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Studies on the Relationship of the Redside Shiner (Richardsonius balteatus) and the Longnose Sucker (Catostomus catostomus) to the Cutthroat Trout (Salmo clarki) Popluation in Yellowstone Lake

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STUDIES ON THE RELATIONSHIP OF THE REDSIDE SHINER -RICHARDSONIUS BALTEATUS AND THE LONGNOSE SUCKER -CATOSTOMUS CATOSTOMUS TO THE CUTTHROAT TROUT -SALMO CLARKI- POPULATION IN YELLOWSTONE LAKE

KENNETH E. BIESINGER

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by

Kenneth E. Biesinger

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Kenneth E. Biesinger

Figure 1. Bridge Bay West Lagoon of Yellowstone Lake in Yellowstone National Park, Wyoming

Figure 2. Arnica Lagoon of Yellowstone Lake in Yellowstone National Park, Wyoming

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INTRODUCTION

Biologists have been concerned about the presence of longnose suckers (Catostomus catostomus) and redside shiners (Richardsonius balteatus) and their effect on the cutthroat trout (Salmo clarki) population in Yellowstone Lake. Many investigators have found unfavorable interactions with the former two species and trout in other waters; this investigation was made to determine the distribution and certain interactions of these species with cutthroat trout in Yellowstone Lake. The effects of the presence of lake chub (Hybopsis plumbea) and longnose dace (Rhinichthys cataractae) are considered to a lesser extent.

Various sample areas were studied by observation, dip nets, minnow traps, fish traps on tributary streams, seines and gill nets to determine the distribution, relative abundance and interactions. The general ecology of Yellowstone Lake was studied in connection with habitat requirements of fish species present. For study purposes the lake was arbitrarily divided into the open lake, bays and lagoons.

A general life history study was made of longnose suckers and redside shiners with emphasis on age and growth, food and feeding habits, reproduction, and habitat requirements. Life histories are considered and correlated with cutthroat trout to elucidate preferences and requirements of each species, and to consider interactions of distribution, spawning and food.

The status of Yellowstone cutthroat trout is considered in relation to interactions with other species present. Management implications, suggestions for further study and findings of this investigation are discussed.

YELLOWSTONE LAKE AND STUDY AREAS

Description

Yellowstone lake lies at an elevation of 7,731 feet, has a surface area of 136.66 square miles, a maximum depth of 320 feet, and a mean depth of 139 feet (Benson, 1961). The annual water level fluctuates from 1.5 to 1.8 meters; it is lowest from January to March and highest in late June or July. The lake is frozen over from December or January to the last week in May or early June.

The mean temperatures in the Yellowstone lake area from 1953 to 1957 were 13° C. in the summer and $-[illegible].5^{\circ}$ C. in the winter. The lake area has prevailing winds from the south and southwest in the summer which usually begin about 1100 and abate in the evening about 1700; they were stronger in 1959 than in the two previous years (Benson, 1961).

The watershed has an estimated area of 1,010 square miles and is vegetated by lodgepole pine (Pinus contorta) forests and alpine meadows (Benson, 1961); there are approximately 14 major and 50 minor tributary streams draining this area (Welch, 1952). There are many active geysers and hot springs in the watershed and some in the lake itself.

The lake is characterized by having an irregular shoreline nearly 100 miles in length with many bays and lagoons. The irregular shape of the basin and the resulting currents are important in the distribution of aquatic plants and the distribution of fish. The bays and lagoons are extremely productive areas. Many lagoons were formed by wave action while others have been partially formed by highway construction. Many

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Many lagoons, now isolated and secluded by highways, were probably present before road construction. Arnica Lagoon (Figure 2) is an exception; it was undoubtedly created by construction work.

Many natural lagoons have narrow channels connecting them with the lake which may be closed by wave action for certain periods; they are usually re-opened during high water periods by tributary streams. Two lagoons have been permanently closed and contain various aquatic insects, crustaceans and amphibians, but no fish. Blotched tiger salamanders (Ambystoma tigrinum) and boreal toad (Bufo boreas) tadpoles are found in great numbers in these lagoons.

Approximately one-half of Yellowstone Lake is accessible by a highway which follows the lake along its western and northern shorelines. During the summer this area receives heavy fishing pressure, especially in certain areas. Cope (1953) as noted by Bulkley (1961) estimated that 95 percent of the fishing pressure on Yellowstone Lake is concentrated at the northern end.

Limnology

Yellowstone Lake is oligotrophic; it is poor in nutrients and has low temperatures (Benson, 1961). It usually becomes thermally stratified in late July or early August with a thermocline developing from 25 to 30 feet below the surface. During summer stagnation surface temperatures vary from 15.5 to 17.8° C. The fall overturn begins by late August or early September. In 1957 free carbon dioxide was found in all samples collected and oxygen was present at all depths.

Bottom types include boulders, rubble, gravel, obsidian sand, clay, silt and organic matter. There are large quantities of boulders on the

the east shore; rubble occurs in areas of heavy wave action along the eastern shoreline of the South and Southeast Arms and other exposed areas, and obsidian sand is found mostly along the northern shoreline. Silty loam constitutes 95 percent of the bottom type of the lake and generally has approximately 2 percent organic matter. Silty loam is the common bottom type in most bay and lagoon areas.

Flora

Submergent and emergent aquatic plants are sparse near Arnica Creek, Fishing Bridge, the Lake area and along the eastern shoreline. Aquatic vegetation is abundant at the tip of the Southeast Arm near the Molly Islands, at the mouth of the Upper Yellowstone River, at the tip of the South Arm, from Flat Mountain Arm to Wolf Point, at the eastern side of Frank Island, in the southwestern part of West Thumb and in most lagoon and bay areas.

The aquatic plants identified from Yellowstone Lake in 1959 include: *Potamogeton Richardsonii*, *P. praelongus*, *P. pusillus*, *P. Robinsii*, *P. gramineous* va. *graminifolius*, *Lemna trisulca*, *Ceratophyllum demersum*, *Najas flexilis*, *Myriophyllum exalbescens*, *Ranunculus aquaticus*, *Fontinalis sp.*, *Elodea canadensis*, *Nitella flexilus*, *Eleocharis sp.*, *Sagittaris cuneata*, *Carex sp.*, and *Sparganium sp.* Known plant distribution in the lake and lagoons is shown in Table 1. In lagoons and bays *Carex sp.* and various species of grass constitute the dominant emergent vegetation; the submerged vegetation includes most of the plants that occur in the lake itself. Filamentous algae is present in the lake but is most abundant in bays, lagoons and other protected areas.

Table 1. Aquatic plant distribution in Yellowstone Lake

Aquatic plants	Area																
	Lake Station Area	Lower Yellowstone River Area	Yellowstone River Lagoon	Cub Creek Area	Clear Creek Area	South East Arm	Molly Island Area	French Island Area	South Arm	Flat Mountain Arm	Solution Creek Area	Little Thumb Lagoon	Rotenone Lagoon	Arnica Lagoon	Sand Point Area	Bridge Bay West Lagoon	Bridge Bay East Lagoon
P. Richardsonii	X	X										X	X				X
P. praelongus	X	X						X									
P. pusillus	X	X		X		X	X		X		X						
P. Robbinsii	X	X				X	X	X	X	X						X	
P. gramineous va. graminifolius														X			
Lemna trisulca	X	X				X	X		X						X		
Ceratophyllum demersum	X	X				X	X		X		X						
Najas flexilis	X	X			X			X									
Myriophyllum exalbescens						X	X					X	X			X	X
Ranunculus aquaticus								X		X							
Fontinalis sp.																	
Elodea canadensis	X	X				X	X						X				
Nitella flexilus									X								
Eleocharis sp.			X										X				
Sagittaria cuneata			X														
Sparganium sp.													X				
Hipperus vulgaris						X											

Note: Plants and their locations are incomplete.

Anabaena sp. and the diatoms Asterionella sp., Melosira sp., Stephanodiscus sp., Staurastrum sp. and Coelastrum sp. are the most common phytoplankters (Benson, 1961). An Anabaena pulse was noted in 1959 in the latter part of July and through the first two weeks in August; at this time the water was clouded by the abundance of these organisms.

Fauna

Common zooplankters are Conochilus unicornis, Diaptomus schoedleri (Benson, 1961), Cyclop sp. and Bosmina sp.

Bottom and littoral zone organisms include: Oligochaeta, Hirudinea, Sphaeriidae, Gammarus lacustris, Hyallela azteca, Hemiptera Odonata, Ephemerella sp., Plecoptera, Trichoptera, Tabanidae, Tendipes sp., Procladius sp., Prodiamesa sp., Culicidae, Coleoptera and Hydracarina.

The amphibians found are western spotted tramp (Rana pretiosa), boreal toads (Bufo boreas), western chorus frog (Pseudacris nigrita) and blotched tiger salamanders (Ambystoma tigrinum).

Indigenous fishes in Yellowstone Lake are cutthroat trout (Salmo clarki lewisi (Girard)) and Longnose dace (Rhinichthys cataractae ocella (Garman)). Welch (1952) mentions that landlocked salmon (Salmo salar (Linnaeus) and rainbow trout (Salmo gairdneri (Richardson)) were planted but these species are not present today. The species now present are cutthroat trout, longnose suckers (Catostomus catostomus (Forster)), redside shiners (Richardsonius balteatus hydrophlox (Cope)), lake chub (Hybopsis plumbea (Agassiz)) and longnose dace. Longnose suckers were probably introduced into Yellowstone Lake in 1923 or 1924 (Benson, 1961). Redside shiners were first observed by U. S. Fish and Wildlife Service personnel in the lake in 1957; lake chub were first noted by C. J. D. Brown in 1949.

METHODS

Collection of Fish

Fish traps

During the spring and summer of 1959, and for several previous years, records were kept of longnose sucker movements into Arnica, Pelican, Cub, Clear, Chipmunk and Grouse Creeks by fish traps. The traps were originally installed for collecting cutthroat trout eggs and sperm and have been used for studying cutthroat trout and longnose suckers. Fish traps captured all fish ascending the streams noted above. Fish traps were used for this study for determining the upstream migration patterns of longnose suckers. All longnose suckers found in traps were destroyed.

Gill nets

Gill nets used for this study included: two experimental gill nets 125 X 6 feet of bar measure meshes 2 1/2 inches, 2 inches, 1 1/2 inches, 1 inch and 3/4 inch in equal proportions; one cotton gill net 104 X 6 feet with 92 feet of 1-inch bar measure mesh and 12 feet of 3/4 inch bar measure mesh; and three minnow gill nets 36 feet 8 inches X 4 feet of 3/8 inch bar measure mesh. These nets are referred to in this paper as experimental gill nets, cotton gill nets, and minnow gill nets, respectively.

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The nets were placed at a 45 degree angle to the shore line as much as possible. All nets were set between the hours of 1600 and 1900 and were recovered from 0700 to 1000 the following morning. From previous work in Yellowstone Lake it was concluded that most fish enter gill nets at night and that the number of hours nets are set is not important as long as they are left overnight. (Rawson and Elsey (1948) found no fish in day sets.) All overnight gill net sets are subsequently considered as equal samples. Gill nets were set at various depths and on the bottom.

Seines

All seines were one-fourth inch bar measure mesh and 6 feet high but varied in length from 25 to 75 feet. For each seine haul data were collected on location, fish recovered, habitat types, bottom organisms, mean depth and area covered. Seining data are considered on the basis of fish caught per 1000 square feet seined. Seining proved rather ineffective in recovering large numbers of fish even though a large bag was allowed to develop; it was used principally for relating habitat with species of fish.

Minnow traps

Standard minnow traps (16 3/4 inches long and 8 3/4 inches in diameter) were set for 48-hour periods. Habitat characteristics such as bottom type, bank type, depth, distance from shore and water temperature as well as fauna and flora present were noted. They proved most effective early in the spring in shallow lagoons and bay areas. Minnow traps were of value only for qualitative rather than quantitative information.

Dip nets

Small dip nets were used to collect fry in considering habitat requirements.

Rotenone

A rotenone containing chemical was used in a small lagoon near the West Thumb public boat landing. An excess of the required amount (one gallon per 6 acre feet of water) was used to insure a complete kill. The chemical was applied and mixed by using an outboard motor boat. All fish were recovered and measured with the exception of cutthroat trout fry. An estimate of the number of cutthroat trout fry was made by counting the fry in several 10-feet-square sample areas. Data obtained from poisoning were used for comparison with gill net data previously collected in this lagoon and to find actual composition of fish.

Fauna and Flora

Notes on the abundance and composition of bottom fauna of lagoons and shallow areas of the lake were taken in connection with minnow trapping and seining. Data collected previously by U. S. Fish and Wildlife Service personnel were also used. Aquatic plants were collected from various areas of the lake and lagoons and were tentatively identified in the field. Samples were pressed and their identification was verified later by Professor Arthur H. Holmgren, Curator of the Intermountain Herbarium, Utah State University.

Stomach Analysis

Intestinal tracts were collected from longnose suckers in all areas of the lake and lagoons. They were placed in cheese cloth and preserved in formalin. Before examining the contents in the laboratory later intestinal tracts were placed in water to soak. A count was made of all organisms in the anterior fourth of the intestinal tracts by placing the contents in a petri dish and examining them under binoculars. Volumetric approximations were made by counting a large number of organisms and measuring their volumetric displacement in water. The number of organisms to be counted depended on their relative size and abundance. Redside shiners were collected from the lake and lagoons and placed in formalin. Intestinal tracts were examined as with longnose suckers but entire intestinal tracts were examined.

Growth Considerations

Scales were taken from longnose suckers in the field and from redside shiners in the laboratory. No correction was made for shrinkage with redside shiners' scales after they had been in formalin. All scales were scale sampled anterior to the dorsal fin and just above the lateral line. Longnose sucker and redside shiner scales were mounted in glycerin and water glass on glass slides and examined with a standard micro-projector at a magnification of 55 diameters. The direct proportion method was used to calculate growth.

Egg Counts

Longnose sucker eggs were estimated by making fifteen counts to 200 and measuring the volumetric displacement of each in water. The mean volume per 200 eggs was used to estimate the number of eggs per female by considering the volumetric displacement of all eggs. All redside shiner eggs were counted.

LIFE HISTORY OF THE LONGNOSE SUCKER

Few longnose suckers are taken by hook and line in Yellowstone Lake; most of those caught are discarded as trash fish. Jordan and Everman (1934) mentioned that longnose suckers are seldom caught by hook and line but are usually captured by hoop or trap net or by spears. They stated that in the Great Lakes and northward the longnose sucker is a food fish of considerable value. Eddy and Surber (1943) stated that the flesh is firm and well flavored but bony. The author found the flesh quite palatable; it is a well flavored, light flaky meat, somewhat oily with small bones. Simon (1946) noted the economic importance as food for man and food for fur bearing animals.

