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EVALUATION OF AN INTRODUCTION OF COLORADO SQUAWFISH IN A MAIN STEM IMPOUNDMENT ON THE WHITE RIVER, COLORADO

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ABSTRACT—We evaluated endangered Colorado squawfish (*Ptychocheilus lucius*) as a potential sportfish in Kenney Reservoir from 1988 to 1990 as part of a mitigation program for the construction of Taylor Draw Dam which impounded Kenney Reservoir on the White River, Colorado. A total of 96,597 fingerling squawfish were stocked into Kenney Reservoir from 1988 to 1990. These fish quickly dispersed throughout the reservoir, and downstream into the White River. A small number moved upstream in 1990. A large proportion, associated with high discharge following stocking, exited over the spillway, and continued to move downstream. Catch-per-unit-effort declined drastically in both the river and the reservoir in 1989 and 1990. The rapid disappearance of squawfish throughout the study area was attributed to flow regime, movement patterns, mortality, sampling ineffectiveness or a combination of these. Telemetry observations of six adult Colorado squawfish revealed no difference in behavior attributable to wild or hatchery origin. Stocking squawfish in Kenney Reservoir did not appear to be an effective mitigation procedure for habitat loss due to impoundment.

The Colorado squawfish *Ptychocheilus lucius* is endemic to the Colorado River Basin. Once abundant, its decline has necessitated full protection as an endangered species (Federal Register, Vol. 39[3]:1175, 1974). The historical range of this large cyprinid extended from Northern Sonora, Mexico to Green River, Wyoming, including much of the mainstem Colorado River and most of its larger tributaries (Colorado River Fishes Recovery Team, 1988). It is now restricted to a fraction of its former range, including the main stem Colorado River from Lake Powell to Palisade; the Green River below Brown's Park; the Yampa River below Craig; the White River below Rio Blanco Reservoir; and in portions of the San Juan River in Colorado, Utah and New Mexico (Colorado River Fishes Recovery Team, 1988; Tyus, 1991).

Main stem impoundments on the Colorado River system have largely contributed to the decline of Colorado squawfish populations by blocking migration routes and altering flow and temperature regimes (Tyus, 1991). The White River, previously free-flowing, was impounded by Taylor Draw Dam in 1985, 16 river-kilometers east of Rangely, Colorado, creating Kenney Reservoir. The dam effectively reduced the suitable habitat available to squawfish in the White River by 80 km by preventing access to areas upstream from the dam. According to unpublished findings of the Colorado Division of Wildlife, this represents about 16% of the documented range in Colorado.

There are no records of Colorado squawfish reproducing in the White River and no suitable spawning conditions have been identified (Carlson et al., 1979; Haynes et al., 1984). In light of this and because of construction mitigation agreements, Colorado Division of Wildlife (CDOW) and the United States Fish and Wildlife Service began a Colorado squawfish stocking program in 1988, calling for 50,000 fingerling-age I Colorado squawfish to be stocked in each of the three years, 1988–1990. After the first stocking in 1988, surveys by CDOW of the reservoir and river indicated the stocked Colorado squawfish had dispersed throughout the reservoir and moved downstream. The study reported here was begun in 1989 to further evaluate dispersal of the 1988 stock and to assess the results of subsequent stockings of Colorado squawfish in Kenney Reservoir. Our primary objectives were to evaluate Colorado squawfish ecology and behavior as they related to attempts to artificially establish these fish in the reservoir as a sport fish, and to evaluate the potential of a sport fishery based on stocked squawfish.

MATERIALS AND METHODS—The study area encompassed the White River from 16 km above Kenney Reservoir at river-kilometer (RK) 192.7 downstream to the Colorado-Utah border (RK 115.5; Fig. 1). In 1988 and June 1989, the river was sampled 16 km upstream and downstream from the reservoir. As it became apparent the squawfish were moving downstream, the study area below the dam was extended to the Colorado-Utah border in July 1989. The river was subdivided into five sections as indicated in Fig. 1.

