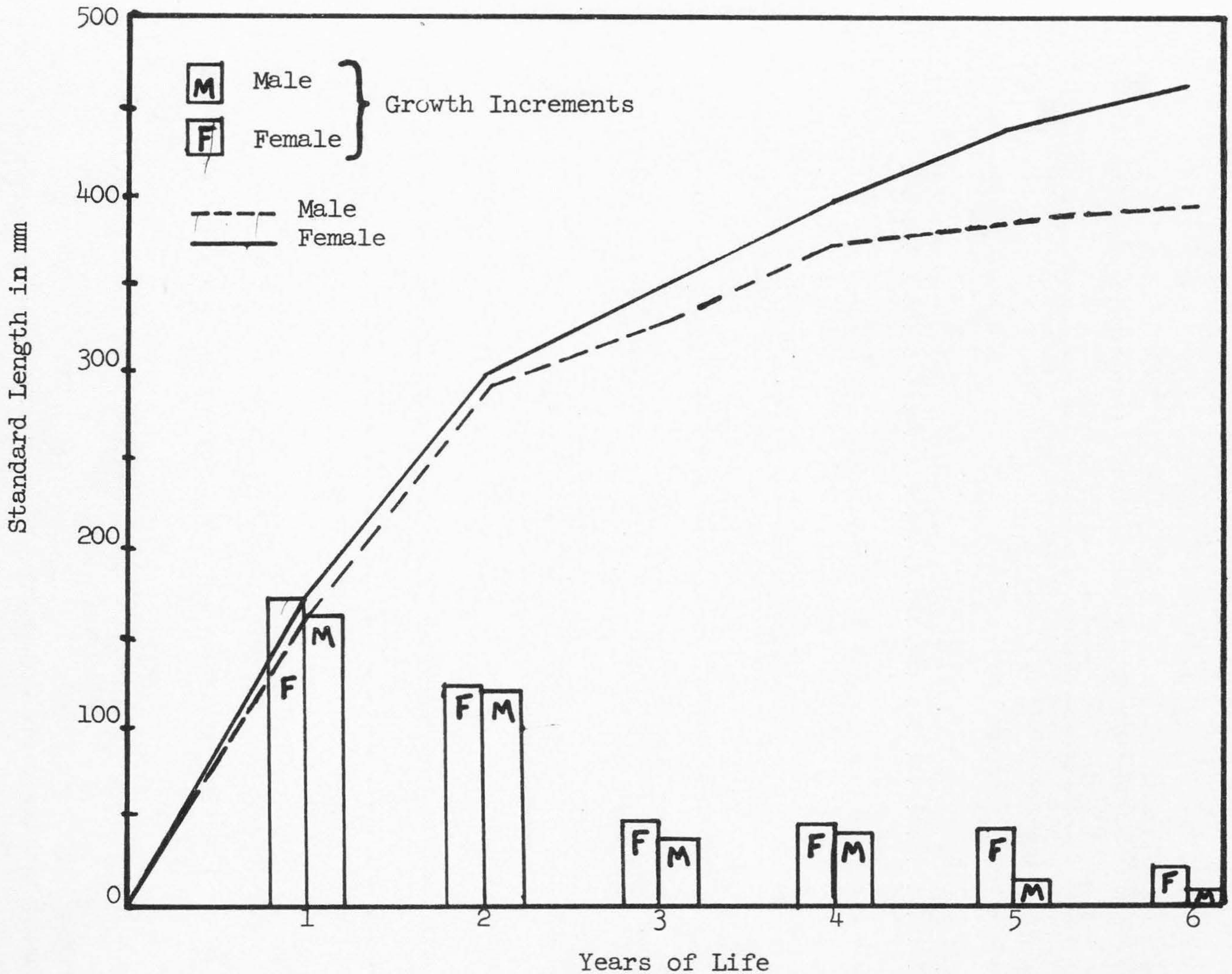

Figure 12. Growth curves of both sexes of walleyes in Utah Lake, 1958-59. (Data from Table 7).

insignificant number of roundworms were also found.

Since the walleye is far below the potential carrying capacity of the lake, its impact on the other species has probably been insignificant. Food supply is definitely not limiting for large numbers of forage fish are found over most of the lake while the only substantial walleye population is found around Bird Island.

Habitat changes in Utah Lake brought on by man have probably favored the walleye in some respects: less littoral zone than formerly and introduction of forage fish (carp and yellow perch). Other changes such as increased salinity, higher water temperatures, and pollution have probably had an adverse effect.

Relative Numbers. A population estimate of walleye numbers wasn't accomplished since anglers seldom took them in the creel, making a marking-recapture program virtually impossible. Although a number of spawning walleyes were marked and released during March, 1959, only two were returned (op.cit.).

The walleye was believed to rank seventh or eighth in total numbers in the lake, along with the black bullhead. There are only nine species consistently found in Utah Lake (Table 17). White bass and black bullheads are increasing while the walleye is apparently decreasing which means the latter species may soon rank last in total numbers present. Redsided shiners, not listed in the catch-per-net-hour in Table 17, are fairly abundant in the lake, but gear selectivity made their estimate impossible.

Stocking Success

Walleye stocking has been successful in lakes where the species isn't already established (Moyle, 1959), although Rose (1949) found that walleye fry stocking didn't prevent depletion of the species in Spirit Lake, Iowa. Best survival was found in fingerling walleyes planted in Spirit Lake.

A relatively low number (2,075,000) of walleyes were stocked in Utah Lake (80,000 acres) as compared to other waters. Five million fry were stocked in 291 acre Escanaba Lake, Wisconsin, from 1933-42 before walleyes started showing in the creel in 1948. Over 250 million walleyes were stocked in Clear Lake, Iowa (3,643 acres) during 10 years to supplement the natural population, yet the creel return of stocked fish was low (Cleary, 1948).

