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Predation by Introduced Fishes on Endangered Humpback Chub and Other Native Species in the Little Colorado River, Arizona

PAUL C. MARSH

Center for Environmental Studies and Department of Zoology, Arizona State University Tempe, Arizona 85287-3211, USA

MICHAEL E. DOUGLAS

Department of Zoology and Museum, Arizona State University Tempe, Arizona 85287-1501, USA

Abstract.—Fishes in the Little Colorado River in the Grand Canyon, Arizona, were sampled monthly from July 1991 to June 1995 as part of a study of the ecology of endangered humpback chub *Gila cypha*. Diets of five introduced predatory fish species were examined. Stomach contents varied among species and were low in diversity and dominated by algae (primarily *Cladophora*), aquatic insects, and fishes. Humpback chub plus other native species were a significant component of the diet (13.7% frequency of occurrence among 219 of 408 stomachs that contained food). Predation mortality from introduced fishes may significantly affect the native species by depleting numbers and reducing recruitment.

Interactions between native and introduced species have been implicated in extirpations of indigenous fishes around the globe (reviewed in Courtenay and Stauffer 1984; Welcomme 1988; Pollard 1989; Rosenfield and Mann 1992). Native fishes of the Colorado River basin of western North American have been affected similarly. In the basin, an historically depauperate ichthyofauna of 36 species (many polytypic) has been subjected to a suite of about 70 nonnative fish species brought intentionally or inadvertently to the region. Coincident with these introductions and with habitat alteration resulting from development of water resources, 3 native species now are extinct and 22 others are listed as endangered or threatened. Predation and competition by introduced fishes have contributed to the present faunal status (Dill 1944; Miller 1946, 1961; Minckley and Deacon 1968, 1991; Moyle et al. 1986), but only recently have these species introductions become a focus of conservation planning for native fishes.

Endangered humpback chub *Gila cypha* is a medium-sized minnow that persists in only seven reaches of four rivers of the Colorado River basin because of habitat loss and modification, hybridization with congeners, and interactions with nonnative fishes (USFWS 1990). The largest remaining population is in the Little Colorado River, the major tributary to the Colorado River in the Grand Canyon, Arizona (Kaeding and Zimmerman 1983; Douglas and Marsh 1996).

We examined predation by nonnative fishes on humpback chub and other native species, and assessed the potential impact on humpback chub. Rainbow trout *Oncorhynchus mykiss* and channel catfish *Ictalurus punctatus* are common and brown trout *Salmo trutta*, black bullheads *Ameiurus melas*, yellow bullheads *A. natalis*, and striped bass *Morone saxatilis* are uncommon in the mouth and lower reaches of the Little Colorado River. Channel catfish predation on humpback chub has been documented from stomach contents (C.O. Minckley, U.S. Fish and Wildlife Service, personal communication) and has been suggested by crescent-shaped bite marks on humpback chub (Kaeding and Zimmerman 1983; Karp and Tyus 1990). However, there are no published data on predation on humpback chub or other native fishes by the introduced species.

Methods

Fishes were captured in the lower 15 km of the Little Colorado River about monthly from July 1991 to June 1995. Hoop nets (0.8 or 1.2 m in diameter, 2.4 or 3.0 m long, 4 or 6 hoops, single or double throat) were deployed in all available habitats deeper than about 0.4 m. Trammel nets (7.6–45.7 m long, 1.8 m deep, 1.3–3.8-mm inner and 30-mm outer meshes) were set in water deeper than 0.5 m in the Little Colorado–Colorado River confluence area, and occasionally near Powell and Salt canyons, (3.0 and 10.6 river kilometers up the Little Colorado from the confluence). We also angled sporadically throughout the stream with baited hooks and artificial lures to collect additional fish.

Fish were identified, counted, measured for total length (TL, mm), and weighed (g). Native species were released near the point of capture after processing. Nonnative fishes were sacrificed and ei-

TABLE 1.—Numbers and mean total lengths (ranges in parentheses) of introduced piscivores and their fish prey in the Little Colorado River, Arizona, July 1991–June 1995. Some prey (ND, not determined) were in states of digestion that prevented species identification, measurement, or both. Native taxa are indicated by an asterisk (*).

