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EFFECTS OF CONVICT CICHLIDS ON GROWTH AND RECRUITMENT OF WHITE RIVER SPRINGFISH

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ABSTRACT.—Observations of changes in population density of native White River springfish (*Crenichthys baileyi*) in Pahranagat Valley led to the following hypothesis: introduced convict cichlids (*Cichlasoma nigrofasciatum*) cause reduced growth and recruitment; cover reduces the magnitude of the effect. The hypothesis was tested by establishing sympatric and allopatric groups of the two species in experimental aquaria with and without cover. Change in volume (= mass) and length of the two species over a three-month period in spring 1986 and 1987 was measured and analyzed using 2 × 2 factorial analyses. Convict cichlids caused reduced growth and eliminated recruitment of springfish under the experimental conditions. Cover did not influence growth but positively affected recruitment of springfish in allopatry. It is likely that a portion of the reduced springfish population densities in nature can be attributed to adverse effects from introduced cichlids.

Key words: exotic species, competition, springfish, population control.

Introduced fishes have been implicated in the decline and/or extinction of native fishes throughout the world. Numerous anecdotal accounts have documented adverse effects, but few have identified the causative mechanism (Schoenherr 1981, Taylor et al. 1984). Moyle et al. (1986) noted that introduced fishes may (1) eliminate native fishes, (2) reduce their growth and survival, (3) change their community structure, or (4) have no effect. Meffe (1985) concluded that elimination of native by exotic fishes in southwestern U.S. is frequently attributable to predation. Schoenherr (1981) demonstrated that competitive interactions with exotic species can reduce survival and produce changes in community structure. Replacement of desert pupfish (*Cyprinodon macularius*) by redbelly tilapia (*Tilapia zilli*) in an irrigation drain near the Salton Sea was attributed by Schoenherr (1985, 1988) to interference with normal behavior patterns. Bestgen and Probst (1987) proposed that reductions of native fish populations in the Southwest, heretofore attributed to interactions with introduced red shiner (*Cyprinella lutrensis*), were more likely due to habitat degradation resulting in elimination of natives from habitats which were then occupied by the alien species. Jennings and Saiki (1990) suggested that a complementary distribution between red shiner and native fishes in the San Joaquin Valley, California, may represent just the first stage in colonization by red shiner. Deacon (1988) reported that after about 20 years of maintaining a complementary distribution, red shiner suddenly expanded its range upstream and, perhaps aided by an introduced parasite (Heckmann et al. 1986), nearly replaced the indigenous woundfin (*Plagopterus argentissimus*) in the Virgin River of Utah, Arizona, and Nevada. Introduced fishes obviously interact in complex and variable ways with native species.

In Pahranagat Valley, Nevada, one population of White River springfish (*Crenichthys baileyi*) was eliminated by nonnative largemouth bass (*Micropterus salmoides*) predation; and two populations were severely depressed, apparently by interaction with convict cichlids (*Cichlasoma nigrofasciatum*), shortfin mollies (*Poecilia mexicana*), sailfin mollies (*P. latipinna*), and mosquitofish (*Gambusia affinis*) (Courtenay et al. 1985). The present study was designed to examine mechanisms that may have caused the observed population reductions. Our hypothesis was that both growth and reproduction of Hiko White River springfish (*C. b. grandis*) are depressed by interactions with convict cichlids and enhanced by cover.

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TABLE 1. Mean volumes (ml) of springfish and cichlids at the beginning (initial) and end (final) of the experimental periods. Numbers in parentheses are one standard deviation.

	Springfish				Cichlids			
	Exp. 1		Exp. 2		Exp. 1		Exp. 2	
	Initial mean	Final mean	Initial mean	Final mean	Initial mean	Final mean	Initial mean	Final mean
Allopatric/ cover	.253 (.152)	.614 (.247)	.461 (.194)	.761 (.223)	1.79 (.847)	2.77 (1.50)	2.09 (1.30)	3.37 (2.41)
Allopatric/ no cover	.256 (.113)	.529 (.204)	.453 (.171)	.776 (.197)	1.07 (.540)	3.23 (1.30)	2.34 (.481)	4.36 (2.57)
Sympatric/ cover	.503 (.154)	.619 (.150)	.553 (.186)	.749 (.189)	.973 (.569)	2.69 (1.44)	2.10 (.987)	4.09 (1.52)
Sympatric/ no cover	.340 (.162)	.523 (.168)	.534 (.210)	.735 (.254)	1.21 (.427)	2.58 (1.18)	1.66 (.576)	4.48 (2.05)