It has been found that stocked walleye fry survival is about 3-15 percent (Niemuth, 1959), although Moyle (1959) estimated only one of a hundred survived to "catchable size" under natural conditions. Of course survival varies considerably with the habitat, but the above estimates serve as a crude index for comparisons.

If a fry survival (to catchable size) of 10 percent was present in Utah Lake during this study, there would have been about 1729 walleyes per square mile. This appears to be an extremely high estimate and probably 10 percent of this, or 173 walleyes per square mile, would be a conservative estimate. This might be expected since many of the 1952-54 stocked fish had probably died from various causes by 1958-59.

Although a walleye population estimate wasn't made in Utah Lake (op.cit.) a rough estimate of something less than five percent of the original walleye stock probably remained in the lake by October, 1959.

Angling

Evidence showed conclusively that walleyes fed actively both day and night throughout the year in Utah Lake, yet anglers seldom took them in the creel. This is probably a result of many things: turbidity, abundant food supply, low population, unfamilarity to anglers, and the natural angling resistance of the species. Where the walleye has been stocked as a predator on nongame species, its angling resistance may be an asset.

Numerous baits known to be excellent for taking walleyes were tried around Bird Island without success. Live minnows, spinner-minnow combinations, various "plugs" and "spoons" were used adjacent to gill net sets where walleyes were taken with food in their stomachs. Trolling, casting and still fishing was tried at all hours particularly during September and October, 1959. A total of about 50 angling hours was unsuccessful, which may be insufficient for definite conclusions, but probably warrants the opinion that walleyes are extremely difficult to catch by hook-and-line in the lake. This opinion was supported by veteran anglers who had taken walleyes elsewhere in the United States.

Lures such as the Johnson Silver Spoon, yellow Doll Fly, Junebug spinner-minnow combination, Daredevils, and the Crippled Minnow are proven walleye catchers. The yellow Doll Fly has been particularly successful in taking spawning walleyes in Kentucky and Tennessee. Herters "Professional Guides Mannual" gives many tips on taking walleyes.

A few walleyes are taken during the spawning season by anglers in the Provo River, but many are apparently "snagged" and seldom do they take a lure by choice. This probably reflects inexperience of the local angler in coaxing the fish to bite.

MANAGEMENT RECOMMENDATIONS

Much effort should be made to encourage anglers to fish for walleyes in Utah Lake. Regulations should be as liberal as possible. The present bag limit of 10 fish (or 15 pounds and one fish) is desirable, but methods of angling and baits allowed should be compatible for harvesting the population as it now stands.

Further study is needed to definitely conclude that the population won't reproduce successfully. Therefore, some restrictions should be imposed on the take of walleyes in the Provo River during the spawning season until the species has been given a fair chance to establish itself. Post spawning fish should be harvested in the river rather than die from natural causes. Law enforcement regulations should be such that "snagging" is enforceable.

It is doubtful that the walleye would ever become a popular sport fish in Utah Lake. Value of the walleye as a predator for control of trash fish in the lake is doubtful. Thus, it appears that another species may be more desirable. Or, it might be better to concentrate on managing the other game species in the lake.

If it is desired to maintain the walleye population in Utah Lake, some consideration should be given to building dikes parallel to and about 50 yards from shore along West Mountain beach for spawning. Occasional breaks should be made in the dikes to allow entry of fish. Artificial spawning areas have been used for spawning by walleyes in Wisconsin, Minnesota, and Ohio. Further studies of possible turbidity inhibition should precede dike building, however.

Some investigation of river and lake spawning walleye "strains" should be made. If a river spawning strain could be secured, the potential spawning area now unused in the Provo River could be utilized. It is possible that Tennessee Valley reservoirs have developed stream spawning strains by necessity as a result of greatly fluctuating water levels.

Some agreement should be worked out with irrigation companies responsible for diverting the Provo River each year about April 15th, in order to protect walleye spawn.

A much greater number of walleyes should be stocked than has been in the past to give the species a fair chance to become established in the lake.

In order to take advantage of the potential of Utah Lake, a long range study of all facets of the biology of the lake is recommended, with various federal and state agencies cooperating.

SUMMARY AND CONCLUSIONS

Utah Lake lies at the foot of the western slopes of the Wasatch Range in central Utah at an elevation of 4489 feet. The interesting geologic epochs of the Bonneville region predetermined Utah Valley and its natural drainages of mountain streams and artesian wells.

Climate of the area is semi-arid, with an average annual rainfall of 15 inches at Provo. Air temperatures are moderate, characteristic of mid-temperate regions.

Fluctuations in the level of Utah Lake are about three feet annually, being influenced greatly by man.

After the pioneers came to the valley in 1849, drastic changes occurred in the physical, chemical, and biological characters of the lake. Numerous legal battles have raged over Utah Lake and its water since the first dam was built across the Jordan River in 1872. Finally, "Compromise Level" was established in 1885 at an elevation of 4486.95 feet, and changed to 4488.95 feet by the U.S.G.S. in 1922.

Pollution of all types flowed into Utah Lake as numerous towns, steel plants, sugar mills, animal processing plants, and various industrial plants sprang up along the eastern shores.

Commercial seining, pollution, irrigation practices, and exotic fish introductions caused the native trout to disappear in Utah Lake. Introduction of carp probably brought about the greatest single biological change during a shorter period than any other factor. Today the channel catfish is the most popular and most abundant game fish species in the lake. Twenty-one species of fish have been introduced into the lake or its tributaries, and at one time Utah Lake was one of the best largemouth bass fisheries in the West. The white bass was recently introduced and shows promise.