Predator			Prey fishes in stomachs		
Species	*N*	Total length (mm)	Taxon	*N*	Total length (mm)
Rainbow trout	3	356 (332–398)	Humpback chub*	3	43 (40–45)
	2	372 (370–373)	Speckled dace*	2	60 (45–75)
	2	353 (335–370)	Fathead minnow	5	42 (30–60)
	1	355	Common carp	1	60
	1	375	Flannelmouth sucker*	1	78
	1	350	Bluehead sucker*	1	ND
	4	351 (319–383)	ND Cyprinidae	9	46 (30–65)
	1	341	ND Catostomidae*	1	43
	10	345 (313–389)	ND	16	96 (34–>150)
Channel catfish	8	554 (375—790)	Humpback chub*	22	115 (85–200)
	5	453 (271–594)	Speckled dace*	6	67 (60–75)
	1	482	Fathead minnow	1	60
	1	476	Common carp	1	116
	2	525 (455–594)	Flannelmouth sucker*	2	175 (150–200)
	4	599 (582–605)	Bluehead sucker*	5	211 (150–250)
	2	480 (477–482)	ND Cyprinidae	6	58 (40–80)
	10	452 (281–595)	ND	11	100 (58–200)
Yellow bullhead	1	167	ND Cyprinidae	3	39 (37–41)
	1	171	ND	1	>100
Black bullhead	2	152 (134–169)	Humpback chub*	2	52 (49–55)
Brown trout	1	341	Speckled dace*	1	77
	1	566	ND	1	118

ther their guts were removed and fixed in 10% formalin or whole fish (<100 mm) were preserved in 95% ethanol. The entire digestive tract was examined and food composition was determined in the lab. Fish prey were identified and measured if enough of the specimen remained. Pharyngeal tooth counts aided in discriminating among cyprinid prey. We also examined stomach contents microscopically to determine if larval fishes had been eaten.

Results and Discussion

Humpback chub remains were identified in 13 (3.2%) of the 408 digestive tracts examined (Table 1). Overall, remains of native fishes were in 13.7% of 219 stomachs that contained food. Common carp *Cyprinus carpio,* speckled dace *Rhinichthys osculus,* fathead minnow *Pimephales promelas,* bluehead sucker *Pantosteus* (=*Catostomus*) *discobolus,* flannelmouth sucker *Catostomus latipinnis,* and unidentified fish remains were in stomachs of 51 predators, 5 of which also had eaten humpback chub (Table 1). Mean length of humpback chub in stomachs (102 mm TL; $N = 27$) did not differ significantly (two-sample *t*-test, Snedecor and Cochran 1967) from that of other ingested fishes (92 mm; $N = 74$). No larval or small postlarval fishes were found, probably due to the transient presence of this fragile stage in predator guts. Rangewide, the humpback chub is represented by several sustaining populations, but assessment of the effects of predation on early life stages on long-term population viability cannot be made until methods to quantify this predation are worked out.

Stomachs of 3 of 174 rainbow trout (prey length 40–45 mm) and 2 of 12 black bullhead (49 and 55 mm TL) contained humpback chub; 22 rainbow trout had eaten other fishes. Speckled dace and an unidentified fish were in 2 of 10 brown trout stomachs, and unidentified fish remains were also in 2 of 10 yellow bullheads. Eight of 202 channel catfish ate 1–7 chub each (85–200 mm). Fish remains were in 25 other stomachs. Channel catfish that ate fish averaged 500 mm TL, which was larger than catfish that had not eaten fish, a result supported by Tyus and Nikirk (1990).

Algae (primarily *Cladophora*) were the most common food of rainbow trout (47% frequency of occurrence), brown trout ate mostly terrestrial invertebrates (20%), and fish was the most common food of other predator species (10–20%; Table 2). Rainbow trout and channel catfish consumed a variety of other items including vegetation, amphipods *Gammarus lacustris,* aquatic insect larvae,

TABLE 2.—Frequency of occurrence of food items as percentage of total stomachs examined for each of five species of predatory introduced fishes collected in the Little Colorado River, Arizona, July 1991–June 1995.

Food item or statistic	Predator				
	Rainbow trout	Brown trout	Channel catfish	Black bullhead	Yellow bullhead
Detritus	0	0	3	8	10
Vegetation	9	0	5	0	0
Algae[a]	47	0	10	0	0
Gammarus	12	0	2	0	0
Corydalidae	1	0	2	0	0
Simuliidae	19	0	4	0	0
Chironomidae	14	0	1	0	0
Gastropoda	1	0	0	0	0
Oligochaeta	0	0	1	0	0
Odonata	0	0	1	0	10
Tipulidae	0	0	1	8	0
Coleoptera	3	0	1	0	0
Ceratopogonidae	0	0	1	8	0
Trichoptera	1	0	0	0	0
Aquatic insects[b]	1	0	9	0	0
Terrestrials[b,c]	3	20	4	0	0
Humpback chub	2	0	4	17	0
Speckled dace	1	10	2	0	0
Common carp	1	0	1	0	0
Bluehead sucker	1	0	2	0	0
Flannelmouth sucker	1	0	1	0	0
Fathead minnow	1	0	1	0	0
Fish[b]	9	10	1	0	20
Fish eggs	1	10	1	0	0
Number of stomachs (number with food)	174 (114)	10 (3)	202 (91)	12 (7)	10 (4)
Mean TL (mm) (Range)	354 (210–491)	397 (296–566)	286 (37–796)	158 (70–228)	166 (75–212)

[a] Primarily *Cladophora*.
[b] Taxa not determined.
[c] Terrestrial invertebrates.

and terrestrial invertebrates. Brown trout contained terrestrial insects and fish (20% each) and fish eggs (10%); black bullheads ate detritus (8%), aquatic insects (16%), and fish (17%); and yellow bullheads contained detritus and odonate naiads (10% each) and fish (20%). Proportion of empty stomachs varied among species from 34% to 70% (Table 2).