The longnose sucker is often regarded as a serious competitor with various species of more desirable game fish; it has been studied in this connection in Great Slave Lake (Rawson, 1951), Shadow Mountain Reservoir (Hayes, 1956; Bassett, 1957), Pyramid Lake (Rawson and Elsey, 1948), Banff National Park (Stenton, 1951), Yellowstone Lake (Brown and Graham, 1953) and in other lakes and streams by numerous investigators.

Age and Growth

The scales from 100 longnose suckers (52-525 mm. total length) were used in calculating the body scale relationship. The scales were collected from fish caught in Yellowstone Lake in July and August 1959. The three assumptions given by Van Oosten (1944) were followed: (1) scales retain their identity and number throughout the life of the fish, (2) annuli are laid down each year at the same time and (3) the growth of scales is proportional to the growth of the fish. The mean calculated total lengths at the end of each year of life agreed relatively close with measured lengths.

Retarded scales were found on 41 longnose suckers. The term retarded scale is used to describe a scale that does not form an annulus after the first year of growth (Laakso and Cope, 1956). A scale was assumed retarded if the number of circuli before the first annulus was more than 9 and/or if the first annuli was found at an excessive distance from the foci. Brown and Graham (1953) suggested that longnose suckers in Yellowstone Lake may go through their first winter without scales; they did not, however, consider retarded scales in computing their body scale relationship. They found that the smallest suckers having scales were 38 mm. total length.

The mean calculated total lengths of 100 longnose suckers were 26.2, 73.8, 156.6, 236.4, 308.0, 370.6, 418.6, 475.8, and 504.9 mm., respectively, for nine years (Table 2). The calculated total lengths of both sexes were consistently under the average measured lengths until age group IX. Brown and Graham (1953) found the mean total length of sucker fingerlings in October to be 30.5 millimeters. As the lake freezes over in December or January and is frozen until June, one would not expect much growth during this period. The mean calculated total length was 26.2, which is somewhat low but may be partially explained by the small number of fish in young age groups and partially by Lee's phenomenon.

Table 2. Mean calculated total lengths and increments of growth of 100 longnose suckers collected in the summer of 1959 in Yellowstone Lake

Age	Sex	Number of specimens	Average calculated total lengths at each annulus									Length at capture
			1	2	3	4	5	6	7	8	9	
I	--	2	37.8									52.0
II	--	3	36.4	100.3								100.3
III	M	7	30.0	83.1	172.2							191.4
III	F	8	28.7	85.8	171.9							185.5
IV	M	17	26.4	79.2	165.0	243.7						257.4
IV	F	13	22.8	70.8	159.3	233.5						244.8
V	M	7	30.2	91.0	169.7	252.8	316.7					328.0
V	F	4	26.9	69.4	157.4	244.8	313.4					330.5
VI	M	7	25.0	71.5	145.8	227.5	295.8	349.2				356.3
VI	F	5	26.1	74.2	163.0	247.1	319.0	378.2				384.0
VII	M	6	24.2	56.2	128.8	205.8	281.8	343.0	380.8			385.5
VII	F	7	22.0	62.4	154.4	245.2	324.4	380.3	414.9			421.8
VIII	F	8	23.8	53.4	131.4	224.7	297.4	382.6	438.4	480.1		483.5
IX	F	6	22.7	68.9	144.0	234.8	320.1	389.9	434.5	470.0	504.9	508.6
Mean total length[a]			26.2	73.8	156.6	236.4	308.0	370.6	418.6	475.8	504.9	
Mean annual increment[a]			26.2	47.8	83.6	82.7	73.3	64.8	33.8	39.1	34.9	

[a]Sexes combined

In age groups III and IV males were larger than females; in age groups V, VI and VII females were larger than males; no males were found in age groups VIII or IX. Brown and Graham (1953) found a one-inch difference between males and females in their fifth, sixth and seventh years; Rawson (1951) reported no difference between the rate of growth of males and females but found that females lived longer than males. In Yellowstone Lake male suckers mature faster and die at a younger age than females; they grow faster during the first four years but are then passed by females. Females live to nine or more years in Yellowstone Lake; males were not found older than seven years. Rawson (1951) mentioned that suckers live to 13 or 14 years in Great Slave Lake.

The mean annual increment of growth in length (Table 2) for the first nine years, respectively, was 26.2, 47.8, 83.6, 82.7, 73.3, 64.8, 33.8, 39.1 and 34.9 millimeters. Growth in length increased during the first three years and then decreased; the one exception in the seventh year probably resulted from the small sample size. Between age groups I and II the increment of growth nearly doubled; during the third year the largest increment occurred. The mean condition factor (K) was 1.22.

Reproduction

In Yellowstone Lake the longnose sucker was observed spawning only in streams. Other workers found longnose suckers enter streams to spawn (Hubb and Lagler, 1941; Hayes, 1956), enter streams or may spawn along wind-swept gravel shoals where the eggs tend to congregate in shallow water (Rawson and Elsey, 1948). It is suspected that longnose suckers have increased in number in recent years in Yellowstone Lake in spite of destruction of spawning suckers in several important tributary streams since the early thirties; thus it was highly desirable to ascertain whether longnose suckers were spawning in the lake. Trautman (1957) mentioned that longnose suckers come into water 25 feet deep in the spring presumably for spawning about the reefs. All evidence found in Yellowstone Lake discredited the hypothesis that they may be spawning in the lake.

Although fish traps on Pelican, Cub, Clear, Grouse, Chipmunk and Arnica Creeks have substantially reduced the spring spawning populations in these streams, the introduced longnose sucker has not only continued to exist but possibly has increased in numbers. The increase is suggested from the large numbers found in the lake and not from suckers ascending streams where fish traps are maintained. As many as 2000 suckers occurred in spawning runs in Pelican Creek in the early forties. Mr. William Dunn, superintendent of the fisheries station in Yellowstone for several years (as reported by Brown and Graham, 1953) noted that the first longnose suckers observed were captured in the seining near Fishing Bridge in 1931 to 1933. Brown and Graham (1953) reported that by the mid thirties a few appeared in the spawning runs in Pelican Creek; by the late thirties the run had increased from 300 to 400 suckers per year; in the early forties 1,500 to 2,000 suckers appeared in the spawning runs. In 1959 there were 330 suckers in the spawning run in Pelican Creek. The number of suckers in Pelican Creek appearing in the spawning runs since 1947 are included in Table 3.

Some longnose suckers have been reported in all streams where traps are located but, with the exception of Pelican Creek, the number of suckers has been small. As suckers have been destroyed for many years in the fish trap in Pelican Creek, the recurrent run must be from

Table 3. Number of longnose suckers found in spawning runs in Pelican Creek from 1947 to 1959

Year	Number of fish
1947	1,863[a]
1948	1,393[a]
1950	1,057[a]
1951	1,302[a]
1952	1,150
1953	15[b]
1954	101[b]
1955	--
1956	38[b]
1957	1,148
1958	24[b]
1959	330

[a]Rough counts made by spawning crews

[b]Rough counts known to be inaccurate

Note: Data from 1947 through 1951 as reported by Brown and Graham (1953).

a resident stream population. In 1959 longnose suckers reported in fish traps of other streams were: Arnica Creek, 2; Chipmunk Creek, 18; Grouse Creek, 10; Cub Creek, 0; and C ear Creek, 0.

Many suckers were found in the Upper and Lower Yellowstone Rivers where spawning undoubtedly occurs. Numerous sucker fry were observed during the latter part of July in quiet pool areas in the Yellowstone Riber below Fishing Bridge and also at the mouth of the Upper Yellowstone River. Other streams which may be used to advantage by spawning suckers include: Cabin, Solution, West Thumb and Little Thumb Creeks. (Brown (1948) reported that 60 young suckers were recovered in a small stream near Arnica Creek by shocking.) Seining in Pelican Creek above the weir during the latter part of July revealed an abundance of sucker fry. Before the trap was removed, large numbers of adult suckers were observed coming downstream near the weir; the recruitment of suckers from Pelican Creek materially contributed to sucker numbers in the lake.

Longnose suckers reach sexual maturity in Yellowstone Lake at age V for males and age VI for females. In age group IV, 12 percent of the males were sexually mature; in age group V, 86 percent of the males and 25 percent of the females were sexually mature; in age group VI all males and 80 percent of the females were sexually mature; in age group VII all fish were sexually mature. In Shadow Mountain Reservoir Hayes (1956) found that the average age of sexual maturity was three years for males and four years for females. In Pyramid Lake Rawson and Elsey (1948) found that 40 percent of the males and 12 percent of the females were sexually mature at four years (spawning in their fifth summer); at five years 65 percent of the males and 20 percent of the females were sexually mature; at six years all fish were sexually mature.

In 1959 longnose suckers spawned in tributaries to Yellowstone Lake from the first of June until the third week in July. The run commenced while the cutthroat trout spawning run was still strong; the latter part of the sucker run occurred after the trout run was over. In 1959 in Pelican Creek 85 percent of the longnose sucker run occurred from June 15 to June 25 when the mean water temperature was 48° F. Rawson and Elsey (1948) reported that spawning occurs in Pyramid Lake from June 10 to the first of July; Hayes (1956) reported that it takes place in Shadow Mountain Reservoir in April and May. Temperature is undoubtedly important in determining the time of spawning. Bassett (1957) stated that although stream temperatures may not be a requisite for spawning a low temperature may retard the date of entrance into a stream for spawning. Longnost suckers spawn over gravel beds but do not prepare a redd in Pelican Creek; Hayes (1956) noted no redd preparation in tributaries to Shadow Mountain Reservoir.

The number of eggs from four female suckers from 397 to 452 millimeters ranged from 26,927 to 36,268 (Table 4).

Table 4. The number of eggs found in four mature longnose suckers in Pelican Creek in 1959

Total length in millimeters	Weight in grams	Number of eggs found
397	709	26,927
398	794	28,277
423	992	34,615
452	907	36,268

Habitat

Longnose sucker fry were collected in small shallow pools, usually in association with emergent aquatic plants. Fry were observed in large schools during the last of July and the first of August in shallow pools in Pelican Creek, and the Upper and Lower Yellowstone Rivers; some fry were observed in Pelican Lagoon, and lagoons near the Upper and Lower Yellowstone Rivers. Observation and efforts with dip nets and seines in shallow areas of the lake and lagoons failed to reveal many fry. Apparently most longnose suckers spend their first summer in pools of tributary streams before entering the lake. Bassett (1957) reported that most longnose sucker fry go to Shadow Mountain Reservoir from tributary streams at a very young age and are found in large numbers at the mouth of inlets.

In Yellowstone Lake all longnose suckers under 201 millimeters were found in water less than 11 feet deep. Most suckers in this size group were found in lagoons and protected bay areas where aquatic plants are abundant. These areas have a silt bottom with a minimum of wave action.

Adult longnose suckers are found in large concentrations in lagoons and bays, usually where aquatic plants are abundant. All were found over a silt bottom in less than 51 feet of water from June to October in 1957, 1958 and 1959.

Food and Feeding Habits

Adult longnose suckers are omniverous; their food to a large extent appears to be related to its relative abundance. They use their suctorial mouths to pick up food from bottom ooze, from submerged aquatic plants and for feeding in open water; there is little or no mastication. In Yellowstone Lake suckers are very proficient in separating food organisms from bottom ooze, sand and silt.

An analysis of 112 longnose sucker stomachs, of which 12 were empty, was made from fish collected from July 13 to August 28, 1959. The fish ranged in size from 170 to 427 mm. total length. The fish were collected from all areas of Yellowstone Lake and its lagoons. Tendipedidae larvae were most important by occurrence and were present in 74 percent of the stomachs having food: *Hyalella* and *Gammarus* were next in importance, followed by *Daphnia*, Trichoptera nymphs, *Ephemerella* nymphs and Tendipedidae pupae. By number *Daphnia* had the most individuals followed by *Hyalella* and *Gammarus*, Tendipedidae pupae, *Cyclops*, *Ephemerella* nymphs, and Trichoptera nymphs.

Hyalèlla and *Gammarus*, and Tendipedidae larvae were almost equal by volume, occupying 29.7 percent and 29.5 percent, respectively; following were *Daphnia* 10.4 percent, *Ephemerella* nymphs 8.7 percent, filamentous algae 5.5 percent, Trichoptera nymphs 3.9 percent, *Cyclops* 3.8 percent and Tendipedidae pupae 3.6 percent; miscellaneous items made up the remaining 4.9 percent. By volume Hyalella and _Gammarus_, Tendipedidae larvae and pupae and _Daphnia_ comprised 73.2 percent of the total stomach contents (Table 5). Rawson and Elsey (1948) found that amphipids (_Gammarus_ and _Hyalella_) comprised 72 percent by volume and tendipedids 19 percent by volume of the food of longnose suckers in Pyramid Lake. Rawson (1951), in Great Slave Lake, found 63 percent of the longnose suckers' diet by volume to consist of amphipods, 15 percent tendipedids, 11 percent aquatic insects and 9 percent sphaerids. Longnose suckers in northern lakes subsist largely on animal organisms and especially on amphipods and tendipedids. This is true in Yellowstone Lake.

Hyalella and _Gammarus_ are considered together but, from several samples identified more precisely, _Gammarus_ was found to constitute over 90 percent of the amphipods. The tendipedids consisted mostly of _Tendipes_ but also included _Prodiamesa_ and _Procladius_. Foreign material, including several shiny pieces of glass, sand particles and silt, was observed but not included.

That longnose suckers feed largely on one organism at one time was apparent by the division of organisms in the intestinal tract. Seven of the 100 stomachs contained only one organism, 23 contained two organisms and the remainder contained three or more organisms; one stomach contained eight different species of animals, another contained 68 percent by volume of filamentous algae, which constituted the bulk of filamentous algae for all stomachs. The food habits of suckers were not found to vary significantly among fish from 170 to 427 millimeters.

Brown and Graham (1953) studied the food habits of longnose suckers in Pelican Creek from August 20 to September 7, 1951. Twenty-four stomachs of fish from 91 to 213 mm. led by volume 35 percent algae,

Table 5. Summer food of 112 longnose suckers in Yellowstone Lake in 1959 expressed by occurrence, number and volume[a]

Food item	Percentage occurrence[b]	Number	Percentage volume
Daphnia	54	32,968	10.4
Bosmina	4	1,964	1.2
Cyclops	8	10,676	3.8
Hyalella and Gammarus	60	21,146	29.7
Unidentified Crustacea	6	228	1.1
Hemiptera	1	4	Tr.
Odonata (nymph)	2	8	.1
Ephemerella			
Nymph	19	2,056	8.7
Adult	1	8	Tr.
Plecoptera (nymph)	11	104	.8
Trichoptera			
Nymph	28	1,272	3.9
Adult	1	8	Tr.
Tendipedidae			
Larva	74	19,957	29.5
Pupa	18	576	3.6
Unidentified Diptera	1	4	Tr.
Coleoptera	4	24	.2
Unidentified Insecta	3	40	.4
Hydracarina	1	4	Tr.
Pisidium	3	52	Tr.
Unidentified animal	1	8	Tr.
Filamentous algae	14	--	5.5
Higher aquatic plants	7	--	.2

[a]Stomachs were collected from July 13 to August 28, 1959; fish ranged in size from 170 to 427 millimeters total length. There were 112 stomachs examined of which 100 contained food.

