Management of the Owens Pupfish, *Cyprinodon radiosus*, in Mono County, California

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ABSTRACT

The Owens pupfish, *Cyprinodon radiosus* Miller, is restricted to Owens Valley along the eastern base of the Sierra Nevada Range of California. When it was described in 1948 it was thought to be extinct. Its depletion, rediscovery, and reestablishment in the Owens Valley Native Fish Sanctuary, a cooperative undertaking between the City of Los Angeles and the California Department of Fish and Game, are described. Two other refuges in Owens Valley are completed or under construction, and the three additional native fishes of this valley will be established in one of these. Such conservation activity reflects the growing concern of the scientific community and the public over the threat to native fishes.

INTRODUCTION

The Owens pupfish (Figure 1), *Cyprinodon radiosus* Miller (1948), a member of the killifish family Cyprinodontidae, is confined to the Owens River drainage in Owens Valley, California. It is one of the several species of this genus that inhabit springs and creeks of the desert region in eastern California and southwestern Nevada. A number of these fishes are now threatened with extinction and the Owens pupfish was recently classified as a rare and endangered species (U. S. Dept. Int., 1968: F-26; Miller, 1969a).

Owens Valley is without outlet and lies at the base of the eastern escarpment of the Sierra Nevada. In the first general treatment of the fishes of this valley, Snyder (1917) referred this species to the desert pupfish, *Cyprinodon macularius* Baird and Girard, but subsequently it was shown that *C. macularius* lives in California only in the Salton Sea basin (Miller, 1943).

Just prior to Snyder's paper, Kennedy (1916) described the habitat, abundance, and feeding habits of the Owens pupfish, noting that ". . . it can probably be used to advantage in combating the mosquito in those parts of the state where these insects are a pest about permanent fresh-water marshes." Evidently its natural range was from near Lone Pine, Inyo County, northward to the source springs that feed Fish Slough, Mono County, about 10 to 12 miles north of Bishop (Figure 2). In the early part of the century, the Owens pupfish was abundant in the springs, shallow sloughs, swamps, irrigation ditches and bog pastures along and near Owens River. Mosquitoes were then relatively uncommon, but as the species became scarce these insects became pests (Miller, 1948: 93).

DEPLETION

With the establishment of exotic fishes in Owens Valley and the disappearance or marked reduction of marshy areas due to removal of much of the water supply through the Los Angeles aqueduct (Heinly, 1910), *Cyprinodon radiosus* rapidly declined. In 1934, Carl L. Hubbs found only a few shallow, fishless pools along the big bend of Owens River northeast of Bishop where Kennedy, 19 years earlier, had observed big schools of this pupfish near the margin of a large tule swamp that lay between Laws and Bishop. Neither in the river near Laws nor at other localities between Bishop and Independence did the Hubbs party find any pupfish. At that time the species did survive in at least two places, for the Mono-Inyo survey of the U. S. Bureau of Fisheries found it to be abundant in Fish Slough in "wide, flat, reedy basins, mostly in water only about 3 to 6 inches deep and very warm," and

