Bonytail (Gila elegans) may enhance survival of Razorback Suckers (Xyrauchen texanus) in rearing ponds by preying on exotic crayfish

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BONTAIL (GILA ELEGANS) MAY ENHANCE SURVIVAL OF RAZORBACK SUCKERS (XYRAUCHEN TEXANUS) IN REARING PONDS BY PREYING ON EXOTIC CRAYFISH

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ABSTRACT

This study examined the potential of bontail (Gila elegans) to enhance survival of young razorback sucker (Xyrauchen texanus) in rearing ponds by serving as a biological control agent for young stages of Red Swamp Crayfish (Procambarus clarkii). Large populations of crayfish in rearing ponds negatively affect the survival of razorback suckers, through predation and competition for food. Traps made with 6.34 mm (0.25 inch) mesh have been used in an effort to reduce crayfish populations, however crayfish less than 17 mm carapace length (CPL) are able to escape. Juvenile bontail in experimental trials ate young crayfish ranging in size from 3 to 15 mm CPL. Crayfish consumption was not reduced in the presence of an alternative food source, but was reduced slightly by the presence of cover. These results suggest that juvenile bontail may reduce numbers of crayfish smaller than 15 mm CPL in ponds used to rear razorback suckers. If so, integration of rearing programs for endangered razorback sucker and bontail could have beneficial effects for both species.

INTRODUCTION

The Colorado River, one of the most controlled rivers in the world, supports a highly differentiated fish fauna, about 75% of which is endemic (Miller 1959, Minckley et al. 1986). Of the 13 native fish species comprising the original ichthyofauna of the mainstream Colorado below Grand Canyon, only 2 (bontail [Gila elegans] and razorback sucker [Xyrauchen texanus]) persist. Both are federally listed as endangered. A third (flannelmouth sucker [Catostomus latipinnis]) has been re-established in a section of the lower mainstream immediately below Davis Dam.

Federal and state agencies are directing a major effort toward recovery of razorback, bontail, and other endangered species of the lower Colorado River. In addition, a coalition of water-user groups, government agencies, and private businesses is developing a major comprehensive program, the Lower Colorado River Multi-Species Conservation Plan (LCRMSCP). The U.S. Bureau of Reclamation, the Lower Colorado River Multi-Species Conservation Plan (LCRMSCP), has been engaged in their own independent programmatic recovery efforts for the lower Colorado River mainstream fishes for years. This study was conducted in support of that U.S. Bureau of Reclamation recovery program.

A large population of razorbacks apparently formed early in the 1950s as Lake Mohave filled. Since that time recruitment has been extremely low (Minckley 1983, Marsh and Minckley 1992, Marsh 1994). Most adult razorback in Lake Mohave and throughout the entire lower Colorado River are now more than 40 years of age, and the indigenous population is declining rapidly (Pacey and Marsh in press). A much smaller population of bontail, today consisting of very few individuals, also persisted in Lake Mohave (Marsh and Minckley 1992). Predation by introduced sport fishes in the lower river has been identified as the primary factor leading to an almost total absence of recruitment into the adult populations of these two species. Both apparently have been spawning annually in Lake Mohave (and perhaps elsewhere in the lower Colorado) and producing large numbers of eggs and larvae since 1950 (Bozek et al. 1991), but the larvae do not survive (Minckley et al. 1991).

For the past several years, U.S. Bureau of Reclamation biologists have captured wild razorback larvae from Lake Mohave, reared them to about 150 mm total length (TL) at Willow Beach National Fish Hatchery, and then moved them to rearing ponds containing no fish species that prey on razorback suckers. Upon reaching a target size of about 300 mm TL, the sub-adults are repatriated back into the lake. Those repatriates began appearing in breeding aggregations in 1993, and in 1999 comprised about 25% of the razorback sucker population in Lake Mohave (Pacey and Marsh in press). A similar recovery effort for bontail is now being attempted. As adult populations of both species decline precipitously, it is increasingly important to develop techniques for rearing large numbers of lar-
vae to sub-adult sizes. Dowling et al. (1996) demonstrated that reintroduction of subadult razorback suckers into the wild population is the most cost-effective way to preserve genetic diversity.