[b]Percentage occurrence of the 100 stomachs having food and not considering the empty stomachs

[c]Includes: Tendipes, Procladius and Prodiamesa

21 percent debris, 19 percent Ephemeroptera, 9 percent Coleoptera, 9 percent Trichoptera, 7 percent Diptera and a trace of higher plants. They examined 50 stomachs of fish between 310 and 495 mm. between July 1 and July 30, 1951, and 1952; of these only 21 contained food. Analysis showed these fish were eating by volume 48 percent Ephemeroptera, 17 percent unidentified organisms and debris, 12 percent algae, 11 percent Trichoptera, 7 percent Diptera, 5 percent Coleoptera and a trace of higher plants. Small fish were eating considerably more algae than large ones. Brown and Graham (1953) found a higher incidence of algae in longnose suckers in tributary streams in 1952 and 1953 than was found in Yellowstone Lake in 1959; 12 percent by volume of algae was found by Brown and Graham in adult longnose suckers in Pelican Creek; in Yellowstone Lake in 1959, 8.7 percent by volume was found in suckers and much of this was found in one fish. In Yellowstone Lake _Hyalella_ and _Gammarus_, Tendipedidae larvae and _Daphnia_ constitute most of the diet, whereas in Pelican Creek aquatic insects and plants constitute most of the diet.

Seasonal differences would be expected but were not found in the short time the stomach analysis covered in 1959; the analysis made by Brown and Graham (noted above) show differences when compared with data taken later in the season in the lake which may be attributed to fish size and habitat. Rawson and Elsey (1948) concluded that there were no seasonal differences between May and September in Pyramid Lake; Rawson (1951) found no significant seasonal differences in food habits of suckers in Great Slave Lake. Hayes (1956) found, in Shadow Mountain Reservoir, that Entomostraca (mostly _Daphnia_) made up 57 percent of the diet of longnose suckers, vascular plants 7.4 percent and algae 6.5 percent during the summer months; Bassett (1957) found the winter diet in the same reservoir to consist of 67 percent filamentous algae by volume and 10 percent vascular plants.

The differences in the food habits of longnose suckers taken in the lagoons and the open lake is shown in Table 6. Longnose suckers in Yellowstone Lake consumed more amphipids, tendipedid pupae and *Daphnia* than suckers in the lagoons. *Cyclops*, most aquatic insects, filamentous algae, Arachnida and *Pisidium* were more abundant in stomachs coming from fish in lagoons. The differences noted confirm the omniverous habits of longnose suckers and the importance of the availability of organisms as to the degree they are utilized as food by suckers.

Table 6. A comparison of the food eaten by 47 longnose suckers in Yellowstone Lake with 53 longnose suckers in the lagoons of the lake as adapted from data used in Table 5, expressed by number and percentage by volume of the entire food on an area basis

Food item	Open lake		Lagoons	
	Number of organisms	Percentage volume	Number of organisms	Percentage volume
Daphnia	22,584	12.6	10,384	7.6
Bosmina	1,868	2.0	96	.1
Cyclops	10,672	6.6	4	Tr.
Hyalella and Gamarus	14,623	36.2	6,523	21.4
Unidentified Crustacea	--	.5[a]	228	2.0
Hemiptera	4	Tr.	--	--
Odonata (nymph)	4	.1	4	.2
Ephemerella				
Nymph	1,496	11.1	560	5.5
Adult	--	--	8	Tr.
Plecoptera (nymph)	76	.5	28	.5
Trichoptera				
Nymph	417	2.3	855	6.2
Adult	--	--	8	Tr.
Tendipedidae				
Larva	8,678	22.6	11,279	38.8
Pupa	372	4.1	204	3.0
Unidentified Diptera	--	--	4	Tr.
Coleoptera	18	.2	4	Tr.
Unidentified Insecta	8	Tr.	32	.8
Arachnida	--	--	4	.2
Pisidium	--	--	52	Tr.
Unidentified animal	8	Tr.	--	--
Filamentous algae	--	.9	--	11.6
Higher aquatic plants	--	Tr.	--	1.8[b]

[a] Includes many eggs of crustaceans.

[b] Includes 1.3 percent by volume of seeds.

LIFE HISTORY OF THE REDSIDE SHINER

The redside shiner has been present in Yellowstone in the Snake River drainage for many years; it was first collected in Yellowstone Lake in 1957 but it may have been present for several years. Redside shiners are important as forage fish in many areas. In other areas, where they have been introduced as forage fish, they have competed with other species. The importance and interactions of redside shiners with other species of fish in Yellowstone Lake will be discussed in later sections.

Age and Growth

Redside shiners ranging in total length from 44 to 105 mm. were used in computing the body scale relation. The fish were collected from Yellowstone Lake and its lagoons from June 19, 1959, to September 4, 1959. From examination there was no apparent size difference between sexes so sexes were combined for considering the mean total length at the end of each year of life and annual increments of growth.

The mean calculated total lengths of 100 redside shiners were 47.3, 67.3 and 91.2, respectively, for three years of life. The mean annual increments of growth were 47.3, 24.0 and 21.8, respectively (Table 7); redside shiners acquire most of their growth in length the first year. The age groups 0 and I can be aged on length alone provided that age group I are aged at the beginning of the growing season during their second summer. The mean condition factor (K) was 1.23.

Table 7. The mean calculated total lengths and increments of growth of 100 redside shiners collected in Yellowstone Lake in 1959

Age	Sex	Number of specimens	Average calculated total length at each annulus 1	2	3	Length at capture
I	M	20	54.9			76.2
I	F	15	54.9			76.2
II	M	36	41.8	64.6		79.3
II	F	23	44.11	71.0		88.8
III	M	3	49.3	69.5	91.1	101.0
III	F	3	48.5	69.3	91.4	99.3
Mean total length (sexes combined)			47.3	67.3	91.2	
Mean annual increment (sexes combined)			47.3	24.0	21.8	

Reproduction

In 1959 redside shiners spawned from the middle of June through the first week in July in Yellowstone Lake lagoons and tributary streams. Simon (1946) stated that in Jackson Hole they spawn during late June and early July. Weisel and Newman (1951) reported they were spawning in a slough near Bearmouth, Montana, from April 8 to June 17 in 1950, but that they were spawning from May 20 to June 30 in Postcreek near Flathead Lake, Montana. The time of spawning in different areas is evidently dependent on water temperature. In Yellowstone redside shiners were spawning in water that varied from 44° to 50° F. in 1959.

In Yellowstone Lake redside shiners reach sexual maturity at age group II when they vary from 70 to 100 mm. total length. They enter lagoons and streams in large numbers during the first of June; during June most shiners are found in these areas; few are found in the open lake.

Redside shiners spawn in lagoons over submerged vegetation and undoubtedly in streams as young fry are found in these areas. Some shiner eggs were found adhering to aquatic vegetation in Pelican Lagoon in water 18 inches deep. Weisel and Newman (1951) reported redside shiners spawn in sloughs fed by warm springs and in streams; they noted them entering riffles and spring holes to spawn. They further noted that few eggs were deposited at one time and that several males apparently attended each female.

On July 28, 1959, redside shiner fry averaging 13 millimeters were found up to two miles above the lake in Pelican Creek, which indicated that fish had ascended the stream to spawn or that there was a resident population in Pelican Creek. As fish, apparently moving upstream, were observed near the trap on several occasions, it is probable that tributary streams are important for redside shiner spawning.

The eggs from two ripe females were counted: the first female, 88 mm. long, had 767 mature eggs; the second female, 92 mm. long, had 832 mature eggs. Weisel and Newman (1951) found the number of eggs per fish to vary from 829 in a specimen 80 mm. to 3,602 in a specimen 104 mm. total length.

Redside shiners do not construct a nest; they broadcast demersal eggs that adhere to aquatic vegetation or rocks. Weisel and Newman (1951) reported redside shiner eggs hatch in three to seven days under laboratory temperatures of 21° to 23° C. remaining as prolarvae for eight days; during the post larvae stage, lasting about 46 days, they are active swimmers and take food.

Habitat

Redside shiners were first noted on May 26, 1959, in Yellowstone Lake near the U. S. National Park Service boat landing before the ice had completely left the lake. Through June and the first two weeks in July most redside shiners are found in lagoons and protected bay areas where temperatures are higher than in the open lake. From the latter part of July to early September fish are found in the littoral zone of the lake as well as in lagoons and bays.

Most redside shiners are found in areas protected from heavy wave action over a silt bottom. In the summer of 1959 all fish were found in the littoral zone in water less than 11 feet deep.

Although nets were set at various depths no nets were set on the surface in deep water areas in 1959. (In 1960 some nets were set near the surface in the limnotic zone; no redside shiners were taken in this area.)[1]

In general, redside shiners are found in areas where vascular aquatic plants are abundant (Table 1). Insects, crustaceans, amphibians and other organisms present in redside shiner habitat include those discussed in the limnology section; these organisms are generally abundant in areas where the largest fish concentrations occur. The most abundant organisms are Gamarus, Tendipedidae and other lower dipterans, Trichoptera, Odonata, Hydracarina, Hemiptera and Bufo tadpoles.

The greatest concentrations of redside shiners at all times during the summer occur in lagoons and bays with some exceptions. The area between the U. S. National Park Service boat docks often has large

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[1]Conversation with Dr. Benson

concentrations of redside shiners. Seine hauls were made and gill nets were set in this area when large numbers of redside shiners were observed; this procedure was highly selective and the data cannot be considered qualitatively with other data from the lake and lagoons. Fish congregate in this area, especially during heavy wave action on the lake; it is significant that they prefer the protection of the docks in preference to unprotected areas in the lake. A noticeable exception to preference of protected areas was found in Mary Bay where several redside shiners occur; Mary Bay is located in the northeastern area of the lake and receives the heaviest wave action of anywhere on the lake. Seining in this area failed to recover fish when wave action was moderate but an overnight gill net set when the lake was rough caught several fish. As the lake is usually calm at night it is probable that the fish moved into this area when the water was calm.

Young redside shiners were found in shallow water in association with emergent aquatic plants in Pelican Creek, Pelican Creek Lagoon and in some of the other lagoons. As fewer fry were found in lagoons than in Pelican Creek, it appears that most spawning is done in tributary streams.

No redside shiners were found near the hot spring and geyser area at West Thumb, but several were found near an underwater hot spring at Pumice Point. A gill net set directly over the hot spring caught several redside shiners and some cutthroat trout; one shiner was caught directly above the warm spring in 76° F. water.

Food and Feeding Habits

A food habit study was made from 117 redside shiner stomachs although 17 were empty. The stomachs were collected from June 19 to September 4, 1959, from Yellowstone Lake and its lagoons. The fish ranged from 44 to 105 mm. total length.

Redside shiners are almost entirely carnivorous, only a trace of plant material was found. They seem to feed largely at or near the surface but also obtain their food from the surface of submerged aquatic plants; they feed very little on the bottom. Redside shiners were observed taking their food with a fast darting motion which often broke the surface. From stomach analysis it is apparent that redside shiners masticate their food before swallowing.

Analysis of redside shiner stomachs revealed 60.7 percent by volume of their diet consisted of Tendipedidae adults. Following tendipedids in importance by volume were 9.3 percent unidentified animal material, 6.5 percent unidentified insects, 5.5 percent Hyalella and Gammarus, 4.8 percent Tendipedidae larvae, 2.4 percent Bosmina and 10.8 percent miscellaneous (Table 8). Tendipedidae adults were most important by number with 2,327 individuals, Hyalella and Gammarus followed with 421, then 420 Bosmina, 348 Tendipedidae larvae, 319 Daphnia and 57 Corixidae. By occurrence Tendipedidae adults were found in 59 percent of the stomachs, Hyalella and Gammarus in 24 percent and Daphnia in 16 percent.

Simon (1953) mentioned that redside shiners feed mostly on insect larvae and crustaceans with small amounts of plant debris; Carl and Clemens (1948) found they are primarily insectivorous. Weisel and

Table 8. Summer food of 100 redside shiners between 44 and 105 millimeters total length in Yellowstone Lake in 1959, expressed by percentage occurrence, number of organisms, and percentage of the entire stomach contents by volume[a]

Food item	Percentage occurrence[b]	Number of organisms	Percentage volume
Daphnia	16	319	.9
Bosmina	1	420	2.4
Hyalella and *Gammarus*	24	421	5.5
Unidentified Crustacea[b]	3	33	.2
Corrixidae	6	57	1.9
Gerridae	1	4	.1
Terrestrial Hemiptera	1	2	.6
Odonata (nymph)	1	4	1.3
Trichoptera			
Nymph	2	9	.3
Adult	5	34	1.2
Tendipedidae[c]			
Larva	12	348	4.8
Pupa	2	27	1.6
Adult	59	2,327	60.7
Tipulidae (larva)	2	5	1.3
Unidentified Diptera	6	34	1.3
Coleoptera	1	1	Tr.
Unidentified Insecta	8	--	6.5
Hydracarina	9	23	Tr.
Unidentified animal	9	--	9.3
Higher aquatic plants	2	--	Tr.

[a]There were 117 stomachs examined, 17 were empty and are not considered in percentage occurrence. Redside shiner stomachs were collected from June 19, 1959, to September 4, 1959.

[b]Includes crustacean eggs.

[c]Includes: *Tendipes*, *Procladius* and *Prodiamesa*.

Note: Trace (Tr.) is less than one-tenth of one percent by volume.

Newman (1951) found that shiners were eating molluscs and algae, water beetles, gammarids, adult dipterans and dragonfly nymphs; during the spawning season some fish were found with eyed eggs of their own species. Larkin and Smith (1953) noted predation of redside shiners on kamloop trout; Simon (1946) noted that redside shiners were preying upon newly released fry. No evidence was found in Yellowstone Lake to indicate that redside shiners are piscivorous.

The redside shiner food habits were also considered in the lake and in its lagoons separately (Table 9). Tendipedidae were most important in both areas: in the lake they constituted 84.7 percent by volume of the diet, whereas in the lagoons they made up only 50.7 percent by volume. Tendipedidae larvae and Daphnia were more important by volume in the lake than on the lagoons; Tendipedidae pupa, Bosmina, Hyalella and Gammarus, unidentified animals and unidentified insects were more important in the lagoons. The diet of the redside shiners in lagoons is considerably more diverse than in the open lake; the various miscellaneous organisms, especially insects, are notably more important in lagoons.

Redside shiners, although consuming various organisms, are somewhat selective in their diet. Of the 100 stomachs containing food, 51 had eaten only one organism, 34 had eaten two organisms, while only 15 had eaten three or more organisms. No difference was noted in food habits of fish from 44 to 105 mm. total length; the food eaten did not change significantly between June 19 and September 4 in 1959.