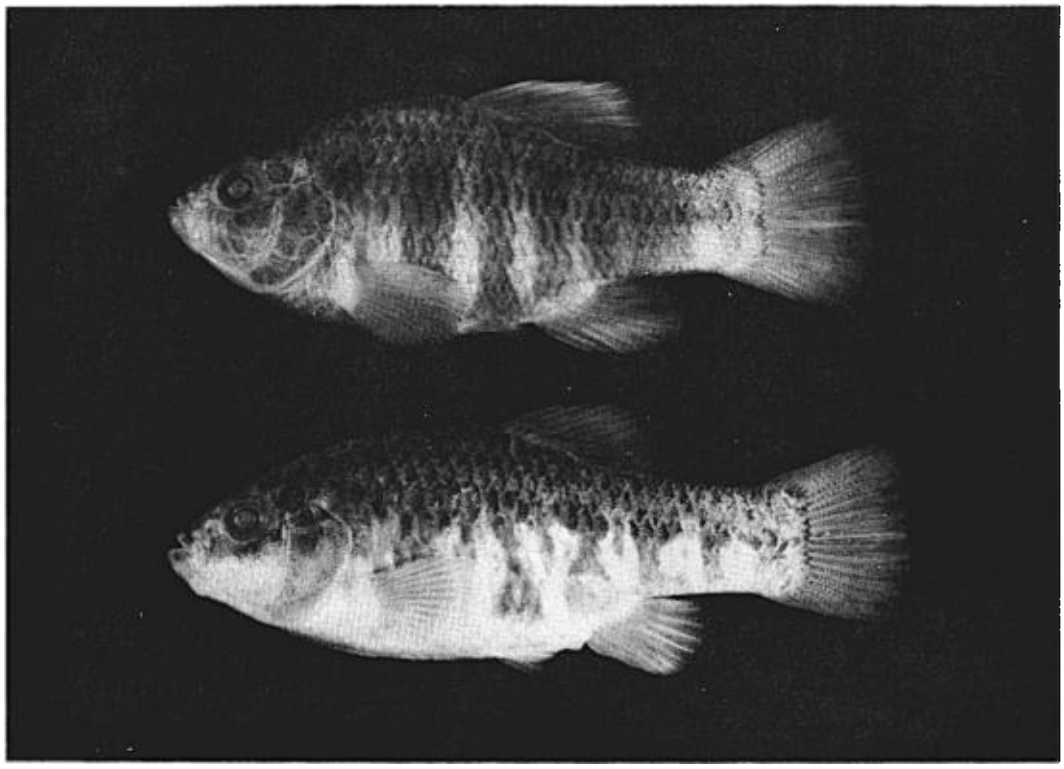

FIGURE 1.—*Cyprinodon radiosus* (UMMZ 189879), male above (33.5 mm S.L.), female below (36.0 mm S.L.). From BLM Spring, on E. side of Fish Slough, Mono Co., California, collected June 29, 1970. The species attains a maximum size here of about 60 mm, total length (50 mm S.L.).

common in a spring or series of springs (Morton's Slough?) near Owens River east of Independence (Miller, 1948: 94).

In July, 1937, a rather hurried check of the lower and middle parts of Fish Slough revealed principally carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*), the latter having been planted in Owens Valley around 1913 (Kennedy, 1916: 180); a few suckers and minnows were also seen, but no pupfish (Miller, 1948: 94). In the upper part of Fish Slough, in 1937, *Cyprinodon radiosus* was still rather common at the head of the westernmost spring and a few individuals were observed in the outflow of the most northerly spring (Figure 2, sta. 1). In 1937, only exotic fishes were seined in the many valley sloughs between Independence and Big Pine.

In July, 1938, the westernmost spring of Fish Slough still supported an adequate population and in April, 1939, Sumner and Sargent (1940: 46–47) had no difficulty collecting the species in numbers adequate for their research. No pupfish were observed by them at any distance below the spring sources, however.

On August 31 and September 1, 1942, not a single pupfish was found by Miller and party in any of the three springs in Fish Slough where they had previously lived. Their complete disappearance from these waters within three years may be attributed chiefly to direct predation by largemouth bass, a species not noted in any of the springs during 1937–1940. Also, in contrast to earlier years, there were fewer minnows and suckers in these springs in 1942 and within about the next decade they too virtually disappeared. Considerable local inquiry at Bishop in 1942 and some investigation of waters between Fish Slough and Big Pine failed to reveal any pupfish. Consequently, when the species was described six years later it was thought to be extinct.

FIGURE 2.—Aerial view of Fish Slough from north end looking southeast, April 29, 1964. 1, northernmost spring; 2, the two westerly springs, comprising the Owens Valley Native Fish Sanctuary; 3, "Rediscovery Pools," where pupfish were taken in 1956 and 1964; 4, BLM Spring.

REDISCOVERY

In June or July 1956, W. M. Richardson and Ralph V. Beck of the California Department of Fish and Game, using a small seine, collected a few Owens pupfish from shallow ponds 200 to 300 feet west of the unimproved road that traverses the east side of Fish Slough, approximately 1.5 miles south of the northernmost spring. The ponds lay east of the main channel of the Slough at this point and were no more than a foot deep. They also contained a chub, carp, sucker, small bullheads, mosquitofish, and juvenile largemouth bass. About one pupfish was obtained per three seine hauls. The fish were kept alive in an aquarium for awhile, and Mr. Richardson was impressed with their pugnacity, but since he did not know that the species was thought to be extinct, they were subsequently discarded.

