Utah Ecology and Life History of the Utah Chub, *Gila atraria,* in Flaming Gorge Reservoir, Utah-Wyoming

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ABSTRACT

The Utah chub is an undesirable and problem fish species in numerous western lakes and reservoirs. The life history and ecology of the chub were studied in Flaming Gorge Reservoir from 1967 through 1971. Density of the species from the first year of impoundment (1963) through 1971 increased dramatically. Speculations are made as to when a population equilibrium would be reached. Body growth was nearly linear and was the fastest yet reported. Fecundity of chubs ranged from 4,900 eggs for a III+ female to 83,800 for V+ female. The species was euryphagic although distribution varied by season on plankton and filamentous green algae. The chub primarily inhabited the pelagic and littoral epilimnion although distribution varied by season and by age-group. The chub spawned amidst vegetation in the eulittoral zone. Suitable spawning habitat varying from marginal to prime made up 42.5 percent of the reservoir eulittoral. Male chubs were mature in their third year of life and most of the females spawned first at age four. Spawning began in June and was completed in August. Young females spawned earlier than older fish. Chub eggs required 130 Temperature Units to hatch in both field and laboratory experiments, which generally occurred in about 72 hours. Although density independent factors were observed to influence year-class strengths, population regulation appeared to be a density-dependent function in the first eight years of impoundment.

Historically, the chub appears to have had a symbiotic relationship with *Salmo*. Speculations on how this relationship evolved and was maintained are made.

INTRODUCTION

The Utah chub, *Gila atraria*, was native to the area inundated by the ancient Pleistocene Lake Bonneville which encompassed much of the Great Basin in Utah, Nevada, and Idaho. The species also ranged naturally outside of the Great Basin above Shoshone Falls in the Snake River drainage (Simon 1939 and 1946, Sigler and Miller 1963). During the past three or four decades, the range of the Utah chub has expanded into the Colorado and Missouri River drainages (Sigler and Miller 1963, Baxter and Simon 1970, Brown 1971). In at least five western states the Utah chub has had a substantial negative effect on salmonid sport fisheries despite the fact that it previously coexisted with a trout species (the cutthroat trout—*Salmo clarkii*) over much of its historic range for thousands of years.[1]

The Tui chub *(Gila bicolor)*, a close relative of the Utah chub, also coexisted with the cutthroat trout in the Great Basin, and with the cutthroat trout and rainbow trout *(Salmo gairdneri)* in California, Oregon and Washington, but a symbiotic *Gila – Salmo* relationship is rare today.

Prior to impoundment of the Green River by Flaming Gorge Reservoir (1962), the Utah chub was not thought to exist in the impoundment basin (Bosley 1960, McDonald and Dotson 1960). It was known, however, from the Ham's Fork of the Black's Fork River less than 100 miles upstream from the impoundment area (Figure 1). The chub was believed to have been introduced in the Ham's Fork and was present in the mid-1950's and reconfirmed in the mid-1960's (unpubl. data, Pinedale office, Wyoming Game and Fish Comm.). Vanicek et al (1970) held the belief that the appearance of the Utah chub in post-impoundment work probably reflected more extensive sampling efforts rather than a change in fish populations. In September 1962, 716 km (455 miles) of the mainstream Green River and its tributaries above the Dam were chemically treated with rotonone to depress undesirable fish populations in favor of more desirable game-fish species (Binns et al undated, Binns 1967) in the new reservoir.

Eleven months following initial impoundment of the reservoir the first Utah chubs were collected in the Henry's Fork Arm (Figure 1) (Eiserman et al 1964). In the years following Utah chubs have become the dominant fish throughout the reservoir. A life history investigation of the Utah chub was initiated in 1967 and continued through 1971 because of the deleterious influence that the species might exert on the salmonid fishery.

DESCRIPTION OF THE AREA

Flaming Gorge Reservoir is located on the Green River in northeastern Utah and southwestern Wyoming (Figure 1). At design pool level (elevation 1,982 m or 6,040') it will be approximately 145 kilometers (90 miles) long, with a surface area of 16,997 hectares (42,000 acres). Surface area during the study varied from 9,136 to 14,548 hectares (26,760-35,920 surface acres). Studies on trout growth (Varley, Regenthal and Wiley 1971), topography, geology and hydrographic features (Eiserman and Stone 1975), plankton (Varley 1967), distribution of fishes, benthic organisms, and diet of salmonids (Eiserman et al, 1967; Wiley and Varley 1975) showed that the habitat grades from oligotrophic nearest the Dam to eutrophic in the Inflow Area (Figure 1). The lower most Canyon Area is narrow, with precipitous walls, well-oxygenated thermally stratified waters, with depths from 61 — 122 m (200 to 400 feet). The Open Hills Area next upstream, an area of littoral bays and shelves, with depths ranging to 61 m (200 feet). The Inflow Area is influenced by the Green and Black's Fork

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[1]Some lacustrine waters known to have had historical coexisting populations of *G. atraria* and *S. clarkii* are: Bear Lake, Utah-Idaho; Utah Lake, Utah; Heart, Jackson, Two Ocean, Enos, and Arizona Lakes, Wyoming.

Rivers, which create a warm and sometimes oxygen deficient zone. Depths range to approximately 24 m (80 feet).

The reservoir has supported one of the mountain-west's outstanding trout fisheries. During the period from 1964 through 1971, as estimated 4.7 million trout were harvested in approximately 1.9 million angler-days (trips).

METHODS

Experimental gillnets were set in each of the three reservoir areas in April and November of each year and the data were combined. Over 216 net-sets were represented. Summer gillnet results were not used due to possible bias associated with the massive chub spawning populations in the littoral zone.
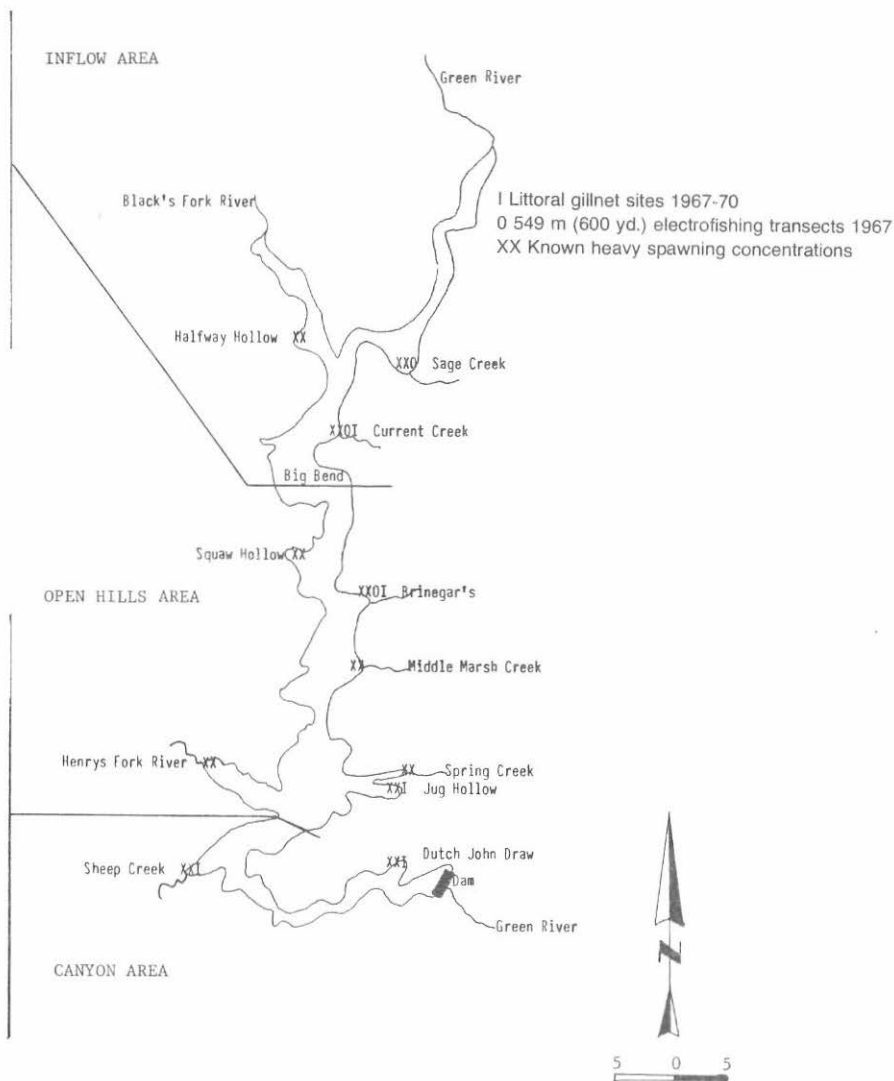

Fig. 1 **Flaming Gorge Reservoir, Utah-Wyoming.**

Gillnets were set overnight during each sampling period and only the hours of darkness were used in computing the catch per gill-net-hour (GNH). Netting activities for chubs over the years have indicated that net efficiency during daylight hours was minimal. There is also a maximum number of chubs that can be netted before the gillnet loses its fishing efficiency.