Table 9. A comparison of the summer food of 49 redside shiners in Yellowstone Lake with 51 redside shiners in Yellowstone Lake lagoons as adapted from data used in Table 8 expressed by number of organisms and percentage by volume of the entire stomach contents by area[a]

Food item	Open lake: Number of organisms	Open lake: Percentage volume	Lagoons: Number of organisms	Lagoons: Percentage volume
Daphnia	282	1.5	37	.2
Bosmina	--	--	420	5.3
Hyalella and Gammarus	141	3.3	280	8.2
Unidentified Crustacea[a]	--	--	33	.4
Corixidae	--	--	57	4.4
Gerridae	--	--	4	.3
Terrestrial Hemiptera	--	--	2	1.5
Odonata (nymph)	--	--	4	2.9
Trichoptera				
Nymph	--	--	9	.6
Adult	--	--	34	2.8
Tendipedidae[b]				
Larva	98	6.2	250	3.1
Pupa	--	--	27	3.5
Adult	1,676	78.5	651	38.3
Tipulidae (larva)	--	--	5	2.9
Unidentified Diptera	--	--	34	2.9
Coleoptera	--	--	1	Tr.
Unidentified Insecta	--	2.3	--	11.8
Hydracarina	19	Tr.	3	Tr.
Unidentified animal	--	8.1	--	10.8
Higher aquatic plants	--	--	--	Tr.

[a]Includes crustacean eggs.

[b]Includes: Tendipes, Procladius and Prodiamesa.

Note: Trace (Tr.) is less than one-tenth of one percent by volume.

INTERRELATIONS BETWEEN SPECIES

Competition

Darwin (1859) defines competition as the demand of more than one organism at the same time for the same resources of the environment in excess of immediate supply. Solomon (1949) added to Darwin's definition: direct active struggle and the occupation or consumption by an earlier arrival of something in limited supply. "Compete" literally means "together seek." Competition in this paper will be restricted to mean the demand of more than one organism for the same resource. Predation will be restricted to mean the destruction by consumation of one organism by another.

Competition with fish is largely for food, space and spawning sites. Fish are unlike most other animals as they have a variable growth rate and an extremely high reproductive potential which enables them to tide over certain periods of competition. Fish are subject to stunting which is most often associated with interspecific competition; a reduction in number of a stunted population results in an increase in size in those remaining. Competition for space often exists because there is social intolerance between species but may also be caused by psychological factors which may only be surmised.

Three factors that limit population increase of an organism are: the organism itself in its adaptation to an environment, the physical environment, and the biological environment. The physical environment may reduce competition by causing an increase of food or other resources fast enough to compensate for a rapid population increase, or it may affect the competitors directly through adverse conditions and thus result in a small ratio of population to resources available. An organism in the biological environment may reduce competition by increasing rapidly, it may inhibit growth or development, or it may cause mortality. One species may act as a buffer for another species; or it may alter the habitat of another species.

Distribution and Spatial Interrelations

The interrelations of distribution and the amount of space are important factors in competition among species. The growth rate of a species and the ability of several species to live together is determined by territorial behavior, aggressive behavior, social dominance, and other factors. A social order of dominance is known to exist in lakes as well as streams. Moore (1941) found that in hatcheries an excess amount of food does not necessarily result in increased consumption or growth; he concluded that space was important in this connection.

Competition for space involves individual struggle against aggressive behavior as well as struggle for environmental resources. Although many species may find suitable environments in the same general area they may exist with varying degrees of success. The spatial distribution of fish in a lake appears to be rather simple as fish are seldom confined to a particular zone. At certain stages of development in their life cycle, however, they may favor certain habitats more than others. The diversity of a fresh water environment as to the currents, bottom types, aquatic plants present, wave action and food organisms present are important factors in considering distribution of a particular species; also, the period of time a particular species has been present in a given body of water. Organisms given sufficient time and opportunity tend to inhabit all areas with conditions compatible with their existence. When a particular species is introduced into a body of water, as the longnose sucker, redside shiner and lake chub have been introduced into Yellowstone Lake, the species would be expected to inhabit the most suitable areas first. The longnose sucker, redside shiner and the lake chub have been present in Yellowstone Lake for relatively short periods of time; their present distribution does not include all areas where these species find preferences. Although they have increased their range, it is apparent that serious competition has not forced them into other areas of the lake. In the future they may be expected to move into other areas of preferable habitat first and then into areas of marginal habitat.

Fish in Yellowstone Lake tend to be littoral or limnetic either as a group or at some particular stage of development in their life cycle. The distributional patterns will be considered from gill net, seine, minnow trap and observational data.

Horizontal distribution

The general distribution of fish in Yellowstone Lake is given in Figure 3. Cutthroat trout are in all areas of the lake and its lagoons. Their greatest concentrations, as inferred from gill net catches on a per net basis, occurs in the Southeast Arm, especially near the Molly Islands, in the mouth of the South Arm near Frank Island and Wolf Point, near the mouth of Pelican Creek, in a small lagoon near the

Figure 3. Map of Yellowstone Lake showing the distribution of cutthroat trout, longnose suckers, redside shiners, lake chub and longnose dace as determined from gill net, seine and minnow trap data

Legend

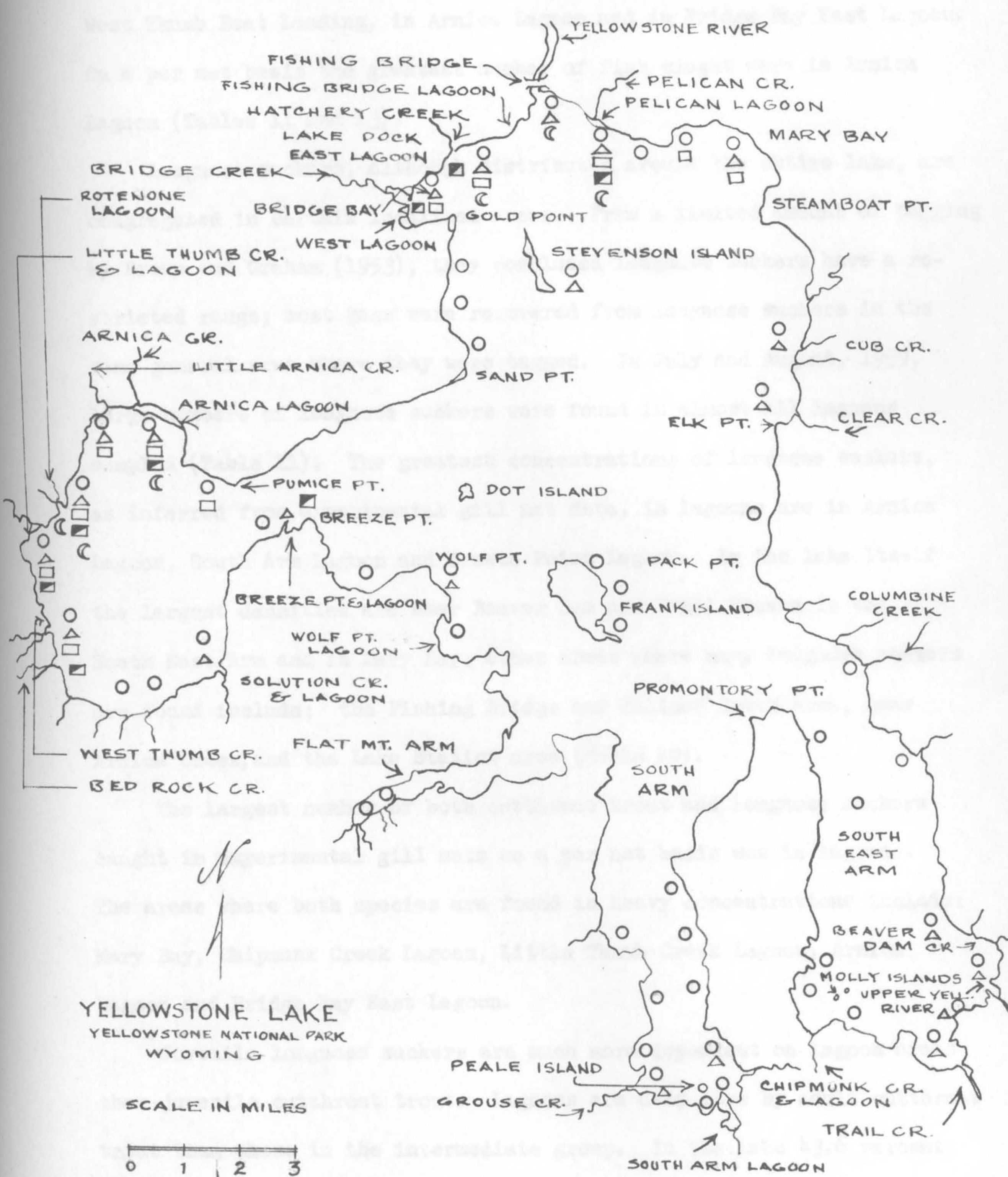
○ Cutthroat trout

◩ Lake chub

△ Longnose suckers

◖ Dace

□ Waterflame


YELLOWSTONE RIVER
FISHING BRIDGE
FISHING BRIDGE LAGOON
HATCHERY CREEK
LAKE DOCK
EAST LAGOON
BRIDGE CREEK
ROTENONE LAGOON
BRIDGE BAY
GOLD POINT
WEST LAGOON
LITTLE THUMB CR. & LAGOON
PELICAN CR.
PELICAN LAGOON
MARY BAY
STEAMBOAT PT.
STEVENSON ISLAND
ARNICA CR.
LITTLE ARNICA CR.
SAND PT.
CUB CR.
ARNICA LAGOON
ELK PT.
CLEAR CR.
PUMICE PT.
DOT ISLAND
BREEZE PT.
WOLF PT.
PACK PT.
BREEZE PT. & LAGOON
FRANK ISLAND
COLUMBINE CREEK
WOLF PT. LAGOON
SOLUTION CR. & LAGOON
PROMONTORY PT.
FLAT MT. ARM
WEST THUMB CR.
BED ROCK CR.
SOUTH ARM
SOUTH EAST ARM
N
BEAVER DAM CR
MOLLY ISLANDS
UPPER YELL. RIVER
YELLOWSTONE LAKE
YELLOWSTONE NATIONAL PARK
WYOMING
PEALE ISLAND
CHIPMUNK CR. & LAGOON
GROUSE CR.
SCALE IN MILES
0 1 2 3
TRAIL CR.
SOUTH ARM LAGOON

West Thumb Boat Landing, in Arnica Lagoon and in Bridge Bay East Lagoon. On a per net basis the greatest number of fish caught were in Arnica Lagoon (Tables 11 and 13).

Longnose suckers, although distributed around the entire lake, are congregated in certain localized areas. From a limited amount of tagging by Brown and Graham (1953), they concluded longnose suckers have a restricted range; most tags were recovered from longnose suckers in the same general area where they were tagged. In July and August, 1959, large numbers of longnose suckers were found in almost all lagoons sampled (Table 11). The greatest concentrations of longnose suckers, as inferred from experimental gill net data, in lagoons are in Arnica Lagoon, South Arm Lagoon and Breeze Point Lagoon. In the lake itself the largest densities are near Beaver Dam and Trail Creeks in the South East Arm and in Mary Bay; other areas where many longnose suckers are found include: the Fishing Bridge and Pelican Creek area, near Arnica Creek, and the Lake Station area (Table 10).

The largest number of both cutthroat trout and longnose suckers caught in experimental gill nets on a per net basis was in lagoons. The areas where both species are found in heavy concentrations include: Mary Bay, Chipmunk Creek Lagoon, Little Thumb Creek Lagoon, Arnica Lagoon and Bridge Bay East Lagoon.

Juvenile longnose suckers are much more dependent on lagoon areas than juvenile cutthroat trout. Lagoons are used more by adult cutthroat trout than those in the intermediate group. In the lake 43.6 percent of the cutthroat trout found were under 300 millimeters, whereas in the lagoons 23.5 percent of the cutthroat trout found were under 300 mm.

Table 10. Number of fish caught by area on a per net basis in Yellowstone Lake in 1957, 1958 and 1959 in experimental gill nets

Location	No. nets set	No. suckers per net	No. trout per net
Pelican Creek area	2	1.00	17.50
Mary's Bay	2	10.00	13.00
Clear Creek area	9	1.33	3.78
Mouth South East Arm	2	--	12.50
Center South East Arm	4	--	12.00
Beaver Dam Creek area	1	12.00	3.00
Trail Creek area	7	5.00	9.00
Molly Island area	1	--	18.00
South Arm	29	.14	10.03
Frank Island area	3	--	15.33
Wolf Point	2	.50	16.50
Flat Mountain Arm	1	--	1.00
Solution Creek area	2	--	11.50
Arnica Creek area	7	2.00	6.29
United States National Park Service boat dock	17	2.53	9.29
Fishing Bridge area	5	2.20	9.00
Stevenson Island area	3	.33	8.33

Table 11. Number of fish caught by area on a per net basis in Yellowstone Lake lagoons in 1959 in experimental gill nets

Location	No. nets set	No. suckers per net	No. trout per net
Pelican Lagoon	1	--	--
Chipmunk Creek Lagoon	1	10.00	9.0
South Arm Lagoon	1	39.0	8.0
Wolf Point Lagoon[a]	1	--	--
Breeze Point Lagoon	1	27.0	2.0
West Thumb Creek Lagoon	1	4.0	12.0
Little Thumb Creek Lagoon	1	21.0	20.0
Arnica Lagoon	1	42.0	25.0
Bridge Bay West Lagoon	1	18.0	8.0
Bridge Bay East Lagoon	3	9.33	15.0
Stevenson Island Lagoon	2	15.5	1.5

[a]Lagoon completely closed off from the lake by wave action

In the lake 41.6 percent of the longnose suckers found were under 300 mm., whereas in the lagoons 70.1 percent of the longnose suckers found were under 300 mm. (as found with tepxerimental gill nets that effectively caught fish above 150 mm.). Comparing both species in the lake there were 43.6 percent cutthroat trout and 41.6 percent longnose suckers under 300 mm. of all fish of each species caught in the lake. If both species caught in lagoons under 300 mm. are compared, 23.5 percent of the trout and 70.1 percent of the suckers were found in this habitat (Table 12).

Table 12. Percentage distribution of longnose suckers and cutthroat trout in Yellowstone Lake and its lagoons by size groups from experimental gill net data collected in 1957, 1958 and 1959 expressed on a per net basis

Size groups in millimeters	Percentage in each size group by species and area			
	Cutthroat trout		Longnose sucker	
	Lake	Lagoons	Lake	Lagoons
101-150	--	.7	--	.5
151-200	11.7	9.9	4.9	15.2
201-250	14.7	6.3	23.9	34.5
251-300	17.2	6.6	12.8	19.9
301-350	28.5	18.4	14.8	10.1
351-400	23.4	39.9	23.6	14.5
401-450	3.9	17.2	15.5	4.8
451-500	.6	1.0	4.5	.5

Cutthroat trout in the 50-150 mm. range are distributed in all areas of the lake and lagoons as revealed by gill net, seine and minnow trap data. They were not heavily concentrated in any area sampled. Seining and observation during the first part of June in 1959 revealed many young trout in lagoons in the South Arm. Young trout are found in the littoral zone of the lake under many habitat conditions and are not as confined to a particular habitat type as other species of fish in Yellowstone Lake.

