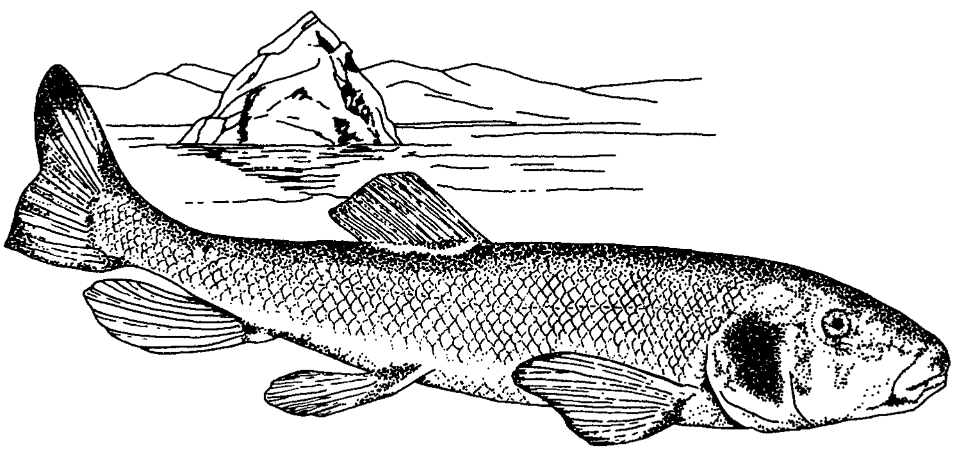
Fish and Wildlife Research 1

Life History and Status of the Endangered Cui-ui of Pyramid Lake, Nevada



UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

FISH AND WILDLIFE RESEARCH

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Cover illustration: A typical young adult cui-ui. Sketched in the background is the emergent rock outcrop from which Pyramid Lake derives its name.

ATTENTION READER This is the first issue of *Fish and Wildlife Research.* It combines material previously published in the series as *Research Report* and *Research Report Wildlife.*

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Contents

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Abstract

Prespawning adult cui-ui (*Chasmistes cujus*) congregate off the mouth of the Truckee River in Pyramid Lake, Nevada, from mid-March to early June. The spawning runs have been largest during years when spring flows in the Truckee River were relatively high. In 1982–84 upstream migration lasted 48 to 59 days and peaked when daily mean water temperatures were 12 to 15°C. Radio-tagged males remained in the river 6.5 to 16.5 days and females 4.0 to 10.5 days. The fish spawned over predominately gravel substrate at depths of 21 to 110 cm, where water velocities were 21 to 140 cm/s. Fecundity ranged from 24,000 eggs for a female 432 mm long (fork length) to 196,000 for a fish 657 mm long. The ratio of males to females in the spawning run was 1:1.3 in 1982 and 1983 and 1:2.5 in 1984. Most cui-ui larvae emigrated downstream to Pyramid Lake soon after swim-up, primarily at night. The interval between the peak of the adult spawning migration and peak emigration of the young was 26 days in 1982 and 29 days in 1984. Marble Bluff Dam, constructed in the Truckee River in 1976, did not appear to cause substantial mortality of emigrating larvae. Opercle bones were used to determine cui-ui ages and growth rates; the aging method was validated by following individual year classes through time. Eleven year classes that were identified included fish from 1 to 41 years old. In 1983, about 92% of the fish in the reproductive population were from the 1969 year class and 5% were from the 1950 or earlier year classes; the rest were divided among six year classes (1967, 1971, and 1973–76). Males and females grew at the same rate until 6 years of life, the age at which they first entered the spawning run; thereafter, females grew faster and lived longer than males. Growth in length virtually ceased by age 20. The estimated numbers of cui-ui in the prespawning aggregation off the mouth of the Truckee River were 187,000 in 1982 and 103,000 in 1983. Larvae in the Truckee River fed primarily on chironomids and zooplankton; yearlings in Mud Lake Slough (near the mouth of the Truckee River) and adults in the prespawning aggregation off the mouth of the river ate mostly zooplankton. Predation by American white pelicans (*Pelecanus erythrorhynchos*) caused substantial mortality of adult cui-ui during their spawning migration in 1982 and 1983.

The cui-ui (*Chasmistes cujus*) is a federally listed endangered species endemic to Pyramid Lake, Nevada. The species is believed to be the last remaining genetically pure member of the genus *Chasmistes* (Miller and Smith 1981). This taxonomic distinction, the severe decline of the cui-ui population, and the favorable outlook for recovery of the species resulted in its receiving a top priority rating for recovery (U.S. Fish and Wildlife Service 1983). Because much natural history information was lacking, the Service supported a 4-year study of the species as outlined in the Cui-ui Recovery Plan (U.S. Fish and Wildlife Service 1978). We present the results of that research.

The primary cause of the decline of the Pyramid Lake cui-ui population was clearly the disruption of the reproductive cycle. During the past 50 years, spawning adults have had only restricted access to the Truckee River, the only permanent tributary of Pyramid Lake. An extensive and shallow delta that formed at the mouth of the river in the 1930's has been a barrier to migrating adults in most years since then. The delta resulted from a drastic lowering of the water level of Pyramid Lake over a relatively short period, as a result of water diversion from the Truckee River. The water level of the lake dropped about 25 m between 1906 and 1982. The completion of the Newlands Project in 1905 (Townley 1977) and the associated construction of Derby Dam diverted an average of 311 million m^3 annually, or about half the river flow.

A series of measures were taken, beginning in the mid-1970's, to attempt to restore the Pyramid Lake sport and Indian food fishery. In 1976, Marble Bluff Dam and Pyramid Lake Fishway, a canal 4.8 km long that bypasses the delta, were completed. The dam diverts water down the fishway, enabling migrating fish to bypass the delta. Also, portions of the water stored in Stampede Reservoir (an impoundment on a tributary of the Truckee River) were reserved to augment flows required for cui-ui spawning.

As a further measure against the possibility of extinction, hatchery propagation of cui-ui for release into Pyramid Lake was begun in 1973, based on techniques developed by Koch and Contreras (1973). A fully equipped cui-ui hatchery, managed and maintained by the Pyramid Lake Paiute Indian Tribe, produced an average of 7 million cui-ui larvae annually in 1980–84 (Alan Ruger, Pyramid Lake Fisheries, personal communication). These larvae were released into the lower Truckee River or directly into the lake.

In 1981, the U.S. Fish and Wildlife Service (Seattle National Fishery Research Center and Reno Great Basin Complex Office) began the present study to provide life history information that might facilitate recovery of the species. Adult cui-ui, taken on their spawning migration, were confined in a natural braid of the lower Truckee River (Scoppettone et al. 1983). Data developed on cui-ui reproduction here, under controlled conditions, served as the basis for the rest of the work in the main stem of the Truckee River. The phase of the life history spent in the river was emphasized because of its obvious importance in determining survival of the species. Included in the work were studies of spawning migration, reproduction, emigration of larvae, age and growth, population size, and food.

Each spring, adult cui-ui congregate at the south or river end of Pyramid Lake before they migrate upstream to spawn (La Rivers 1962). The concentration is greatest near the mouth of the river (Koch 1972). Catches per unit of effort in gill nets fished in Pyramid Lake near the Truckee River and the Pyramid Lake Fishway were greatest when river flows were high (Sonnevil 1981). Historically, cui-ui spawned from mid-April to late May, primarily in the lower 40 km of stream (Snyder 1918). In more recent years, spawning was observed in Pyramid Lake itself from May through July (Johnson 1958; La Rivers 1962; Koch 1973). However, the high salinity in the lake is lethal to incubating eggs (Chatto 1979). Even the hatching success of eggs deposited at a freshwater inlet was questionable (Koch 1973). In the river, adult cui-ui spawned in riffles over predominantly gravel substrate, burying their adhesive, demersal eggs at depths as great as 10 cm (Snyder 1918; Scoppettone et al. 1983). Cui-ui spawning behavior was described by Scoppettone et al. (1983), early life stages by Koch (1972), and embryology by Bres (1978). At 10°C, eggs hatch in 13 days and larvae swim-up about 5 days after hatching (Koch 1972; Koch and Contreras 1973). Bres (1978) observed that the mouth of cui-ui larvae opened 16 days after hatching.

When not congregated at the river end of the lake, adult cui-ui live primarily in littoral waters less than 23 m deep (Johnson 1958; Vigg 1980). Zooplankton (not further identified) was reported to be the primary food of adults (Johnson 1958; La Rivers

1962). Robertson and Koch (1978), who evaluated techniques of aging cui-ui by means of scales, otoliths, and opercles, concluded that all three methods were reliable. Although Johnson (1958) found it extremely difficult to identify definitive scale annuli, Koch (1976) used the scale method for aging.

Study Area

Pyramid Lake is in western Nevada and lies totally within the boundaries of the Pyramid Lake Paiute Indian Reservation. It is a terminal lake (area in 1983 about 467 km^2) from which water is lost solely through evaporation. As a result, it is moderately saline; the concentration of total dissolved solids in 1983 was 4,900 to 5,000 mg/L. Galat et al. (1981) described the lake's general limnological characteristics.

Pyramid Lake is the largest vestige of pluvial Lake Lahontan (Russell 1885; Hubbs and Miller 1948). The fact that lacustrine cui-ui are endemic to Pyramid Lake adds credence to Benson's (1978) assertion that it is the only Lake Lahontan vestige that has not completely desiccated during the past 9,000 years. Early in this century, cui-ui did occur in Winnemucca Lake, which once lay east of Pyramid Lake. The two lakes were connected at their southern ends by Mud Lake Slough (Fig. 1). The primary source of water to Winnemucca Lake was overflow from Pyramid Lake; this overflow virtually ceased with the completion of Derby Dam in the early 1900's. Winnemucca Lake had desiccated by 1938 (Sumner 1940). By 1983, Mud Lake Slough still received a modest amount of agricultural return water, but none of it reached Winnemucca Lake.

The Truckee River, which is Pyramid Lake's only permanent tributary, originates at Lake Tahoe (elevation 1,898 m above mean sea level), flows 190 km northeasterly, and then discharges into Pyramid Lake (elevation 1,156 m in 1984). The river's primary water sources are the Sierra Nevada and the Carson mountain ranges. Flow is largely controlled; Lake Tahoe, which once overflowed into the Truckee River, is regulated by a dam, as are Donner and Independence lakes; three of the larger tributary systems also have one or more reservoirs (Fig. 1).

The lower Truckee River, which includes the historical cui-ui spawning area (La Rivers 1962), is a low-gradient stream descending at a rate of about 1.5 m/km. In the early 1980's, the stream channel had only a sparse riparian corridor, dominated by Fremont cottonwood (*Populus fremontii*). In 1982–84, average daily flows ranged from 1 to 206 m^3/s, and average daily spring flows from 18 to 206 m^3/s.