Kenney Reservoir's upper limit was designated as RK 175.9 and the lower limit as RK 167.8 at the dam axis. The reservoir is 8 km long and 1.2 km across at its widest point, with a maximum depth of 15.2 m near the dam. When filled in 1985 it covered 275 ha and held 17 million m^3 of water. The high silt load of the White River decreased the reservoir's capacity an undetermined amount by filling the upper end of the reservoir with silt deposits for about 1.5 km. There is an outlet gate at the base of the dam but most of the flow was released over the spillway during the study to allow repair and modification of the outlet gate.

Dexter National Fish Hatchery and Technology Center (DNFHTC) staff in New Mexico provided Colorado squawfish eggs to Willow Beach National Fish Hatchery, Arizona, where they were raised for the stocking program. The initial goal of stocking 150,000 Colorado squawfish during the three-year study was not met due to mortality during rearing. Only 96,597 age-1 fingerlings were stocked into Kenney Reservoir and all received an internal tetracycline mark along with an external identification mark for each batch stocked (Table 1).

Kenney Reservoir was sampled by seining, gillnetting, and electrofishing (Table 2). The bag seine used was 12.2 m long, with 9.5 mm mesh. Shoreline areas were seined monthly from May through November. Catch per unit of seining effort was derived by dividing the total number of fish caught by the units of seining effort expended during the month. One unit of effort was equal to the seining of 100 m^2. Two multifilament gill nets were used; one was 45.7 m long and 3.6 m wide with 19-mm mesh and the other was 30.5 m long and 1.5 m wide with 19-mm mesh. From May through October, gill nets were set overnight in all major habitats (e.g., shallow coves, deep coves, cliffs, sloping areas, surface, bottom, midlake). Electrofishing was conducted with a boat-mounted variable voltage pulsator (Coffelt Mfg. VVP-15), using spherical electrodes. Six to seven 15-minute reaches of shoreline were sampled May through August in 1989, and in July 1990.

The White River was sampled similarly with seines, gill nets, electrofishing and drift nets (Table 2). Backwater sites were seined monthly from June through September, with effort and location varying each month because of changes in flow. Gill nets were occasionally set immediately below the dam to take advantage of the reduced current while the bottom outlet of the dam was closed. Electrofishing was conducted once each May, as low flows precluded electrofishing in later months. The drift nets were; two rectangular frame 2.4 m × 0.6 m, 6.3 mm mesh nets, and two 1.2 m diameter shad trawls. Drift nets were set in the channels directly below the spillway and were checked twice daily; these nets consisted of two rectangular-frame nets with 6.3-mm mesh and two shad trawls 1.2 m in diameter.

Telemetry observations of adult Colorado squawfish of both hatchery and wild origin were made in 1990. Seven squawfish were surgically implanted with both radio and sonic transmitters on May 12, 1990. Use of the two types of tags in each fish facilitated tracking in both the reservoir and river. Four fish were taken from broodstock at DNFHTC, and three wild fish were collected from the White River for implantation. Surgical procedures followed those of Tyus and McAda (1984). The combined weight of the tags ranged from 1.7 to 3.5% of the weight of the fish. All fish received a PIT (Passive Integrated Transponder) tag (Chart and Bergersen, 1988).

Radio transmitters were Advanced Telemetry Systems (ATS) modules with loop antennae, powered by 6-month mercury batteries, and operating in the 40.320 to 40.680 MHz range. These tags were monitored with an ATS programmable digital radio search receiver, using a whip antenna and a directional loop antenna. The sonic transmitters, 14-month Sonotronics, Inc., tags, were monitored with a Sonotronics Model DH-2 hydrophone and USR-5B digital receiver system. Monitoring of telemetered fish was conducted bi-weekly in the reservoir and monthly in the river.

RESULTS—When released into the reservoir, fingerling Colorado squawfish swam away in compact schools and quickly dispersed throughout the reservoir. Specimens were collected across the reservoir from the stocking site near the spillway in three days, and were found at many sites throughout the reservoir within one week. Sites where the stocked fish were collected remained well distributed along the shoreline.