Longnose suckers in the 50-150 mm. range were found in greatest concentrations in minnow gill nets in the West Thumb Boat Landing Lagoon, Trail Creek Lagoon, Rotenone Lagoon, Arnica Lagoon, Breeze Point Lagoon and Yellowstone River Lagoon (Table 13). They were taken by seining only in lower Pelican Creek (Table 15). Minnow traps captured them most frequently in Pelican Creek; but also near the U. S. National Park Service Boat Dock, Arnica Creek Lagoon, Little Thumb Creek Lagoon and Pelican Creek Lagoon (Table 16).

The general distribution of redside shiners, lake chub and longnose dace is given in Figure 3. The distribution of these species corresponds closely to areas near the Yellowstone Highway and includes the northern part of Yellowstone Lake and most of the West Thumb area. Of these three species only one lake chub was found across the lake; this was in Breeze Point Lagoon. Few longnose dace are found in the lake itself; they are mostly restricted to lagoons and tributary streams. Longnose dace are most numerous in the Yellowstone River Lagoon near Fishing Bridge, near the National Park Service boat dock, in the lagoon that was rotenoned, Bridge Bay and Pelican Creek Lagoons. Lake chub are abundant in West Thumb Creek Lagoon, Arnica Lagoon, Bridge Bay East Lagoon, South West Thumb Lagoon, Pelican Lagoon and near Gull Point in the lake (as inferred from gill net, seine and minnow trap data) (Tables 13, 14, 15 and 16).

Redside shiners, although found in many areas of the northern part of the lake, are in largest concentrations in the Pelican Creek, Bridge Bay and West Thumb areas and their lagoons, and in the Lake Station area. The largest concentrations found by minnow gill nets (considered on a per net basis) were in the area between docks of the U. S. National Park Service boat dock at Lake Station, the Rotenone Lagoon, Pelican Lagoon, Bridge Bay and Mary Bay (Tables 13 and 14). By seining (considering results on a 1,000 square foot basis) the largest numbers were caught in Pelican Creek Lagoon, Little Thumb Creek Lagoon, lower Pelican Creek and Bridge Bay West Lagoon (Table 15). In minnow traps (considering data on a per day basis) the largest number of redside shiners were caught in Pelican Creek Lagoon (Table 16).

The fry of cutthroat trout, longnose suckers, redside shiners, lake chub and longnose dace are all found in much the same habitat, distributed in the same areas as juveniles and adults. With the exception of lake chub fry, the fry of all species are congregated in largest numbers in shallow pools of tributary streams. In the lake and lagoons fry were observed in shallow areas usually in association with emergent aquatic plants. The fry of suckers, shiners, chub and dace were observed only in lagoons and protected areas of the lake; trout fry, although found in great numbers in these areas, are not as dependent upon them as other species. Trout fry are found in the open lake in shallow water under all habitat conditions; however, the largest concentrations are in areas that fry of other species depend on.

Table 13. Number of fish caught by area, expressed on a per net basis, in Yellowstone Lake lagoons from August 5 to September 5, 1959, in 32 minnow gill nets[a]

Location	No. nets set	No. fish caught per net: Cutthroat trout	Longnose suckers	Redside shiners	Lake chubs	Longnose dace
Pelican Creek Lagoon	2	--	.50	17.00	.50	--
Beaver Dam Creek Lagoon	1	--	--	--	--	--
Trail Creek Lagoon	2	6.00	2.50	--	--	--
Wolf Point Lagoon[b]	1	--	--	--	--	--
Breeze Point Lagoon	2	.50	1.50	.50	.50	--
South West Thumb Lagoon	1	10.00	1.00	1.00	2.00	--
West Thumb Creek Lagoon	1	--	---	--	16.00	--
West Thumb Dock Lagoon	2	1.00	--	--	--	--
West Thumb Boat Landing Lagoon	1	--	3.00	--	1.00	--
Roetnone Lagoon	4	.75	2.25	19.00	1.25	2.75
Arnica Lagoon	6	.33	1.83	1.50	15.67	.17
Gull Point Lagoon[b]	2	--	--	--	--	--
Bridge Bay West Lagoon	1	--	--	31.00	--	--
Bridge Bay Center Lagoon	1	--	--	--	--	--
Bridge Bay East Lagoon	3	--	--	13.00	6.70	--
Yellowstone River Lagoon	2	--	1.50	--	--	7.00

[a]Most fish were between 50 and 150 millimeters.

[b]Lagoons closed off from the lake by wave action

Table 14. Number of fish caught by area, expressed on a per net basis, in Yellowstone Lake from August 4 to September 6, 1959, in 41 overnight minnow gill net sets

	No.	No. fish caught per net				
Location	nets set	Cutthroat trout	Longnose suckers	Redside shiners	Lake chubs	Longnose dace
Storm Point	1	--	--	--	--	--
Mary's Bay	5	--	--	4.60	--	--
Trail Creek Bay	3	4.00	1.67	--	--	--
Molly Island area	2	1.50	--	--	--	--
Promontory Point	1	8.00	--	--	--	--
Peale Island area	2	.50	--	--	--	--
Flat Mountain Arm	2	3.50	--	--	--	--
West Thumb Creek area	2	.50	--	--	--	--
Little Thumb Creek area	2	.50	.50	.50	--	1.50
Arnica Creek area	2	--	--	--	--	--
Pumice Point	1	1.00	--	9.00	--	--
Sand Point	2	3.50	--	--	--	--
Gull Point	2	11.00	.50	--	2.50	--
Bridge Bay	2	--	--	15.50	--	2.00
Between landings of United States National Park Service boat dock[b]	3	2.33	.33	115.00	--	.33
United States National Park Service boat dock area	1	2.00	--	10.00	--	--
Stevenson Island area	2	--	--	--	--	--

[a]Most fish caught were between 50 and 100 millimeters total length.

[b]Fish were observed in this area in large numbers before gill nets were set; this data should not be considered on an equal basis with other minnow gill net data.

Note: Nets set below 15 feet are not considered in this data as no fish were taken in this size group below this depth.

Table 15. Number of fish caught per 1,000 square feet seined in Yellowstone Lake and tributaries in June, July and August 1959

Location	Area seined in 1,000's of square feet	Date	No. of fish per 100 square feet Trout	Suckers	Shiners	Chub	Dace
Peale Island area	15.10	6-2	--	--	--	--	--
South Arm Lagoon	11.35	6-2	1.23	--	--	--	--
Grouse Creek Bay	22.50	6-3	.09	--	--	--	--
Chipmunk Creek Bay	22.50	6-4	.53	--	--	--	--
South Arm area	45.00	6-11	--	--	--	--	--
Lower Pelican Creek	3.75	7-6	--	--	2.13	--	.27
	11.25	7-28	7.11	3.11	1.96	.27	1.42
Upper Pelican Creek	6.25	7-28	7.52	--	--	--	5.28
Pelican Creek Lagoon	1.25	6-19	--	--	27.20	--	--
	.80	6-25	--	--	33.75	--	1.25
Lake near Pelican Creek	12.00	6-19	.33	--	.25	--	--
Meadow Creek Lagoon	2.50	6-23	--	--	--	--	--
Beaver Dam Creek Lagoon	2.10	6-23	1.43	--	--	--	--
Little Thumb Creek Lagoon	1.90	6-24	--	--	2.63	--	--
Lake near Clear Creek	2.87	6-25	.35	--	--	--	--
Lake near Cub Creek	3.08	6-25	--	--	--	--	--
Mary Bay	2.25	6-25	--	--	--	--	--
Arnica Creek Lagoon	2.58	6-26	--	--	--	--	--
Frank Island Lagoon	.16	6-30	--	--	--	--	--
Lake by Frank Idland	.75	6-30	--	--	--	--	--
Stevenson Island Lagoon	2.25	7-1	--	--	--	--	--
Lake by Stevenson Island	3.75	7-1	--	--	--	--	--
Solution Creek Lagoon	6.00	7-1	--	--	--	--	--
Lake by Solution Creek	2.25	7-1	--	--	--	--	--
Bridge Bay West Lagoon	2.58	8-6	--	--	1.16	--	--
Bridge Bay	2.58	8-6	--	--	--	--	--
West Thumb Dock Lagoon	3.75	8-24	1.60	--	--	--	--
Lake near Meadow Creek	3.00	6-23	.67	--	--	--	--

Table 16. Number of fish caught per day in minnow traps set in Yellowstone Lake and its lagoons in June and July 1959

Location	No. days fished[a]	No. of fish caught per day				
		Cutthroat trout	Longnose suckers	Redside shiners	Lake chub	Longnose dace
Peale Island area	8	.12	--	--	--	--
Chipmunk Creek Lagoon	4	1.00	--	--	--	--
Grouse Creek Mouth	4	---	--	--	--	--
South Arm Lagoon	12	--	--	--	--	--
Lake Station area	24	---	--	--	--	--
United States National Park Service boat dock	24	---	.25	--	--	4.17
Pelican Creek Lagoon	58	.02	.02	1.09	.19	.07
Lake near Pelican Creek	4	.50	--	--	--	--
West Thumb	8	--	--	--	--	--
Arnica Creek Lagoon	98	.02	.12	.29	.72	.11
Little Thumb Creek Lagoon	114	.02	.09	.04	.04	.12
Frank Island Lagoon	8	--	--	--	--	--
Stevenson Island Lagoon	6	--	--	--	--	--
Mouth of Arnica Creek	78	--	--	--	.08	.04
Pelican Creek by weir	24	.08	.83	.12	--	.58
Gull Point Lagoon	52	--	--	--	--	--

[a]The number of days fished often includes data from several minnow traps.

It is apparent, from all gill net, seine and minnow trap data (Tables 13, 14, 15 and 16), that distribution interactions are greatest in lagoons and tributary streams rather than in the lake itself. Cutthroat trout, longnose suckers, redside shiners and lake chub are found in association in Breeze Point Lagoon, South West Thumb Lagoon, Rotenone Lagoon, Arnica Lagoon, Pelican Creek Lagoon, Pelican Creek and Little Thumb Creek Lagoon.

The largest concentrations of juvenile cutthroat trout in lagoons occurs in areas where the density of other species is low, suggesting an intolerance between species. Cutthroat trout are more versatile in in their habitat requirements than other species present, but, as the lagoons and bays include many of the most productive parts of the lake, competition may have a detrimental effect on the trout population and result in a reduced growth rate and higher mortality in the juvenile stage of development. The high concentrations of other species and the low concentrations of trout in northern lagoons suggests active competition is already present in these areas.

Vertical distribution

In Yellowstone Lake 113 experimental gill net sets were made at various depths up to 150 feet in 1957, 1958 and 1959. Cutthroat trout were found to a depth of 130 feet; longnose suckers to a depth of 50 feet. Rawson (1951) found that longnose suckers were common from 10 to 20 meters in depth in Great Slave Lake but rarely below 30 meters; largest numbers were found under 15 meters in depth. Odell (1932) reported longnose suckers were usually found in water 15 to 30 feet in depth in New York lakes. In Yellowstone Lake the depth distribution of cutthroat trout and longnose suckers is shown on a per net basis in Figure 4. In water less than 26 feet deep (on a per net basis) 59.8 percent of the trout and 73.8 percent of the suckers were found in Yellowstone Lake; in water less than 51 feet deep 88.7 percent of the trout and 100 percent of the suckers occurred (Table 17).

Table 17. Percentage of cutthroat trout and longnose suckers occurring between various depths and accumulative percentage to the depth specified in Yellowstone Lake in 1957, 1958 and 1959[a].

Depth in feet	Cutthroat trout		Longnose suckers	
	Percentage found	Accumulative percentage	Percentage found	Accumulative percentage
0-25	59.8	59.8	73.8	73.8
26-50	28.9	88.7	26.2	100.0
51-75	9.2	97.9	--	--
76-100	1.8	98.7	--	--
101-125	No nets were set in this depth range.			
126-150	1.3	100.0	--	--

[a]Data from 113 experimental gill nets expressed on a per net basis.

Depth distribution by size groups of cutthroat trout and longnose suckers is considered (Tables 18 and 19) from experimental gill net data. (Fish are usually 150 mm. long or more before they are effectively caught in these nets.) Suckers caught between 151 and 200 mm. total length were caught in water less than 11 feet deep; trout in this same size group were caught at most depths up to 85 feet. No significant difference in depth distribution was found of trout and suckers from 201 to 450 mm. The fish of both species over 451 mm. were all found in water less than 36 feet deep.

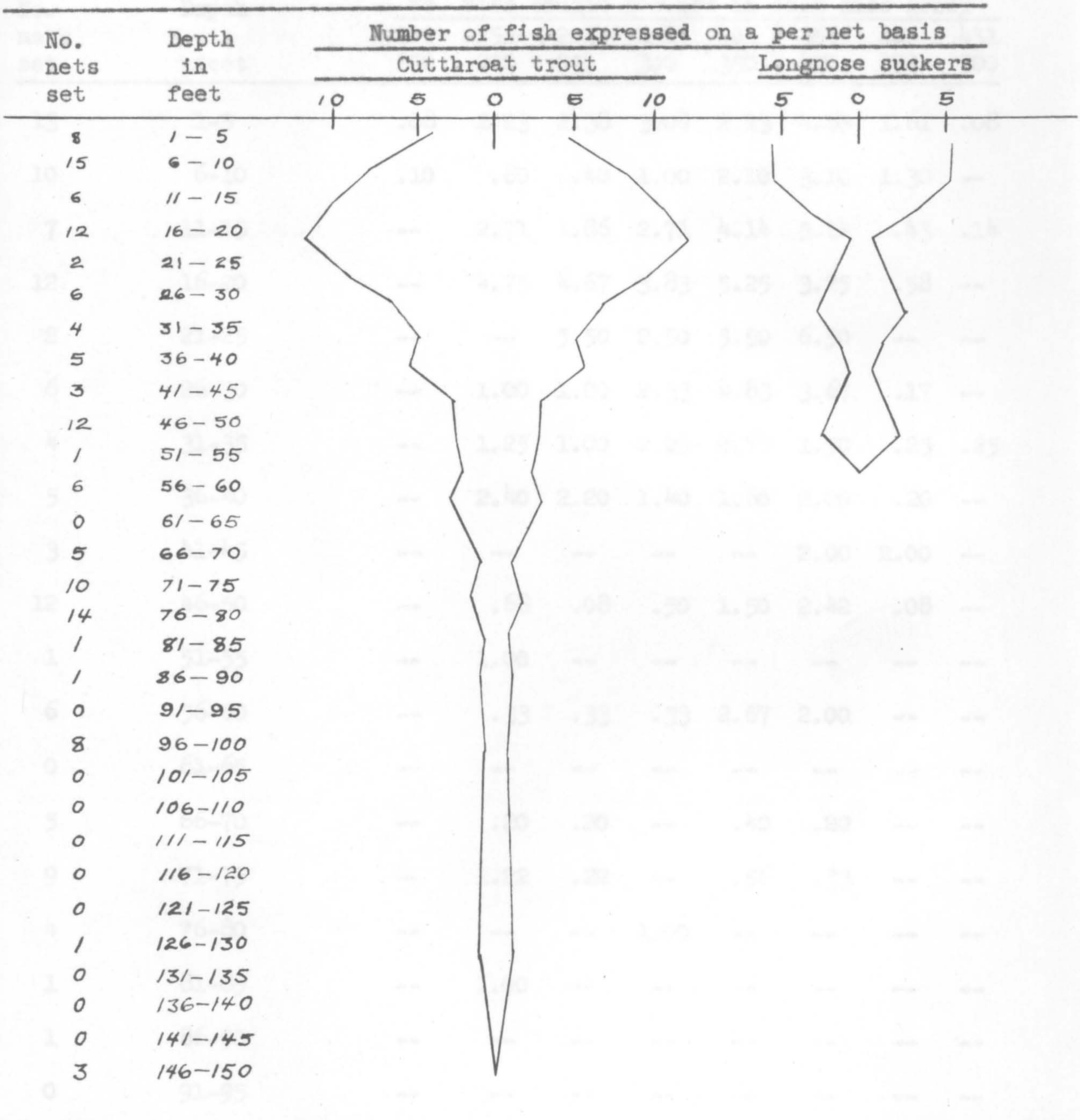


Figure 4. Depth distribution of cutthroat trout and longnose suckers, expressed on a per net basis, from 113 experimental gill nets set in Yellowstone Lake in the summers of 1957, 1958 and 1959