Annual population trends were determined by spring and fall overnight gillnetting using experimental gillnets 38.1 m (125 ft) long and 1.83 m (6 ft) deep with graduated bar mesh sizes from 19 to 51 mm (¾ to 2 in). Floating and sinking gillnets set in summer months specifically to capture spawning chubs were 30.5 by 1.2 m (100 x 4 ft) and 30.5 by 1.8 m (100 x 6 ft), respectively. Graduated bar mesh sizes ranged from 13 (0.5 in) to 38 (1.5 in) mm. In 1967, spawning fish were also counted and collected at night utilizing an electro-fishing boat (alternating current) along established 549 m (600 yd) transects (Figure 1). Vertical distribution was determined in the Canyon and Open Hills Areas twice yearly using gangs of five vertical gillnets 30.5 m (100 ft) deep and 1.8 m (6 ft) wide. Individual net bar-meshes ranged from 19 (¾ in) to 76 (3 in) mm. Sampling by habitat is defined in Figure 4, along with limnological terms. Water temperatures were monitored in littoral waters using thermometers in which the sensor depth varied between 40 cm to 1.5 m (16-10 in).

In 1967, sampling during spawning was at night using gillnets and an elector-fishing boat. Eulittoral sampling was done with an electrofishing boat along established 656 m (600 yard) transects. Gillnets were used in littoral sampling. In 1968-1969, collections were made using gillnets at Brinegar's Bay and Jug Hollow Bay. Eulittoral net sets were made at 1.2 m (4 ft) depth and littoral sets were made at depths from 3 m (10 ft) to 4.6 m (15 ft).

In all three years sampling was begun prior to spawning and continued at weekly intervals until the completion of the spawning season. In all, 2,263 females were examined and classified as to condition: Ripe — some portion of the egg mass remained or no spawning had yet occurred, or Spent — few or no eggs in the egg membrane. Partially-spent females were common and were used to determine when the spawning period began.

Scales were collected during the summer and were taken from an area below the dorsal fin and above the lateral line. Impressions were made on plastic cards and read using a microprojector at 68X magnification.

All chubs were measured to the nearest millimeter for total length and weighed to the nearest five grams.

Egg incubation was determined in 1969 and 1970 by artificially spawning adults and monitoring eggs and water temperatures under both reservoir and laboratory conditions. Techniques well-known in salmonid culture were used (Leitritz 1960).

Observations on behavior were based on aquaria surveillance and scuba observations represented several hundred hours effort. Chub activities in the littoral zone were easily observed in the clear water of the reservoir from boats, boat docks, cliffs and truck cabs.

POPULATION TRENDS

From 1963 through 1971 trend data in each of the three reservoir areas fitted curvilinear solutions (Figure 2). The Inflow Area showed the greatest population increase beginning in 1964 at 0.2/GNH and increasing to a high of 5.8/GNH in 1970 but showed the poorest correlation over time (r=0.724). The Open Hills Area showed an increase from 0.25/GNH in 1965 to 4.8/GNH in 1971 with a correlation of 0.895. The population expansion of chubs in the Canyon Area lagged behind populations on the other two areas ranging from 0.1/GNH in 1965 to 1.0/GNH in 1970 and 1971, and had a correlation coefficient of 0.93.
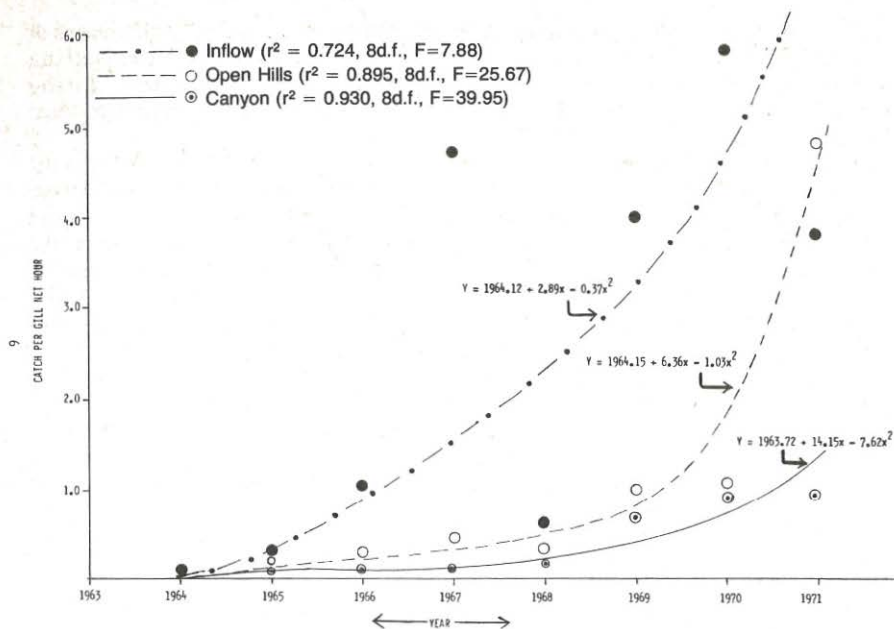
Fig. 2 Flaming Gorge Reservoir, Utah Chub Population Trends, 1963-1971, by Area.

In 1963, forty experimental gillnet sets yielded 1,002 rainbow trout and 4 Utah chubs (plus 280 fish comprising six other species) (Eiserman et al 1964). Since the number of rainbows in the reservoir was known, a simple expansion would suggest that the nettable chub population in the reservoir was a minimum of 1,400 and may have been as high as 9,000.

During seven years of chub population growth the Inflow population showed a 20-fold increase, the Open Hills a 19-fold increase and the Canyon group increased about 10-fold.

AGE AND GROWTH

A polynomial equation best described the body length (TL)-scale radius relationship: $Y = 51.0955 + 2.8655X$ where $Y =$ total body length and $X =$ total scale radius ($F-332.79$, $p = 0.01$, 103 df).

It was expected that the body growth rate would decline as population density increased. Growth actually increased although there were no significant differences between the years 1967-1969 (Table 1).

Table 1.

Growth of Flaming Gorge Reservoir chubs by captive year 1967-1969

Captive year		n	Calculated TL at each annulus				
			1	2	3	4	5
1967	TL	100	80	108	143	178	229
	sd		5.6	13.8	17.4	26.3	19.5
	se		0.6	1.4	.8	5.6	13.8
1968	TL	77	86	128	163	199	244
	sd		7.3	19.4	17.6	25.4	26.1
	se		0.8	2.2	2.0	4.5	8.7
1969	TL	104	81	144	184	212	243
	sd		6.1	18.3	22.7	25.0	32.4
	se		0.6	1.8	2.6	3.7	10.8

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Growth was compared with three natural waters where chubs are enzootic and four reservoirs where the species was introduced and have been long-established. These comparisons clearly showed superior chub growth in Flaming Gorge Reservoir (Table 2). Growth of Flaming Gorge chubs was greatest in the first year of life: 37 percent greater than enzootic populations and 29 percent greater than exotic reservoir populations. Difference decreased steadily thereafter so that by the sixth year Flaming Gorge chubs were 16 percent longer than endemic populations but only 1 percent longer than established reservoir populations.

Table 2.   Flaming Gorge Reservoir Utah chub growth 1962-1967, compared with chub growth from three natural lakes with endemic poplutions and four Utah and Montana reservoirs where chubs are exotic.

Growth catagory	1	2	3	4	5	6	7	8	9
Endemic growth - 3 lakes 1)	52	97	139	175	211	240	267	294	314
Exotic growth - 4 reservoirs 2)	58	117	171	214	243	270	302	323	—
Flaming Gorge Reservoir	82	127	162	200	242	273	—	—	—
growth increment	82	45	35	38	42	31			
standard deviation	6.57	22.9	25.6	28.3	27.8	23.8			
standard error	0.39	1.37	1.66	2.8	6.2	10.6			

Calculated TL at each annulus 3) spans columns 1–9.

1) Heart Lake, Wyo., Dean and Mills (1970); Bear Lake, Utah, McConnell et al (1957); Utah Lake, Utah, Carbine (1936)
2) Panguitch Res., Otter Creek Res., Strawberry Res., Utah, Carbine (1936); Hebgen Lake, Montana, Graham (1961)
3) Some standard lengths converted to total by factor 1.264

When growth data were plotted from hatching through the sixth year of life the result was a significant linear relationship (r=0.984) although a curved line described the fit slightly better (r=0.996). An instantaneous growth rate of 0.177 and nearly linear growth to age six may suggest minimal intra- or inter-specific competition in the reservoir. Fast linear growth is apparently accomplished at the expense of "old" or maximum potential age. Extrapolating from the linear growth equation suggests a maximum theoretical age of 9 years for Utah chubs in Flaming Gorge Reservoir compared with slow-growing enzootic and introduced, though long-established populations (Carlander 1969, Dean and Mills 1970), is a relatively short life span of the species.