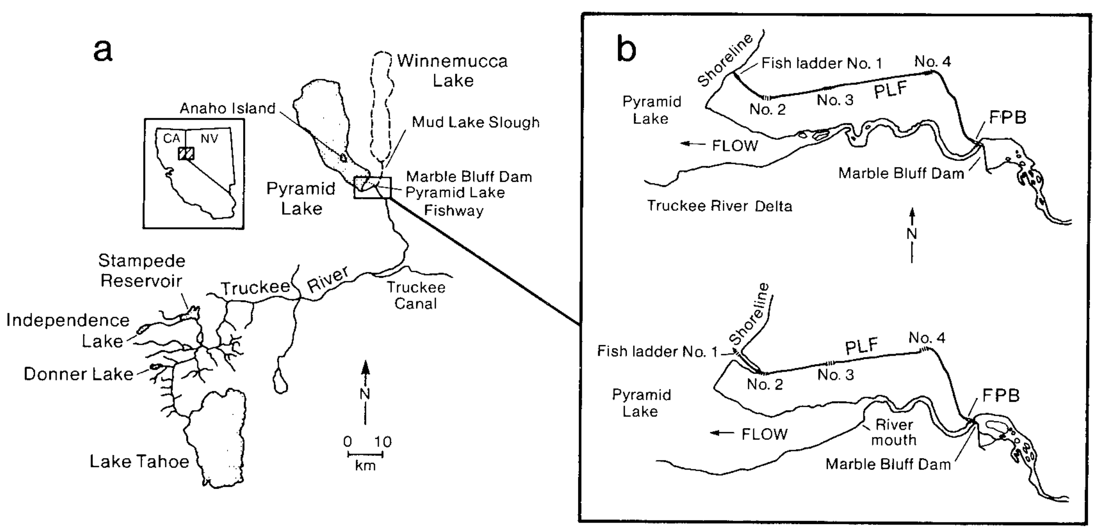

Fig. 1. (*a*) Truckee River, Pyramid Lake, and connected waters. (*b*) Lower reaches of the Truckee River, showing the location of Pyramid Lake Fishway (PLF) and its four ladders, Marble Bluff Dam, and the fish processing building (FB); the mouth of the Truckee river in 1982 and 1983 (*upper sketch*), advanced 2 km upstream in 1984 (*lower sketch*).

Marble Bluff Dam (here termed MB dam; Fig. 2) was constructed 5 km upstream from the mouth of the Truckee River in 1976. It is 12 m high and serves to divert water into the Pyramid Lake Fishway (here termed fishway). The fishway flows at about 1.1 m^3/s and has four modified "Ice Harbor" ladders (i.e., similar to those at Ice Harbor Dam in the Snake River) along its 4.8-km course. At the upstream end of the fishway and adjacent to MB dam is a fish processing building (FPB), where migrating adult cui-ui are trapped and released upstream from MB dam (Fig. 2). A V-shaped trap at the base of the north end of the dam is intended to collect fish that have traversed the Truckee River Delta. The capture efficiency of the trap is unknown. The fish captured are elevated 10 m into the FPB, and eventually released upstream from MB dam.

Before 1984, the Truckee River Delta extended about 2 km upstream from the river mouth. In most years it consisted of shallow, braided channels; typically, none were deep enough to allow cui-ui access upstream to the main stream channel. Even in 1983, when daily average spring river flow reached 206 m^3/s, there were access problems. The river mouth was up to 1.5 km wide, and the entire delta area was submerged under water averaging less than 0.3 m deep. The submerged delta was riddled with numerous discontinuous channels that were up to 1 m deep but were only 50 to 60 m long and ended in shallow water. In spring, a large population of American white pelicans (*Pelecanus erythrorhynchos*) occupied the delta, preying on migrating cui-ui and other fishes that attempted to traverse the shallow water. By 1984, after two extraordinarily wet years, Pyramid Lake had risen about 7 m and the channel below MB dam had downcut about 2 m. These hydraulic changes effectively abolished the Truckee River Delta for the first time in 50 years and moved the river mouth 2 km closer to MB dam (Fig. 1). Average water depth immediately upstream from the mouth exceeded 1 m.

Spawning Migration

Prespawning Aggregation

We used gill nets to monitor the formation and persistence of the pre-spawning aggregation in Pyramid Lake, as well as to collect fish for tagging, to enable us to estimate the population of cui-ui in the aggregation. Three nets were systematically set in Pyramid Lake from mid-March to late June in 1982 and 1983 (hydraulic changes at the river end of Pyramid Lake prevented gill netting in 1984). One net was fished off the mouth of the fishway and two others off the mouth of the Truckee River (one on either side). Nets were set parallel to the shoreline in water 3–4 m deep. Each net was of a different mesh size (121, 130, and 152 mm, stretched measure), and was 15.2 m long and 4.6 m deep. The nets were rotated after each daily sampling period. In 1983 we fished two additional nets, each 61 m long and 4.6 m deep; mesh size was 102 mm in one and 178 mm in the other. These nets were also set in water 3–4 m deep, just off and parallel to the mouth of the Truckee River, in the same area at each sampling. We sampled 1 to 3 days weekly (depending on the weather) in 1982 and 1 day per week in 1983. The three 15.2-m nets were set for two 1.5-h intervals in both years, and the two longer nets for a single 3-h period; netting began at 0700 h (1982) or dawn (1983). All fish captured were marked with Floy anchor tags near the base of the dorsal fin and released at the site of capture.

We equipped 11 cui-ui with sonic tags on 3–7 April 1982 to enable us to follow movements of fish in the prespawning aggregation. The tags (64 mm long and 16 mm wide, constructed by Sonotronics, Tucson, Arizona) were surgically implanted into the abdominal cavity of nine fish by the technique of Hart and Summerfelt (1975), and applied externally to two fish (as later described for radio-tags). All fish were initially captured in gill nets, either off the Truckee River Delta or off the fishway. Fish were released at the point of capture within 2 h after the tags were attached or implanted. Estimated longevity of the tags was 16 months. Our primary tracking unit was a Smith-Root Sonic Receiver Type TA60. To pinpoint and map locations of individual fish at a given time, we took bearings with a Lietz pocket transit from two or three established reference points along the shoreline.

In both 1982 and 1983, the prespawning aggregation began to form off the Truckee River Delta in mid-March and persisted until mid-June, although it began to wane by late May, during peak migration through the fishway. Of 526 cui-ui marked with Floy tags in late March to early April during the 2 years, 45 were recaptured in the FPB, 35 to 77

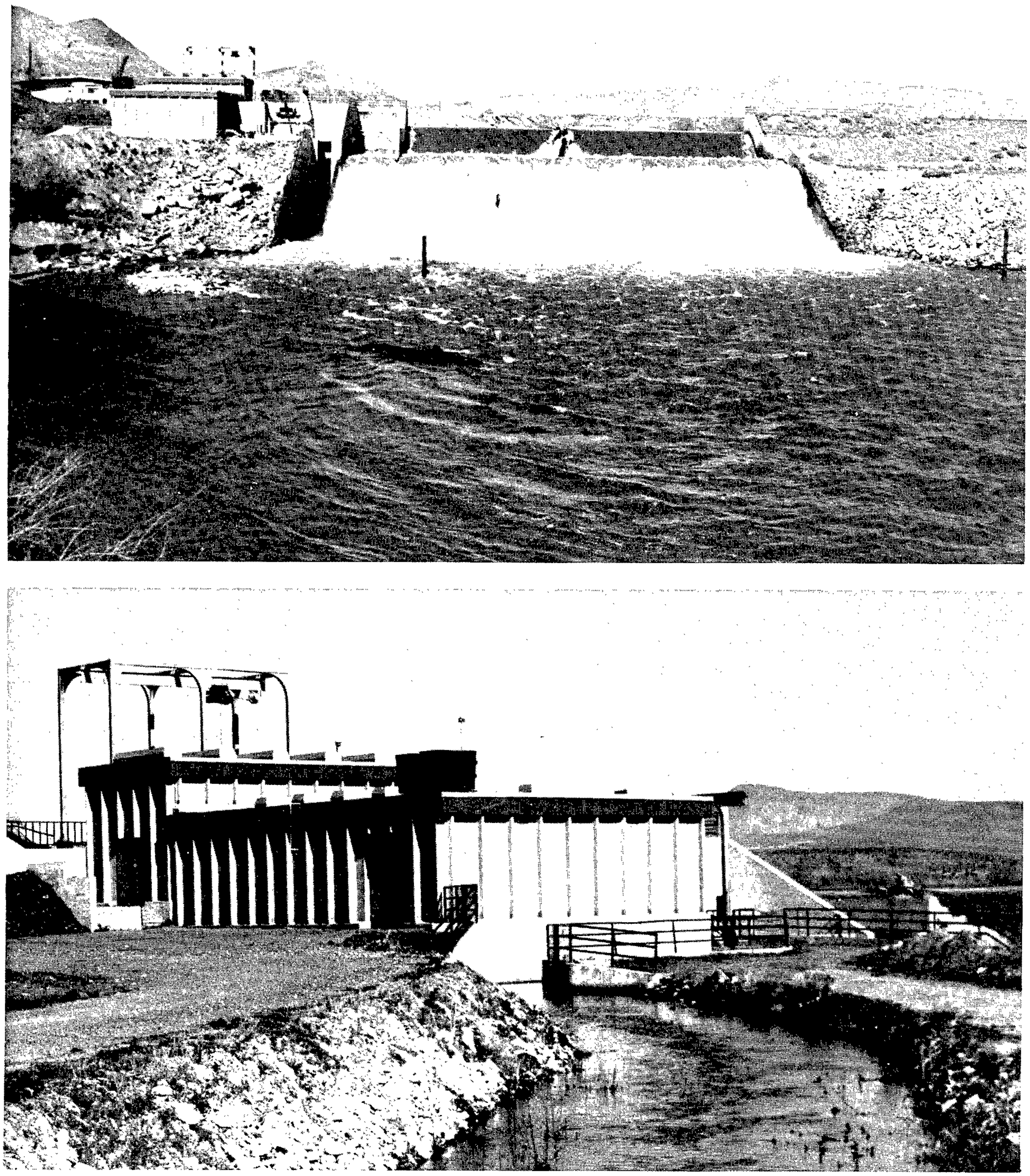

Fig. 2. *Upper photo:* Marble Bluff Dam and adjacent fish processing building; entrance of the river trap is at the left end of the dam. *Lower photo:* Pyramid Lake Fishway entering the fish processing building.

days after they were tagged. They had remained offshore an average of 55 days. Similarly, 11 cui-ui marked with sonic tags in early April remained offshore for 6 to 8 weeks, where they remained fairly active. Four that were tracked for 24 h traveled distances of 7 to 12 km, moving mostly at night (Fig. 3). Activities during such night movement probably included feeding and seeking access to the river.

During daylight and at any time of day just before peak river migration, cui-ui with sonic tags remained just offshore, usually within 1 km from either the delta or the fishway (Fig. 3). No sonic-tagged cui-ui entered the FPB, however, and by 6 June 1982 we had lost the last of the offshore signals. Presumably the tagged cui-ui either spawned in the fishway or delta, where turbulence prevented detection, or returned to deeper water and resorbed their gametes. In November 1982, 7 months after tagging, we relocated 7 of the 11 sonic-tagged fish along the periphery of Pyramid Lake—indicating that survival was high.