Table 18. Depth distribution of cutthroat trout by size groups from 113 experimental gill nets set in 1957, 1958 and 1959 in Yellowstone Lake.[a]

No. nets set	Depth in feet	No. fish caught per net in each size group 100-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500
13	1-5	.08	2.23	2.38	3.00	2.23	4.85	1.61	.08
10	6-10	.10	.80	.40	1.00	2.10	3.10	1.30	--
7	11-15	--	2.71	1.86	2.71	4.14	5.14	.43	.14
12	16-20	--	4.75	4.67	3.83	5.25	3.25	.58	--
2	21-25	--	--	5.50	2.50	5.50	6.50	--	--
6	26-30	--	1.00	1.00	2.33	4.83	3.67	.17	--
4	31-35	--	1.25	1.00	2.25	2.75	1.50	.25	.25
5	36-40	--	2.40	2.20	1.40	1.60	2.00	.20	--
3	41-45	--	--	--	--	--	2.00	2.00	--
12	46-50	--	.68	.08	.50	1.50	2.42	.08	--
1	51-55	--	1.00	--	--	--	--	--	--
6	56-60	--	.33	.33	.33	2.67	2.00	--	--
0	61-65	--	--	--	--	--	--	--	--
5	66-70	--	.20	.20	--	.40	.20	--	--
9	71-75	--	1.22	.22	--	.56	.33	--	--
4	76-80	--	--	--	1.00	--	--	--	--
1	81-85	--	1.00	--	--	--	--	--	--
1	86-90	--	--	--	--	--	--	--	--
0	91-95	--	--	--	--	--	--	--	--
8	96-100	--	--	.12	.12	.12	.12	--	--
(See footnote b)									

[a]Four nets were set October 15, 1958, two nets were set September 6, 1959; the remaining nets were set in July and August.

[b]Four nets set below 100 feet; one net set at 130 feet had one fish.

Table 19. Depth distribution of longnose suckers by size groups, from 36 experimental gill nets set in 1958 and 1959 in Yellowstone Lake

No. nets set	Depth in feet	No. fish caught per net in each size group[a] 100–150	151–200	201–250	251–300	301–350	351–400	401–450	451–500
7	1-5	.14	4.71	6.00	1.00	.29	.57	--	.14
8	6-10	--	1.62	6.62	4.62	4.13	3.50	1.12	--
3	11-15	--	--	--	1.67	2.00	4.33	2.33	.33
4	16-20	--	--	.25	.50	.75	.25	1.75	.75
2	21-25	--	--	1.00	--	1.00	1.00	--	--
3	26-30	--	--	.67	1.00	2.67	1.67	2.67	1.00
3	31-35	--	--	--	.33	--	.33	.33	1.67
3	36-40	--	--	--	.33	.33	.33	.33	--
0	41-45	--	--	--	--	--	--	--	--
3	46-50	--	--	1.33	3.00	3.00	4.67	3.33	--

[a]Lengths in millimeters

Note: Data from gill nets having suckers set in July and August in Yellowstone Lake and lagoons

Small cutthroat trout and longnose suckers taken in minnow gill nets and experimental gill nets between 50 and 200 mm. and all redside shiners, lake chub and longnose dace were all taken in water less than 15 feet deep in the littoral zone. Many fish of all species were caught in minnow traps and by seining in water less than three feet deep in June and early July. Use of minnow traps and seines was carried on only in shallow water. They were not used extensively after the first of August, as these methods failed to catch many fish. Minnow gill netting showed most fish had moved out of the extremely shallow areas during the latter part of July. Water temperatures in the shallow areas of the lagoons reached as high as 78° F. at this time and were undoubtedly responsible for a general movement into deeper water.

Shiners moved into shallow water in lagoons and bays during the first of June; water temperatures were much higher than in the open lake at this time. About the middle of July there was a definite movement into deeper water in lagoons and bays and also in the littoral zone of the lake. In June, although redside shiners of all sizes were found in shallow water, schools of fish in age group I were observed more frequently in more shallow water than schools of older age fish.

No information was obtained about diurnal movements which Crossman (1959) noted in Paul Lake as being a daytime movement into deeper water and a nocturnal movement into shoal areas. He noted that redside shiners were found in Paul Lake in British Columbia on shoal areas in May and June, at the shoal edge in July and August, on the shoal again in September and in water 30 feet deep during the winter months. Redside shiners were studied from June to September in 1959 in Yellowstone Lake; during this period no fish were taken in deep water.

The fry of all species of fish were all observed in water less than three feet deep; when first observed fry were in heaviest concentrations in water less than one foot in depth but later moved out over deeper water.

Relative Population Composition by Species and Habitat

A comparison of the relative number of cutthroat trout to longnose suckers in Yellowstone Lake as taken by experimental gill nets and cotton gill nets requires certain assumptions concerning structures of the species, their habitat, and movement patterns regarding vulnerability to be taken in gill nets. Moyle (1949) stated that when gill net catches are evaluated on a comparative basis, shape and structural differences of fish causing nets to be selective can be disregarded if it is assumed that association and movement patterns for any species of fish would be expected to be similar under similar conditions. Other factors to be considered regarding the use of gill nets for determining relative composition of species include movement of the species, depth distribution, vertical distribution in water strata, and horizontal distribution. In Yellowstone Lake all gill nets were set on the bottom and, assuming all other factors to be equal, one would expect more longnose suckers than cutthroat trout to be captured, especially in the lake itself as distinguished from shallow lagoons where this distinction would not be valid.

From 132 cotton gill net and experimental gill net sets made in Yellowstone Lake and its lagoons in 1957, 1958 and 1959 there were 1,125 cutthroat trout and 554 longnose suckers taken; this is close to a 2 to 1 ratio of cutthroat trout to longnose suckers if gill nets and locations where they were set are considered non-selective. There were approximately 4 cutthroat trout to 1 longnose sucker on a per net basis in the lake, and 3 cutthroat trout to 7 longnose suckers in the lagoons (Table 20).

Considering only data from experimental gill net sets by years, in the lake excluding lagoons, there were considerably more fish of both species taken in 1959 per net than in either 1957 or 1958. The number of cutthroat trout per experimental gill net set was 3.73, 9.96 and 12.91, respectively, for 1957, 1958 and 1959; the number of longnose suckers was .09, 1.52 and 4.61, respectively.

Table 20. Comparison of the relative numbers of cutthroat trout to longnose suckers in Yellowstone Lake and its lagoons in 1957, 1958 and 1959

Area	No. nets set	Number of fish caught on a per net basis: Cutthroat trout	Longnose suckers
Lake	112	8.74	1.78
Lagoons	20	7.30	17.65
Lake and lagoons	132	8.52	4.20

Note: Experimental and cotton gill net data. Overnight sets were made in the lake in 1957, 1958 and 1959; they were made in the lagoons only in 1959.

Depth of setting appeared to be the most important factor contributing to differences noted in catches during these three years. On a per net basis depth distribution data show that 88.7 percent of the cutthroat trout and 100 percent of the longnose suckers are taken in water less than 51 feet deep during spring and summer months. In the three years nets were set the number and proportion of nets set at given depths varied considerably. In 1957, 1958 and 1959, respectively, 22.7 percent, 66.7 percent and 78.3 percent of the nets were set in water less than 51 feet deep. A correlation will be noted in Table 21 between the percentage of nets set in water less than 51 feet in depth and the number of fish caught per net.

Table 21. Comparison of the percentage of nets set in water less than 51 feet in depth with the number of fish caught per overnight gill net set

Year	No. nets set	Number nets set	Percentage of nets in water less than 51 feet in depth	Number trout per net	Number suckers per net
1957	22		22.7	3.73	.09
1958	54		66.7	9.96	1.52
1959	23		78.3	12.91	4.61

Note: Data from experimental gill nets only considering data collected in the lake but not in the lagoons.

On August 26, 1959, rotenone was used to poison a small lagoon approximately two miles east of the intersection at West Thumb. This was done to find the relative composition, numbers and lengths of each species present and to compare this data with gill net catches made in this lagoon prior to poisoning. The area poisoned was approximately 33,750 square feet with a mean depth of 18 inches and a maximum depth of four feet. The extremely shallow area less than six inches deep had few fish and was not considered in poisoning or in the area.

An estimate of the total number of cutthroat trout fry was 4,442; numerous samples of fry collected revealed that these were the only fry present. Other than cutthroat fry the composition of fish in this lagoon was 26 cutthroat trout, 201 longnose suckers, 215 redside shiners, 32 lake chub and 6 longnose dace. There is a close correlation between species composition and the number of fish caught in gill nets if data from rotenone poisoning are compared with data from four minnow gill nets and one cotton gill net on a percentage basis (Table 22).

Table 22. A comparison of the species present in a lagoon of Yellowstone Lake with the results from four minnow gill nets and one cotton gill net

Species	Fish found using rotenone		Fish found in gill nets	
	Number	Percentage[a]	Number	Percentage[a]
Cutthroat trout	26	5.4	6	3.4
Longnose sucker	201	41.9	77	44.0
Redsided shiner	215	44.8	76	43.4
Lake chub	32	6.7	5	2.9
Longnose dace	6	1.2	11	6.3

[a] Percentage of all species

The approximate ratio of fish in this lagoon as determined by rotenone poisoning was 5 cutthroat trout, 42 longnose suckers, 45 redside shiners, 7 lake chub to 1 longnose dace if cutthroat fry are excluded. The ratio as determined from gill net sets was approximately 3 cutthroat trout, 44 longnose suckers, 43 redside shiners, 3 lake chub and 6 longnose dace.

Data suggest that gill nets are selective to species if species of fish in this lagoon are broken into size groups, and the composition of fish caught effectively in minnow gill nets as compared with the same size groups found present in the lagoon. The the 51-125 mm. range redside shiners are much more vulnerable to minnow gill nets than longnose suckers (Table 23). However, considering cutthroat trout and longnose suckers over 200 mm. taken in the cotton gill net there were 3 cutthroat trout to 66 longnose suckers compared with a composition of 4 trout to 4 suckers as disclosed by rotenone. The gill net undoubtedly succeeded in catching most of the fish in this size group as it was set prior to using rotenone.

Table 23. Fish of all species caught in minnow gill nets compared with fish taken by rotenone, considering only fish from 51 to 125 mm., in the rotenoned lagoon

Species	Fish composition by rotenone		Fish composition by gill nets	
	Number	Percentage[a]	Number	Percentage[a]
Cutthroat trout	21	5.2	3	2.9
Longnose sucker	132	32.5	9	8.6
Redsided shiner	215	53.0	76	73.1
Lake chub	32	7.8	5	4.8
Longnose dace	6	1.5	11	10.6

[a]Percentage of all species

No valid conclusion can be made as to the selectivity of cotton gill nets. Minnow gill nets appear to be more selective to redside shiners than longnose suckers, possibly because redside shiners tend to be active swimmers and to congregate in schools, whereas longnose suckers tend to be more sluggish and do not show such a tendency.

Spawning Interactions

Competition for spawning sites may result in use of marginal sites, destruction or superimposition of redds, or physiological reproductive changes. The use of marginal sites may expose fish to abnormal predation which may result in a slower growth rate and low survival. If redds are disturbed by superimposition, fewer fry may emerge.

In Yellowstone the spawning time of cutthroat trout, longnose suckers and redside shiners overlaps to a great degree. Trout spawn from May to late July (Laakso and Cope, 1956), longnose suckers spawn from June through July during the latter part of the cutthroat trout run, and redside shiners spawn in June. Cutthroat trout and longnose suckers spawn only in tributary streams; redside shiners spawn in lagoons and at the mouths of small streams in addition to tributary streams. All three species spawn in gravel riffle areas; cutthroat trout and longnose sucker spawning is restricted to these areas, but redside shiners also spawn over submerged vegetation.

Cutthroat trout dig redds in gravel areas; longnose suckers and redside shiners release demersal adhesive eggs over gravel areas with no nest preparation. It is not apparent that suckers or shiners destroy trout redds. Hayes (1956) stated that competition between trout and suckers for spawning sites and space has not been shown to occur naturally. There may be an intolerance between these species which restricts spawning but it was not observed. It is probable that a limited amount of competition for spawning sites and destruction of eggs between longnose suckers and redside shiners exists. Redside shiners feed while spawning while longnose suckers do not. Longnose sucker or redside shiner eggs may be disturbed by the other species during spawning activities. No information is available on area, time of spawning or spawning interactions for lake chub or longnose dace in Yellowstone Lake.

Competition among cutthroat trout, longnose suckers and redside shiners for spawning sites was not found to be present in tributary streams to Yellowstone Lake. It appears that competition could be more severe between longnose suckers and redside shiners than between either or both of these species and cutthroat trout.

Food Interactions

Riley (1953) stated that two species living on the same food may have different food preferences; the same preference but the inferior species can exist on other types of food; they may exist on the same food but variations in the physical environment may alter their relative feeding efficiency; or they may live on the same food but have different habitat requirements, or be able to adapt to a less favorable habitat.

That two or more species feed on the same organism is not direct evidence that there is competition; the food may be abundant and feeding on it may have little effect on its abundance. There is little indication that food organisms of fish in Yellowstone Lake are limiting factors. Bottom sampling by U. S. Fish and Wildlife Service personnel revealed that in the Fishing Bridge and Lake Station areas, where all five species of fish are found, there is a greater abundance of bottom organisms than in other areas of the lake where only cutthroat trout and longnose suckers are found. Benson[1] has suggested that this may be due to intense fishing pressure in this area.