Utah Lake is unique in that it lies in the heart of an arid region, receiving water from clear mountain streams, yet it is always turbid. About 95 percent of the bottom type is calcareous clay. At the present, the lake covers about 120 sq. miles in area. Water temperatures (°F.) range from the low 30's to the mid 80's. Many warm and cold springs flow into the lake from beneath its surface, furnishing about 22 percent of the total water inflow.

Records show that the lake water has become increasingly saline over the years. This is generally attributed to irrigation practices, but differing opinions are found. Inconsistent results of chemical analyses of Utah Lake water probably reflects the heterogeneous nature of the water supplies: underground springs and mountain streams.

Biological changes over the years are good indications of what has happened in the lake. Disappearance of certain desirable species of flora and fauna, and the subsequent invasion by undesirable species has generally been the pattern for many years. Presence of tubifex worms found by Neuhold in 1955 points to pollution. Various crustaceans and Diptera larvae are locally abundant throughout the lake.

Most of the walleyes used in this study were taken in experimental gill nets. Seines, other net types, electrical gear, a trawl, a weir, and anglers produced the remainder of fish used. Various techniques were employed in collecting and analyzing the walleye and other fish populations in the lake. Data were analyzed by standard accepted methods as described by Sigler, et al.

The range of the walleye has been extended greatly in recent years. The Utah Fish and Game Department stocked 2,075,000 fry in Utah Lake over a four year period from 1952-56.

Walleyes are quite tolerant in their habitat requirements, but large lakes with little vegetation and water temperatures usually below 80°F. seem to be preferred. Spawning habitat may be somewhat exacting since gravel, rubble, or boulder areas are required along a wind swept shoreline. Turbidity may be a limiting factor in reproduction. Utah Lake seems to be favorable for growth.

Feeding was noted at all hours the year around in the lake, and seemed to be more intense after windy periods along gravel reefs off Bird Island. A migration toward the north end of the lake occurred in the winter. Turbidity made observations impossible, except by indirect methods, in the lake.

The walleye spawning run in the Provo River occurred during March and April in 1958-59-60. Most of the data on reproduction in this study were collected during 1959. Females were found to contain an average of 21,550 eggs per pound of body weight which is slightly below average for the species in the United States. It is a common belief that fast growing walleye females produce fewer eggs proportionately, than do slower growing fish.

Most of the spawning migration occurred during late March when daily water temperatures were between 39° and 49°F. Migration occurred principally at night, males preceding females to the area.

Spawning was observed between the hours of 7:00 p.m. and midnight in water 45°-46°F. No spawning was observed during daylight hours. Walleyes usually retreated to deep pools during the day. Much of the spawning occurred in water 2-3 feet deep over gravel just below the weir, although many water depths were utilized elsewhere. Only a fraction of the apparently good spawning area was used in the Provo River. About 1900 fish were estimated in the spawning run and were primarily three and four year olds.

Evidence was found of spawning in the lake along West Mountain beach. Two 1-inch walleye fry were seined in a school of small yellow perch on June 15th, 1959, in this area.

Spawning area isn't lacking in the lake, particularly along the western shore.

Very little spawning success was observed, either in the Provo River or the lake. Although eggs incubated artificially hatched in 22 days in the river, no walleye fry were seined in the river. Strength of year classes also shows very little natural reproduction growing to 6-8 inches. Only two explanations of lack of reproductive success seems plausible: turbidity and infertility. Turbidity doesn't account for the apparent lack of success in the river, while infertility from various causes seems to be common in the species elsewhere.

A "homing instinct" may explain why only a few walleyes spawn in the Provo River while others stay in the lake. About 250,000 walleye fry were stocked in the Provo in 1954, which tends to support the "homing" theory.

Spawning success thus far has been lacking, but further study is needed before definite conclusions can be made.

Four forage fish species made up almost 100 percent of the identified food found in Utah Lake walleyes collected continuously over a 13 month period. These four species were redsided shiners, Utah chubs, yellow perch and carp. Some specific feeding trends were observed. The redsided shiner became increasingly abundant in the diet as the season progressed from July to March, 1958-59. Feeding was curtailed in both hot and cold weather. Most active feeding occurred during October when water temperatures ranged from 55^{o}-65^{o}F. Availability probably played an important part in food habits of Utah Lake walleyes.

Three year old walleyes were dominant in the catch during the study but many of these were males taken during the spawning runs in the Provo River during 1958-59. Most of these fish were believed to have been stocked as fry in 1956.

Growth was found to be excellent in Utah Lake walleyes and condition factors were unusually high for the species. The female grew faster than the male after the second year of life. A length weight relationship expressed by the empirical formula,

$$\text{Log } W = 4.79031 + 3.02554 \log L$$

was found.

All evidence indicates the walleye is as exceptional competitor in Utah Lake and harbors very few parasites or diseases. The impact of the walleye on the largemouth bass or any other game species in the lake is slight, but this probably reflects the low walleye population believed to be present in the lake. Mortality has been chiefly a result of old age and the 1952 year class appeared to dwindle during 1959. Habitat changes brought on by man have probably favored the walleye in some respects, and the population is far below the carrying capacity of the lake now. About 173 walleyes per square mile are estimated to be in the lake and the majority tend to stay close to Bird Island in the summertime. A relatively low number of walleyes have been stocked in

Utah Lake as compared to other waters, yet the stocking success has been fair. Walleyes probably rank 7th in total numbers present in the lake.

Anglers seldom take a walleye in the lake, but a few are taken in the Provo River during the spawning season. Various proven walleye lures were used with little success in areas where walleyes were known to inhabit. Turbidity, abundant food supply, unfamilarity of the species to anglers, low population number, and inherent angling resistance of the species probably accounts for the failure of walleyes to show up in the creel.

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APPENDIX

Table 11. Chemical analyses of the water of Utah Lake (Tanner, 1936).