Predation by Odonate nymphs may limit survival of larval razorback sucker in rearing ponds near Lake Mohave, Arizona-Nevada (Horn et al. 1994). The recent colonization of rearing ponds by introduced red swamp crayfish (Procambarus clarki) adds another predator with the potential to significantly reduce survival of larval as well as juvenile razorback. In an effort to reduce this presumed adverse effect, large numbers of adult crayfish have been removed using a modified 6.34-mm (0.25-inch) barrel type minnow trap (Morgan et al. 1999). However, reproduction by even a reduced adult crayfish population maintains high enough population density to suppress survival of razorback suckers (and possibly of bonytail as a similar program for that species is developed).

The bonytail diet is known to consist of aquatic and terrestrial insects, plant material, and filamentous algae (Vanicck and Kramer 1969). Although there are no crayfish native to the Colorado River system, they have become widely distributed as a result of introduction. While no previous studies have shown that juvenile crayfish are eaten by bonytail, the fact that bonytail do prey on aquatic and terrestrial insects suggests the possibility they may also prey on small crayfish.

This study represents an effort to learn whether bonytail can be used to help reduce abundance of the early crayfish life stages presently capable of escaping traps. Mesh size of a trap limits its effectiveness for removal of small crayfish. This limitation, combined with the high fecundity of crayfish, has reduced the effectiveness of control efforts. If crayfish are preyed upon by bonytail, they might be used to help aid their own survival and that of razorback suckers. To determine this, the following questions were asked: What sizes of crayfish escape traps being used for crayfish control? Will juvenile bonytail eat crayfish, and if so, what sizes are most susceptible to predation by juvenile bonytail? Will bonytail eat crayfish in the presence of other food sources? Will escape cover reduce effectiveness of bonytail predation on crayfish?

**METHODS**

Experiments were conducted at Willow Beach National Fish Hatchery (WBNFH), Arizona, 17 km (11 mi) downriver from Hoover Dam, AZ/NV. Bonytail 100-200 mm TL, acquired from existing hatchery stock were used. Bonytail were anesthetized (MS-222), measured (TL), weighed (0.1 g), and then placed in experimental aquaria for a period of seven days before being used. Weekly prophylactic treatments of 25 mg/L formalin and 0.05 mg/L malachite green were applied to all aquaria, to reduce the possibility of infection. Fish were fed trout pellets daily except on the day of the trial at which time they were offered crayfish, a known number of pellets, or a combination of both.

Adult red swamp crayfish were collected from backwater ponds at Lake Mohave on September 24-27, separated by sex, and placed in separate compartments of an indoor raceway (22-29 °C) at the hatchery where they were fed trout pellets four times per week. Upon discovering that crayfish were crawling over the partition to mate, the partition was removed, permitting mating to occur freely through October 2, when males were removed to reduce population density.

Females produced eggs from about October 8 through mid-November 1999, at which time all non-ovigerous females were removed. During this same period one to six ovigerous females were placed in 38 L nursery aquaria supplied with an air stone and several 100-mm sections of 101.6-mm diameter PVC pipe. Aquaria were connected to a warm water (22-29 °C) circulation system. As young crayfish hatched and separated from their mothers they were removed to separate aquaria where they were fed trout pellets daily. Brood size varied from about 150-500. Juvenile crayfish growth was highly variable, but averaged about 1-2 mm per week. Prior to use, juvenile crayfish were placed in a petri dish over 1 mm grid paper and their carapace length (CPL) was measured under a dissecting microscope. Instar 2 (approximately 3 mm CPL), the first stage capable of separating from the mother (Huner and Barr 1984), was the smallest size used in experiments.

Tanks containing bonytail were siphoned clean prior to beginning trials. Crayfish were measured and sorted and tanks were given a known number and size of crayfish or a known number of 2 mm or 3 mm trout pellets. Photoperiod was 24:0. Numbers of crayfish remaining were counted at hr 1, 2, 4, 16, and 20 hrs. Numbers of trout pellets were counted at hr 1 and 2, after which time disintegration prevented reliable enumeration. At the end of each trial, remaining crayfish were enumerated by capturing them with a dip net, siphoning remaining material from the bottom of the tank, pouring that material through a dip net, and finally visually inspecting the tank to determine whether any crayfish had been missed. For the first three trials, food was withheld from fish for three days prior to testing. For all subsequent trials the experimental food was offered on the day of the trial, but food was not withheld prior to that day.