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[1]Discussion with Dr. Benson

Competition for food undoubtedly occurs with fry of all species in Yellowstone Lake; they are generally found under the same habitat conditions and share a plankton diet. Competition for food is also suggested among juvenile stages of all species and among juvenile cutthroat trout, juvenile longnose suckers, adult longnose dace, adult redside shiners and adult lake chub. Juvenile trout are not found in large numbers in lagoons and bays where other species are abundant; although this fact suggests competition, there is no indication that food is a limited resource in these areas. Elton (1946) and many other investigators have found that the amount of food is generally sufficient for all populations; the limiting factor of population growth is generally something else.

Many authors have suggested that suckers are potential competitors of game fish on the basis of common diets. Hayes (1958) stated it is generally true that best game fish populations are generally found where rough fish are absent. Rawson and Elsey (1948) stated duplication of food suggests competition between rainbow trout and longnose suckers.

To determine food interactions in Yellowstone Lake among longnose suckers, redside shiners and cutthroat trout the food habit data presented earlier are compared with a previous study of food habits of 409 cutthroat trout by Benson. Food habits are considered in relation to relative numbers of each species, their distribution and habitat, and to general abundance of bottom organisms.

Table 24 shows the food habits of cutthroat trout, longnose suckers and redside shiners expressed as total volume of stomach contents by percentage. All three species of fish eat largely cladocerans, amphipods and tendipedids. Daphnia, Hyalella and Gammarus, and

Table 24. A comparison of the summer food habits of cutthroat trout, longnose suckers and redside shiners expressed as percentage by volume of the total stomach contents[a]

Food item	Percentage by volume of the total stomach contents		
	Cutthroat trout	Longnose suckers	Redside shiners
Daphnia	35.9	10.4	.9
Bosmina	--	1.2	2.4
Cyclops	--	3.8	
Diaptomus	3.2		
Hyalella and Gammarus	20.6	29.7	5.5
Unidentified Crustacea		1.1	.2
Hemiptera		Tr.	2.6
Odonata (nymphs)		.1	1.3
Ephemerella			
Nymph	3.8	8.7	
Adult		Tr.	
Plecoptera (nymphs)	.2	.8	
Trichoptera			
Nymph	2.0	3.9	.3
Adult		Tr.	1.2
Tendipedidae[b]			
Larva	1.7	29.5	4.8
Pupa	2.2	3.6	1.6
Adult	11.1		60.7
Tipulidae (larva)			1.3
Unidentified Diptera		Tr.	1.3
Coleoptera		.2	Tr.
Unidentified Insecta	2.4	.4	6.5
Hydracarina	Tr.	Tr.	Tr.
Other Arachnida	Tr.		Tr.
Gastropoda	Tr.		
Pisidium	Tr.	Tr.	Tr.
Trout eggs	Tr.		
Trout	16.8		
Unidentified animal		Tr.	9.3
Filamentous algae		5.5	
Higher aquatic plants		.8	Tr.

[a]Stomachs from 409 trout, 112 suckers and 117 redside shiners were examined with respectively 352, 100 and 100 containing food. Data for trout adapted from a study made by Dr. Norman Benson; data for suckers and redside shiners from Tables 5 and 8.

[b]Includes: Tendipes, Procladius and Prodiamesa species.

Tendipedidae constituted 71.5, 73.2 and 73.5 percent by volume of the total food contents of cutthroat trout, longnose suckers and redside shiners, respectively. Although these items together were similar, notable preferences were exhibited by each species. Daphnia were most important to cutthroat trout comprising 35.9 percent by volume; in longnose suckers they constituted 10.4 percent and in redside shiners only .9 percent. Hyalella and Gammarus were first in importance to longnose suckers, making up 29.7 percent by volume; they constituted 20.6 percent of the cutthroat trout's diet and 5.5 percent of the redside shiner's diet. Amphipods are especially important to cutthroat trout and longnose suckers. If Tendipedidae larvae, pupae and adults are considered together, they were more important than amphipods to longnose suckers; they constituted 33.1 percent of the longnose sucker diet, 15.0 percent of the cutthroat trout diet and 67.1 percent of the redside shiner diet. The preferences of the three species varied as to developmental stages of Tendipedidae; cutthroat trout and redside shiners ate mostly adults, whereas longnose suckers consumed mostly larvae. Although overlapping, the main food items were generally preferred more by one species than the other two. All three species ate mostly animal matter. A trace of higher aquatic plants was found in redside shiner stomachs; filamentous algae and higher aquatic plants constituted 6.3 percent of the longnose sucker diet; no plant material was found in cutthroat trout stomachs. All species consumed miscellaneous organisms but were not dependent on these items for food.

Benson (1958)[1] examined the stomachs of 48 lake chub; 32 had food and were empty, from Squaw Lake near Yellowstone Lake. He found _Gammarus lacustris_ was the most important food item by number and occurrence; _Pisidium_, _Trichoptera_, Tendipedidae larvae, insect fragments and vegetable matter constituted the rest of the diet. Benson concluded from an examination of cutthroat trout and lake chub stomachs that their feeding habits are similar; _Gammarus lacustris_ was the dominant food of both species. (One lake chub was found in a cutthroat trout stomach.) Simon (1946) mentioned that lake chub are carniverous feeding almost entirely on insect larvae; longnose dace feed mostly on plant material, algae and slime, crustaceans, insect larvae and small snails; he also mentioned that longnose dace have been accused of eating the spawn of trout.

Although all five species apparently eat much the same food, there is not complete identity of food habits and preferences seem to vary. Only the summer period was studied; it is possible that competition for food could be more critical in the late fall and winter than during the summer months.

In their feeding habits some species are highly specialized, others partially specialized and others omniverous. As competition is most acute with species that are highly specialized, one would not expect great competition at the present with adult fish in Yellowstone Lake. Cutthroat trout are partially specialized but longnose suckers are omniverous. One would expect longnose suckers to change their food habits rather than to enter into severe competition with cutthroat trout. Preferences were noted with cutthroat trout and longnose suckers, yet these species are apparently versatile.

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[1]Benson, N. G., 1958. Lake chub in Squaw Lake (Indian Pond). Unpublished typewritten report. 5 pp.

Another factor to consider is the spatial feeding habits. Although all species feed largely in the littoral zone, adult cutthroat trout and longnose suckers feed in deeper water than fry and juveniles of these species and juvenile and adult lake chub, redside shiners and longnose dace. The fry of all species undoubtedly feed in shallow areas. Juvenile cutthroat trout and longnose suckers and juvenile and adult redside shiners, lake chub and longnose dace feed in the same general habitat with certain preferences already noted. Certain differences in feeding habits were noted: longnose suckers feed primarily on the bottom; redside shiners feed mostly on the surface; cutthroat trout feed largely in the intermediate strata. These distinctions are important; it is the overlap between these general characteristics where competition for food would be greatest. Both cutthroat trout and redside shiners feed in all areas; longnose suckers rarely feed on top but utilize other strata to advantage.

Overlap in feeding has too often been assumed to be competition and has led to many misconceptions and false conclusions. Usually there is a scarcity or rareness of most species in relation to the amount of available food; this is usually because another factor which is not known is limiting numbers.

Competition for food in fish populations is often inferred by stunted populations, a preponderance of older age fish in proportion to young, a decrease in catch per unit effort of game fish because rough fish are becoming too numerous, or a decrease in the growth rate. Gause (1934) demonstrated that when two species compete for the same food in a given environment the growth rate of both will be reduced and eventually one species may eliminate the other. If both survive in a balanced condition neither species will be able to reach the population potential that would be possible if the other species was absent. In Yellowstone Lake there has been an increase in growth rate with a decrease in trout density due to increased fishing pressure. This could mean either interspecific or intraspecific competition is present. The effect of a reduction of cutthroat trout numbers on other species present is not known, although it is thought other species may have benefited. As bottom organisms appear to be abundant in many areas of intense fishing pressure, it appears that competition between species and within species is more acute with some factor other than food.

Cutthroat Trout

Yellowstone Lake is one of the few areas where Yellowstone cutthroat trout reproduce naturally and maintain good fishing without artificial planting. In the past spawn has been taken from Yellowstone cutthroat trout for planting fish in other areas by many states and for planting back into Yellowstone Lake. At present no spawn is taken and no cutthroat trout are planted in the lake. Even with increasing fishing pressure the catch-per-unit-effort has not declined. The annual catch of cutthroat trout has increased from 200,015 in 1950 to 393,467 in 1959 (Bulkley, 1961). Bulkley stated that the increase in growth rate and decrease in older aged fish are assumed to be the result of increased fishing pressure. He mentioned that this is probably a healthy condition provided it is not accompanied by a decrease in the mean size of the fish caught. A minor increase in growth rate of cutthroat trout could result from a greater depletion of the cutthroat trout population than was expected. He concluded that excessive harvesting of cutthroat will occur in the next few years if fishing pressure continues to increase.

The number of cutthroat trout in the spawning runs of the six tributary streams where fish traps are operated was the highest in 1959 since 1952; Pelican Creek had the highest run since 1949. As catch-per-unit-effort has not decreased even with increased fishing pressure, and as the spawning runs of cutthroat trout in the various streams have not declined, it appears that competition is not acute in Yellowstone Lake at the present. An increased growth rate in cutthroat trout and fewer older age fish with increased harvest suggests interspecific competition is more severe in limiting production than intraspecific competition with other species. Intraspecific competition may limit an increase in cutthroat trout numbers and result in a proportionally smaller increase than would result from a reduction of cutthroat trout alone.

In the future longnose suckers, redside shiners and lake chub may be expected to increase in number and benefit from selective harvest of cutthroat trout. The habitat, distribution, food and feeding habits, and social intolerance of these species as found in Yellowstone Lake may be expected to result in severe competition with cutthroat trout. Hayes (1956) reported that suckers by virtue of their abundance and ecological tolerance must alter any trout producing environment in which they occur. Larkin and Smith (1953) studied the effects of the introduction of redside shiners on Kamloop trout in Paul Lake, British Columbia. This investigation showed: (1) both species were eating the same food; (2) shiners were eating young Kamloop trout; (3) Kamloop trout were eating redside shiners; (4) Kamloop trout were losing one year's growth due to severe competition with redside shiners; (5) catch per unit effort declined even with a decline in fishing pressure; and (6) the introduction of redside shiners resulted in a decline in kamloop trout numbers.

Parasites and Predators

Parasites

A tapeworm (*Ligula intestinalis*) is present in the body cavity of longnose suckers. Few tapeworms are found in longnose suckers in most areas of the lake; however, in the tip of the South Arm over 50 percent of the longnose suckers are infected. Longnose suckers thus infected are apparently in good condition and show no apparent distress.

A small leech (*Illinobdella sp.*) is noted on many longnose suckers and cutthroat trout taken in the lake and its tributaries. Other parasites found on cutthroat trout include a small crustacean (*Salmin-cola sp.*), and a round worm (*Bulbodacnitis sp.*) found in the flesh. Simon (1953) reports a fluke (*Crepidostomum transmarinum*) is also found in cutthroat trout in Yellowstone Lake.

Another parasite noted is an unidentified round worm which was found in the body cavity of one longnose sucker and one redside shiner of those examined.

Predators

Predatory birds of Yellowstone fishes include osprey, herons, mergansers, kingfishers, gulls, terns, cormorants, eagles and pelicans. Mammalian predators are mink, otters, fishers and bears. Longnose suckers, redside shiners, lake chub and longnose dace are undoubtedly eaten by many of the predators and may have some importance as a buffer for cutthroat trout. Brown and Graham (1953) found 23 tags from suckers on the Molly Islands (403 tags were put on longnose suckers); these investigators concluded that these suckers were in a weakened condition from handling and that this may have been the reason for such a large number being taken by pelicans.

The food preference of predators, predator population density, and prey population density are important factors when considering the importance of a buffer species. The food preference of the predators is not known. The predator population density of most species in Yellowstone is high compared with most other areas as animal life, with the exception of fish, is rigidly protected. Longnose suckers are numerous enough to act as a buffer and are found in areas where pelicans are abundant. Redside shiners, lake chub and longnose dace undoubtedly act as buffers to a limited extent in certain areas of the lake; lake chub remains have been found on the Molly Islands. At present, however, it appears the importance of these species as buffers for cutthroat trout is limited.

Interspecific predation of Yellowstone Lake fishes has not been found to occur as suggested from stomach analysis. However, stomach analysis has been done on cutthroat trout from the lake and not in lagoon areas where many redside shiners, lake chub, longnose dace and longnose suckers congregate. Some cutthroat trout stomach analysis has been done with fish from tributary streams; this has revealed only canibalism. Cope (1958) notes that lake chub in Squaw Lake (tributary to Yellowstone Lake) are being used to a small extent for food by cutthroat trout. Larkin and Smith (1954) found interspecific competition between kamloop trout and redside shiners resulted in a decrease in growth rate of kamloop trout thereby making young kamloop trout subject to predation for a longer period of time to a third species, squaw fish. As competition becomes more severe in Yellowstone Lake interspecific predation may become an important factor.

Stenton (1951) reported that longnose suckers were eating brook trout eggs in Banff National Park, but only those exposed and drifting downstream. Brown and Graham (1953) found no evidence of cutthroat trout eggs in longnose sucker stomachs in Pelican Creek. Redside shiner stomachs were analyzed from lagoons where cutthroat fry were abundant, but no fry were found in their stomachs; it is thought this species is predaceous on fish when other food organisms are not as abundant. Weisel and Newman (1951) state redside shiners were eating their own eggs; Simpson (1941), as reported by Weisel and Newman (1951), found shiners feeding on newly released grayling fry. Evidence of cannibalism with cutthroat trout was found in stomach analysis by Welch (1952). He reported heavy predation on cutthroat on cutthroat trout fry by age groups I and II in Arnica Creek.

MANAGEMENT IMPLICATIONS AND SUGGESTIONS FOR FURTHER STUDY

At the present competition between species of fish in Yellowstone Lake is most severe in the fry stage with all species, and the juvenile stages of cutthroat trout and longnose suckers with juvenile and adult redside shiners, lake chub and longnose dace. In the future competition can be expected to become more acute as apparently longnose suckers, redside shiners and lake chub are increasing in number. Increased fishing pressure every year and the selective removal of cutthroat trout will undoubtedly favor the undesirable species.

The problem of rough and undesirable fish control has been approached in many ways with varying degrees of success. Many studies have reported success in an increase of game fish following reduction of rough fish, especially in warm water lakes. Work on cold water lakes has been limited and effects are less well known. Complete removal by poisoning is most effective in rough fish control but is not feasible in large lakes. Certain control procedures will be considered that could help control undesirable species in Yellowstone Lake.

The destruction of suckers entering streams to spawn has unquestionably helped retard the increase in sucker numbers in Yellowstone Lake. It is suggested that this practice be continued in the future on streams where fish traps are now located; if longnose suckers continue to increase it is suggested that fish traps on the Upper and Lower Yellowstone Rivers and other streams be installed to destroy spawning suckers. As many longnose suckers spend their first two or three years of life in lagoons, and as many redside shiners and lake chub move into and out of these areas, fish traps could be installed at the entrance to lagoons and used to destroy undesirable species.