	A	B	C	D	E	F*	G*
Cl	4.04	35.48	26.23	24.74	26.87	285	307
SO_4	42.68	26.53	28.43	28.25	30.14	327	375
CO_3	19.88	2.66	10.23	12.35	8.48	10	0
Li	-	-	-	.06	-	-	-
Na	5.81	26.20	19.28	18.19	18.34	199	186
K	-	-	2.34	2.17	1.75	33	13
Ca	18.24	7.58	6.25	5.90	5.34	108	60
Sr	-	-	-	.15	-	-	-
Mg	6.08	1.55	7.18	6.18	6.85	47	61
SiO_2	3.27	-	-	2.00	2.23	35	22
Tot. Alk.	-	-	-	-	-	-	194
pH	-	-	-	-	-	-	8.4
Dissol.Sols	-	-	-	-	-	-	1223
Fe & Al Ox.	-	-	-	-	-	-	8
HCO_3	-	-	-	-	-	-	118
$CaCO_3$ Hard	-	-	-	-	-	-	400
Free CO_2	-	-	-	-	-	-	16
Salinity	306	892	1281	1165	1254	1113	-

A. By F. W. Clarke, Bull. U.S.G.S. # 9, 1884, p. 20.
B. By F. K. Cameron, 1899.
C. By B. E. Brown, 1903.
D. Mean of three analyses by A. Seidell, May, 1904.
E. By B. E. Brown, August, 1904.
F. By L. B. Decker and Chas. E. Maw, April, 1933.
G. By N. E. Lachlan, Salt Lake City chemist, 1940, Jordan pumphouse.

* Given as ppm; all others (except salinity) given as percentages.

Table 12. Total salts determined in ppm and reduced to normal carbonates[1]

Samples	$MgCO_3$	$CaCO_3$	$CaSO_4$	NaCL	KCL	KNO_3	$NaSO_4$	Total
Provo Bench	158	7	341	51	300	tr	51	925
Compromise Point	160	-	376	442	58	tr	78	1113
Crater Springs	195	42	558	506	82	-	70	1473

[1] From the paper by Decker and Maw (1933).

Table 13. Dissolved salts of Utah Lake and Jordan Narrows by Dr. J. W. Thayne, 1930[1]. (Totals reported in normal carbonates)

Sample	$Ca(HCO_3)2$	$Mg(HCO_3)2$	$MgSO_4$	$NaNO_3$	Na_2SO_4	NaCL	Total
Pumping Plant	291	39	262	3	48	410	953
Pumping Plant	163	108	223	0.5	-	477	959
Jordan Narrow	240	87	251	3	66	384	943
Jordan Narrow	163	135	240	0.5	153	433	997

[1] From the paper by Decker and Maw (1933).

Table 14. Fecundity of Utah Lake Walleyes[1]

Date of Capture	Body Wt. (Lbs)	Number of Eggs	Eggs/Lb. Body Wt.
January 16, 1959	7.80	185,404	23,770
February 4, 1959	2.82	67,420	23,908
February 4, 1959	2.84	58,995	20,773
February 18, 1959	2.54	53,933	21,233
February 19, 1959	5.63	102,253	18,162
AVERAGE			21,569

[1] Water displacement method (Sigler, 1950), allowing 5 percent of ovary for connective tissue, blood vessels, etc.

Table 15. Weights of gonads and mesenteric fat in Utah Lake walleyes

Month of Collection	Sex	Number of Fish	Percentage Body Weight: Testes	Ovaries	Mesenteric Fat
October 1958	M	1	7.1		
	F				
December 1958	M	4	4.2		
	F	5		9.0	
January 1959	M	2	3.9		
	F				
February 1959	M	5	4.9		7.6
	F	4		10.7	8.1
AVERAGES (WTD.)			4.7	9.7	

Table 16. Standard Length frequency distribution of 329 Utah Lake walleyes

Standard Length (15 mm Groups)	0	I	II	III	IV	V	VI	M	F	Unknown[1]
116-130	2								1	1
131-145	1									1
146-160	3							1		2
161-175	2							1		1
176-190	5	2						1	2	4
191-205	5	5						1	4	5
206-220	1	6						2		5
221-235	4	8						6	2	4
236-250	1	3						2		2
251-265		3	1					2	1	1
266-280		4						2	1	1
281-295		2	6					6	1	1
296-310			8					7		1
311-325			21	1				21		1
326-340		1	22	7				25	4	1
341-355			22	9				26	5	
356-370			21	17	4	3		24	19	2
371-385			7	10	7	1	4	17	12	
386-400			5	6	11	3	4	11	18	
401-415			1		7	2	7	11	6	
416-430				1	4	2	5	8	4	
431-445				2	3	2	4	5	5	1
446-460				1		1	6	7	1	
461-475					1	2	5	3	4	1
476-490					1		5	2	4	
491-505						2		1	1	
Over 505						1	6		7	
TOTALS	24	34	114	54	38	19	46	192	102	35

[1] Includes immature when sex was doubtful.