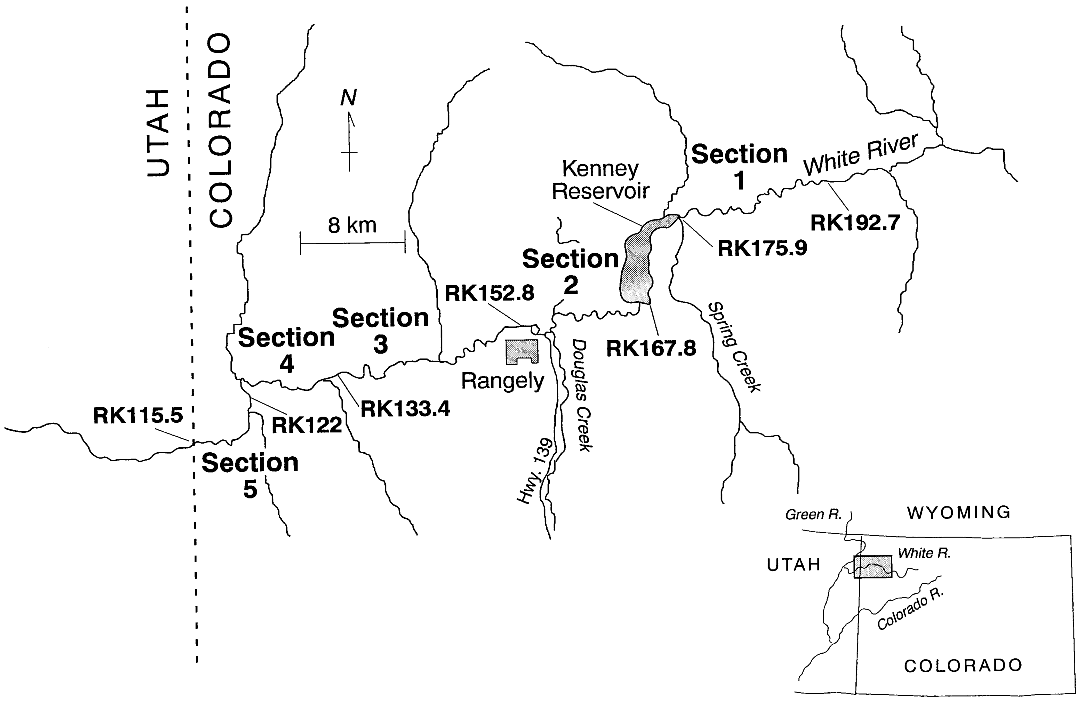

FIG. 1—White River Study area. Locations are in river kilometers (RK) from the White River and Green River Confluence in Utah. Taylor Draw Dam is located at RK 167.8, 16 km east of Rangely, Colorado.

Fingerling Colorado squawfish were present in schools with other small fish. Large schools were composed of as many as seven species, including Colorado squawfish, roundtail chub (*Gila robusta*), flannelmouth sucker (*Catostomus latipinnis*), fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), carp (*Cyprinus carpio*), and black crappie (*Pomoxis nigromaculatus*).

Colorado squawfish distribution in the reservoir after the first two months following stocking was unknown, because few fish were caught (Fig. 2). Only four fish were caught in their second summer (age 2) in the reservoir. These fish were collected in gill nets set at depths of 4.5 to 6 m near cliffs or steep shoreline areas.

Colorado squawfish were collected below the dam within two days of stocking. Colorado squawfish emigration from the reservoir was high, although no precise estimate of the numbers was possible. Of all squawfish collected, the percentage caught below the dam varied from 18.5 to 45% (Table 3), but total escapement was believed to be much higher. Fingerling squawfish contin-

TABLE 1—Lengths, weights, and identification marks of Colorado Squawfish stocked in Kenney Reservoir, 1988, 1989 and 1990.

Stocking date	Number stocked	Length (TL mm)		Weight (g)		Batch mark
		Range	$\bar{X}$	Range	$\bar{X}$	
4/28/88	17,000	49–90	65	1–6	3.0	left pelvic clip
4/26/89	32,000	41–80	58	1–5	2.2	right pelvic clip
5/24/90	32,000	51–101	73	1–10	3.4	red spray mark
8/06/90	1,397	96–141	114	—	7.0	left pelvic clip
9/12/90	14,200	73–172	114	2–30	10.3	yellow spray mark
Total	96,597					

TABLE 2—Summary of sampling techniques and effort for monitoring stocked Colorado squawfish in Kenney Reservoir and the White River, 1989–1990. Numbers of Colorado squawfish captured are given in parentheses.[1] A seine haul of 100 m^2 constituted one unit of seining effort; gill net and electrofishing efforts are reported as, respectively, hours and minutes.