In early April, 1963, Robert K. Liu, E. P. Pister and other personnel of the California Department of Fish and Game, spent two days in the Fish Slough area searching for *Cyprinodon radiosus*. In the northernmost spring and its outflow they found only mosquitofish and largemouth bass and saw, in the spring hole, a "cyprinid 2 to 6 inches long" (perhaps some were *Catostomus*, seen in 1964). Fish were generally scarce. In the two northwestern springs feeding Fish Slough, they found only mosquitofish. They did not relocate the population sampled by Richardson and Beck.

On July 10, 1964, Hubbs, Miller, Pister and party "rediscovered" the population of Owens pupfish that had been sampled in 1956. It inhabited an elongate pool maintained by overflow of cool water from the adjacent main, spring-fed ditch, 2.2 miles by jeep road south of the northernmost spring of Fish Slough (Figure 2, sta. 3; T5S, R32E, near NE corner of sec. 25—see U. S. Geological Survey Bishop Quadrangle, 15-minute series, 1949). The

FIGURE 3.—Typical pupfish habitat—wide, flat, open, shallow, marshy pools—at "Rediscovery Pools," July 10, 1964. From a Kodachrome transparency.

pool of very clear water was about 100 yards long, varied from 15 to 40 feet in width, and there was dense *Chara* covering the firm, mud bottom; scattered stands of *Scirpus* grew in the shallow water (2 to 6 inches deep) and the shore was an open marshy swamp and meadow (Figure 3). Only a slight current was perceptible at the end nearest the ditch. The air was 91 F and the water 92 F at 3 PM. *Cyprinodon radiosus* had an estimated population of perhaps 200 individuals, comprising juveniles to large adults and including fish in breeding colors.

In life, the brightest (breeding) males have the dorsal fin pinkish tan to orange and either black-bordered or not. The anal fin is pinkish tan to chalky blue or turquoise, sometimes with a black border. In bright sunshine one can see a blue to turquoise predorsal stripe, and the whole body may be brilliant blue under such favorable light conditions. Not infrequently a unilateral blackened area (head, side, and caudal peduncle) was noted in both sexes and sometimes it formed a bilateral melanism (on caudal peduncle and base of caudal fin). The caudal fins of the showiest breeding males have a narrow, dusky to black terminal border, which was quickly lost on preservation or as the males ceased reproductive or aggressive behavior. Hence, it is not surprising that this species was described as lacking the terminal black border on the caudal fin that characterizes the male of the genus *Cyprinodon*. (The occurrence of this feature in *C. radiosus* was first noted and photographed by Robert K. Liu in 1964.) At the height of nuptial or aggressive behavior the broad vertical bars on the side become intensified and take on a brilliant metallic blue color; the first bar (shorter than the second) lies just behind the head and is followed by about five bars of which the longest and broadest are the second and third. They are not narrowed ventrally, as in other species of the genus. The development of this banding may be unique for species of *Cyprinodon*.

FIGURE 4.—Most westerly spring and outflow in Fish Slough, type locality of *Cyprinodon radiosus*, looking southeastward. February 2, 1968.

When the fish are not engaged in mating or fighting these bars pale to a grayish blue, or they may disappear altogether and such fish appear pale grayish or chalky blue or even brownish. The narrower interspaces between the vertical bars are milky white in life. The pectoral fin, chalky blue to turquoise, is black-margined. The pelvics are whitish to chalky blue or turquoise and light-bordered, definitely lighter overall than the pectorals; they may be black-tipped, however.

Females have smaller dorsal, anal, pectoral, and pelvic fins, lack the terminal caudal band, may or may not show a black blotch or spot along the midbase of the dorsal or on its posterior rays (occasionally also on the posterior rays of the anal fin), are generally olivaceous brown to deep olive on the back and upper sides and silvery or whitish below, and have an increased number of irregularly shaped brownish vertical bars that are much narrower than those of the male.