Table 17. Experimental gill netting results in Utah Lake from May, 1958 to October, 1959

Month	Net Hours	SPECIES AND NUMBER PER NET HOUR									Total Fish
		Carp	Chub	C.Catfish	Perch	Sucker	Walleye	Bullhead	WH.Bass	Other[1]	
June 1958	225	1.52	1.83	0.62	0.03	0.15	0.12	0.06	0.01	none	976
July	401	1.59	1.35	0.42	0.18	0.13	0.14	0.08	1 fish	0.01	1561
August	263	1.85	0.55	0.57	0.17	0.06	0.11	0.22	0.07	1 fish	947
Sept.	174	1.33	0.92	0.28	0.10	0.11	0.12	0.14	1 fish	1 fish	523
Oct.	137	0.54	0.93	0.15	0.23	0.16	0.47	0.20	0.04	0.02	374
Nov.	160	0.28	0.61	0.07	0.32	0.05	0.05	0.04	1 fish	none	228
Dec.	203	0.12	0.80	none	0.66	0.08	0.07	0.04	0.02	1 fish	364
Jan.,1959	260	0.12	0.35	1 fish	0.22	0.13	0.02	none	0.01	none	220
Feb.	266	0.16	0.22	0.07	0.04	0.05	0.06	0.02	0.01	none	164
Mar.	58	0.14	0.83	0.05	0.05	0.26	0.24	0.02	0.02	none	93
April	234	0.85	1.52	0.20	0.05	0.04	0.14	0.14	0.04	2 fish	698
May	220	0.69	0.85	0.15	0.09	0.27	0.02	0.02	1 fish	none	459
June	132	0.44	0.19	0.42	0.02	0.36	0.13	0.04	0.02	none	212
July	245	2.69	1.32	0.37	1 fish	0.08	0.08	0.04	0.01	none	1141
Aug.	156	2.04	1.29	0.23	0.21	0.03	0.01	0.18	0.02	none	626
Sept.	200	0.95	1.22	0.15	0.09	0.17	0.09	0.23	0.02	0.09	602
TOTALS	3334	15.31	14.78	3.60	2.46	2.13	1.87	1.47	0.29	0.12	9188
AVERAGES[2]		0.96	0.92	0.23	0.15	0.13	0.12	0.09	0.02	0.00	574

[1] Made up mostly of redsided shiners (Gila balteata), and a few largemouth bass (Micropterus salmoides), and trout (Salmo clarki and S. gairdneri).

[2] Weighted where total net hours during 16 months is considered.

Table 18. Vascular plants found in and around Utah Lake, October, 1959

Species and Formation Types[1]	Zone (s) [2]
MARSH	
Lemna minor, Lemna trisulca, Chara sp.	A
Salix amygdaloides,* Phragmites communis, Roripa	B
nasturtium, Eragrostis hynoides, Polygonum sp.,*	B
Ranunculus sp., Epilobium sp., Sonchus asper,	B
Bidens frondosa, Echinochloa crusgalli, Cyperus	B
strigosus, Leptochloa fasicularis, Veronica sp.,	B
Anserina sp.	B
Glycyrrhiza lepidota, Melilotus alba,* Leptilon	C
canadensis, Echinopsilon hyssopifolium, Hordeum	C
jubatum,* Polypogon monspeliensis, Asclepias	C
speciosa.	C
Rumex maritimus,* Salix exigua,* Populus deltoides,*	B,C
Panicum capillare,* Carex spp.,* Juncus balticus,*	B,C
Atriplex hastata, Xanthium italicum.	B,C
Scirpus validus,* Scirpus americanus,* Typha	A,B,C
angustifolia,* Typha latifolia.*	A,B,C
SALT MARSH	
Potomogeton filiformis.*	A
Chrysothamnus nauseosus.	C
Salicornia rubra,* Allenrolfia occidentalis,	B,C
Distichlis stricta.*	B,C
SHINGLE BEACH	
Aster oregonus.	B
Salsola pestifer, Iva axillaris, Helianthus annuus,*	C
Taraxacum officinale.	C
SANDY BEACH	
Medicago sativa.	C
Heliotropium spathulatum, Tamarix gallica.*	B,C
BENCH LAND	
Agropyron spicatum,* Bromus tectorum,* Grindelia	C
squarrosa, Erigeron annuus.	C
Artemesia tridentata,* Monolepsis nuttalliana.	B,C

*Cosmopolitan species.

[1] As classified by Cottam (1926).

[2] Zone A from present water's edge into lake; Zone B lies between normal low and high water; Zone C from high water mark landward until unaffected by moisture from lake and marsh areas.

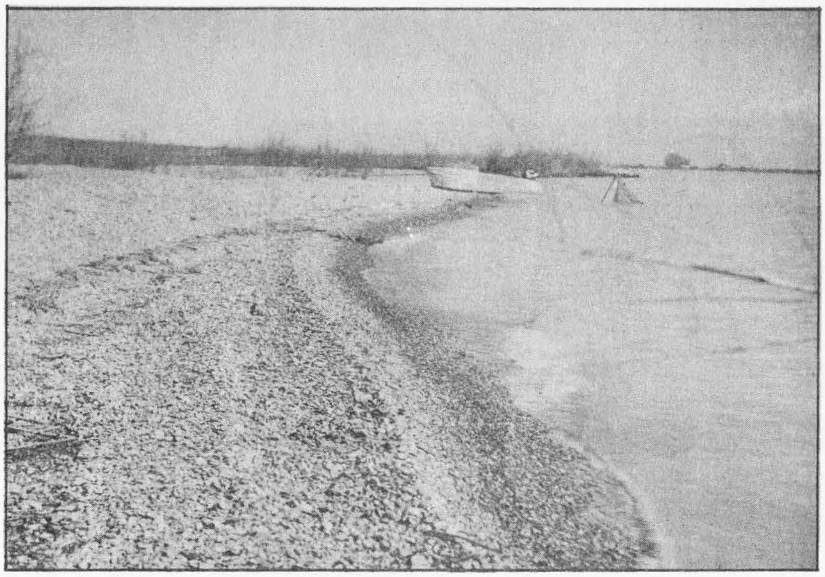

Figure 13. Shingle beach type along west shore of Utah Lake, April, 1959.