Gill nets would have limited or questionable beneficial effects in the control of undesirable species. In an attempt to improve angling, Rawson and Elsey (1948) used gill nets and seins to reduce the longnose sucker population in Pyramid Lake, Alberta. After longnose sucker removal they found an increase in survival rate of young longnose suckers since fish were first taken in gill nets the year they became sexually mature. Removal was not accompanied by a noticeable improvement of rainbow trout. Minnow gill nets in Yellowstone Lake may help control redside shiners and lake chub; as small longnose suckers were found to avoid these nets, it is doubtful that they would appreciably help control longnose sucker numbers. Experimental gill nets may be of some value in controlling adult longnose suckers.

A limited amount of poisoning carried out in lagoons in June would be beneficial in control of longnose suckers, redside shiners and lake chub. If the lagoons are poisoned in June a maximum number of the undesirable species and a minimum number of cutthroat trout would be killed.

With increasing fishing pressure, which may be expected, regulations should limit the catch and/or gear to insure sufficient cutthroat trout numbers so they will be able to maintain themselves against excessive competition from other species. If control measures for rough fish are initiated soon serious competition may be prevented; this will insure the welfare of cutthroat trout and provide good fishing in Yellowstone Lake in the future.

It is suggested that a study similar to this be conducted in the future to determine the changes in relative composition of fish and their interactions.

A statistically sound quantitative study of bottom organisms in a lagoon at the northern end of Yellowstone Lake, where all five species of fish are found, carried out simultaneously with a similar study of a lagoon at the southern end, where only cutthroat trout and longnose suckers are found, would aid in determining the degree of competition for food and space.

More should be learned regarding the spawning habits of longnose suckers and redside shiners in Yellowstone Lake. A question still exists concerning all areas utilized for spawning by these species.

A paucity of information was found about redside shiner and longnose sucker fry; fry were observed only in tributary streams and in shallow waters of lagoons. Shiner fry were observed in shallow waters and then apparently disappeared; they may have moved into deeper water. More information about fry would be beneficial.

A food habit study through all seasons of fry and juvenile fish of all species, especially where interactions occur, is highly desirable. The food habits of trout in lagoons and bays has been given only superficial attention.

Gill nets set in different water strata from the surface to the bottom throughout the seasons would reveal seasonal vertical and horizontal movements of species. Trap nets could be used to find diurnal and nocturnal movements of species.

DISCUSSION AND CONCLUSIONS

The presence of longnose suckers, redside shiners and lake chub in Yellowstone Lake has concerned sportsmen and biologists since these species have reduced game fish populations in other waters. The interrelations of fish in Yellowstone Lake have been considered by studying the life histories of longnose suckers and redside shiners and their interactions with cutthroat trout. Consideration has been given to the limnology of Yellowstone Lake, its bottom types and organisms, and to habitat preferences of the fish species present. Although all species (cutthroat trout, longnose suckers, redside shiners, lake chub and longnose dace) are found in dense concentrations in lagoon and bay areas, some species prefer this habitat more than others. Juvenile cutthroat trout , juvenile longnose suckers, adult redside shiners, adult lake chub and adult longnose dace were all found in water less than 11 feet deep in the spring and summer months in 1959. Juvenile cutthroat trout, although found in large concentrations in lagoons, were also found in the littoral zone of the open lake and were not as dependent on protected areas as were the other species. Although all species have habitat preferences, they are not confined to a particular habitat type.

In 1959 the distribution of redside shiners, lake chub and longnose dace was restricted to the northern end of the lake. Redside shiners and lake chub, unlike longnose dace, are not indigenous to Yellowstone Lake; they have already increased their range to approximately one-half of the littoral zone of the lake. As there are many other areas of equally suitable habitat in the lake there is no reason to assume that they will not extend their present range. These species will move into areas of preferable habitat first, which also includes the most productive areas for cutthroat trout, and later areas of marginal habitat. Longnose suckers, although still congregated in certain areas, may be expected to increase their range and become more numerous. There are still many areas of excellent habitat in the lake where longnose suckers are either absent or few in number.

Although generalizations have been made about lagoons it should be pointed out that each lagoon is distinct; some lagoons favor certain species more than others because of certain characteristics. Important factors are relative areas at certain depths, bottom types, fauna and flora, amount of water exchange with Yellowstone Lake, and the size and/or number of tributaries entering lagoons. Certain lagoons of similar habitat favor fry of one species more than fry of another species suggesting social intolerance. It is possible that longnose suckers, redside shiners, lake chub and longnose dace, although living with cutthroat trout, are not conducive to large concentrations and are forcing cutthroat trout into less productive areas. Juvenile cutthroat trout, unlike longnose suckers, redside shiners, lake chub or longnose dace, are not usually found in large schools. The avoidance of large concentrations of other species by cutthroat trout is important in evaluating competition.

It appears that fry of all species subsist on a plankton diet in shallow pool areas, preferring association with their own species. At this stage of development there is apparent competition for pools and also for food. Juvenile fish of all species tend to congregate in areas somewhat deeper than fry but generally in areas where aquatic vegetation is abundant. Although mixed species schools are present, most fish of a particular species tend to school together. At present the most severe competition in Yellowstone Lake appears to be among the fry and juvenile stages of all species and among juvenile cutthroat trout, juvenile suckers, adult redside shiners, lake chub and longnose dace.

The depth distribution of trout and suckers was studied using gill nets; the data included settings up to 150 feet in depth but only considered the distribution near the bottom; no nets were set in the open limnotic part of the lake. The depth distribution study showed that 100 percent of the suckers and 88.7 percent of the trout were found in less than 51 feet of water which indicated the importance of this area in the lake to both species.

Rotenone poisoning in a small lagoon revealed large concentrations of juvenile and adult longnose suckers and redside shiners, and cutthroat trout fry. The composition of fish in the lagoon determined by rotenone poisoning was correlated with minnow gill net data. Redside shiners are especially vulnerable to minnow gill nets; longnose suckers are not very vulnerable. The importance of lagoons for cutthroat fry is suggested from the large concentration found in this lagoon. Fry of other species were not found here but were found in other lagoons suggesting an intolerance.

In Yellowstone Lake and its lagoons the relative number of trout to suckers for 1957, 1958 and 1959 was found to be close to a 2 to 1 ratio as determined by gill net data. The ratio of trout to suckers in the open lake was about 4 to 1; in the lagoons it was about 3 to 7. This data does not consider selectivity of gill nets, location of gill net sets and many other factors. It indicates, however, the relative composition and that large concentrations of longnose suckers are found in Yellowstone Lake.

Parasites are found on cutthroat trout, longnose suckers and redside shiners but there is no indication that they are causing great distress or mortality to their hosts. There are many mammalian and avian predators of fish in Yellowstone as these species are protected. A possible beneficial relation of longnose suckers, redside shiners, lake chub and longnose dace to cutthroat trout is that these species act as a buffer. Interspecific predation in fish was not found in Yellowstone Lake; cannibalism was noted with cutthroat in tributary streams.

Competition for spawning sites is not considered important although there is an overlap in time and places of spawning. There is no evidence that longnose suckers or redside shiners destroy the redds of cutthroat trout. Destruction of redside shiner eggs by longnose suckers or longnost sucker eggs by redside shiners is possible.

There is a definite overlap in the food habits of cutthroat trout, longnose suckers and redside shiners; other food habit studies indicate this overlap also includes chub. Differences in the feeding habits included a vertical feeding pattern: longnose suckers feed largely on the bottom, cutthroat trout in the middle water strata and redside shiners primarily on the surface; however, these species also feed in other zones as well. Competition for food is not important as yet as there is no indication that food organisms are limited. Bottom organisms were found to be more abundant in the Fishing Bridge and Lake Station areas, where all species were present and longnose sucker numbers are high, than in other areas where only cutthroat trout and few longnose suckers are found. Bottom organisms in lagoons have not been considered quantitatively; competition for food may be an important factor in these areas.

The increase in fishing pressure with no decrease in catch-per-unit-effort, along with an increased growth rate of cutthroat trout and fewer older age fish, suggests that intra-specific competition has been greater than interspecific competition. However, the increased growth rate could mean that competition with other species as well as within species has been acute and that a reduction of cutthroat trout numbers, as well as favoring remaining cutthroat, trout has also favored longnose suckers, redside shiners, lake chub and longnose dace. If fishing pressure continues to increase, as is expected, this will continue to favor the undesirable species.

Undoubtedly the destruction of suckers moving into fish traps has helped control sucker numbers and it is suggested that this procedure be carried out in the future. Other suggested control measures are additional weirs, gill netting, and poisoning of certain lagoons at an optimum time. It is suggested that control measures be initiated before competition becomes severe to insure the welfare of cutthroat trout and provide good fishing in the future.

The effects of interspecific competition are difficult to segregate under natural conditions. It is relatively simple to evaluate competition between two individuals under controlled conditions but very difficult to evaluate competition in wild populations. A valid mathematical model would provide the answer to evaluating competition, but there are so many variables for studying competition in wild fish populations that a formula will be difficult to develop.

Competition as suggested by distributional patterns, habitat preferences, spring spawning in much the same areas, social intolerances, space factors, and overlaps in food and feeding habits is present in Yellowstone Lake. As longnose suckers, redside shiners and lake chubs have recently been introduced and have not yet increased their range to the potential expected competition has not yet become severe in most areas of the lake. Competition in certain lagoon and bay areas is undoubtedly causing unfavorable conditions for cutthroat trout at the present. Social intolerances appear to be important in connection with living room and in limiting cutthroat trout numbers in productive areas occupied by other species. As the numbers of longnose suckers, redside shiners and lake chub increased, competition may be expected to become more severe; cutthroat trout will be forced to use marginal habitat areas and the growth rate may be expected to decline. Selective harvest of cutthroat trout will favor the rough species of fish in Yellowstone Lake unless preventive measures are initiated.

SUMMARY

1. The presence of longnose suckers and redside shiners has aroused concern for the welfare of cutthroat trout in Yellowstone Lake. This study was undertaken to determine the interactions among these species; lake chub and longnose dace are considered to a lesser extent.

2. The general morphology and limnology of Yellowstone Lake are given. Bottom types, flora and fauna are considered in their relationships to fish habitat requirements.

3. Mean calculated total lengths in mm. of 100 longnose suckers were: 26.2, 73.8, 156.6, 236.4, 308.0, 370.6, 418.6, 475.8 and 504.9. Annual increments of growth in mm. were 26.2, 47.8, 83.6, 82.7, 73.3, 64.8, 33.8, 39.1 and 34.9. Most longnose sucker males reach sexual maturity in age group V, females in age group VI spawning from the first week in June to the third week in July in Yellowstone Lake's tributary streams. They spawn adhesive demersal eggs over gravel beds with no redd preparation.

4. Longnose sucker fry are found in shallow protected pools in Yellowstone Lake. Juvenile longnose suckers are found mostly in lagoons and protected bay areas. Adults are found in lagoons and bay areas and in other areas of the lake having a silt bottom.

5. Stomach analysis of adult longnose suckers showed Tendipedidae larvae were most important by occurence; Daphnia were most important by number. By volume the most important food items were Hyalella and Gammarus which constituted 29.7 percent of the total volume and

Tendipedidae larvae which constituted 29.5 percent, Daphnia, Ephemerella nymphs and filamentous algae followed. No important seasonal differences were found during the period under investigation.

6. Mean calculated total lengths in mm. of redside shiners by year of life were 47.3, 67.3 and 91.2. Annual increments of growth were 47.3, 24.0 and 21.8. Redside shiners reach sexual maturity in age group II and spawn adhesive demersal eggs in lagoons and tributary streams to Yellowstone Lake.

7. In the spring most shiners were found in shallow areas of lagoons and bays; they later moved into deeper water.

8. Stomach analysis of redside shiners showed Tendipedidae adults were most important by number followed by Hyalella and Gammarus, Bosmina, Tendipedidae larva and Daphnia. By occurrence Tendipedidae adults, Hyalella and Gammarus and Daphnia were most important; by volume Tendipedidae adults constituted 60.7 percent by volume of the total stomach contents.

9. Competition with fish is largely for food, space, spawning sites and factors of the physical environment.

10. Cutthroat trout are found in all areas of Yellowstone Lake, its bays and lagoons; longnose suckers are found in most areas but are concentrated in certain localized areas. Redside shiners, lake chub and longnose dace are found largely in areas close to the Yellowstone Lake highway. The fry of all species are found in shallow pool areas or near the surface in shallow water. Fry are found in greatest concentrations in tributary streams; cutthroat fry are not as dependent as other species fry on the habitat of protected areas.

11. From all gill net, seine and minnow trap data it is apparent that greatest interactions occur in lagoons and other protected areas.

12. From experimental gill net data, 88.7 percent of the trout and 100 percent of the suckers were taken in water less than 51 feet deep. All redside shiners, lake chub and longnose dace were taken in water less than 11 feet deep.

13. From gill nets set in Yellowstone Lake and its lagoons in 1957, 1958 and 1959, not considering selectivity as to species or locations, the ratio of trout to suckers was 2:1; in the open lake the ratio was 4:1 and in lagoons 3:7 (approximately).

14. There was no evidence that longnose suckers or redside shiners destroy or damage cutthroat trout redds, physiologically disturb, or otherwise compete with trout for spawning sites.

15. The overlap in food habits of juveniles and adults of all species suggests competition in certain areas. Stomach analysis of cutthroat longnose suckers and redside shiners expressed in volume by percentage revealed that all three species ate largely Daphnia, amphipods and tendipedids; together they constituted 71.5, 73.2 and 73.5 percent by volume of the total food contents of the three fish species, respectively. Differences noted in feeding habits were that redside shiners feed largely on the surface cutthroat trout in the center water strata and longnose suckers primarily on the bottom.

16. An increase in the growth rate of cutthroat trout and a decrease in older age fish suggests competition with other species does not appear to be great as yet. Selective harvest of cutthroat trout in the future and an expansion of the present range of longnose suckers, lake chub and redside shiners will increase competition and favor the undesirable species.

17. Competition appears to be most important with younger age fish, especially in lagoon and bay areas. Other species of fish may be causing a movement of trout out of highly productive areas because of spatial and social intolerances.

18. There was no apparent distress or mortality noted from several parasites occurring in Yellowstone Lake fishes. Longnose suckers, redside shiners, lake chub and longnose dace may have some importance as buffer species. No interspecific predation was noted with fish in Yellowstone Lake; some cannibalism was noted with cutthroat trout.

19. Management possibilities are suggested to control undesirable species and include: fish traps, selective poisoning of certain lagoons, gill nets and regulations.

20. Suggestions for further study include: a study of bottom organisms quantitatively in lagoons, more study of the spawning habits of longnose suckers and redside shiners, a food habits study of fry and juvenile fish of all species, a food habits study of cutthroat trout in lagoon and bay areas, and a study of the distribution and movements of fish in different water strata.

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