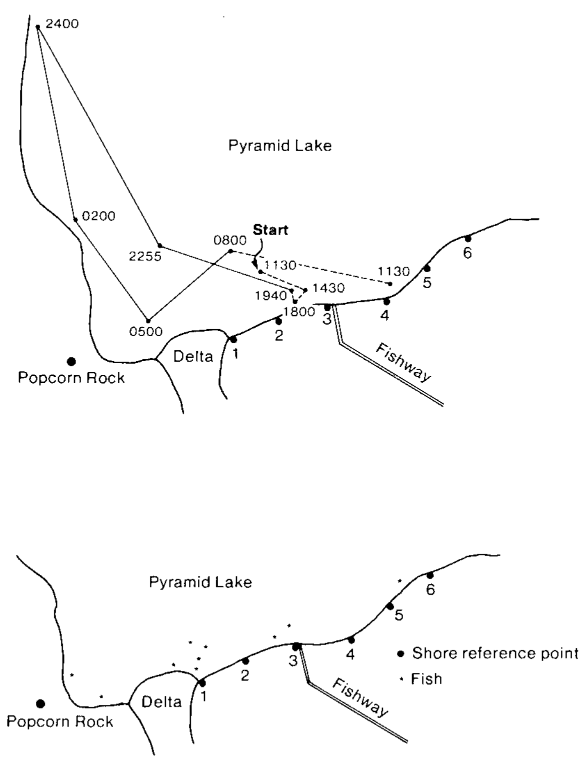

Fig. 3. Movement of cui-ui tagged with sonic tags. Shore reference points (solid dots 1 to 6) are spaced at 0.5-km intervals. *Upper sketch*: Movement of a member of the prespawning aggregation over a 24-h period beginning at 1130 h on 21 April 1982. *Lower sketch*: Positions (asterisks) of 10 sonic-tagged cui-ui at 1000–1200 h, 26 April 1982.

History of Recent Spawning Migrations

From the time when the Truckee River Delta was formed in the 1930's until the completion of MB dam and the fishway in 1976, there was no documentation of cui-ui spawners entering the river. They were observed on several occasions attempting to do so, seemingly without success (Johnson 1958; La Rivers 1962). Successful migration was observed only after completion of MB dam and the fishway. Except in 1984, virtually all cui-ui migrants captured in the FPB had entered through the fishway. However, cui-ui did not use the fishway during the first 2 years of operation (1976 and 1977). There was some concern that water velocity and perhaps water turbulence in the fishway were unfavorable, and early fishway history seemed to support this concern. Cui-ui entered the fishway in both 1976 and 1977 but did not ascend it beyond the lower reach of ladder 1 (Sonnevil 1978). During the next three spawning seasons, after this ladder had been partly modified to reduce velocity and turbulence, successively larger numbers of cui-ui used the ladder and were captured at the FPB: 33 in 1978, 139 in 1979, and 4,984 in 1980 (Table 1). This trend was disrupted in 1981, when only 47 cui-ui used the fishway, even though all four ladders had been modified. The relatively small run in 1981 after the large run in 1980 suggested that ladder modification alone had not influenced the size of the cui-ui run.

Sonnevil (1981) observed that the numbers of cui-ui in the prespawning aggregation off the mouth of the river were greatest in high-water years. Runs up the fishway or river were also large when flows in the Truckee River were high in March through May (in 1980 and 1982–84; Table 1). Fishway flows have remained almost unchanged since it opened.

During the 9 years after installation of the MB dam and fishway complex in 1976, cui-ui entered the FPB by way of the Truckee River in 3 years (1982, 1983, and 1984). Except in 1984, however, the size of the river runs was inconsequential (1 fish trapped in 1982 and 20 in 1983). In both years, most cui-ui traveled through the fishway (13,804 in 1982 and 5,994 in 1983). In 1984, however, all cui-ui taken in the FPB came by way of the river; 11,374 were caught in the river trap (Table 1). After two extraordinarily wet years, river access was no longer impeded by the Truckee River Delta, and cui-ui abandoned the use of the fishway.

Upstream Migration

Cui-ui on their spawning migration up the fishway and into the FPB were collected, counted, sexed, measured (fork length), and checked for tags. The fish were then either released into a backwater area directly above the dam or trucked farther upstream and released into the main stem of the Truckee River.

In 1982–84 the cui-ui migration began as early as 9 April (in 1984) and ended as late as 21 June (in 1982). The three migratory runs lasted 48 to 59 days, while water temperatures ranged from 9 to 20 °C; however, migration peaked ≥500 fish per day) when water temperatures ranged from 9 to 17 °C and daily means were 12 to 15 °C (Fig. 4). Subjective observation indicated that upstream migration was generally stimulated by rising temperatures and dampened by falling temperatures. These responses to temperature seemed to be both seasonal and diurnal; over a 24-h period the cui-ui run was heaviest in late afternoon and evening, when temperatures were highest. This relation between water temperature and the spawning migration of catostomids in general has been observed by others (Bailey 1969; Corbett and Powles 1983; Geen et al. 1966).

To enable us to follow migrating adult cui-ui in the river and locate spawning areas, we applied external radio-tags to 57 fish captured at the FPB—8 in 1982, 27 in 1983, and 23 in 1984 (totals exclude 1 fish bearing a transmitter that failed to operate). A stainless steel wire was routed through the base of the pterygiophores and each end was fastened to a plastic harness trailing behind the dorsal fin. Radio-tags were of three sizes; the largest was 60 mm long and 12 mm wide and weighed 20 g. Transmission life was 30 to 60 days. A Smith-Root RF-4 receiver was used to track fish in the field, and a Smith-Root Field Data Logger (FDL-10ER) was set at the FPB to record the date and time when tagged fish dropped over MB dam as they returned to Pyramid Lake.

Of the 57 fish tagged (28 males and 29 females), 12—most of which had been tagged late in the run—returned to the lower river over MB dam within a few hours after their release. The rest remained in the stream for 4 days or longer.

The radio-tagged cui-ui migrated only short distances after they were released above the dam. After being tagged at the FPB (after they had moved

Table 1. *Numbers of cui-ui entering the fish processing building (FPB) through the Pyramid Lake fishway and the river trap, 1976–1984.*

Year	Number entering FPB: Through fishway	Number entering FPB: Through river	Identifying numbers of ladders modified [a]	Total flows March through May in Truckee River (hectare-meters)
1976	0	0	None	9,565
1977	0	0	None	1,172
1978	33	0	1	2,470
1979	139	0	1	4,830
1980	4,984	0	1, 2	19,405
1981	47	0	1–4	9,018
1982	13,804	1	1–4	59,283
1983	5,994	20	1–4	83,653
1984	0	11,374	1–4	32,983

[a] *See* Fig. 1 for location of ladders. In ladder 1, velocity was reduced in 1978 and turbulence in 1979. Similar modifications were made in ladder 2 in 1980 and in ladders 3 and 4 in 1981.

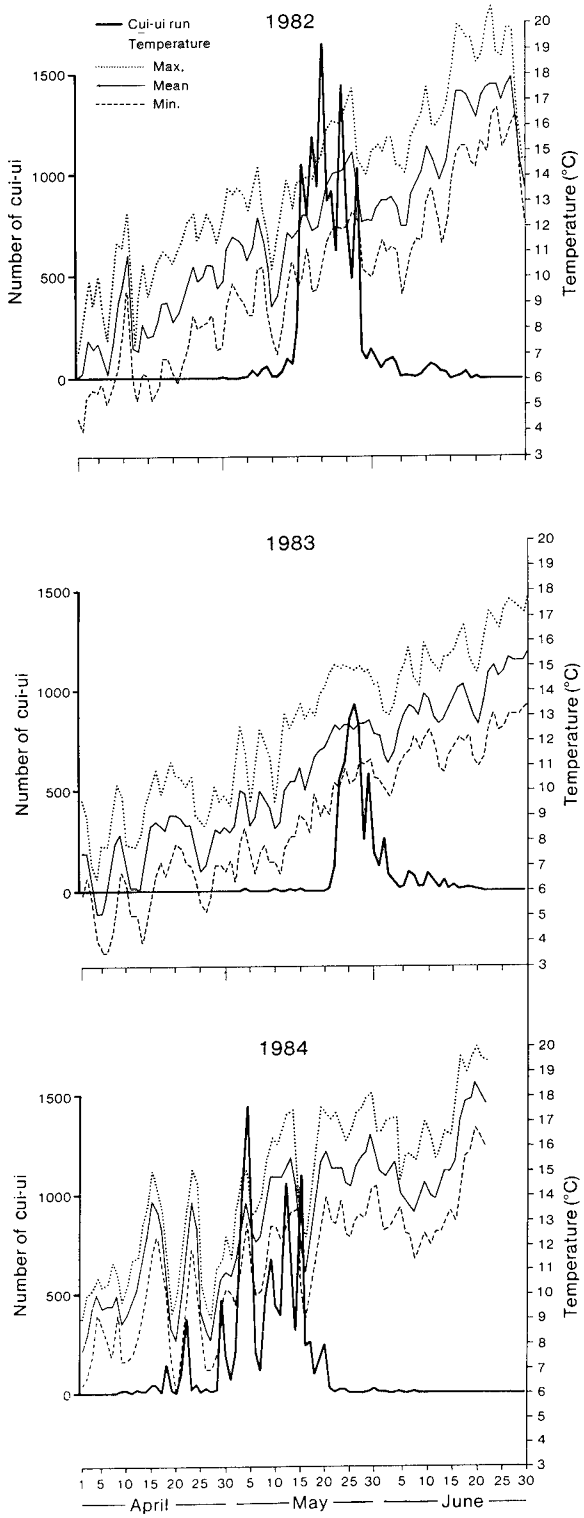

Fig. 4. Cui-ui spawning migration and daily water temperatures in the Truckee River 1982–84.

4.8 km up the fishway or 3.0 km up the river to MB dam), they traveled an average of only 2.1 km (range, 0.5 to 4.8 km) farther upstream. Once the migrating fish were above MB dam, they generally moved about for 1 or 2 days (presumably seeking a spawning site), remained in a limited area for several days (presumably to spawn), and then returned to the lake. Males occasionally spent several days at each of two or more locations—suggesting that they spawned at more than one site. Radio-tagged males remained in the river for 6.5 to 16.5 days and females for 4.0 to 10.5 days. Downstream migration back to the lake took place primarily at night, confirming similar observations by Scoppettone et al. (1983). The behavior of radio-tagged fish was presumably the same as that of untagged fish; Scoppettone et al. (1983) reported that cui-ui reproductive behavior was unaltered by externally applied radio tags.

Reproduction

Cui-ui first entered the spawning run at lengths of 380–420 mm, at 6 years of age. In the FPB, the ratio of males to females was 1:1.3 in 1982 and 1983 and 1:2.5 in 1984. These sex ratios essentially represent the sex ratio for a single year class—that of 1969 (sex ratios for other year classes are discussed later). Why there were proportionately fewer males in the 1969 year class in 1984 than in other years is open to conjecture; however, the migratory route taken to the FPB may have been a factor. After the completion of MB dam and the fishway, 1984 was the first year that all cui-ui entered the FPB by way of the river trap. Conceivably the fishway ladders were restrictive to females. If so, the 1984 sex ratio probably represents our least biased sample. We cannot comfortably make meaningful comparisons with previously documented sex ratios, because all were potentially biased. Early fishway runs were influenced by ladder modifications or small sample size, and sex ratios published by Koch (1972, 1973, and 1976) were at least partly based on catches in gill nets that were clearly selective for females (the larger fish).