METHODS

The following experiments were conducted in March–May 1986 (experiment 1) and 1987 (experiment 2). Springfish and cichlids were kept in separate 208-liter stock aquaria for three months in 1986 and one month in 1987 prior to introduction into experimental aquaria. Experimental fish were weighed (volume displacement), measured (total length [TL], mm), and sexed at the beginning and end of the 63-day experimental period (Table 1). Volume displacement and TL were used to minimize trauma from handling. Allopatric groups containing five pairs of springfish or five pairs of cichlids were established in each of two 76-liter aquaria with and without cover. Sympatric groups, each containing three pairs of springfish and two pairs of cichlids, were established in each of two aquaria with and without cover. Cover consisted of assorted rocks and plastic plants, all used in approximately equal amounts. Commercial "spawning grass" was placed in all aquaria to encourage spawning. Fish were fed Tetramin® Staple Food at a rate of approximately 6.0% body mass twice daily to ensure that food was not a limiting factor. All aquaria were maintained at 23–26 C. One sympatric/no cover aquarium in 1986 suffered a heater malfunction and was terminated. Biological filtration was utilized in experimental aquaria: under-gravel filtration in 1986, biological-sponge filtration in 1987. The stock aquaria were filtered with outside power filters. Seventy-five percent of the water in each aquarium was changed weekly. Observations of chasing behavior were made daily for a one-minute period per aquarium. Fin and body damage was also recorded.

A series of 2 × 2 factorial analyses (Montgomery 1984, Chapter 7) was used to examine the influence of sympatry/allopatry and cover/no cover on growth in volume (mass), TL, number of chases, and extent of fin damage for each species. Significance of differences (at 5% significance level) is summarized in ANOVA tables.

RESULTS

Data on increases in volume and TL produced the same analytical results for both springfish and cichlids; only the analyses for volume are presented (Table 2). Springfish in allopatric groups grew more rapidly than they did when cichlids were present. Cover had no significant effect, but a slight interaction between sympatry/alloptary and cover/no cover may mask the main effect of cover on growth. If so, cover has a slightly negative effect. For cichlids, higher mean growth by sympatric groups was significant, but cover did not influence growth and there was no interaction between the two factors (Table 2).

Chasing by cichlids was nearly all intraspecific and caused no detectable fin damage to springfish. Among cichlids (Table 3), the two factors, sympatry/alloptary and cover/no cover, had no significant effect on aggressive behavior as measured by chasing or fin damage. Nevertheless, cichlids in experiment 2 were significantly more aggressive than in experiment 1. During experiment 2, all springfish in one sympatric tank without cover were found dead five days before experiments were terminated. We attribute this to aggressive behavior by a nesting pair of cichlids. The dead fish were intact and were weighed,

TABLE 2. Average increase in volume (ml) of springfish and cichlids fed at 12% body weight per day for 63 days (I = increase in volume; *n* = number of fish).

	Allopatric				Sympatric			
	Cover		No cover		Cover		No cover	
	I	*n*	I	*n*	I	*n*	I	*n*
EXPERIMENT 1								
Springfish	.36	10	.27	10	.12	12	.23	12
Cichlids	1.19	10	1.80	8	1.72	8	2.37	7
EXPERIMENT 2								
Springfish	.30	10	.32	10	.20	12	.17	6
Cichlids	1.28	10	1.29	7	1.99	8	2.2	6

Analysis of variance of growth data (ml) for springfish and cichlids. Factor A is sympatry/allopatry; factor B is cover/no cover.

		Springfish		Cichlids	
Source	d.f.	MS	*F*	MS	*F*
A	1	0.0351125	17.453416**	0.9248	19.9957**
B	1	0.0000125	0.006211	0.2738	5.9200
AB	1	0.0028125	1.397515	0.0072	0.1557
Error	4	0.0020125		0.04625	
Total	7	0.0065696		0.19869	

**significant at the 5% level.

TABLE 3. Mean number of intraspecific chases by cichlids per observation period and percentage of cichlids sustaining fin damage during the experimental period (experiment 1 results from Tippie and Deacon 1987).

	Chases		Fin damage	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2
Sympatric, no cover	0.64	1.9	87.5	100
Allopatric, no cover	0.70	6.6	60.0	100
Sympatric, with cover	0.71	5.3	62.3	100
Allopatric, with cover	0.41	9.5	50.0	90

Analysis of variance. Factors = four combinations of treatments; block = experiments 1 and 2.

	Chases			Fin damage		
Source	d.f.	MS	*F*	d.f.	MS	*F*
Factors	3	4.6959	0.8939	3	189.5883	2.1084
Block	1	54.2882	10.3349**	1	2119.0050	23.5650**
Error	3	5.2529		3	89.9217	
Total	7	64.2370		7	2398.515	

**significant at the 5% level.

measured, and included in the analysis despite a 58- rather than a 63-day growth period.

Chasing by springfish was also more prevalent in experiment 2 (Table 4) but resulted in relatively little fin damage. Most chases were more likely attributable to mating behavior than to aggression.