At the time of observation (late afternoon) a behavior aptly termed leapfrogging was repeatedly observed and was engaged in by both sexes. This consisted of individuals leaping sideways nearly vertically over a fallen stem of *Scirpus*; some of the fish bit at the stem as they passed over it, whereas others only butted it and did not jump. The same fish often flipped back and forth several times over the stem. The pattern of movement was at times that of figure eights, at other times a circular (counter clockwise) motion, leaping over-swimming under-and leaping over. This type of behavior was also noted for the mosquitofish (*Gambusia a. affinis*), which swarmed in the pool. Also associated with the pupfish were speckled dace (*Rhinichthys osculus*), scarce, and juvenile largemouth bass. At 10 AM the next day, the water temperature was only 79 F and very few pupfish, chiefly young and juveniles, were seen.

REESTABLISHMENT

The obviously precarious position of *C. radiosus* demanded that action be initiated at the earliest possible date to create refugia where the species could be reestablished without danger of extermination by predatory, exotic fishes or further threatened by competition with mosquitofish. With this basic thought in mind, C. L. Hubbs, R. R. Miller, and E. P. Pister toured the Fish Slough area on June 26, 1967, and conceived the idea of establishing a refugium utilizing the two northwestern springs, of which the most westerly is the type locality of the Owens pupfish (Figure 4). In addition, it was decided that the other native fishes of the Owens Basin (a dace, *Rhinichthys*; a chub, *Gila*; and a sucker, *Catostomus*) should also be established there.

This concept was discussed and agreed upon with the landowner (the Los Angeles Depart-

FIGURE 5.—View southeastward across westerly spring in Fish Slough after completion of Owens Valley Native Fish Sanctuary. Compare with water level in Figure 4. Outflow from northwesterly spring in left background. February 2, 1970.

ment of Water and Power), and all engineering assistance and design work was provided by that agency. The exotic fish barrier was based on a design worked out by the engineering staff of the Nevada Department of Fish and Game and used successfully for the White River springfish, *Crenichthys baileyi* (Gilbert), at Sunnyside, Nevada, in 1963.

Approval for the Owens Valley Native Fish Sanctuary was granted by the California Fish and Game Commission at its April, 1968, meeting, funds were budgeted, and construction was completed in October, 1969, by inmate labor crews from the Inyo-Mono Conservation Camp under the direction of John N. Clark of the California Division of Forestry.

The refuge covers a surface area of 5.6 acres and is surrounded by a five-strand barbed wire fence (Figure 5). The total area enclosed is 21 acres. Depth may be lowered as much as three feet by the removal of flashboards in the outlet structure. At maximum depth (about six feet) an ideal range of depths exists, from abundant shoals for the pupfish to deeper water best suited for dace, chubs, and suckers. In April, 1970, the refuge was reduced to minimum volume to facilitate chemical treatment and desiccate any eggs of exotic species (e.g., carp and bass) that might have been deposited earlier. On May 20 the sanctuary was treated with calcium hypochlorite (commercial HTH) in the shoals and liquid rotenone in the deeper parts. To assure a complete kill, this procedure was repeated on June 3. The sanctuary was then filled to optimum (maximum) volume in anticipation of the forthcoming introduction of the native species.

The precarious position of *C. radiosus* is well illustrated by the following event which occurred during August, 1969, and which nearly resulted in the loss of the few remaining individuals in Fish Slough and, consequently, in complete extinction of the species. At that time an insidious decrease in the flow of the springs supplying Fish Slough occurred. The exact cause of the failure has not been determined, but is presumed to be the result of a natural summer decrease combined with transpiration from an unusual amount of riparian vegetation caused by abnormally heavy precipitation during the winter of 1968–69. Irrespective of the cause, the level of Fish Slough dropped to a point where the marsh area

supporting the only known remaining pupfish population completely lost its water supply. Fortunately, this condition was noted by Robert E. Brown, a graduate student at the University of California (Los Angeles), working as a summer employee for the Department of Fish and Game. Approximately 800 individuals were rescued from the small, rapidly drying ponds below the northwestern springs of Fish Slough and placed in hastily constructed live cages in the main slough channel. Again, inmate labor crews from the Inyo-Mono Conservation Camp provided invaluable assistance by deepening the water supply channels to the habitat areas.