	1989							1990						
Location	May	June	July	Aug.	Sept.	Oct.	Nov.	May	June	July	Aug.	Sept.	Oct.	Nov.
Reservoir														
Seine		25.2	28.4	27.1	27.1	27.1		15.7	16.3	47.6	23.4	16.8		
		(154^a)	(71^a)	(0)	(0)	(0)		(227^c)	(52^c)	(38^c)	(1^f)	(9^g)		
Gill net		154	207	228	97			60		331.5	481		192	
		(2^b)	(1^b)	(0)	(1^a)			(0)		(0)	(1^a)		(0)	
Electrofish	120	90	90	120						90				
		(5^b)	(12^b)	(0)						(1^c)				
River-upper 16km														
Seine		5.0	14.6	3.0	2.0		2.0		7.1	10.5	9.3	4.1		
		(0)	(0)	(0)	(0)		(0)		(10^c)	(33^c)	(0)	(0)		
River-lower 48km														
Seine		11.7	49.3	45.1	19.5		8.8	12.5	72.8	48.4	30.0	18.1		1.0
		(109^a)	(45^a,1^b)	(32^a)	(5^a)		(5^a)	(7^c,1^a)	(44^c,4^a)	(0)	(1^c,24^d)	(1^c,6^d)		(1^d)
Gill nets			28								2.0		4.0	
			(2^e)								(0)		(0)	
Electrofish	530									30				
	(11^c)									(1^a)				
Drift nets			100.0	141.0				168.0			355.5			
			(1^a)	(0)				(0)			(1^f)			

[1] Superscripts refer to original stocking date or source of wild-caught specimens; a = 1988, b = 1989, c = May 1990, d = specimens from isolated pool immediately below dam, e = wild adult specimens, f = August 1990, g = September 1990.

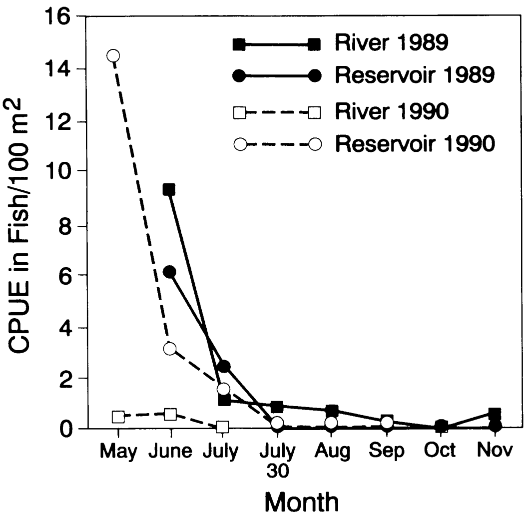

FIG. 2—Catch-per-unit-of-effort for Colorado squawfish in the White River and Kenney Reservoir, 1989 and 1990.

TABLE 3—Percentages of the total number of squawfish captured in the White River each month, per section of the study area (Fig. 1).

Year section	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
1989								
2	0	100	78	44	0	0	40	
3	0	0	18	44	100	0	0	
4	0	0	4	12	0	0	60	
Total	0	109	55	32	5	0	5	206
1990								
2	100	80	0	0	0	0	0	
3	0	20	0	0	0	0	0	
4	0	0	0	100	100	0	0	
Total	7	44	0	1	1	0	0	53

ued to move downstream after exiting the reservoir, as indicated by the collection of squawfish farther downstream on each successive sampling occasion in 1989 (except September) and in 1990 (Table 3). The majority of Colorado squawfish that emigrated appeared to have done so during a short time between May and June each year.

Section 2, immediately downstream from the dam, showed percentages that decreased, suggesting an initial "pulse" of dispersal. Relatively more squawfish were collected in section 2 in June and July, section 3 in September, and section 4 in November. No squawfish were collected in section 5, probably due to a lack of suitable backwater habitat. This mass of squawfish moving downstream was also discernable in 1990, although smaller sample sizes make it less evident (Table 3).