A linear regression of log body weight on log total length yielded a relationship described by the equation:

Log Y=4.8984+2.9962 Log X

where X=log total length and Y=log body weight (F=1702, r^2=0.972, 99 df).

The conversion factor computed to predict standard length from total length if one is known was derived from a linear regression. The equation, Y=7.3525+0.8358X where X=total length and Y=standard length, was significant (F=9039, r^2=0.995, 99 df).

DIET

Planktonic organisms and filamentous green algae formed most of the food found in 69 Utah chub stomachs collected in July and November, 1967 (Table 3). In the July sample, *Daphnia* and copeods predominated in stomachs followed by *Spirogyra*. Phytoplankton and fixed filamentous algae were consumed in the fall. The presence of attached, filamentous algae (*Cladophora, Spirogyra*), the amphiod *Hyalella*, and perhaps the Insecta, implies a littoral feeding habit. The remainder of the food items identified could be either littoral or pelagic. The

cladocera, and copepoda and chrysophyta consumption in both months coincided with the abundance of those groups in the reservoir at those times of the year (Varley 1967).

Table 3.　Contents of 69 Utah Chub Stomachs, July and November 1967, Flaming Gorge Reservoir.
Range of T.L. 135-280mm x=189mm

Groups identified from stomachs	Percent occurrence in the total sample	
	n=44 July	n=25 November
Insecta		
Unidentified	—	2.3
Amphipoda		
Hyalella sp.	0.6	—
Cladocera		
Daphnia sp.	23.8	2.3
Copepoda		
Cyclops sp.	4.7	—
Unident. sp.	—	0.9
Nauplii	4.0	—
Rotatoria		
Unident. sp.	0.6	—
Chrysophyta		
Diatoms	—	86.7
Tribonema sp.	—	0.9
Chlorophyta		
Mougeotia sp.	—	3.2
Cladophora sp.	—	0.9
Spirogyra sp.	4.7	0.9
Vegetation		
terrestrial	—	0.9
Organic Debris*	61.7	1.0

*Organic debris was largely unidentifiable plankton remains.

In Fish Lake, Utah, Sigler (1963) found that *Daphnia* and *Gammarus* were most commonly eaten followed by algae. Microcrustacea and the green alga, *Cladophora,* were about equally consumed in a later study on the same lake (Gaufin 1964). Graham (1955) and Olsen (1959) analyzed chub stomachs from two mountain reservoirs and concluded that chubs were versatile feeders. In Two Ocean Lake, Wyoming, John (1959) concluded that chubs less than 170 mm (6.7 in) fork length fed mainly on zooplankton and larger fish were omnivorous, feeding extensively on *Ceretophyllum* and *Myriophyllum.* John also found the remains of cyprinids in chubs over 320 mm (12.6 in) fork length. Jordan and Evermann (1896) stated that chubs were destructive of young trout although they later (Jordan and Evermann 1923) modified this statement to, "It is said to be very destructive to the eggs of trout" but added that the point had never been fully investigated.

It can be concluded that the chub is euryphagic, opportunistic and is obviously successful in a variety of food niches in Flaming Gorge Reservoir (Figure 4).

FECUNDITY

Eggs were counted from 32 female Utah chubs using the water displacement method. As females at ages III + through V + made up the bulk of the spawning

population, the observed average number of eggs per female per age were as follows: III+ 4,911, IV+ 15,600, V+ 83,800. A plot of the relationship between increasing length and an increasing number of eggs shows close agreement with empirical data (Figure 3).
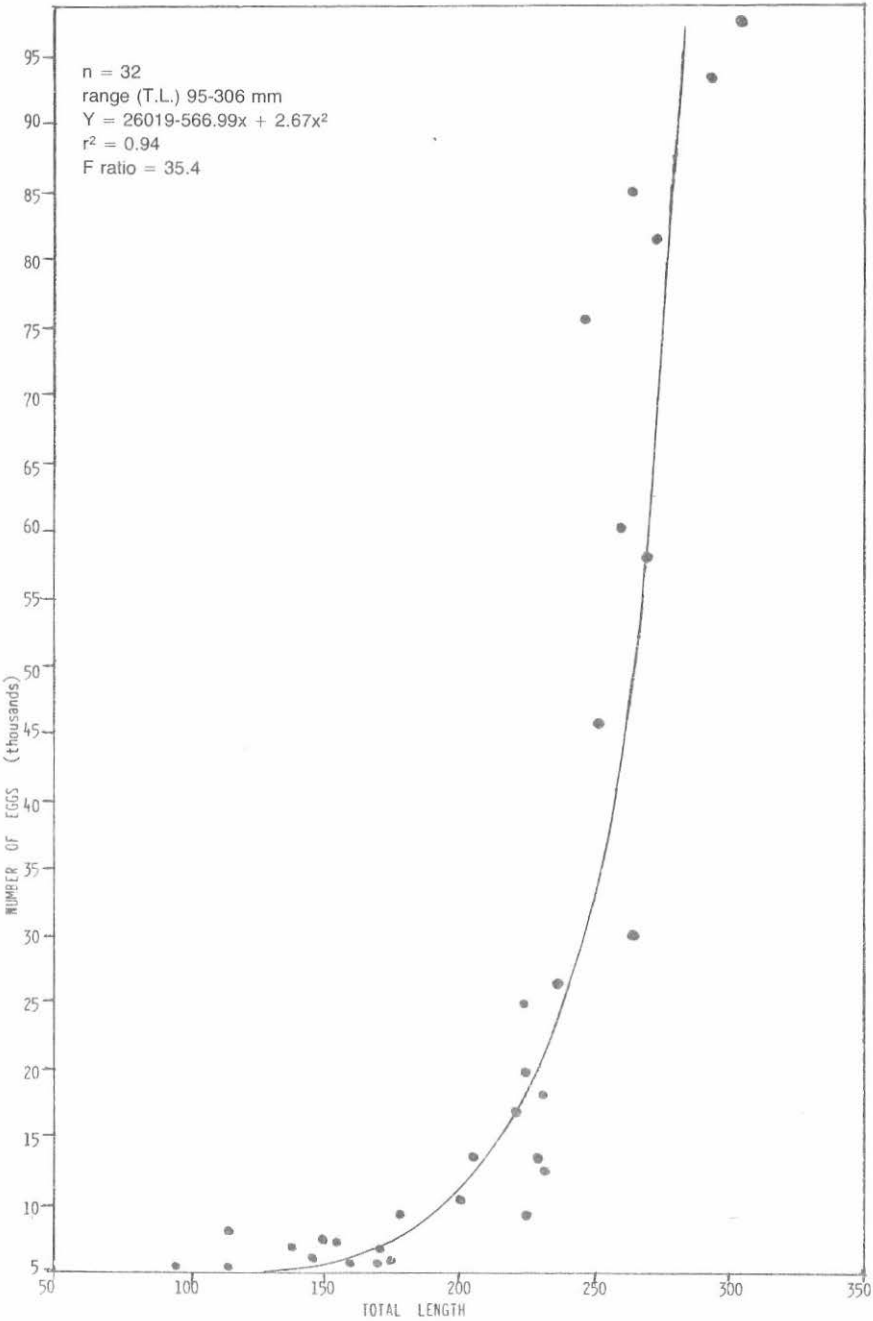

Fig. 3 Predicted and Actual Fecundity of the Utah Chub, Flaming Gorge Reservoir.

The fecundity of Flaming Gorge chubs was substantially higher than the fecundity of comparable size chubs reported from Hebgen Lake, Montana (Graham 1955) and Scofield Reservoir, Utah (Olsen 1959). The average number of eggs per spawning female reported from Hebgen Lake (40,750) and Scofield Reservoir (25,282) were substantially higher than was observed in 1969 in Flaming Gorge (13,841). This is thought to reflect the predominance of younger age females in the 1969 Flaming Gorge population. The vigor of a young, expanding population, not at equilibrium with its environment, may explain the higher fecundity at given sizes.