Fecundity

Fecundity was determined from females that were dropped along the fishway by American white pelicans (predation by pelicans is discussed later), or that died of injuries in the FPB; a few specimens of selected sizes were sacrificed. Fecundity estimates were made by volumetric displacement, as described by Raney and Webster (1942). For each fish, we took five egg samples along the gonads, each sample consisting of at least 1 mL of eggs from complementary sites in both ovaries. The mean number of eggs per milliliter was counted for the five samples, and the volumetric displacement of the ovaries determined. The total number of eggs in the ovaries was then estimated by direct proportion.

Fecundity estimates ranged from 24,000 eggs for the smallest female, 432 mm long, to 196,000 for the largest, 657 mm long (Fig. 5). The relative consistency of estimates for the 2 years leads us to believe that fecundity was lower in 1983 than in 1982. Least squares analysis showed that a female 558 mm long (the average length) produced 104,000 eggs in 1982 and 76,000 in 1983. The reduction in eggs in 1983 paralleled a reduction in relative gonad weight, from 18% of total body weight in 1982 to 15% in 1983.

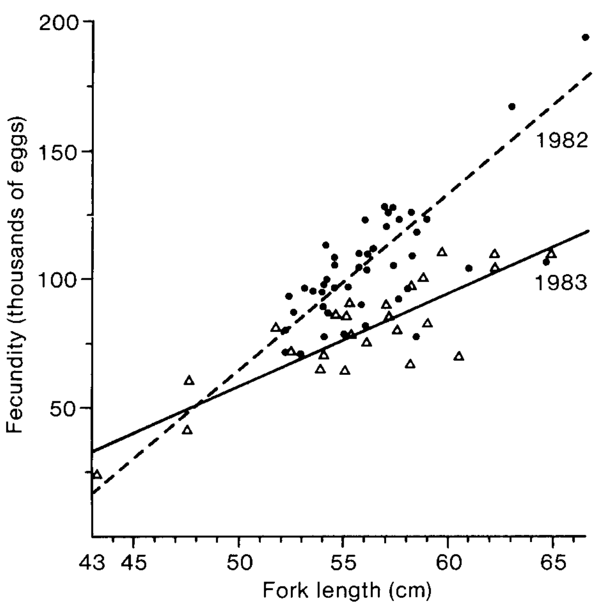

Fig. 5. Cui-ui fecundity as a function of fork length of 44 females in 1982 and 25 in 1983.

Spawning Habitat

Cui-ui, like other catostomids, spawn in groups, depositing their eggs over a broad area (Scoppettone et al. 1983). The tracking of radio-tagged fish released above MB dam revealed the location of 15 more or less discrete spawning areas during the 3 years of study. One to five depth and water velocity measurements were taken at each area, depending on the size of the area and the relative concentration of eggs; more measurements were

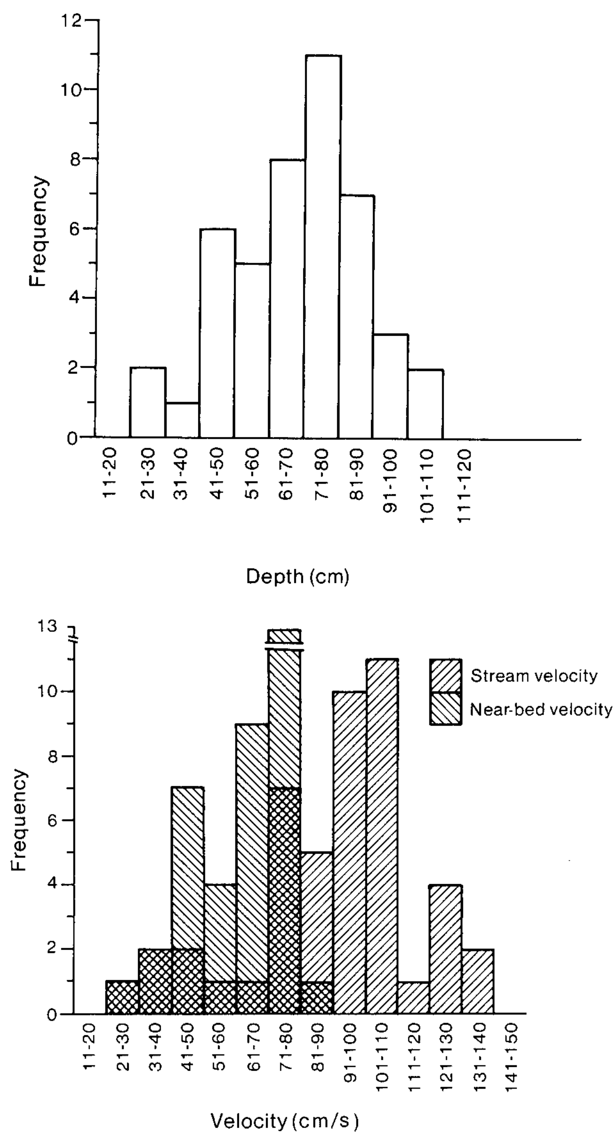

Fig. 6. Frequency of use of spawning sites as a function of stream depth, stream velocity, and near-bed velocity, 1982–84.

taken in the more heavily used areas. We made 8 depth and velocity measurements in 1982, 23 in 1983, and 14 in 1984. Near-bed velocity (10 cm above the bottom) was measured only at the spawning sites found in 1983 and 1984. Average stream flow (m^3/s) during the spawning period was 85 in 1982, 170 in 1983, and 37 in 1984.

Cui-ui spawned over predominantly gravel substrate in water 21 to 110 cm deep, where stream velocities were 27 to 140 cm/s and near-bed velocities were 21 to 90 cm/s (Fig. 6). Most spawning was at depths of 71 to 80 cm, at stream velocities of 101 to 110 cm/s, and near-bed velocities of 71 to 80 cm/s. These depths and velocities were slightly greater than those reported for the June sucker, *Chasmistes liorus*, by Shirley (1983), and greater in general than those reported for other stream-spawning catostomids (McCart and Aspinwall 1970; McSwain and Gennings 1972; Burr and Morris 1977).

Emigration of Larvae

Timing of Outmigration

Downstream migration rates of young cui-ui were determined by fishing three plankton nets in the fishway or downstream from MB dam. The nets were of l-mm mesh, had a rectangular mouth 43.2 cm long and 30.5 cm wide, and were 115 cm long; the collection bucket was 3.8 cm wide and 10.2 cm long and lined with 0.5-mm mesh plastic screen. We fished the nets at the end of the fishway in 1982 and 1983 (when unusually high flows made it difficult to fish them in the main stem of the river) and below MB dam in 1984, when the river flow was lower. The nets were fished 3 nights per week (Tuesday, Wednesday, Sunday) from 29 May to 30 July in 1982, on alternate nights from 29 May to 14 August in 1983, and on alternate nights from 3 May to 20 June and twice weekly from 21 June to 2 July in 1984. All nets were fished from 2000 to 2400 h and checked hourly. This fishing period was based on catches in 12 24-h periods along the lower Truckee River in 1981 (unpublished data), which showed that emigration was primarily at night. The samples were held until the following morning, and young catostomids from each net were preserved in 10% formalin. We separated cui-ui larvae from those of Tahoe suckers (*Catostomus tahoensis*) and mountain suckers (*C. platyrhynchus*)—the other suckers that spawned in the Truckee River—by using a key devised by Snyder (1983).

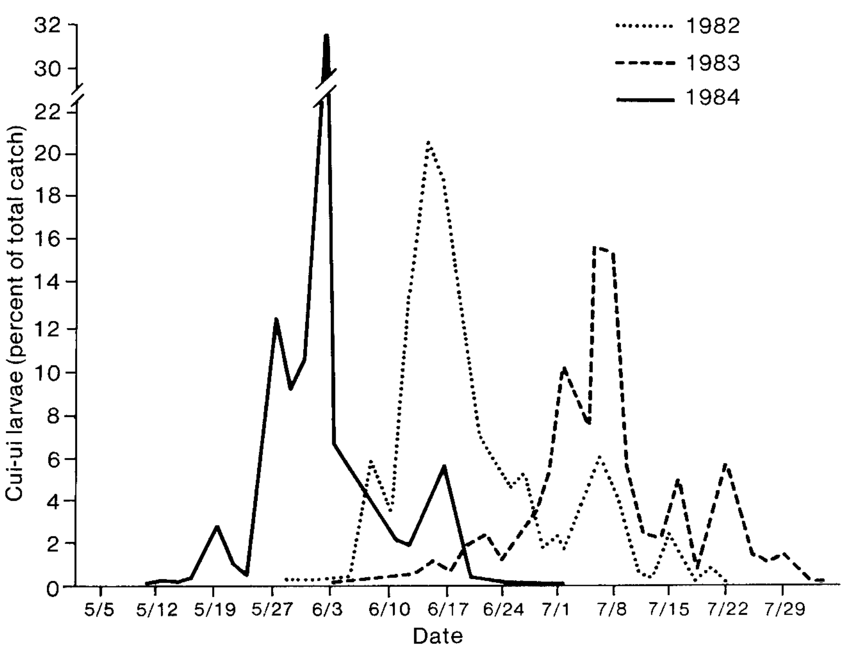

Fig. 7. Emigration pattern of larval cui-ui in the Truckee River (1982 and 1984) or the Pyramid Lake Fishway (1983).

More than 98% of the downstream migrants captured in the plankton nets were swim-up larvae, 10.5–12.5 mm long, with well-developed yolk sacs. The rest, which were 13.0–30.0 mm long and typically captured later in the season, had obviously remained in the river for various periods after swim-up. We believe that our samples reflected typical outmigrations in 2 of the 3 years of fishing: In 1982, emigration began on 29 May, peaked on 15 June, and ended on 22 July; and in 1984 the emigration dates were 10 May, 3 June, and 2 July (Fig. 7). The peak emigration followed peak adult migration by 26 days in 1982 and 29 days in 1984; adult migrations peaked on 20 May in 1982 and 3 May in 1984 (Figs. 4 and 7). The rather brief period between peak migration of adults and that of larvae is consistent with our observation that radio-tagged adults spawned soon after they were released from the FPB.

A comparison of catches in the plankton nets in 1982 and 1983—years in which we monitored emigration at both the upper and lower ends of the fishway—suggests that our catches in 1983 may not have been representative. Whereas the numbers of larvae captured in the upstream and downstream ends were identical in 1982 (indicating that the larvae had been produced in the river upstream) fewer larvae were taken in the upstream nets than in the downstream nets in 1983 (indicating that cui-ui spawned in the fishway itself—even though it afforded poor spawning habitat and generally yielded few larvae—and that recruitment from the river was low). Consequently we are not confident that the 1983 emigration pattern (Fig. 7) clearly reflects the behavior of river emigrants in that year.

Daily Pattern

The plankton netting station was operated over one or more 24-h periods in each of the 3 years of river study. Effort was most intensive in 1984, when we conducted four 24-h studies at 1-week intervals—one before, two during and one after peak emigration—at a station below MB dam.

Larval cui-ui emigrated downstream almost exclusively at night in 1984—primarily between 2200 and 0300 h (Fig. 8). Results in 1982 and 1983 (not shown) were essentially identical. Nocturnal emigration is not unique to larval cui-ui, but has also been noted in other catostomids (Geen et al. 1966; Clifford 1972), as well as in other species (e.g., Northcote 1969).