Colorado squawfish were not found upstream from the reservoir in 1988 or 1989. In 1990 fish were found at sites 7.2 km upstream from the reservoir in June and again at one site, a large, deep (>1.8 m) backwater, 1.6 km upstream from the reservoir in July. None were collected after July, mirroring the decline in catch-per-unit-effort in the reservoir and in areas downstream from the reservoir.

Total collections of fingerling squawfish were a small percentage (1.0%) of the 96,597 stocked, despite intensive sampling. Of all fish collected during this study, squawfish accounted for 0.4% in 1988, 1.4% in 1989, and 1.0% in 1990. Based on seining data, catch rates of stocked squawfish (number per 100 m^2) declined precipitously in the months following stocking in both the reservoir and the river (Fig. 2).

Telemetered Colorado squawfish exhibited wide-ranging movements throughout the reservoir. Based on these erratic movements, the fish did not appear to establish home ranges. Of the four hatchery fish tagged, two died within 29 days without leaving the reservoir. One fish moved upstream and then back to the reservoir within 36 days of being tagged. The fourth fish was last contacted in the reservoir on 12 June, and subsequently recontacted 12 km downstream from the dam 58 days later where it remained into October.

Of the three wild fish tagged, one died in eight days. A second remained in the reservoir until early July and then moved upstream 3.2 km. It was last located in August, 1.6 km above the reservoir. The remaining fish exited downstream on 12 June, and remained downstream from the dam into October.

DISCUSSION—Early hopes that Kenney Reservoir might imitate a large instream pool or backwater, inducing the Colorado squawfish to remain in the reservoir, were not realized. Instead, large numbers of Colorado squawfish exited the reservoir and continued downstream, and catch rates declined in all areas. The rapid disappearance of the species from the study area has several possible explanations including any or a combination of flow regime, movement patterns, mortality and sampling effectiveness.

The short period of escapement, or "pulse" of downstream movement of the majority of the Colorado squawfish was associated with high spring flows following stocking. Clark (1942), Louder (1958), Elser (1960) and Powell and Spencer (1979) all found high fish emigrations over spillways related to season rather than magnitude of discharge, with most migration occurring in spring. Lewis et al. (1968) found such movements related to heavy rainfall events in the spring, with none occurring after heavy rainfall in July.

The spillway at Kenney Reservoir offers no deterrents or barriers to fish emigration. Colorado squawfish stocked during the spring high flows in 1988, 1989, and 1990 were collected in relatively large numbers downstream from the dam. A single Colorado squawfish from late summer stockings in 1990 was captured below the dam in a drift net two days after stocking. None were collected in subsequent seining downstream from the dam (Table 3). Our data suggest that Colorado squawfish exit the reservoir regardless of the time of year when stocked, however, it appears that lesser numbers exit the reservoir during periods of lower flows.

Catch-per-unit-effort, (CPUE) declined throughout the summer sampling period and approached zero (Table 3). When sampling was resumed the following spring, CPUE for the previous year-class of squawfish was found to be at the same level as that in the fall, one or two fish per several hundred square meters seined. The CPUE then resumed a downward trend until no fish were collected at the end of their second summer. It is a matter of speculation whether these fish are reentering the backwaters at high water after spending the winter months in the main channel, or have recently exited the reservoir during spring runoff. The recent exit theory supports the "pulse" hypothesis proposed above.

Emigration and resultant downstream movement of Colorado squawfish may represent a genetic and age-related tendency. Young Colorado squawfish tend to move or drift downstream after "swim-up" to more suitable nursery habitat (Tyus, 1991). Juveniles have generally only been found downstream of identified spawning areas. No spawning sites for Colorado squawfish have been identified and no wild juveniles less than 267 mm long have been collected in the White River (Chart and Bergersen, 1992). Apparently the White River is not highly suitable habitat for young Colorado squawfish; this may be one explanation for the downstream dispersal and probable mortality of the stocked fish.

The small size of the squawfish at stocking could have contributed to increased mortality. Although no evidence of predation on squawfish was collected, potential piscid and avian predators were present in the White River and Kenney Reservoir, including black crappie, roundtail chub, channel catfish and brown trout. The effect of predation on the stocked squawfish is unknown, but is likely to be significant. A rapidly expanding population of black crappie, whose numbers increased from 0.4% of the community in 1988 to 3.8% in 1989 and 17% in 1990 could seriously affect future stocking of fingerling Colorado squawfish.