Reproduction by both species was variable (Table 5). Springfish produced no young during or after the experimental periods in any tank with sympatric cichlids. In contrast, springfish eggs and/or fry were observed at some time during, or following, the experimental period in all allopatric tanks. Fry were present in one of two allopatric aquaria at termination in experiment 1, but not in experiment 2; however, 14 days after removal of experimental animals, newly hatched springfish appeared in allopatric aquaria in experiment 2.

DISCUSSION

We conclude that convict cichlids can have a significant adverse effect on growth and

TABLE 4. Mean number of intraspecific chases by springfish per observation period and percentage of springfish sustaining fin damage during the experimental period (experiment 1 data from Tippie and Deacon 1987).

	Chases		Fin damage	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2
Sympatric, no cover	0.32	5.4	0	0
Allopatric, no cover	0	10.8	0	20
Sympatric, with cover	0.15	4.9	0	0
Allopatric, with cover	0	7.9	0	0

Analysis of variance. Factors = four combinations of treatments; block = experiments 1 and 2.

	Chases			Fin damage		
Source	d.f.	MS	*F*	d.f.	MS	*F*
Factors	3	3.3585	0.8422	3	50	1.0
Block	1	101.7451	25.5121**	1	50	1.0
Error	3	3.9881		3	50	
Total	7	109.0917		7	150	

**significant at the 5% level.

TABLE 5. Reproduction occurring during the experimental period: # = number of tanks in that category containing eggs or fry at some time during or after the experimental period; N = number of fry surviving at termination; T = number of fry appearing following termination.

	Allopatric						Sympatric					
	Cover			No cover			Cover			No cover		
	#	N	T	#	N	T	#	N	T	#	N	T
Springfish	2	11	4	2	0	9	0	0	0	0	0	0
Cichlids	1	49	0	0	0	0	1	0	0	2	99	0

recruitment of White River springfish under the experimental conditions. It seems probable that the lack of recruitment by springfish living sympatrically with cichlids results from cichlid predation on springfish eggs and fry. Presence or absence of cover had no statistically identifiable influence on growth of either species. It did positively affect springfish recruitment, but not that of cichlids. Cichlid aggression is largely intraspecific; however, when cichlids are guarding the nest, aggression can be lethal to adult springfish. Faster growth by cichlids in sympatric experimental populations may be due to their smaller number and biomass in those tanks rather than to a salubrious interspecific relationship. Conversely, springfish grew faster in allopatric aquaria in spite of higher density.

The above conclusions help interpret conditions observed in natural populations. Introductions of convict cichlids into Ash Spring in 1965 and Crystal Spring in the 1970s were closely followed by sharp drops in their respective springfish populations (Courtenay et al. 1985). Reduced growth and recruitment might well produce that result.

More recently, however, Hiko Spring added a puzzling variation to this seemingly straightforward explanation. Following elimination of springfish by largemouth bass and subsequent disappearance of bass from the spring, springfish were reintroduced. The day successful recruitment was confirmed, a few convict cichlids were observed (Baugh et al. 1985). We predicted expansion of both populations, followed by a decline in springfish numbers. The expansion occurred, but the decline did not (Deacon, unpublished data), and we therefore suspected that additional factors might be contributing to low springfish populations at Ash and Crystal springs.

At Ash Spring, elevated ammonia and nitrite levels, apparently leading to increased susceptibility of springfish to bacterial infection from *Pseudomonas* and *Aeromonas*, are factors that may contribute to low population numbers (Taylor et al. 1990). The U.S. Bureau of Land Management, following notification of the problem, took steps to remove cattle. The result was a decrease in contaminants and an increase in densities for all fish species (Taylor et al. 1990). Springfish density nonetheless remains below levels recorded prior to introduction of cichlids and mollies (Courtenay et al. 1985).

No likely alternative explanation for low springfish populations has been identified at Crystal Spring. It would seem prudent to attempt to discover whether agricultural chemicals or other potentially toxic materials or practices are associated with manipulation of the waters for irrigation. None is apparent.

Maintenance of an abundant springfish population at Hiko Spring for three years indicates that sympatry with introduced convict cichlids, while perhaps stressful, need not invariably result in scarcity of the native species. Our results demonstrate that convict cichlids can depress growth and recruitment of springfish and, under some circumstances, may cause mortality of adults. Those may be the primary causes of low populations at Ash and Crystal springs. At Hiko Spring, however, springfish are to date maintaining essentially natural population densities despite the presence of convict cichlids, mollies, and mosquitofish.

It remains unclear why the springfish population at Hiko Spring should be responding differently from those at Ash and Crystal springs. The interaction is obviously more complex than predation on larvae or depression of growth. Any or all of the following factors may be important: (1) habitat complexity, (2) differences in resource availability, (3) escape cover for larvae, (4) selection of spawning sites, or (5) other behavioral responses developed by populations of springfish and cichlids upon becoming established in a new habitat simultaneously. Clearly, a simple predator-prey model is insufficient to explain variations in springfish population densities resulting from introductions of other species.

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