It is generally accepted that in fishes there is a broad relationship between fecundity and the care accorded the eggs. The high fecundity in the chub is necessary because there is no nest construction or guarding of the eggs.
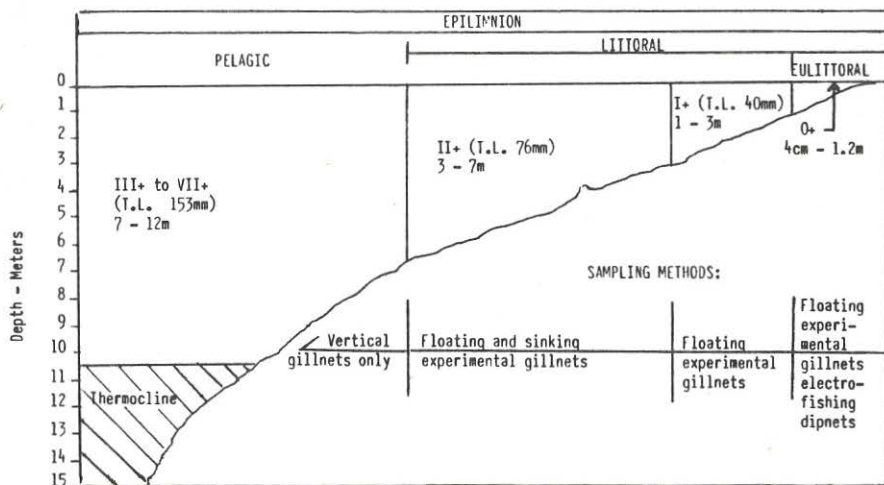

Fig. 4 **Typical summer distribution of the Utah chub in Flaming Gorge Reservoir by age group and habitat association. Limnological terms used in the text are defined and reservoir sampling methods are detailed, 1967-71.**

SEASONAL DISTRIBUTION OF THE CHUB

During the initial 2-3 months of life, fry (0+ fish) schooled along the shoreline in water approximately 4 cm (0.6 in) to 1.2 m (40 in) in depth (Figure 4). Schools were almost entirely associated with aquatic or submerged terrestrial vegetation[2]. During this period, the sensory attributes of the fry were poorly developed; i.e., the fish could be caught with handnets with ease. By approximately 3 months of age, fright reactions external stimuli (i.e. fast movements) had become increasingly acute. "Fright" movements were generally shoreward, usually towards vegetation cover. No diel movements were observed. The 0+ chub remained in the eulittoral zone through the fall and winter months where individuals were occasionally found frozen in shelf-ice on the shoreline margin.

In spring, I+ chubs tended to range lakeward to include water up to approximately 3 m (10 ft) in depth or deeper where vegetation cover was

Table 4.   A Comparison Between the Diet of Utah Chub from Flaming Gorge Reservoir; Hebgen Lake, Montana; and Scofield Reservoir, Utah.

			Percent volume of Utah Chub stomachs		
Group	Hebgen Lake Summer 1948	Hebgen Lake Summer 1953-54	Scofield Res. Summer 1959	Flaming Gorge Summer 1967	Reservoir 3 Fall 1967
Insects, zooplankton	24.3	36.0	27.0	33.7	5.5
Algae, higher aquatics	69.3	19.0	73.0	4.7	92.6
Unidentified material	3.6	9.0	0.0	61.7[4]	1.8

1) Modified from Graham (1955)   2) Modified from Olsen (1959)   3) Present study   4) Mostly unidentifiable plankton remains

available (Figure 4). Sensory development by then required sophisticated sampling techniques (i.e. electrofishing). Throughout the year I+ chubs remained in schools, closely associated with vegetation, but would tend to wander slowly outward from the shore during daylight hours when not being preyed upon by salmonids. No major diel movements nor shifts in the above described pattern were observed. John (1959) was of the opinion that the younger age groups of chubs moved lakeward at night and remained inshore during the day.

Age II+ chubs remain in schools in deeper water (3-7 m, 10-23 ft., Figure 4). Schools generally cruised parallel to the shoreline and near escape vegetation. Chub schools that were approached underwater on bare substrate areas were noticeably apprehensive, whereas those observed over or in vegetated areas were markedly more docile. At some unobserved period between age (late) II+ and when they become (early) age III+ fish, chub venture out into pelagic waters (Figure 4) and, with reference to diel and seasonal behavior, join the mature population. Schooling however, by age and/or size group may remain sharply defined.

Age III+ and older chub distribution and movement were not as clearly defined. Except during the spawning period, mature chubs were found dispersed throughout pelagic and littoral waters although apparently favoring the pelagic epilimnion. Prior to the commencement of spawning (mid-June to mid-July) the majority of the population moves into littoral and eulittoral waters (Figure 5). Netting, electrofishing and scuba observations showed that the pre-spawning[2] and spawning population (both sexes) moved shoreward into the littoral from mid-to-late afternoon and moved lakeward, into pelagic water, by or during the early morning hours.

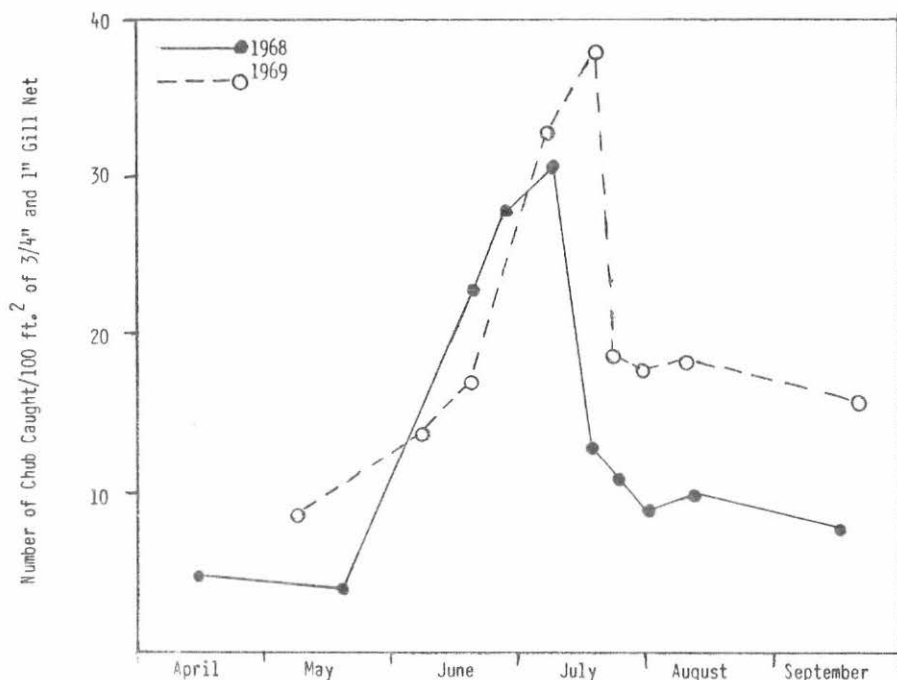Fig. 5   Density of Age III+ and Older Utah Chub in the Littoral Zone, Flaming Gorge Reservoir, 1968-1969.

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[2] The term "pre-spawning population" refers to the aggregation of chubs in the spawning zone several weeks prior to actual spawning activities.

Following spawning distribution again became widespread. The importance of the pelagic epilimnion is evident from vertical gillnet data (Unpublished data, Wyoming Game and Fish Comm.). Pelagic sets indicated that 92 percent of the chubs in a column of water from the surface to 32 m (105 ft) were caught in the upper 5 m (16 ft) of the epilimnion. Over two-thirds of the catch were taken between 1 and 3 m (3-10 ft). The mean capture depth was 3 m (10 ft) and the range extended from 40 cm to 12 m (16 in 39 ft).

Graham (1955) concluded from his study on Hebgen Lake, Montana, that the chub population was concentrated in deep waters in the winter. Gaufin (1964) suspected that chubs in Fish Lake, Utah, spent the winter in deeper (and warmer) waters. Chub distribution data from Flaming Gorge Reservoir generally agrees with the conclusions of Graham (1955), and Gaufin (1964), John (1959) and Olsen (1959) regarding population distribution except for the winter period. Gillnet data from winter sets in Flaming Gorge Reservoir (unpublished data, Utah Wildlife Resources and Wyoming Game and Fish Comm.) indicate that chubs are relatively active throughout the winter in both pelagic and littoral zones. Supportive data were from net sets under the ice and in open waters and applies to both juvenile and mature age groups.

Olsen (1959) concluded from a mark-recapture experiment that the chub does not actively migrate from one area to another (over 500 yards). In Two Ocean Lake, immature chubs were territorial and older chubs "had a tendency" to be territorial (John 1959).

Table 5.

Utah Chub Spawning and Nursery Habitat Estimated to be Available in Flaming Gorge Reservoir in 1967, Elevation 1973m (6015 ft.).