Effect of Marble Bluff Dam

Larval mortality due to trauma from passage over MB dam was investigated in 1984. Three groups of hatchery-reared larvae were released at the top of the dam, and representative samples were recaptured in plankton nets immediately below it. The larvae were then held in an aquarium supplied with Truckee River water. The aquarium was aerated and partly immersed in river water to control tempera-

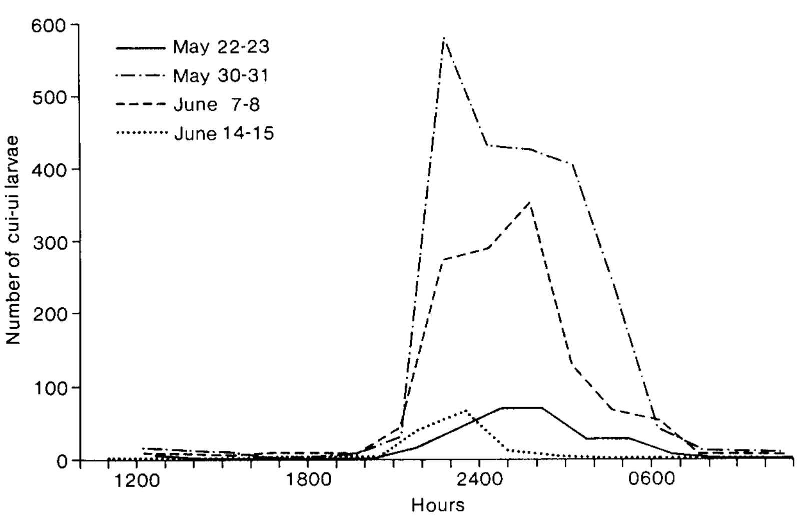

Fig. 8. Diel emigration patterns of larval cui-ui monitored weekly in 1984.

ture. A total of 100 larvae placed directly into another aquarium served as controls. Survival was 99% in the controls and 89 to 93% in the test groups (Table 2). Our inconclusive subjective evaluation was that the modest losses were due as much to trauma from impingement on the recapture net as to dam passage.

Age and Growth

The reliability of scales, the most widely used structure for determining the age of freshwater fishes, has been questioned for catostomids because ages of old fish are often underestimated (Dence 1948; Coots 1965; Geen et al. 1966; Coble 1967; Beamish 1973; McAda and Wydoski 1980; Minckley 1983). Strong evidence of age underestimation has also been reported in the cui-ui; fish recaptured up to 7 years after they were tagged with Carlin tags showed no increase in the number of scale annuli (Gary Sonnevil, U.S. Fish and Wildlife Service, Great Basin Complex, Reno, Nevada, personal communication).

In contrast, the use of opercle bones to age cui-ui proved successful. We used opercle bones taken from dead cui-ui collected along the fishway, in the FPB, or at the Pyramid Lake Paiute Indian Cui-ui Hatchery; from fish sacrificed in food and fecundity studies; and from museum specimens. Fresh opercles collected in 1982–84 were boiled to separate tissue from bone. In preserved (museum) specimens, the tissue was separated by scraping it off the opercles with a scalpel. Cui-ui were aged by counting annuli from the centrum out to the edge (Fig. 9). In older fish, the fenestrated bone associated with the expansion of the opercle-hyomandibular socket was ground to expose the first one to three annuli. Opercles were selected over fin rays, otoliths, and vertebrae because they were easy to interpret and could be conveniently processed for reading. Annuli were determined according to the criteria of Casselman (1973) for cleithra of northern pike (*Esox lucius*). Relatively transparent regions of the opercle were accepted as being areas of the greatest calcium concentration, indicative of slow or winter growth, and the more opaque regions were accepted as indicating a greater concentration of proteinaceous material and accelerated growth. The outer limit of each anulus was generally represented by a narrow transparent zone. In cui-ui more than about 20 years old the transparent zone was greatly reduced. An annulus was defined as the region where the outer edge of a transparent zone abutted an inner edge of an opaque zone. Although some young adults collected late in the spawning run had already formed the annulus and part of the opaque zone, most mature fish appeared to form the annulus after the spawning season. In assigning ages, we credited these fish with a "virtual" annulus at the outer edge of the opercle until the annulus was formed.

Beamish and McFarlane (1983) stressed the importance of validating annuli in older fish to verify that they were indeed being formed. Our technique of aging was validated by monitoring individual year classes through time. The 355 opercle specimens collected in 1956–84 included fish 1 to 41 years old, but only 11 year classes were represented in this broad span. Once these year classes were tentatively identified, the addition of annuli could be followed in succeeding years. For example, because the 1969 year class was dominant in the population in 1982–1984, opercular annuli could be easily verified by monitoring this group each year. In the first

Table 2. *Survival of cui-ui larvae recaptured and held in Truckee River water for 48 h after passage over Marble Bluff Dam. Survival in control fish similarly held was 99%.*

Date (June 1984)	River flow (m^3/s)	Number of larvae		Survival 48 h after recapture (%)
		Released above dam	Recaptured below dam	
4	65	3,000	70	89
13	45	2,300	59	88
22	23	5,000	140	93

year for which we had a sizable collection of opercles (spring 1978), we recognized four year classes: 1942, 1946, 1950, and 1969 (Table 3). In this collection, 32 of 79 fish were of the 1969 class (9 years old). By 1982, fish of the 1969 year class had become dominant, and had added four additional annuli; they had 14 annuli in 1983, and 15 in 1984. Several fish from this group were also collected in 1975, 1976, and 1977. Other year classes that we were able to follow similarly were those of 1942, 1950, 1973, 1975, and 1976.

Fish of the 1950 year class, which made up our second-largest collection, apparently dominated the population before the 1969 year class became dominant. Annual additions of annuli were followed as they were in the 1969 year class. In addition, we obtained (from the museum at the University of Nevada, Reno) seven cui-ui of the 1950 year class that were collected in 1956; other collections of fish of this year class were made in 1978 and 1982–84.

We had little difficulty with false annuli except in fish of the 1950 year class. This group had several false annuli within the first 6 years of life. To determine which were the most plausible annuli, we compared opercles of fish of the 1950 year class with those of fish from other year classes.

To our knowledge, the cui-ui 28–41 years old (Table 3) represent the oldest validated catostomids reported in the literature. However, catostomids in general are long-lived: Beamish (1973) validated white suckers (*Catostomus commersoni*) of age 17, and Minckley (1983) believed that razorback suckers (*Xyrauchen texanus*) in the lower Colorado River reached 30 years of age. The longevity of the cui-ui has undoubtedly had highly significant survival value for the species because of the scarcity of high-water years during which cui-ui were able to enter the river to spawn. Of the 11 year classes identified, 8 were hatched before the installation of MB dam, and during high-water years when spring flows

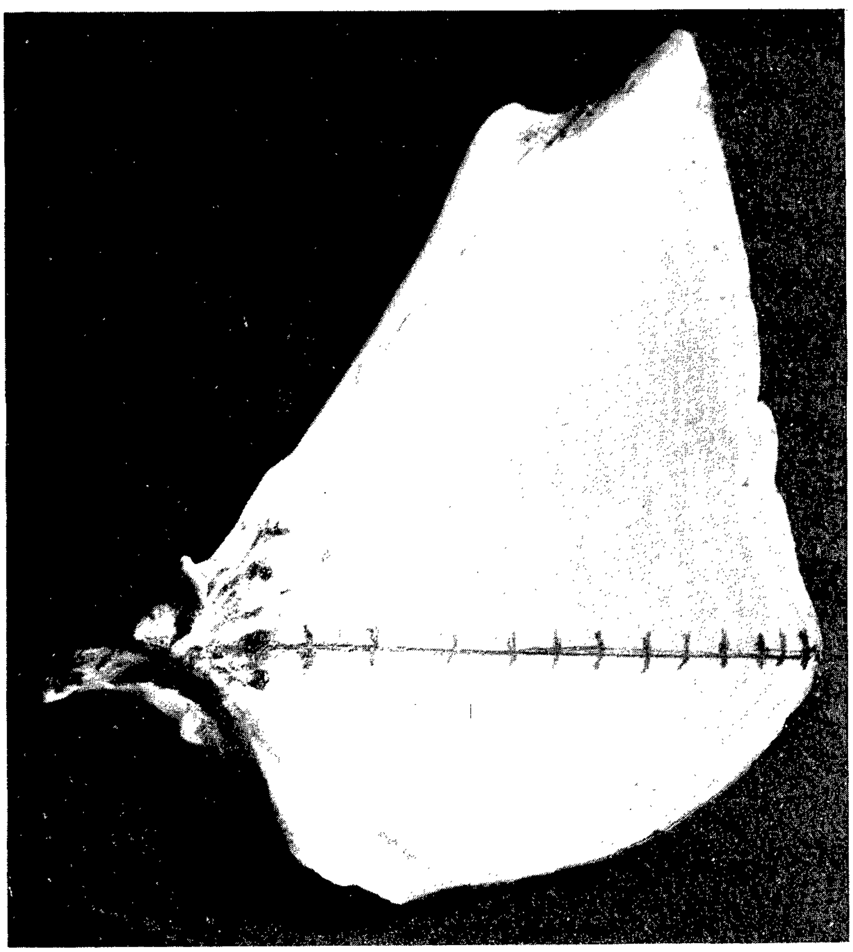

Fig. 9. Cui-ui opercle bone, showing annuli (denoted by hatched line) from centrum to edge, and plane along which growth measurements were made.

were apparently sufficient to permit at least limited access through the delta. Fish of the 1976 and 1978 year classes were either produced in the hatchery or were the progeny of the few fish that traversed the delta and spawned downstream from MB dam. The presence of the 1980 year class can probably be attributed to adult spawners reaching the lower Truckee River through the fishway (Table 1).

Growth rates were estimated for both of the dominant year classes, 1969 and 1950. We used the opercle collections made in 1982 and 1983 to estimate growth of fish of the 1969 year class and the collections in 1978, 1982, and 1983 to estimate growth of fish of the 1950 year class. We used opercles from 73 males and 93 females of the 1969 year class and 50 females of the 1950 year class, from which only 3 males were available (13 other specimens were too decomposed to be sexed or accurately measured). This disproportionate sex ratio among old fish was also apparent in the catches made during our 1983 offshore gill netting; of 140 fish captured that were recognized as "old" (see later discussion) only 3 were males. These observations clearly suggested that females lived longer than males—a common phenomenon among catostomids (Hauser 1969).

Opercle bones were also used to back-calculate cui-ui growth rates. Measurements were made on the left opercle with a vernier caliper to the nearest 0.01 mm, from the base of the centrum posteriad along the inner side of the opercles (Fig. 9). To back-calculate the growth rate of fish of the 1969 year class, we correlated fork lengths of cui-ui to opercle length, as described by Miller (1966) for scales. The estimated mean annual length of fish at each age was then computed.