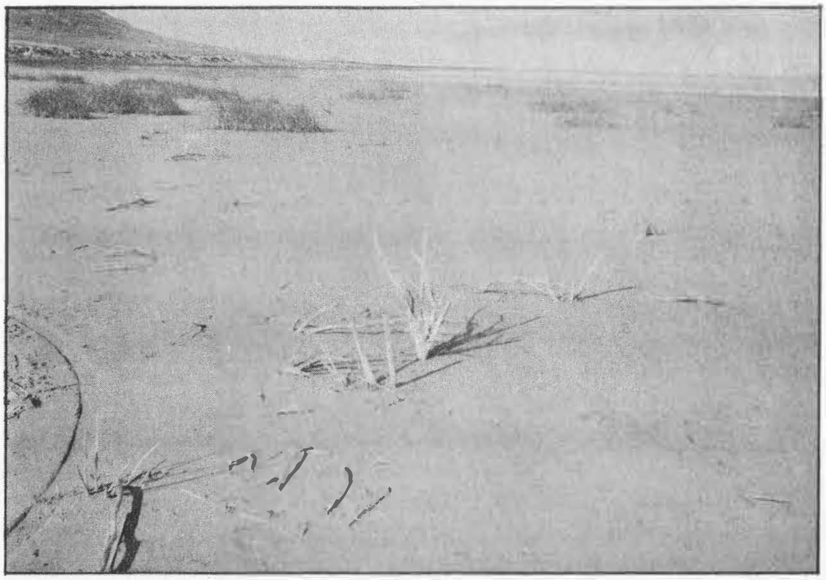

Figure 14. Sandy beach - Marshland types found along parts of entire lake shore (showing Scrrpus and Tamarix spp.).

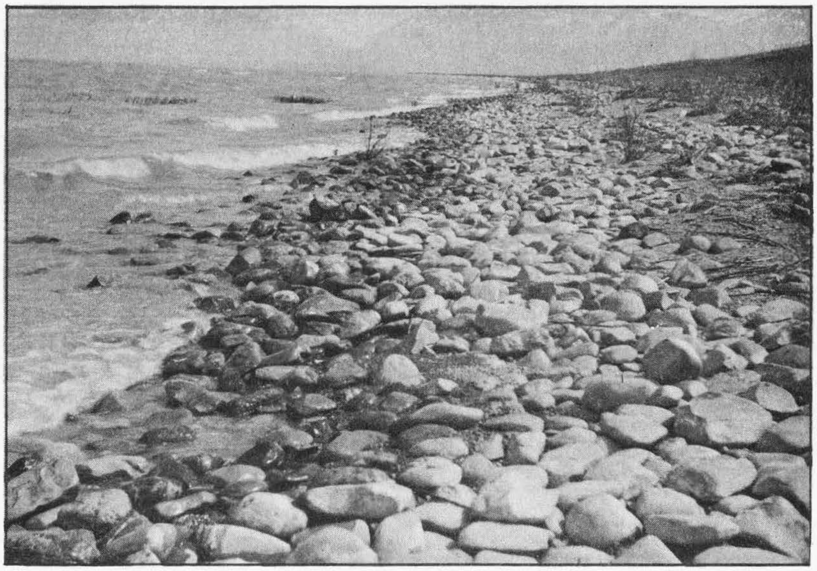

Figure 15. Rubble - boulder area, along West Mountain beach where walleye spawning occurred in 1959 (taken April 7, 1959).

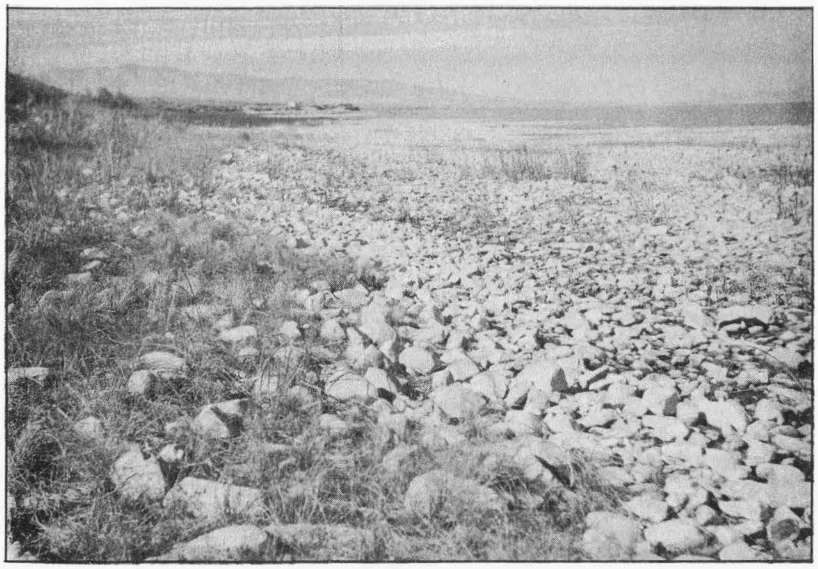

Figure 16. More rocky shoreline along West Mountain beach where ripe walleyes were taken in April, 1959.

Figure 17. Commercial seining in Utah Lake

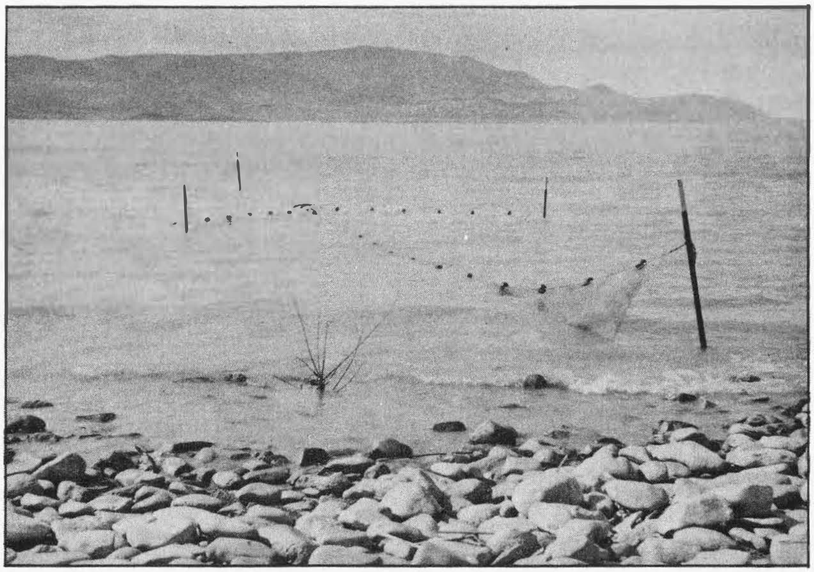

Figure 18. Trap net setting along West Mountain beach, Utah Lake.