Habitat description	Spawner and fry abundance	Spawning area-km (mi.) and Percent		
		Canyon area	Open Hills inflow areas	Reservoir-wide
Prime Habitat				
gradual sloping littoral; protected from the wind; sand, mud, silt substrate; submerged terrestrial or aquatic vegetation present.*	Very abundant	5.6(3.5) 1.4%	111.8(69.5) 27.9%	117.4(73.0) 29.%
Marginal Habitat				
steep sloping littoral; wind protection variable; sand, mud, silt substrate; vegetation present but less abundant.	Common to sparse	12.9(8.0) 3.2%	40.2(25.0) 10.0%	53.1(33.0) 13.2%
Poor Habitat				
steep or gradual rocky littoral with ledges, slides. Usually little protection from winds; very little or no vegetation.	Chubs seldom observed	79.7(49.5) 19.8%	151.3(94.0) 37.7%	231.0(143.5) 57.5%
Subtotals and totals		98.4(61.0) 24.4%	303.3(188.5) 75.6%	401.5(249.5) 100.0%

*Most of the vegetation was of the submerged terrestrial type. Drowned terrestrial plants were typically intertwined with a vigorous growth of filimentous green algae (Cladophora, Spirogyra). In years of minimal reservoir fluctuation, aquatic vascular plants would appear in shallow, wind protected bays and inlets.
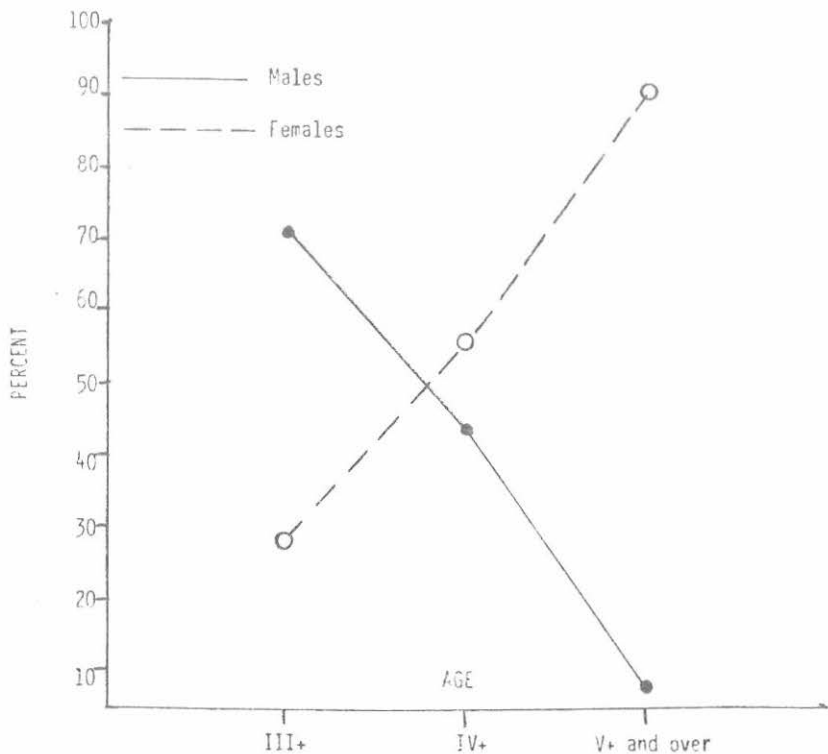
Fig. 6 The Ratio of Male to Female Chub in the Spawning Population, 1967 through 1970, Flaming Gorge Reservoir.

UTAH CHUB SPAWNING

Chub spawned in the eulittoral zone where vegetation was present over a substrate of silt, mud and sand. In Flaming Gorge Reservoir, such habitat was most common in areas of gradual slope with some protection from wind and intensive wave action.

Submerged terrestrial and aquatic vegetation appeared to be the prime factor in the utilization of an area for spawning and nursery purposes. Areas that met all other criteria but lacked vegetation were seldom used. The preferred spawning habitat found in the reservoir was similar to that found for the Utah chub in other studies (Olsen 1959, John 1959, Graham 1961, Gaufin 1964).

Fry, one and most two-year-old chubs generally remain in the same habitat where they were spawned. This feature in their life history protects them from intensive predation by salmonids.

A 1967 survey of the eulittoral zone indicated that approximately 29.3 percent of the reservoir shoreline could be classified as prime spawning and nursery habitat (Table 5). An additional 13.2 percent was categorized as being poor habitat. Prime and marginal habitat in the Canyon Area consisted of only 4.6 percent of the shoreline while, in contrast, 37.9 percent of the eulittoral in the Open Hills and Inflow Areas was considered habitat of prime or marginal quality (Figure 1, Table 5).

Most male chubs were sexually mature in their third year of life; females at age four, the same as has been reported in Hebgen Lake, Montana (Graham 1961), and Fish Lake, Utah, (Gaufin 1964). In Scofield Reservoir, Utah, Olsen (1959) found female chubs matured at age three with males maturing one year

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Table 6. **Age composition of spawning Utah chubs 1967, 1968, 1969, and 1971, Flaming Gorge Reservoir**

% of each age-group in the spawning population

Age group	1967	1968	1969	1971
III	75	57	40	17
IV	22	31	48	52
V	3	8	9	27
VI	0	4	3	4
No. fish in sample	189	174	175	126

earlier. In Two Ocean Lake, Wyoming, John (1959) found that III+ chubs were all immature, 15 percent were mature at age IV, 75 percent at age V and all fish were mature by age VI.

Upon attaining maturity, males showed a higher rate of mortality than did females. Among III+ chubs the sex ratio favors male chub by a ratio of 4 to 1 indicating the earlier maturation by males (Figure 6). At IV+, when both sexes are fully recruited into the spawning population, the sex-ratio was closer to being even. In the five-year-old and older group, females outnumbered males by a factor of almost 10 to 1 (Figure 6). When the spawning population from 1967 through 1970 was treated in its entirety, the male to female ratio was 48.1 and 51.9 percent, respectively. No statistical differences in sex-ratio were noted in the pre- or post-spawning populations within years or between years.

Graham (1969) stated that few Hebgen Lake male chubs survived beyond six years and few females reached age seven and eight. John (1959) noted that mortality rose rapidly in age group VI so that eight-year-old chubs were uncommon and nine-year-old chubs were rare.

Movement into spawning areas by all mature age groups began four to six weeks prior to the commencement of spawning during 1968 and 1969. Popula-
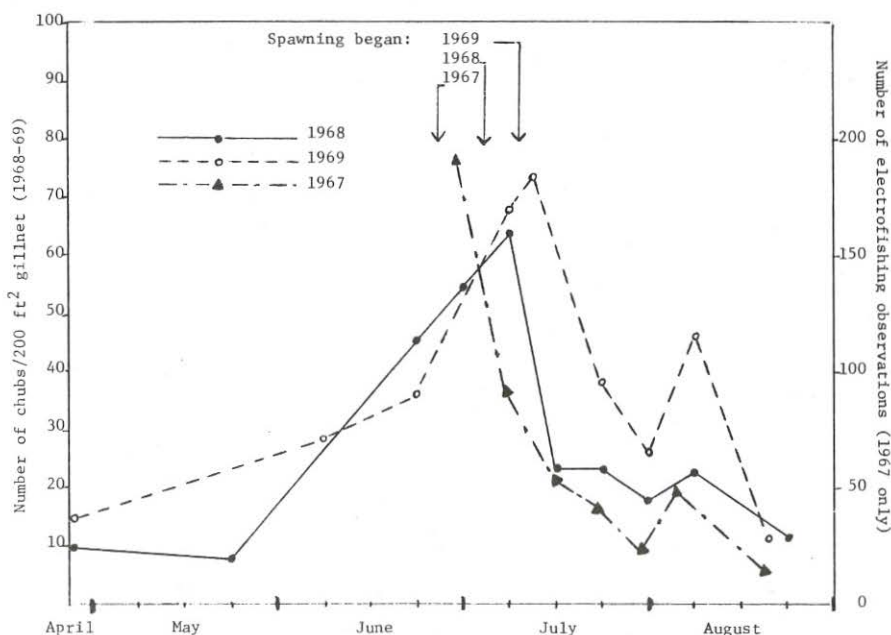

Fig. 7 **Density of Utah chubs in the littoral zone, Flaming Gorge Reservoir, 1967-69. Chubs represented are predominantly age III+ and IV+ and have been equated to 200 ft.² net, ¾" and 1" bar mesh for 1968-69 and are predominantly age III+ for 1967. 1967 data represents observations of chubs over 102 mm (4 in.) length in an electrical field.**

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tion abundance was highest in the initial two weeks of spawning activity and steadily decreased through July. A second and lesser peak was observed during the first two weeks of August (Figure 7). The slight biomodal characteristic of the curves was apparent in each successive year. The first peak in each curve represents predominantly young females (III+ and some IV+). During the August peak, older females (some IV+ and V+, VI+) dominated.