It was difficult to develop a sound growth curve for the 1950 year class because data for older cui-ui tagged with Floy tags showed that growth in length had virtually ceased. However, growth of fish bones

Table 3. *Estimated ages of 355 cui-ui collected in Pyramid Lake in 1956–84. Numbers of fish are shown in boldface.*

Year class	Year of collection								
	1956	1975	1976	1977	1978	1981	1982	1983	1984
1942					36 **1**			41 **2**	
1946					32 **6**				
1950	6 **7**				28 **40**		32 **6**	33 **15**	34 **2**
1967								16 **1**	
1969	6 **3**	7 **1**	8 **2**	9 **32**			13 **56**	14 **113**	15 **44**
1971								12 **1**	
1973								10 **2**	11 **1**
1975							7 **1**	8 **2**	
1976							6 **4**	7 **5**	8 **2**
1978									6 **2**
1980					1 **4**				

continues through life (Simmons et al. 1970), and thus the growth of opercle width and body length was disproportionate. For fish in the 1950 year class we constructed two growth curves (Fig. 10)—one for the proportional growth of opercle width to body length throughout life, and one based on the assumption that growth ceased in fish 20 years old or older. (It was also near the 20th year that annuli began to coalesce.)

Growth rates of fish of the 1969 year class were virtually the same for both sexes in their first 6 years of life (Fig. 10); thereafter, the growth of females was the faster. (Six-year-old fish were also the youngest we found in the spawning run.) The growth pattern in cui-ui was thus somewhat similar to that in longnose suckers (*Catostomus catostomus*) in Yellowstone Lake, among which growth also diverged—the females growing faster after age 4, when males became sexually mature (Brown and Graham 1954).

We believe that our modified curve for 33-year-old females (Fig. 10) better depicts cui-ui growth than does the curve based on direct proportion. (This hypothesis can perhaps be tested as fish of the dominant 1969 year class increase in age in future years.) We were unable to find comparable growth curves for catostomids in the literature. Much of the voluminous literature on catostomid growth either concerned short-lived species, did not include validation of the aging method, or combined the growth rate of the sexes (Brown and Graham 1954; Harris 1967; Bailey 1969; Hauser 1969; Dauble 1980; McAda and Wydoski 1980; Vondracek et al. 1982).

The growth rate of females up to 14 years old appeared to be somewhat faster in the 1969 year class than in the 1950 year class, as shown by the solid curves in the upper and lower graphs of Fig. 10. To us, the most appealing explanation for the difference is that the substantially larger cui-ui population of the early 1950's described by Koch (1976) resulted in greater population density and perhaps greater competition for food and space, and thus reduced growth.

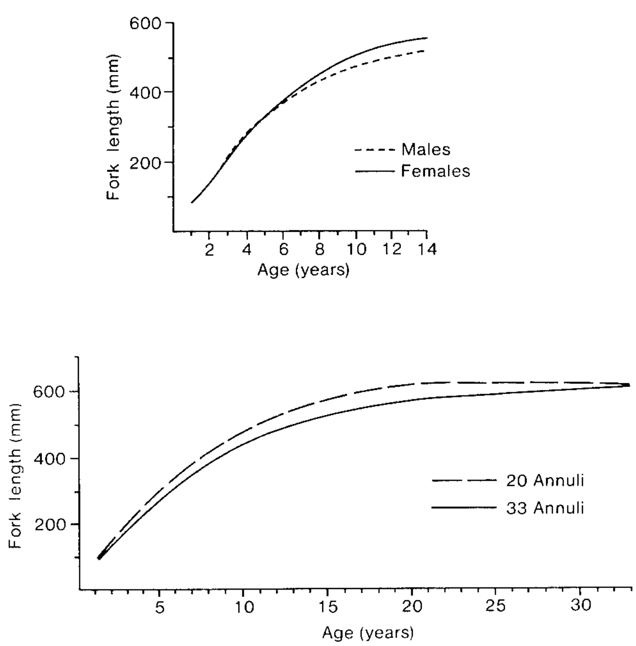

Fig. 10. Back-calculated growth of cui-ui in Pyramid Lake. *Upper graph:* Females (n = 93) and males (n = 73) of the 1969 year class collected in 1983–84. *Lower graph:* Female (n = 50) of the 1950 year class, based on 33 annuli and 20 annuli (*see* text for discussion).

Age Structure of Population

An understanding of the age structure of the cui-ui population in Pyramid Lake is facilitated if one considers the prespawning aggregation as consisting of two subpopulations, categorized simply as young fish and old fish. Of the 11 cui-ui year classes identified (Table 3), young fish were considered to be those of the 1967 and later year classes and old fish those of the 1950 and earlier year classes. Members of the two subpopulations were generally easy to distinguish. Most old fish were females, in about 10% of which the anal fin was abraided or missing, presumably as a result of spawning in previous seasons (Scoppettone et al. 1983). The presence of large brown spots, usually around the anal fin, in the stomach region, or on the head, was typical. However, the most distinguishing morphological characteristic was the large ratio of head length to body length. Behaviorally, old fish concentrated at the terminal ladder of the fishway, but seldom migrated beyond that point. Cui-ui that moved through the fishway were almost exclusively from the subpopulation of younger fish.

Of the 5,994 fish that passed through the FPB in 1983 (the year in which our largest sample of opercles was taken), more than 97% were of the 1969 year class. Before making this estimate, we tested the hypothesis that fish in our sample of 119 cui-ui collected along the fishway (excluding the old fish) were representative of cui-ui that entered the FPB. Using a chi-square test, we compared the observed length frequency of the fishway sample with the length frequency of fish that entered the FPB. Males and females were tested separately. Both samples proved to be representative of the run. The age structure of cui-ui captured in the FPB was probably representative of that of the young fish offshore. We then determined the relative age structure of the offshore population by estimating the relative number of old and young fish in this population in 1983. From this estimate, we deduced that 92% of the fish in the offshore population were of the 1969 year class, 3% were young fish of year classes other than that of 1969, and 5% were old fish.

The predominance of the 1969 year class in the cui-ui population in 1982–84 was further supported by records of cui-ui captured at the FPB in 1978–83, which showed that mean length of fish of both sexes increased progressively (Fig. 11). The impact of this dominant group on the population was also reflected in data from the systematic gill netting conducted in Pyramid Lake during 1977–83 (Fig. 12). The subpopulation of young fish increased in length, whereas that of old fish retained nearly the same length frequency, but declined in numbers. This decline was probably due to natural mortality or sample size (also, the heads of some old fish may have become too large to permit their capture in the largest mesh size of the gill nets that we used).

The reason for the domination of the population by the 1969 year class is open to conjecture. We

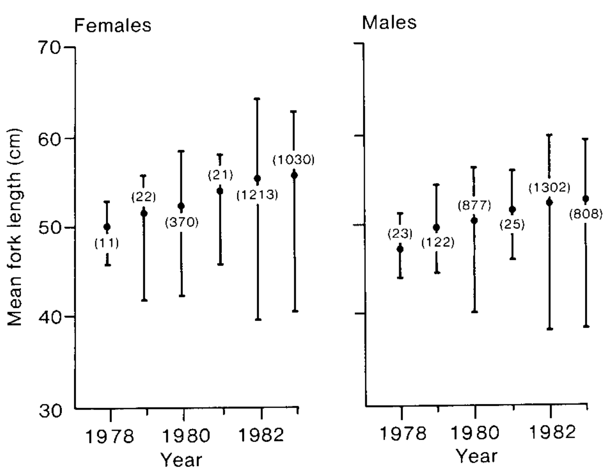

Fig. 11. Length distribution of male and female cui-ui that entered the fish processing building during the 1978–83 spawning migrations. Data given are mean and range; sample size is shown in parentheses.

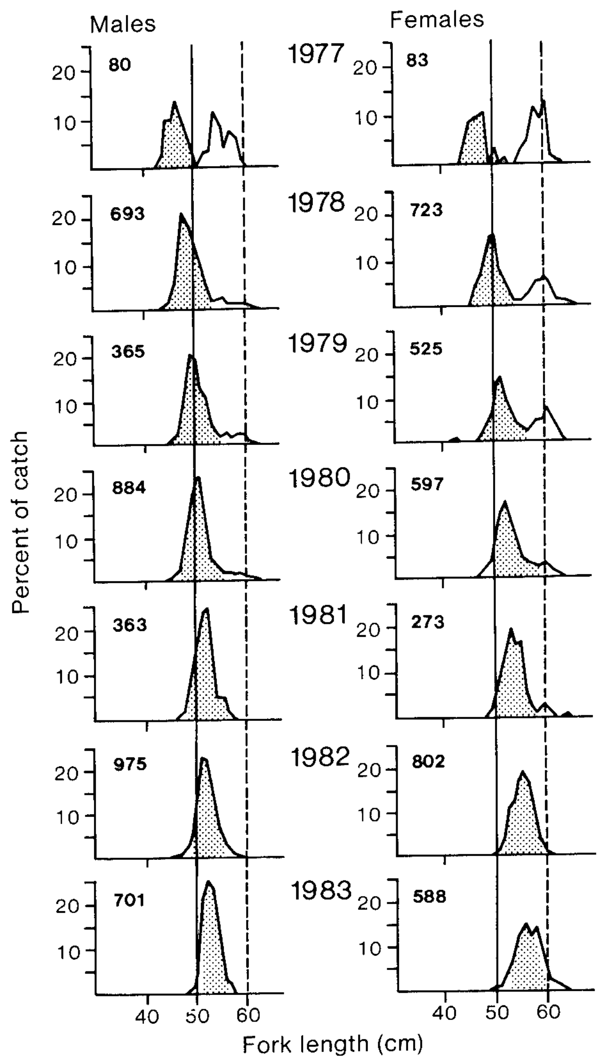

Fig. 12. Length distribution of male and female cui-ui gill-netted from the prespawning aggregation in Pyramid Lake off the mouth of the Truckee River, 1977–83. Numbers in the upper left corner of each panel show numbers of fish; stipled areas denote the 1969 year class.

believe that it was linked to unrestricted river access in that year. Spring flows in 1969 were among the highest in 50 years. Although high flow alone does not facilitate movement over the delta, perhaps one or more of the numerous delta channels was deep enough to permit easy passage. Our observation that most old fish were from the 1950 year class strongly suggests that it once dominated the population. Again, the reason for success of this group is unexplained, but it may have been a result of the construction of a spawning channel in 1946 at the site of the later fishway (La Rivers 1962). The Truckee River was diverted down the channel until fall 1950, when high flows destroyed the diversion dam. Spring flows in 1946 and 1950 were the only sizable ones in the spawning channel's brief history.

Length Frequency of Adult Population

Length frequencies overlapped broadly among year classes of cui-ui. For example, among fish of the 1969 class, the fork length ranges were 458–546 mm for males and 533–590 mm for females in 1982, and 480–545 mm for males and 534–610 mm for females in 1983. Among fish of the 1950 class collected in 1983, males were 540–582 mm long and females 580–673 mm long. Nevertheless, from the relative size composition of fish in the population, some useful inferences could be made. Cui-ui first entered the spawning population at lengths of 380–420 mm, at 6 years of age. When they were 460–480 mm long, they were usually at least 8 years old, and females 520–540 mm long were about 10 years old. These younger fish were only sparsely represented among those seen in the FPB during the present study (Fig. 13). suggesting alarmingly low recruitment to the population after 1969.[1]

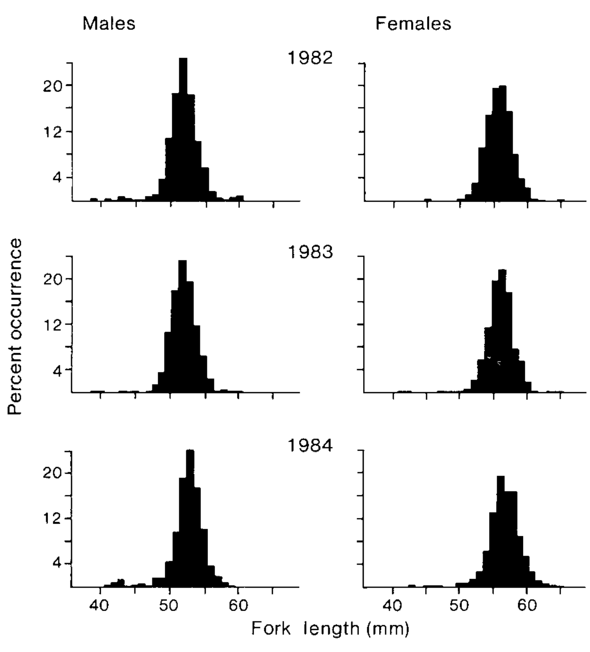

Fig. 13. Length distribution of random samples of cui-ui taken in the fish processing building during the spawning migration of 1982–84. Sample size was 500 fish of each sex in each of the 3 years.