As these channels were deepened, gravel percolator dams were placed in them to minimize the possibility of invasion by exotic species, and groups of *C. radiosus* were reintroduced into four locations within the slough area. One introduction was made into "BLM Spring," an isolated spring source on the east side of the slough (Figure 2, sta. 4). This site was hurriedly prepared for a transplant by chemical treatment (calcium hypochlorite) to remove the resident fish population (carp, mosquitofish, and largemouth bass), and 400 pupfish were introduced into this spring on August 18, 1969. Three gravel barriers were placed in the stream channel leading out of BLM Spring to assure that predatory species could not ascend into the spring area. Although chemical treatment was successful in removing the larger species, enough mosquitofish survived to start another population in competition with the pupfish. However, this transplant is the only one known to be completely successful, although one female pupfish was seen in the main (northernmost) spring by E. P. Pister on May 15, 1970. Since the August 18, 1969, transplant, the pupfish in BLM Spring increased significantly from the 400 initially transplanted; in late June, 1970, it was conservatively estimated that the spring contained 1,000 individuals.

Between June 26 and 30, 1970, collections of Owens pupfish were made in the lower part of BLM Spring by trapping and seining in order to secure a stock for introduction into its rehabilitated habitat, the Owens Valley Native Fish Sanctuary. This operation was assisted by the authors and by Carl L. and Laura C. Hubbs, Frances H., Laurence B., and Benjamin R. Miller, David Soltz (a graduate student from U.C.L.A. under summer employment by the Department of Fish and Game), Robert E. Brown, Fred Partridge (a student from Humboldt State College), Raimond Clary (a graduate student from the University of California at Berkeley), and was filmed for television by Bill Burrud Productions of Hollywood. All fish trapped and netted were held in a live cage in the outlet of the Sanctuary. It was decided that only *Cyprinodon radiosus* would be introduced at this time in order to assure establishment of the species prior to stocking the three other native fishes of Owens Valley (see below).

Prior to introduction into the Sanctuary, the pupfish were sorted by age and sex, with the following results: males, 142; females, 249; immatures, 37. The total introduced during the afternoon of June 30, 1970, was 428; water temperature in the Sanctuary was 74 F. Subsequent observations reveal that the Owens pupfish is becoming adjusted to the newly created habitat. Long-term observations on the success of the transplant will be made. Plans also call for the setting aside of this area as an ecological reserve by the California Fish and Game Commission under a recent act (1969) of the California legislature.

A sanctuary for *C. radiosus* at BLM Spring, on the east side of Fish Slough, will be jointly designed by the Bureau of Land Management and California Department of Fish and Game and will be constructed by inmate labor. Costs will be borne in part by the John Muir Institute.

A third refugium was constructed in the spring of 1970 at Warm Springs, located at the base of the White Mountains in Inyo County, about five miles north of the town of Big Pine. This was also built by inmate crews from the Inyo-Mono Conservation Camp with a design similar to that used at Fish Slough. Construction was under the supervision of the California Department of Fish and Game on City of Los Angeles property. The Warm Springs Sanctuary was inspected by us, accompanied by Dr. and Mrs. Hubbs, on June 29, 1970. It was decided that this site should be used initially as an area to test the interspecific relationships and reactions of

all four of the Owens Valley native fishes. Plans are now under way to locate suitable stocks of the dace, chub, and sucker for transplantation to this sanctuary, at which time *C. radiosus* will also be introduced.

The above-mentioned activities reflect an increased awareness among both the scientific community and the public concerning endangered species in general and the Death Valley system fishes in particular (Miller, 1969b; Bunnell, 1970; Deacon and Bunnell, 1970). A Pupfish Task Force (U. S. Department of the Interior, 1970) chaired by James T. McBroom, Assistant Director of the U. S. Bureau of Sport Fisheries and Wildlife, was established by the Department of the Interior in May, 1970.

A symposium concerning the rare and endangered fishes of the Death Valley system was held at Furnace Creek in November, 1969 (Pister, 1970), and a second meeting is scheduled for November, 1970. A general plan for species preservation was prepared and is constantly being updated as old problems are solved and new ones are created. Hopefully, these activities will provide adequate safeguards for the protection of all desert fishes and other aquatic organisms in the face of ever-increasing encroachments into their native habitats.

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