Four experiments were conducted. Experiment 1 was designed to determine sizes of crayfish capable of escaping from a 6.34-mm mesh trap. Juvenile
crayfish of four sizes (13.9±1.1, 16.6±1.2, 20.4±1.6, and 27.2±2.2 mm) were enclosed in cylindrical cages placed in 38-L aquaria. Cages were 23 cm tall, 13 cm in diameter, and constructed of 6.34-mm wire mesh material with seams closed using aluminum wire. Frozen squid was placed outside each cage to encourage crayfish to escape. After three to four days, crayfish in and outside the cages were enumerated and measured.

Experiment 2 was designed to determine sizes of crayfish eaten by four size-classes of juvenile bonytail (104, 131, 147, and 172-mm mean TL). In these experiments three crayfish 3, 4, 6, and 7 mm CPL were offered to single bonytail in 38-L aquaria. Three or more replicates were performed for each bonytail size class. Five crayfish 10-15 mm CPL were offered to groups of three bonytail (131, 147, and 172-mm mean TL) held in 76-L aquaria. Data for these experiments are presented as percent of crayfish eaten over time.

To supplement these data, 22 bonytail ranging in size from 101 to 204 mm TL held individually in 38-L aquaria were repetitively (3-6 repetitions) offered single crayfish varying in size from 9-21 mm CPL. Data for these experiments are presented as percent of crayfish eaten. These variations in experimental design represent our efforts to glean maximum possible information from the limited number of juvenile crayfish available.

Experiment 3 was designed to determine whether bonytail predation on crayfish might be reduced in the presence of an alternate food source. Three bonytail were placed in 38-L aquaria, and offered respectively, 12, 3-mm trout pellets, 12, 3-mm trout pellets plus 60 crayfish (6 mm CPL), or 60 crayfish (6 mm CPL). Three replicates were performed. A t test was used to determine significance of differences between mean numbers of food items consumed.

Experiment 4 was designed to test the effect of two cover types on crayfish susceptibility to bonytail predation. One type was a 23 cm × 44 cm horizontal sheet of 6.34-mm wire mesh placed 7.9 mm above the aquarium floor, the other was a vertical cylinder made of 6.34-mm wire mesh, 23 cm tall by 13 cm in diameter. These cover structures were placed in each of three, 38-L aquaria. Three, 38-L aquaria with no cover structures were also used. Fifty crayfish (5.6 mm CPL) and three bonytail (mean size 131 mm TL) were placed in each aquarium. Crayfish were placed inside the cover in those aquaria containing cover. Numbers of crayfish remaining were recorded at the end of each trial period.

RESULTS

Experiment 1

At the end of the 4-day trial period, most (73%) crayfish <14 mm CPL were outside the cage, while most (91%) crayfish >17 mm CPL were inside the cage (Table 1). No crayfish >20 mm CPL escaped the cage.

Experiment 2

Bonytail of the smallest size class (104 mm mean TL) consumed most of the 6 and 7-mm crayfish within 1 hr, most of the 4-mm crayfish within 2 hr, and most of the 3-mm crayfish within 4 hr (Fig. 1a). Juvenile bonytail (131 mm mean TL) showed a similar pattern with 6 and 7-mm crayfish disappearing more rapidly than 3 and 4-mm crayfish, but almost all crayfish of these four sizes were consumed after 4 hr. Only 20% of the 10-mm crayfish and none of the crayfish of larger sizes were consumed after 4 hr (Fig. 1b). Juvenile bonytail (147 mm mean TL) showed nearly the same pattern except that they took 20% of the 15-mm crayfish, and ate the 3-mm crayfish more slowly (Fig. 1c). The largest size class (172 mm mean TL) consumed crayfish 10, 4.6, and 7 mm most rapidly, but also consumed about half of the crayfish 3, 11, 14 and 15 mm CPL within 4 hr (Fig. 1d).