The age composition of the spawning population was determined by gillnet samples in 1968, 1969, and 1971 and by electrofishing in 1967 (Table 6). The average age of spawners increased in each successive year sampled: 1967, 3.26 years; 1968, 3.59 years; 1969, 3.75 years; and 1971, 3.90 years. The increasing average age was correlated over time ($r^2=0.9938$) and is described by the equation $y=2.58+0.432X-0.035X^2$ (Figure 8). Extrapolation of this equation indicates that future average age or stabilization of age in the spawning population would occur at slightly below 4.0 years in 1972.
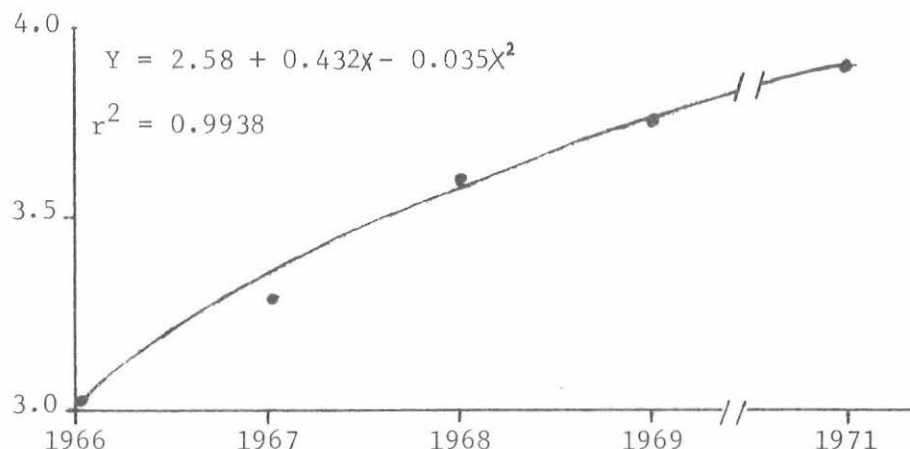

$$Y = 2.58 + 0.432x - 0.035x^2$$

$$r^2 = 0.9938$$

Fig. 8 **The average age of Utah chub spawners in Flaming Gorge Reservoir in the spawning population 1966, 1967, 1969 and 1971. Data for 1969 is based on limited data.**

Analysis of year-class strength in the years sampled is obscured by the expansion of stock density in this new environment although some speculation can be made. Chubs from the 1962 (before impoundment) and 1963 (first year of impoundment) year-classes and the strong 1964 year-class (second year of impoundment) indicates that a substantial number of mature chubs were present in the reservoir basin following the 1962 chemical rehabilitation effort or that substantial numbers were introduced or emigrated into the new reservoir.

The presence of a strong 1964 year-class was expected as that year was the first in which the impoundment had a degree of stability (annual fluctuation 14 m or 43 ft). In addition, intra- and interspecific competition was minimal. In 1965, the year-class produced was obviously much weaker than in 1964. In 1965, with a strong group of yearlings already established in the spawning and nursery area from the strong 1964 year-class, the young-of-the-year may have faced intense competition from their own kind. The reservoir level rose at an abnormally high rate of 30 cm (1 ft) per day throughout much of the spawning period in 1965 as well. Eggs may have either succumbed in cooler water or hatched out in deeper waters offering fry less habitat security.

In 1967, spawning probably began in the last week in June; in 1968 and 1969 the first week and second week in July, respectively. Spawning activity was concluded in late August each year. The duration of spawning activity in 1967 was approximately 60 days, 45 days in 1968 and about 30 days in 1969. The later spawning start was due to delayed warming of the littoral waters. As the

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reservoir filled, the increased water volume gained and lost heat more slowly. There were also more older age females in the population each year which spawn later in the season than do younger females.

Spawning began when water temperature in the eulittoral approached 19.4 degrees C (67 degrees F) in each of the years (Figure 9). Spawning steadily continued into August despite fluctuating water temperatures.
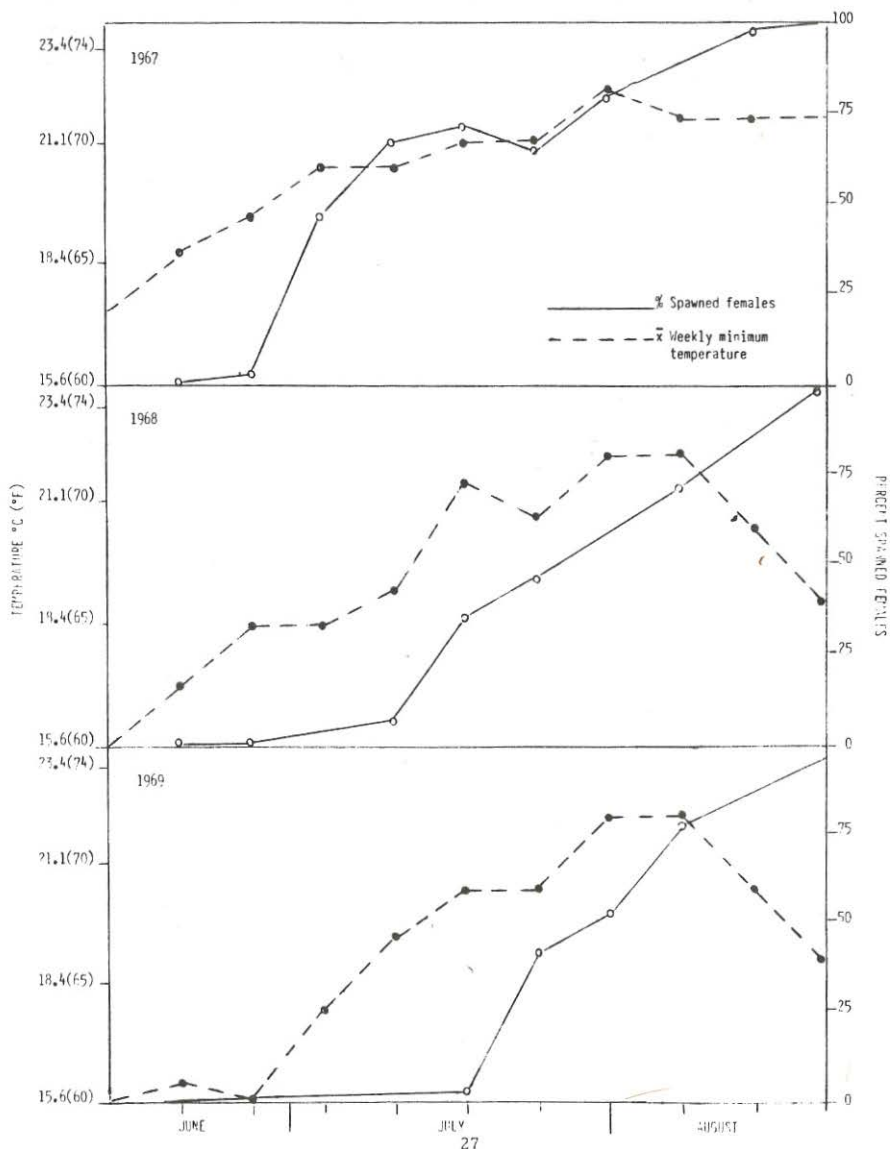

Fig. 9 The relationship of Utah chub spawning with the average weekly minimum temperature in the eulittoral zone, Flaming Gorge Reservoir, 1967 through 1969.

A multiple linear regression was used to test the relationship of the variables of time, of spent females and the maximum and minimum mean weekly water temperature. Data on the summertime increase in temperature and percentage

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of spent females in the population were averaged from three years' data (Figure 9). Results showed that the highest simple correlations were found with the combinations of time on average weekly minimum temperature ($r=0.991$) followed by time on percentage of spent females ($r=0.908$) and average weekly minimum temperature on spent females ($r=0.970$, $r^2=0.988$, $F=209.0$). Results using the maximum weekly water temperature yielded significant results ($r=0.958$, $r^2=0.978$, $F=91.0$) but was inferior to minimum temperature in describing the relationship.

Graham (1961) reported that Utah chubs in Hebgen Lake began major spawning effort when water temperatures reached 12 degrees C (54 degrees F). Gaufin (1964) found a similar relationship in Fish Lake, Utah. On Scofield Reservoir, Utah, Olsen (1959) stated that during the peak of spawning activities average monthly water temperatures (May and June) were 10.5 degrees C (52 degrees F) and 14.5 degrees C (58 degrees F), respectively.

The disparity between the reported spawning temperatures and those recorded in this study may be due to actual differences between populations or, perhaps more likely, the fact that temperatures at Flaming Gorge were measured in warmer eulittoral waters rather than cooler pelagic stations.

Observations of III+ females at the beginning of the spawning season indicated that the duration of spawning activity averaged between 10 to 12 days. There appeared, however, to be a positive correlation between increased fecundity (and thus age) of females and the length of time needed to expend all eggs.

Spawning began and ended about the same time for females in different age groups (Figure 10). In 1967, however, first year females (III+) made up the larger percentage of spent fish early in the spawning season indicating a faster rate of completion. Older females showed a relatively uniform rate of completion later in the spawning period. It is thought that young females complete their spawning more rapidly because they contain fewer eggs.