Although most of the recaptured Colorado squawfish were found in the reservoir or downstream, the few that were captured above the reservoir in 1990 raise some interesting questions because upstream movement is unusual in juveniles. That the stocked Colorado squawfish were able to swim upstream against a current and even negotiate small rapids at sizes less than 100 mm are both important findings of the present study because previous data had suggested that juveniles do not normally move upstream (Tyus, 1991). The behavior of Colorado squawfish changes with growth and sexual maturity. They become more mobile, particularly during the spawning season when they undertake long spawning migrations (Tyus and McAda, 1984). Such behavior would tend to make any Colorado squawfish remaining in the reservoir more likely to emigrate as they reach maturity.

The telemetry portion of the study explored behavioral differences between wild and hatchery-raised adult Colorado squawfish; specifically to determine if fish raised to maturity in a hatchery would exhibit less tendency to make a spawning migration, or would have greater tendency to remain in the reservoir particularly during high movement periods in June and July. Although sample sizes were too small for statistical comparisons, our results indicate no greater tendency of hatchery reared fish to remain in the reservoir. A hatchery fish was the first to be located below the dam, and descended many kilometers before returning. Another moved upstream into the river and back shortly before death. Two of the three wild fish moved out of the reservoir into the river and seemed to survive the experience more successfully (2 out of 3 survived, compared to only 1 out of 4 hatchery fish surviving until the end of the study). There was no discernable difference in behavior between the surviving fish attributable to their origin. Implanting dual tags may have contributed to the unusually high (43%) mortality of the tagged fish, confounding the results.

Low recapture may also be attributable to the difficulty of sampling Colorado squawfish in the size range 100 mm to 250 mm. Wild specimens are seldom collected in this size range, although recruitment into the adult size-classes occurs. The stocked fish may reappear at a larger size. In support of this is the recent recapture of adult squawfish in the Colorado River that were marked with coded wire tags and stocked as fingerlings in 1982, 1983 or 1984. Three out of 21 adult Colorado squawfish collected during spring sampling in 1990 had coded wire tags, although their stocking year could not be determined without surgery (B. Burdick, pers. comm.).

Not only did catch rate decline following stocking, but, also, total capture success in the reservoir was quite low. One percent of the total fish stocked were eventually recaptured. Only 14 fish were collected in their second year. Only four of these fish were caught in Kenney Reservoir. Five of these were collected in 1991, one in the reservoir, three above, and one below. No squawfish were collected in the third year after stocking.

Unless the Colorado squawfish subsequently reappear at a larger size when they are more susceptible to capture, little additional information can be gained from this stocking effort. Incidental catch by anglers may also contribute information on the fate of any surviving Colorado squawfish. Due to the small number and sizes (112 to 184 mm) of stocked fish collected in 1991, the Colorado Division of Wildlife recommended that further intensive evaluation of stocked Colorado squawfish be postponed until evidence is obtained, either through sampling or creel survey, that any of the stocked fish remaining in the reservoir are vulnerable to angling capture. The success of subsequent stockings of squawfish might be improved by stocking larger-sized fish after runoff. Some fish loss could be prevented by modification of the spillway and release procedures. Techniques employed to minimize fish escapement over the spillway should be explored if future stocking is planned. This strategy should include efforts to minimize the magnitude and duration of surface releases at the time of stocking.

The concept of establishing a sport fishery for Colorado squawfish has been previously proposed and discussed as a recovery strategy (Wydoski, 1982). Colorado squawfish are attractive, silvery fish that reach trophy sizes, take lures readily, are strong fighters, and are reputed to be delectable. In short, they have all the prerequisites of a fine sportfish except for the regard of the anglers, and wide ranging movements that may exceed the confines of small-sized mainstem impoundments. The low return of stocked fish, regardless of the cause, does not generate much promise for establishing a sportfishery. Nor does stocking Colorado squawfish in mainstem reservoirs appear to be an effective mitigation procedure for habitat loss due to impoundment.

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