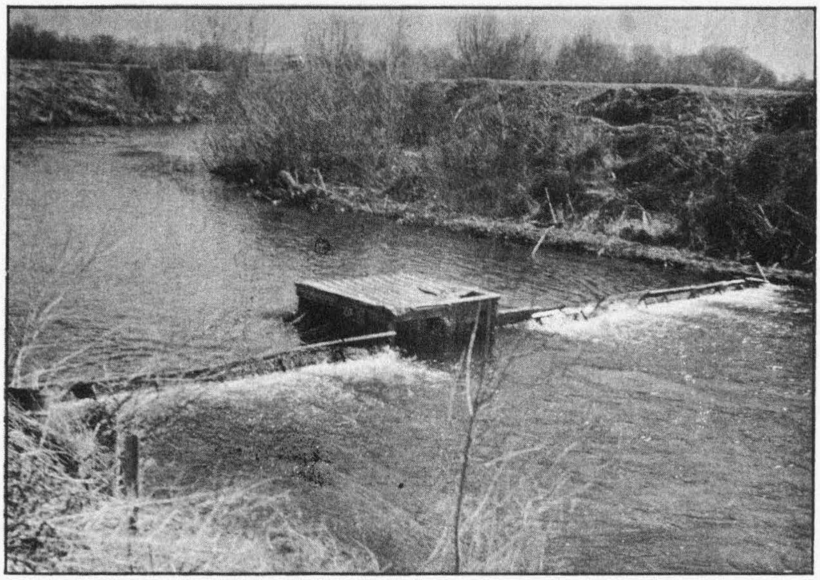

Figure 19. Weir placed in Provo River from March 9, 1959 to April 8, 1959.

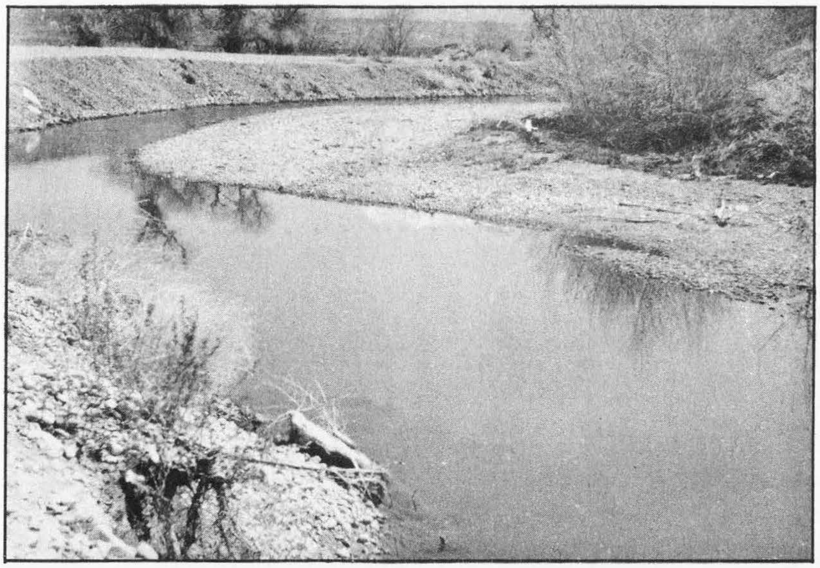

Figure 20. Typical spawning grounds in Provo River used by walleyes during 1958-59; taken April 20, 1959 after water was diverted for irrigation.

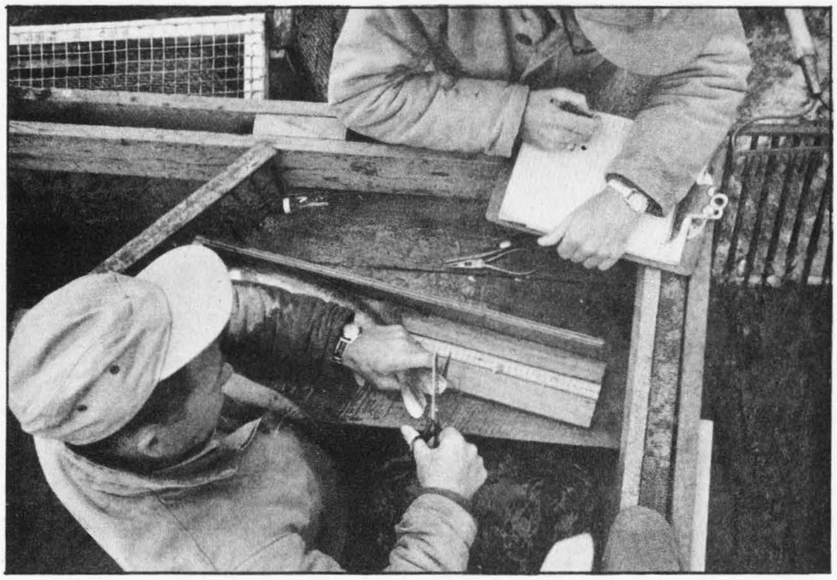

Figure 21. Fin clipping, measuring and sexing walleyes taken in the Provo River weir, March, 1959.