In early evening during the peak of the spawning season a school consisting of all mature age-groups of chubs would be observed to orient themselves in a band
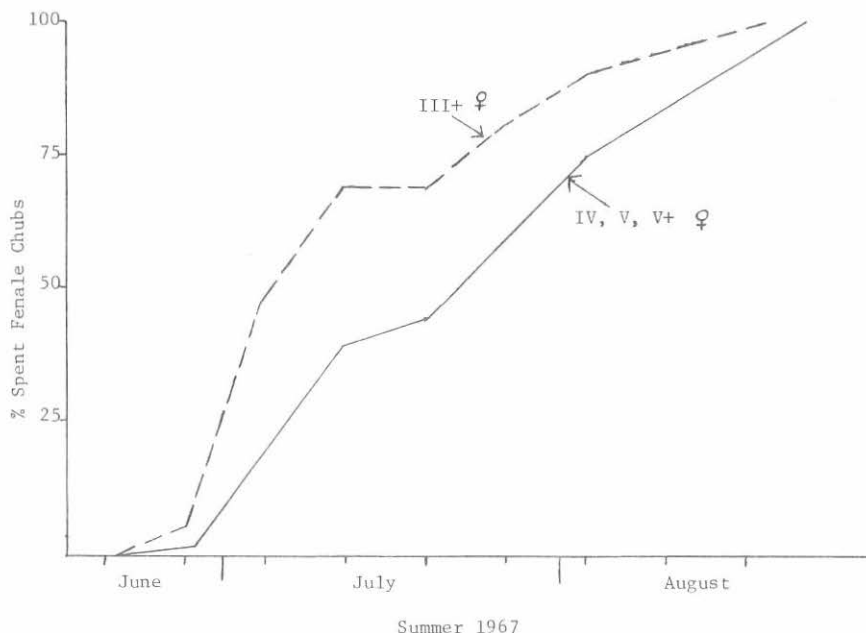

Summer 1967

Fig. 10 Relationship of spent female chubs through time, and by age group, Flaming Gorge Reservoir, 1967.

just off the shoreline in about 1.2 m (4 ft) of water. The erratic movements that followed in 1.2 m (2-4 ft) deep water were thought to be spawning activities although disposition of spawn was not actually seen. Olsen (1959) observed spawning in water less than 0.6 m (2 ft); Graham (1955) recovered chub eggs in Hebgen Lake in water from 0.3 to 1.2 m (1-4 ft) deep, and John (1959) observed spawning in waters less than 0.5 m (1.6 ft) deep in Two Ocean Lake.

Utah chub females broadcast their eggs which are fertilized by the sperm of a number of escorting males (Olsen 1959). Olsen (1959) and Graham (1955) concluded that nest construction was not attempted.

Reservoir and laboratory incubation studies in 1969-1970 revealed that eggs from ripe females were golden-yellow in color and with minimal hand pressure flowed freely from the vent. When considerable hand pressure was needed to force spawn from the female, eggs were whitish-yellow and were never viable following fertilization. Ripe females were common in the evening collections and much less so in morning samplings suggesting that most spawning took place during the evening, dawn and/or in darkness.

Fertilized chub eggs were very adhesive initially but lost this characteristic when water-hardened (>1 hour). Fertilized eggs measured 1.59 mm in diameter (Table 7). The results from artificially collected and incubated spawn under field and laboratory conditions corroborated each other. Seven replicate experiments over a three-year period indicated that 130 Temperature Units (Leitritz 1960) were required to hatch chub eggs. In both field and laboratory, eggs began to hatch in approximately 72 hours. Average water temperature in both laboratory and field fluctuated close to 21.6 degrees C (71 degrees F). John (1969) observed, under laboratory conditions, that incubation took 6 days at 19.6 degrees C (67.3 degrees F) and 9 days at 18 degrees C (64.8 degrees F).

This agrees with our estimate of the number of Temperature Units required.

Day-old chub fry measured about 4.6 mm (0.2 in), increased to 10.1 mm (0.4 in) at 44 days and 80 mm (3.1 in) at 365 days (Table 7).

The appearance of noticeable numbers of fry in the eulittoral each year was variable due to the differing times that spawning began, but abundant fry were generally present in the second or third week of July.

Chub fry coexist with redside shiner, *Richardsonius balteatus hydroplox,* fry in the eulittoral zone. The fry of both species closely resemble each other even to the extent of coloration, although separations were possible by inspection of the location of the forward base of the dorsal fin in relation to a vertical axis downward to the base of the pelvic fins. The origin of the pelvic fin was to or aft of the axis for the chub and forward of the axis for the shiner.

Table 7.

Growth of Utah Chub Fry in Flaming Gorge Reservoir, 1969-70.

Size	Total Length mm	Number In Sample	Standard Deviation
Fertilized Eggs	1.59	44	0.212
Fry: 1 Day-old	4.60	30	0.486
Fry: 7 Days	5.99	14	0.471
Fry: 15 Days	6.62	11	0.383
Fry: 22 Days	7.37	9	0.551
Fry: 38 Days	8.50	17	0.834
Fry: 44 Days	10.06	13	1.159
Fry (I+): 365 Days	80.00	17	5.261

The Utah chub generally made up slightly over fifty percent of the shoreline collections, the remainder being mostly redside shiners and occasional specimens of fathead minnow, *Pimephales promelas,* and young-of-the-year carp, *Cyprinus carpio.*

DISEASES

Considerable mortality was observed among spawning chubs each year. At times mortalities were large enough to suspect a widespread epidemic pathogen. Diseased, dead chubs were examined in 1971 and both dead and alive diseased fish were analyzed in 1972.

In 1971, pathology included two species of myxobacteria having characteristics much like columnaris and peduncle disease. *Saprolegnia* was diagnosed and a flagellated protozoan, *Costia,* was tentatively identified (D. L. Mitchum, Wyo. Game and Fish Comm., Pers. Comm.).

In 1972, *Aeromonas liquifaciens* and *Pseudomonas fluorescens* were identified and an unidentified species of myxobacteria was again diagnosed (R. W. Goede, Ut. Wildlife Res., Per. Comm.).

Pathologists agreed that the pathogens identified from reservoir chubs were virulent only if the resistance of the host was low as would likely be the case with some individuals in a stressed spawning population. The diseases observed were considered to be an enzootic and normal phenomena among the spawning population.

John (1959) noted "acute fungal infections" in chubs during the spawning season at Two Ocean Lake. He also observed heavy infections of various nematodes among chubs and parasitism by larvae tapeworms in about 1 percent of the population.

Flaming Gorge Reservoir chubs were infrequently infected by the cestode, *Ligula intestinalis,* despite a high incidence of the parasite in the redside shiner, *Richardsonius balteatus hydroplox.* A parasitic copepod of the subclass Copepoda were occasionally observed on chubs.

DISCUSSION

Historically, populations of chub and cutthroat trout occurred in natural lakes of their original range. What form did this coexistence take, and how was it maintained? Undoubtedly, we can never really know. Dams, water diversions, angling, introduction of exotic species, pollution and other changes have altered these natural ecosystems to the extent that they no longer exist. Ecological harmony between the two species has changed so that chub populations in many western waters dominate to the point of effectively destroying or depressing salmonid fisheries. It is not known whether this will occur in Flaming Gorge Reservoir because this study dealt with a new and expanding fish population, responding to a dynamic-transitional environment. Comparisons with stabilized chub populations in other waters, however, yield some perspectives to the possible problem.

In Flaming Gorge Reservoir, the success of the Utah chub between 1963 and 1971 was principally due to the ecological survival offered the species by the reservoir, the expansive biology of the chub, and a "headstart" factor.

The "headstart" factor accommodates several features. The first assumes that a broodstock of chubs existed in the reservoir basin at the time of impoundment or shortly thereafter. Existence of a seed stock during 1963 is the simplest explanation for the explosive population expansion observed in the reservoir in its first eight years, regardless of the pre-impoundment eradication. Netting data from 1963 and 1964, plus age determinations support this contention.

Given a 1963 female population of 700 chubs and an average length of 151 mm (5.9 in), the potential egg deposition creating the 1963 year-class could have been 4.2 million. This year-class (1963) was fully recruited into the mature population by 1967, which was also the year that the chub gained numerical dominance in the reservoir (Eiserman et al 1967). Strong year-classes of chubs were fairly consistent during the eight years of impoundment. During this time, fingerling trout (annual size range from 51 mm (2.0 in)-80 mm (3.1 in) were being stocked at a rate ranging from 1.6 to 4.7 million per year. Fingerling survival, however, declined each successive year and the majority of trout were creeled before, or close to first maturity (avg. size from 202-335 mm or 8.0-13.2 in., Varley et al 1970). Thus, it is apparent that the chub population was initially and continually prepared to dominate the reservoir while the salmonid population was late-starting and imperfect from a size and density standpoint.

The inherent expansive biology of the chub aided materially to the success of the species. Age three through five females typically spawned from 4,900 to 84,000 eggs/female/year. Females broadcast a portion of their spawn each night over a period of 10 days, or more each night in different locations and with different males; egg incubation time is a short 3 days; and spawning duration ranged from 30 to 90 days.

Quasieutrophication of the new reservoir also resulted in good productivity of food organisms for chubs (Varley 1967). The reservoir has a diverse mixture of plankton species that are plentiful throughout the year (Varley 1967, Longley 1969). Varley (1967) observed that over 90 percent of the standing crop of phytoplankton and 86 percent of the zooplankton were concentrated in the upper 5 m (16 ft) of the epilimnion. Unpublished data (Utah and Wyoming Game and Fish Dept.) indicate that salmonids are largely excluded from the pelagic and littoral epilimnion due to high temperatures during much of the summer and early fall months. This favors the Utah chub by giving the species first and nearly exclusive options to the optimum food niche in the reservoir.