Population Estimate

We estimated the population of the offshore prespawning aggregation in 1982 and 1983 (Table 4) on the basis of cui-ui captured in gill nets in the prespawning aggregation, marked with Floy tags, and recaptured at the FPB. (Dimensions and operation of the nets were previously described.)

As judged by recaptures at the FPB, Floy-tagged cui-ui seemingly mixed randomly in the aggregation. Previous experience with cui-ui that were gill netted from the prespawning aggregation for transport to the hatchery indicated that tagging probably caused little mortality. Also, we saw virtually no signs of

[1] We are nevertheless cautiously optimistic that several sizable year classes of cui-ui will become evident by the late 1980's. After this manuscript was essentially completed, numerous young cui-ui, 13–350 mm long were collected in Pyramid Lake. The smaller of these (13–60 mm) were seined near shore in summer 1984 and the larger (100–350 mm) were gill netted regularly in the winter of 1984 and in 1985 (Lee Carlson, Pyramid Lake Fisheries, personal communication). Previously, the only known capture in the lake of a fish shorter than 350 mm was a 32-mm specimen taken in 1938 (R. R. Miller, Department of Zoology, University of Michigan, personal communication). Cui-ui have reproduced so infrequently in the last 50 years that they simply have not been available for capture.

Table 4. *Estimated number of cui-ui in the prespawning aggregation in Pyramid Lake in 1982 and 1983.*

Item	Year 1982	1983
Tagging		
Dates	3/17–6/16	4/6–6/16
Number of fish	1,092	1,122
Recoveries in FPB		
Dates	5/15–6/11	5/22–6/8
Percent of total tagged	7.1	5.7
Estimated prespawning aggregation		
Number	187,065	103,407
95% confidence limits	151, 883–236,451	82,270–134,161

short-term loss of tags among fish entering the FPB. Using a modified Schnabel population estimator for our computation (Ricker 1975), we estimated the prespawning aggregation of cui-ui to be 187,000 fish in 1982 and 103,000 in 1983. The large number of cui-ui offshore in 1982 and 1983, compared with much smaller runs at the FPB, indicated that the fishway was not totally effective in letting fish pass. In 1982, 13,804 fish—only 7.4% of the estimated offshore population—entered the FPB; in 1983, this number was 5,994 (5.8%).

Food

Adults

To determine food of adult cui-ui in the prespawning aggregation, we collected gut samples from fish captured at offshore gill-netting stations. The guts were immediately removed and preserved in 10% formalin, and the contents of the anterior third of the intestinal tract were later determined. We used a dissecting microscope to count the

Table 5. *Stomach contents of 14 adult cui-ui collected from the 1983 prespawning aggregation (T = trace, less than 0.5%).*

Stomach contents	Total number (%)	Frequency of occurrence (%)	Total carbon (%)
Macroinvertebrates			
Chironomidae			
Chironomus sp. (larvae)	T	21	T
Pseudochironomus sp. (larvae)	T	36	T
Zooplankton			
Copepoda			
Cyclops vernalis	T	21	T
Diaptomus sicilis	46	100	71
Nauplii	T	57	T
Cladocera			
Ceriodaphnia quadrangula	54	100	29
Algae	T	86	T

individually sorted macroinvertebrates, and identified and counted zooplankton with the aid of a compound microscope (× 100). Numerical analyses of zooplankton were made by counting the organisms in a Sedgewick-Rafter cell; three to five counts from the 1-mL cell were made for each fish and extrapolated for the entire sample volume. The relative food value of each organism eaten was estimated from the carbon equivalents developed by Galat and Vucinich (1983) for Pyramid Lake.

Of 17 adult cui-ui collected from the prespawning aggregation off the delta in 1983, 14 contained food (Table 5). This observation differs from those of Johnson (1958) and Koch (1972), who suggested that adults ceased feeding after they entered the prespawning aggregation. The fish collected had fed almost exclusively on two species of zooplankton—*Diaptomus sicilis* and *Ceriodaphnia quadrangula*. Lider and Langdon (1978) found these two species to be the most abundant zooplankters in Pyramid Lake, ranked in the same order of abundance as in the cui-ui guts examined. Although *D. sicilis* composed only 46% of the total number of organisms eaten, it contributed 71% of the total carbon. Chironomid larvae and algae occurred in only trace amounts. Other members of the genus *Chasmistes* are also believed to be planktivorous (Hubbs and Miller 1953; Moyle 1976; Miller and Smith 1981). This belief is based on the similar terminal position of the mouth, and the presence of long filamentous gill rakers.

Most catostomids feed most actively at night (Moyle 1976), and we suspect that peak feeding among members of the prespawning aggregation was at night, since this is when zooplankters are concentrated near the surface (Lider and Langdon 1978) and when our fish bearing sonic tags were most active. During most of the day the fish remained near the mouth of the river, where foraging opportunity was known to be limited.

Larvae and Young of the Year

Food of larvae and postlarvae in the Truckee River was determined by placing test fish, taken from the Pyramid Lake Cui-ui Hatchery immediately after swim-up on 21 April 1981, into a fabricated backwater habitat that consisted of two shallow meandering channels dug off a natural braid of the lower Truckee River, 20 km upstream from Pyramid Lake. The habitat closely approximated that in backwaters along the lower Truckee River. Larvae were introduced 3 weeks after the channels were constructed. The fish were able to leave by entering either an upstream or downstream trap. More than 80% of the larvae eventually caught were taken in the downstream trap within 3 days after their release. As the remaining fish moved out, a small

Table 6. *Stomach contents of 42 larval and early juvenile cui-ui (12–28 mm long) from a natural side channel of the Truckee River, 1981 (T = trace, less than 0.5%).*

Stomach contents	Total number (%)	Frequency of occurrence (%)	Total carbon (%)
Macroinvertebrates			
Chironomidae			
Larvae	26	86	56
Pupae	1	10	1
Amphipoda	1	5	3
Zooplankton			
Copepoda	20	69	18
Cladocera	32	36	15
Ostracoda	3	14	5
Rotifera	1	7	T
Nauplii	10	21	2
Algae	T	70	T
Pollen	7	5	T

sample was collected and preserved in 10% formalin each week. The largest cui-ui taken was 28 mm long and had remained in one of the channels for 5 weeks. We later identified and counted the contents of the entire gut. (Larvae captured at our plankton net stations were not used for food analysis because they were held overnight before being separated from the tangle of filamentous algae taken with them in the collecting net.)

Of a sample of 51 young cui-ui 12–28 mm long, 42 contained food. Chironomids were found in 86%, copepods in 69%, and algae (primarily diatoms) in 70% (Table 6). Numerically, cladocerans accounted for 32% of the food items eaten, followed by chironomid larvae (26%). In terms of energy potential, chironomid larvae were the most important food item, representing 56% of the total carbon consumed, followed by copepods (18%), and cladocerans (15%).

Larvae 12–20 and 21–28 mm long generally ate the same food except that only the smallest fish (12–13 mm long) ate copepod nauplii, and the larvae longer than 20 mm ate larger numbers of the cladocerans and ostracods that are typically associated with the benthos. These organisms were rarely eaten by smaller fish.

Cui-ui larvae were rather selective in their feeding, taking individual organisms from the water column, as has been observed in other catostomids (Willsrud 1971; Corbett and Powles 1983). In most other catostomids, however, the mouth shifts to a more ventral position when the postlarval stage is reached and the fish become more bottom oriented and feed less discriminatively; sand and silt are ingested, together with algae and invertebrates (Moyle 1976; Marrin 1983). There is no morphological change in the mouth parts of cui-ui at the onset of the postlarval stage (Miller and Smith 1981), and our limited data on yearlings suggested that they, too, feed on zooplankton.

Four yearling cui-ui collected from Mud Lake Slough in 1981 had apparently passed through the Indian Ditch irrigation diversion as larvae in 1980, and moved into Mud Lake Slough with agricultural return water. We preserved the fish in 10% formalin and later identified and counted the contents of the anterior one-third of the gut (as previously described for the adults). Zooplankton made up over 97% of the food items and 90% of the total carbon (Table 7). Diatoms and filamentous green and blue-green algae were noted in the guts of all four fish but were of negligible importance in terms of energy potential.

Since food is linked to both environmental conditions and food availability (Vondracek et al. 1982; Marrin et al. 1984), specific food items eaten

Table 7. *Stomach contents of four yearling cui-ui (104–120 mm long) collected in Mud Lake Slough on 31 March 1981 (T = trace, less than 0.5%).*

Stomach contents	Total number (%)	Frequency of occurrence (%)	Total carbon (%)
Macroinvertebrates			
Chironomidae			
Larvae	2	75	7
Pupae	T	25	T
Amphipoda	T	25	1
Nematoda	1	75	1
Annelida	T	25	T
Zooplankton			
Copopoda	9	100	14
Cladocera	59	100	72
Ostracoda	T	25	T
Rotifera	28	100	4
Nauplii	T	50	T
Algae	T	100	1

by yearling cui-ui could reasonably be expected to differ between Pyramid Lake and Mud Lake Slough because the ecosystems differ substantially. However, the meager evidence is that yearling cui-ui are discriminative feeders.

Predation

Adult cui-ui are exposed to predation by American white pelicans during their spawning migration. In 1982 we accounted for 427 cui-ui lost to pelicans; of these, 355 were either dropped or regurgitated by the birds along the fishway or along the delta, and 72 were counted on Anaho Island, the site of a pelican rookery in Pyramid Lake. The fish dropped were 510–630 mm long and weighed 1.8–3.1 kg; 84% were females. We did not determine why the fish were dropped, but once the fish were on the ground, the pelicans did not attempt to recover them.

The bones from the 72 cui-ui on Anaho Island were obviously from the 1982 migration; older bones were also present, but they were generally broken and buried in the soil.

In spring 1983, the spawning migration of the cui-ui—like that of the Tahoe sucker and mountain sucker, the other two major species migrating to the FPB—were delayed. During peak fish migration in late May, relatively few pelicans foraged along the fishway and only 26 fish carcasses were recovered. In 1984, cui-ui migrated up the Truckee River exclusively, and no cui-ui carcasses were found along the fishway or on the delta. Because water depth at the delta exceeded 1 m, most fish probably remained beyond the reach of the pelicans (Knopf and Kennedy 1981).