Food habits of potential piscivores were unremarkable. The relatively low diversity of food items probably reflected a paucity of food in the Little Colorado River. Diets of individual species were qualitatively consistent with other reports from the Colorado River basin (Minckley 1973, 1982; Marsh 1981; AZGFD 1987; Tyus and Nikirk 1990) and elsewhere (Calhoun 1966). All studies concluded that channel catfish were opportunistic omnivores and that fish were a small part of their diet.

Predatory fishes represent a threat to humpback chub in the Little Colorado River and may exert a major negative effect on the population there. Our data indicate that on average about 3% of rainbow trout and channel catfish ate an average of 2.3 humpback chubs. If our estimated average meal of 2.3 prey is taken once a week, a predator population of 1,000 would annually consume 3,588 humpback chub. Predatory fishes probably number in the thousands. Recent population estimates generated under five different models for adult (>150 mm TL) humpback chub in the Little Colorado River were 4,508–10,444 (Douglas and Marsh 1996). Although most humpback chub in predator stomachs were juveniles, channel catfish ate humpback chub as large as 200 mm TL and other fish up to 250 mm (Table 2). Thus, predation may not only limit recruitment by removing juveniles from the population, but it might also increase total adult mortality. Although some streams like the Little Colorado River retain a natural character (particularly hydrologic features) thought to favor native over introduced fishes (Minckley and Meffe 1987), predation impacts may limit native species populations.

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References

AZGFD (Arizona Game and Fish Department). 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand canyons. Final Report to U.S. Bureau of Reclamation, Contract 4-AG-40-01810, Salt Lake City, Utah.

Calhoun, A., editor. 1966. Inland fisheries management. California Department of Fish and Game, Sacramento.

Courtenay, W. R., Jr., and J. R. Stauffer, Jr., editors. 1984. Distribution, biology, and management of exotic fishes. Johns Hopkins, Baltimore, Maryland.

Dill, W. A. 1944. The fishery of the lower Colorado River. California Fish and Game 30:109–211.

Douglas M. E., and P. C. Marsh. 1996. Population estimates/population movements of *Gila cypha*, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia 1996:15–28.

Kaeding, L. R., and M. A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado rivers in Grand Canyon. Transactions of the American Fisheries Society 112: 577–594.

Karp, C. A., and H. M. Tyus. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green rivers, Dinosaur National Monument, with observations on roundtail chub (*G. robusta*) and other sympatric fishes. Great Basin Naturalist 50:257–264.

Marsh, P. C. 1981. Food of channel catfish in the Coachella Canal, California. Journal of the Arizona–Nevada Academy of Science 16:91–95.

Miller, R. R. 1946. The need for ichthyological survey of the major rivers of western North America. Science 104: 517–519.

Miller, R. R. 1961. Man and the changing fish fauna of the American southwest. Papers of the Michigan Academy of Science, Arts and Letters 46: 365–404.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix.

Minckley, W. L. 1982. Trophic interrelations among introduced fishes in the lower Colorado River, southwestern United States. California Fish and Game 68:78–89.

Minckley, W. L., and J. E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species." Science 159:1424–1432.

Minckley, W. L., and J. E. Deacon, editors. 1991. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

Minckley, W. L., and G. K. Meffe. 1987. Differential selection by flooding in stream fish communities of the arid American southwest. Pages 93–104 *in* W. J. Matthews and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Moyle, P. B., H. W. Li, and B. A. Barton. 1986. The Frankenstein effect: impact of introduced fishes on native fishes in North America. Pages 415–426 *in* R. H. Stroud, editor. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, Maryland.

Pollard, D. A., editor. 1989. Introduced and translocated fishes and their ecological effects. Australian Bureau of Rural Resources, Proceedings 8, Canberra.

Rosenfield, A., and R. Mann, editors. 1992. Dispersal of living organisms into aquatic ecosystems. University of Maryland, Sea Grant College, College Park.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames.

Tyus, H. M., and N. J. Nikirk. 1990. Abundance, growth, and diet of channel catfish, *Ictalurus punctatus*, in the Green and Yampa rivers, Colorado and Utah. Southwestern Naturalist 35: 188–198.

USFWS (U.S. Fish and Wildlife Service). 1990. Humpback chub recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado.

Welcomme, R. L. 1988. International introductions of inland aquatic species. FAO (Food and Agriculture Organization of the United Nations) Fisheries Technical Paper 294.

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