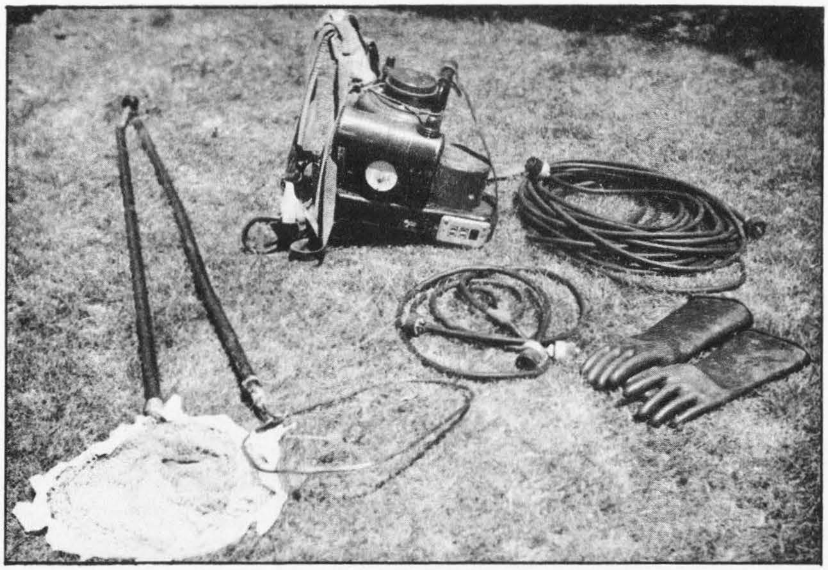

Figure 22. Lear Lite portable AC generator, 115 volts, 12.5 amperes.

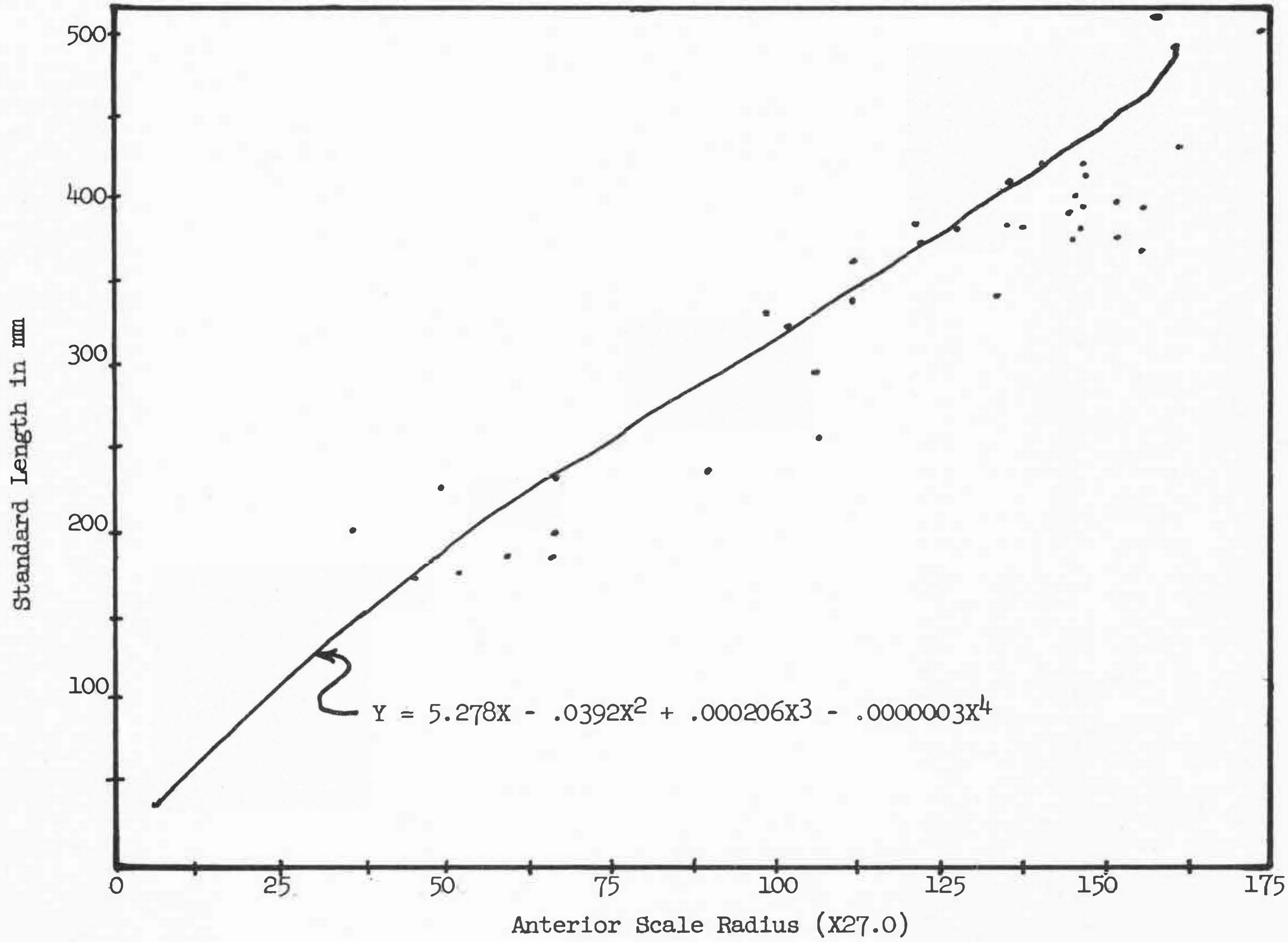

Figure 23. Body-scale relationship of 39 Utah Lake walleyes based on key scales.