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References

Bailey, M. M. 1969. Age, growth, and maturity of the longnose sucker *Catostomus catostomus*, of western Lake Superior. J. Fish. Res. Board Can. 26:1289–1299.

Beamish, R. J. 1973. Determination of age and growth of populations of the white sucker *(Catostomus commersoni)* exhibiting a wide range in size at maturity. J. Fish. Res. Board Can. 30:607–616.

Beamish, R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112:735–743.

Benson, L. V. 1978. Fluctuations in the level of pluvial Lake Lahontan for the past 40,000 years. Quat. Res. 9:300–318.

Bres, M. 1978. The embryonic development of the cui-ui, *Chasmistes cujus* (Teleostei, Catostomidae). M.S. thesis, University of Nevada, Reno.

Brown, C. J. D., and R. J. Graham. 1954. Observations on the longnose sucker in Yellowstone Lake. Trans. Am. Fish. Soc. 83:38–46.

Burr, B. M., and M. A. Morris. 1977. Spawning behavior of the shorthead redhorse *Moxostoma macrolepidotum* in Big Rock Creek Illinois. Trans. Am. Fish. Soc. 106:80–82.

Casselman, J. M. 1973. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. Pages 13–27 *in* T. B. Bagenal, ed. Proceedings of an international symposium on the ageing of fish. European Inland Fisheries Commission of FAO, The Fisheries Society of the British Isles and The Fish Biological Association. Unwin Brothers.

Chatto, D. A. 1979. Effects of salinity on hatching success of the cui-ui. Prog. Fish-Cult. 41:82–85.

Clifford, H. F. 1972. Downstream movement of white sucker, *Catostomus commersoni*, fry in a brown-water stream of Alberta. J. Fish. Res. Board Can. 29:1091–1093.

Coble, D. W. 1967. The white sucker population of South Bay, Lake Huron, and effects of the sea lamprey on it. J. Fish. Res. Board Can. 24:2117–2136.

Coots, M. 1965. Occurrences of the Lost River sucker, *Deltistes luxatus* (Cope), and shortnose sucker, *Chasmistes brevirostris* (Cope) in northern California. Calif. Fish Game 51:68–73.

Corbett, B., and P. M. Powles. 1983. Spawning and early-life ecological phases of the white sucker in Jack Lake, Ontario. Trans. Am. Fish. Soc. 112:308–313.

Dauble, D. D. 1980. Life history of the bridgelip sucker in the central Columbia River. Trans. Am. Fish. Soc. 109:92–98.

Dence, W. A. 1948. Life history, ecology and habits of the dwarf sucker, *Catostomus commersoni utawana* Mather, at the Huntington Wildlife Station. Roosevelt Wild Life Bull. 8:82–150.

Galat, D. L., E. L. Lider, S. Vigg, and S. R. Robertson. 1981. Limnology of a large, deep North American terminal lake, Pyramid Lake, Nevada, U.S.A. Hydrobiologia 82:281–317.

Galat, D. L., and N. Vucinich. 1983. Food partitioning between young of the year of two sympatric tui chub morphs. Trans. Am. Fish. Soc. 112:486–497.

Geen, G. H., T. G. Northcote, G. F. Hartman, and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes on Sixteen Mile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish. Res. Board Can. 23:1761–1788.

Harris, R. H. D. 1967. Growth and reproduction of the longnose sucker, *Catostomus catostomus* (Forster), in Great Slave Lake. J. Fish. Res. Board Can. 19:113–126.

Hart, L. G., and R. C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictis olivaris*). Trans. Am. Fish. Soc. 104:56–59.

Hauser, W. J. 1969. Life history of the mountain sucker, *Catostomus platyrhynchus*, in Montana. Trans. Am. Fish. Soc. 98:209–215.

Hubbs, C. L., and R. R. Miller. 1948. The Great Basin with emphasis on glacial and postglacial times. II. The zoological evidence. Univ. Utah Bull. 38:17–166.

Hubbs, C. L., and R. R. Miller. 1953. Hybridization in nature between the fish genera *Catostomus* and *Xyrauchen*. Pap. Mich. Acad. Sci. Arts Lett. 33:207–233.

Johnson, V. K. 1958. Fisheries management report—Pyramid Lake. Federal Aid in Fish Restoration Project FAF-4-R. Nevada Department of Wildlife, Reno.

Knopf, F. L., and J. L. Kennedy. 1981. Differential predation by two species of piscivorous birds. Wilson Bull. 93:554–556.

Koch, D. L. 1972. Life history information on the cui-ui lakesucker *(Chasmistes cujus* Cope, 1883) endemic to Pyramid Lake, Washoe County, Nevada. Ph.D. thesis, University of Nevada, Reno. 343 pp.

Koch, D. L. 1973. Reproductive characteristics of the cui-ui lakesucker (*Chasmistes cujus* Cope) and its spawning behavior in Pyramid Lake, Nevada. Trans. Am. Fish. Soc. 102:145–149.

Koch, D. L. 1976. Life history information on the cui-ui lakesucker (*Chasmistes cujus* Cope, 1883) in Pyramid Lake, Nevada. Occas. Pap. Biol. Soc. Nev. 40 pp.

Koch, D. L., and G. P. Contreras. 1973. Hatching technique for the cui-ui lakesucker *(Chasmistes cujus* Cope, 1883). Prog. Fish-Cult. 35:61–63.

La Rivers, I. 1962. Fishes and fisheries of Nevada. Nevada Fish and Game Commission, Reno.

Lider, E. L., and R. W. Langdon. 1978. Plankton ecology. Pages 241–293 *in* W. F. Sigler and J. L. Kennedy, eds. Pyramid Lake ecological study. W. F. Sigler and Associates, Inc., Logan, Utah.

Marrin, D. L. 1983. Ontogenetic changes and intraspecific resource partitioning in the Tahoe sucker, *Catostomus tahoensis*. Environ. Biol. Fishes 8:39–47.

Marrin, D. L., D. C. Erman, and B. Vondracek. 1984. Food availability, food habits, and growth of the Tahoe sucker, *Catostomus tahoensis*, from a reservoir and natural lake. Calif. Fish Game 70:4–10.

McAda, C. W., and R. S. Wydoski. 1980. The razorback sucker, *Xyrauchen texanus*, in the Upper Colorado River Basin, 1974–76. U.S. Fish Wildl. Serv., Tech. Pap. 99. 15 pp.

McCart, P., and N. Aspinwall. 1970. Spawning habits of the largescale sucker, *Catostomus macrocheilus*, at Stave Lake, British Columbia. J. Fish. Res. Board Can. 27:1154–1158.

McSwain, L. E., and R. M. Gennings. 1972. Spawning behavior of the spotted sucker, *Minytrema melanops* (Rafinesque). Trans. Am. Fish. Soc. 101:738–740.

Miller, E. E. 1966. Age and growth determinations. Pages 57–69 *in* A. Calhoun, ed. Inland fisheries management. California Department of Fish and Game, Sacramento.

Miller, R. R., and G. R. Smith. 1981. Distribution and evolution of *Chasmistes* (Pisces: Catostomidae) in western North America. Occas. Pap. Mus. Zool., Univ. Mich. 696.

Minckley, W. L. 1983. Status of the razorback sucker *Xyrauchen texanus* (Abott), in the lower Colorado River Basin. Southwest. Nat. 28:165–187.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley. 405 pp.

Northcote, T. G. 1969. Lake migration of young trout (*Salmo gairdneri*) in the upper Lardeau River, British Columbia. J. Fish. Res. Board Can. 26:33–45.

Raney, E. C., and D. A. Webster. 1942. The spring migration of the common white sucker *Catostomus c. commersonii* (Lacepede) in the Skaneateles Lake inlet, New York. Copeia 1942:139–148.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191.

Robertson, D., and D. L. Koch. 1978. Life history of the cui-ui *Chasmistes cujus* Cope. Pages 51–68 *in* W. F. Sigler and J. L. Kennedy, eds. Pyramid Lake ecological study. W. F. Sigler and Associates, Inc., Logan, Utah.

Russell, I. C. 1885. Geological history of Lake Lahontan. U.S. Geol. Surv. Monogr. 11. 288 pp.

Scoppettone, G. G., G. A. Wedemeyer, M. Coleman, and H. Burge. 1983. Reproduction by the endangered cui-ui in the lower Truckee River. Trans. Am. Fish. Soc. 112:788–793.

Shirley, D. S. 1983. Spawning ecology and larval development of the June sucker. Proc. Bonneville Chap. Am. Fish. Soc. 18–36.

Simmons, D. J., N. B. Simmons, and J. H. Marshall. 1970. The uptake of calcium-45 in the acellular-boned toadfish. Calcif. Tissue Res. 5:206–221.

Snyder, D. E. 1983. Identification of catostomid larvae in Pyramid Lake and the Truckee River, Nevada. Trans. Am. Fish. Soc. 112:333–348.

Snyder, J. O. 1918. The fishes of the Lahontan system of Nevada and north-eastern California. U.S. Bur. Fish. Bull. 35:31–86.

Sonnevil, G. M. 1978. Cui-ui investigations; Pyramid Lake, 1978. Unpublished report, U.S. Fish and Wildlife Service, Fisheries Assistance Office, Reno, Nev. 17 pp.

Sonnevil, G. M. 1981. Evaluation of the cui-ui restoration program; 1977–1980. Unpublished report, U.S. Fish and Wildlife Service, Fisheries Assistance Office, Reno, Nev. 25 pp.

Summer, F. H. 1940. The decline of the Pyramid Lake fishery. Trans. Am. Fish. Soc. 69:216–224.

Townley, J. M. 1977. Turn this water into gold: the story of the Newlands Project. Nevada Historical Society, Reno, Nev.

U.S. Fish and Wildlife Service. 1978. Cui-ui recovery plan. U.S. Fish and Wildlife Service, Endangered Species Program, Region 1, Portland, Oreg. 38 pp.

U.S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery priority guidelines. Fed. Regist. 48(76):16756–16759.

Vigg, S. 1980. Seasonal benthic distribution of adult fish in Pyramid Lake, Nevada. Calif. Fish Game 66:49–59.

Vondracek, B., L. R. Brown, and J. J. Cech. 1982. Comparison of age, growth, and feeding of the Tahoe sucker from Sierra Nevada streams and reservoirs. Calif. Fish Game 68:36–46.

Willsrud, T. 1971. A study of the Tahoe sucker, *Catostomus tahoensis* Gill and Jordan. M. S. thesis, San Jose State University, San Jose, Calif. 77 pp.

Scoppettone, G. Gary, Mark Coleman, and Gary A. Wedemeyer. 1986. **Life history and status of the endangered cui-ui of Pyramid Lake, Nevada.** U.S. Fish Wildl. Serv., Fish Wildl. Res. 1. 23 pp.

The cui-ui (*Chasmistes cujus*) is a federally listed endangered species endemic to Pyramid Lake, Nevada. Because of a decline of the Pyramid Lake cui-ui population, a 4-year study was undertaken to provide life history information that might facilitate recovery of the species. Included in the work were studies of spawning migration, reproduction, emigration of larvae, age and growth, population size, and food. Research results are presented.

Key words: Cui-ui, spawning migration, larvae, reproduction, population, life history, year class.

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