Life history phenomena whereby the young-of-the-year, I+ and II+ age-groups, remain in the same area as they were spawned also tended to favor survival of chubs. In 1967, some 42 percent (170.5 km, 106 mi) of the reservoir shoreline was considered marginal spawning and nursery habitat. This littoral habitat provides abundant cover and food through inundated terrestrial and aquatic vegetation. The submerged terrestrial vegetation is transitory and will ultimately disappear from the reservoir eliminating the predominant chub cover observed during the study years. The magnitude of reservoir fluctuation in a given year will determine the extent of aquatic vascular plants and at-tached algae, and hence the breadth of chub cover in the future.

Except possibly for the redside shiner, there was probably little interspecific competition between the chub and other species during the summer and early fall months when food and temperatures were at their optimum in littoral areas.

There were factors identified, and others that can be speculated on, that reduced chub population densities from what they would have otherwise been. The rapid (35 cm or 1 ft per day) rise in the reservoir level in 1965 appeared to produce a weaker than normal year-class. Cooler water, lengthened incubation time, and hatching in deep water were the factors thought to be involved. In 1964, the reservoir level was relatively stable and a strong year-class was produced. The influence of water level is clouded somewhat by an indication throughout the study years of alternating strong and weak year-classes. Where 0+ and I+ chubs coexist to some extent in nursery habitat, a strong biological rationale could be developed explaining alternate year-class strength.

Spawning began later and the duration was shorter each year of the study. This is thought to have inhibited recruitment due to competition for spawning sites by mature fish, and competition for food and space by fry hatched in the shorter interval.

At some seasons of the year considerable numbers of piscivourous birds

(principally mergansers) utilize the reservoir. It is thought that they prey primarily on the chub because of widespread availability in the littoral and pelagic epilimnion.

Wiley and Varley (1975) observed that brown trout over 251 mm (8.9 in) and rainbows over 451 mm (17.8 in) take substantial amounts of fish in the diet. The Utah chub was the most numerous of the identifiable forage species. Field observations of very large (1.8-5.9 kg, 4-13 lb) rainbow, brown and cutthroat trout stomach indicate a near exclusive diet of fishes. Utah chub and trout were the most frequently observed fishes in these stomachs.

John (1959) observed that large Utah chubs prey on cyprinids, and thus cannibalism may be a significant mortality factor. He also suggested that the redside shiner may have been an important predator of young-of-the-year chubs in Two Ocean Lake.

Ice in the eulittoral forms at a constant rate during the winter because the reservoir level continually decreases. At times, young-of-the-year and yearling chubs are trapped and frozen in the shelf-ice. Both salmonids and chubs inhabit the same habitat during this period and perhaps more important, the chub's normal escape route to the eulittoral is blocked by the ice covering. The extent of salmonid predation under these circumstances is not known.

Mortality caused by disease was commonly observed in mature fish during spawning. The diseases observed were thought to be stress-related and a natural occurrence. The low incidence of parasitism observed is thought to have an insignificant effect on the population.

Despite the observed factors influencing mortality in the Utah chub, it is thought that population regulation during the period studied is largely a density dependent function. Density independent variables were not significant enough to have major impact because the overall population density was below carrying capacity. A predictive equation on the annual increase in the average age of spawners suggests stabilization of the population in 1972. The appearance of eight and nine-year-old fish and reduction in the rate of growth to a more conventional curvilinear state would further indicate that such a state had been reached.

Sigler and Miller (1963) observed that the only practical chub control is total kill using chemical piscicides. This is not practical in waters the size of Flaming Gorge Reservoir.

Clues to natural suppression of chubs might lie in the historical relationships between chubs and cutthroats. While knowledge of these historic fisheries are obscure some insights emerge: historically, each of the large natural lakes involving sympatry sustained substantial populations of large cutthroat trout. Early writers consistently wrote of cutthroats up to 5.5 kg (12 lbs) in Utah Lake (Jordan and Evermann 1923); fish from 2.7-4.6 kg (6-10 lbs) in Bear Lake, Utah-Idaho (Kemmerer et al 1923); and from 1.8-5.5 kg (4-12 lbs) in Jackson, Two Ocean, and Heart Lakes, Wyoming. The cutthroats in these waters coexisted with large populations of Utah chubs and frequently one or more species of the family Coregonidae (Jordan 1891, Smith and Kendall 1921, Kemmerer et al 1923, Jordan and Evermann 1923, unpublished data National Park Service Archives, Yellowstone Park). The historic size of cutthroats in these natural lakes indicates a terminal predator within these ecosystems. As is common with predators at the apex of the food pyramid, these fishes never made up a majority of the fish biomass and probably never exceeded one-quarter to one-third of the total fish weight (Dean and Varley 1974).

It is also noteworthy that in Utah, Bear, Jackson, Two Ocean, and Heart Lakes, each was frequented by significant populations of the white pelican, *Pelecanus erthrorhychos,* and other avian piscivores. Thus, it is apparent that the evolution of the Utah chub occurred in the presence of substantial fish and avian predatory pressure. The evolutionary selectivity of this predation is borne out by the high fecundity of the Utah chub. Odum (1959) observed that severe

interaction between predator and prey tend to be quantitatively small where the interacting populations have had a common evolutionary history in a relatively stable ecosystem.

From a historical standpoint, therefore, re-creation of a salmonid population with significant numbers of large individuals may be one step towards establishing a relationship between Utah chub and trout populations in Flaming Gorge Reservoir. The chubs susceptibility to intense predation may have been borne out by the complete disappearance of the species from Utah Lake, Utah following the introduction of white bass (J. White, Pers. Comm.) and their disappearance from Willard Bay Reservoir, Utah, after the introduction of walleye and largemouth bass (R. Stone, Pers. Comm.). Reestablishment of a cutthroat population such as described historically may not be possible in the face of heavy fishing exploitation or competition from introduced exotic species (lake, brown, rainbow trout, etc.). Also, the cutthroat genotypes which originally produced these large predators may no longer exist.

A potentially successful salmonid chub association would also necessarily assume that the chub did not exceed forage size at youthful ages as in Flaming Gorge Reservoir during the study years. Chub growth in lakes where they were native is sufficiently slow to insure forage size well into the mature age groups (Tables 1 and 2). This is significant because the mature chub population is the only segment that is available to salmonids on a year-around basis.

Forage size is relative to the average size of the predator (salmonid) population rather than a finite length. Nikolsky (1963) and Ivlev (1961) observed that in predators it is common for the size of prey to increase at roughly the same rate as the size of the predator. Evidence of this relationship is found in Flaming Gorge Reservoir and several other lakes where salmonids coexist with cyprinids (Varley, Unpubl. data). Following a diet of benthos and plankton during immaturity a threshold size is reached at approximately 358 mm (14.1 in) where the cutthroat first ingests fish. Prey-size in larger sizes of the cutthroat generally ranged between 22 to 30 percent (avg. 26.0%) of the predator's length. Thus, an average cutthroat size of approximately 375 mm (14.8 in) may have been required to exert predatory pressure on II+ chubs in the three lakes where the chub is native (Table 2) but an average cutthroat size of approximately 490 mm (19.3 in) would have been required to consume significant numbers of II+ chubs in Flaming Gorge Reservoir during the study period (Table 2). As in the lakes with predator trout in the range of 456-711 mm (18-28 in) would be capable of preying on the bulk of the chubs in the reservoir (age-groups 0+ through V+). (age-groups 0+ through V+).

From 1963 through 1970, the average size of rainbow trout in the reservoir varied from 202 mm (8.0 in) to 335 mm (13.2 in, Varley et al 1970). If a similar predator-prey and diet relationship occurs in the rainbow as in the cutthroat, it may partially explain why the population expansion of chubs was unimpeded during the study years. Fish diet studies from the reservoir (Wiley and Varley 1975) suggest that a more efficient salmonid-Utah chub relationship may have been best accomplished with the brown trout. Reservoir brown trout began feeding on fishes at one-half the mean size (251 mm or 8.9 in) of rainbow trout (451 mm or 17.8 in). Both diet and distribution data indicated that brown trout were less likely to leave warm, littoral waters during summer than rainbow or cutthroat trout. Brown trout made up only 3% of the total fingerling salmonids stocked from 1963-1970, and thus did not have the density necessary to potentially influence the chub population.

In the future, the Utah chub in Flaming Gorge Reservoir may be expected to reach a population equilibrium. At that time body growth rates would be expected to decline which, if the average size of salmonid predators increases significantly should exert some pressure on chub populations. Other methods of reducing chub growth such as reducing the average water temperature (largely a function of hydroelectric operation), introduction of a small (forage size) and

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superior planktivore to compete with the chub for epilimial limnoplankton and enhance predator growth rates, and introduction of a host specific parasite/disease, could aid in developing a suitable predator-prey association.

In several waters, spot poisoning has been attempted, but the biology and history of the species strongly suggests that population regulation in the chub is a density dependent function and, therefore, such partial programs are predisposed failures. Thus, it would seem that a management program based upon a restoration of the historical chub-trout association offers some promise.

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