In the feeding trials in which single crayfish were offered to single juvenile bonytail, we obtained the following results: 9 mm CPL, 100% consumed (N=5); 10 mm CPL, 80% consumed (N=5); 13 mm CPL, 17% consumed (N=6); 14 mm CPL, 33% consumed (N=3). Single crayfish 16, 17, and 21 mm CPL were not consumed. Most crayfish consumed had a CPL that was ≤8% of the TL of the fish consuming them. The most extreme example was one instance in which a bonytail 107 mm TL consumed a 13-mm CPL crayfish (13% of its TL).

Experiment 3

Over a 2-hr period, bonytail consumed significantly fewer food pellets in the presence of crayfish (M = 7.7, SD = 2.1) than in the absence of crayfish.

Table 1. Relationship between crayfish size and ability to escape a trap constructed of 6.34 mm wire mesh.

<table>
<thead>
<tr>
<th>Crayfish size (CPL, mm)</th>
<th>Standard deviation</th>
<th>Start</th>
<th>1 hour</th>
<th>End of trial</th>
<th>Percent</th>
<th>Number of crayfish remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>73%</td>
<td>1</td>
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<td>27</td>
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<td>11</td>
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<td>11</td>
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<td>1</td>
</tr>
</tbody>
</table>
Bonytail may enhance survival of Razorback Suckers • Lenon, Stave, Burke, and Deacon

Figure 1. Crayfish consumption rate by juvenile bonytail of four size categories. Total numbers of bonytail of each of the four sizes used were respectively from the smallest to largest 18, 26, 21, 31. Total numbers of crayfish used for each of the four size classes were respectively from smallest to largest 51, 60, 50, 69.
Experiment 4

After 16 hr, none of the 50 crayfish remained in tanks without cover, 14% remained in tanks with horizontal cover, and 26% remained in tanks with vertical cover. Availability of cover appears to reduce the short-term effectiveness of juvenile bonytail predation on crayfish. Vertical cover appears to offer more protection than does horizontal cover.

DISCUSSION

Morgan et al. (1999) used modified 6.34-mm mesh barrel traps to substantially reduce crayfish density in razorback sucker rearing ponds. Thousands of adult crayfish were removed using the traps, but large numbers of young remained. Lodge et al. (1986) noted that trapping differentially selects for males. Berried females and females bearing young tend to stay hidden, making them less susceptible to trapping (Merkle 1969, Mason 1970, Reid 1972). We showed that young crayfish <17-20 mm CPL are not captured by 6.34-mm mesh traps. Thus, trapping may reduce populations of male and nonreproductive female crayfish, however, reduction in population density of reproductively active female and young crayfish requires other techniques.

Our data suggest that juvenile bonytail show potential to reduce density of young crayfish. Red swamp crayfish in warmer climates are capable of mating year-round and may produce up to three generations per year. Eggs and instar 1 remain attached to the mother’s abdomen, and may be therefore invulnerable to predation by juvenile bonytail. Instar 2 (approximately 3 mm CPL), the first stage capable of separating from the mother, was the smallest size used in our experiments. All size classes of bonytail tested fed on this early instar, but appeared to prefer larger sizes. Juvenile bonytail 100-200 mm TL readily consumed young crayfish ranging in size from 4-10 mm CPL, and somewhat less readily 3 mm and 11-15 mm CPL sizes (Fig. 1). These sizes cannot be removed from razorback rearing ponds by trapping.

Razorback sucker rearing ponds are more complex than are 38-L aquaria, and have a more diverse array of food items. Bonytail used in these experiments were hatchery-raised on trout pellets and therefore habituated to that food. When presented with a choice between pellets and crayfish, however, feeding intensity on crayfish was not reduced. In fact, presented with that choice there was evidence of reduced feeding intensity on pellets, suggesting a preference for crayfish. The average consumption rate of about 15 crayfish/hr, if approximated for even a part of each day in razorback rearing ponds, could result in removal of a very large number of young crayfish before they reach a size capable of preying on young razorback. It is conceivable that by applying such a high rate of predatory pressure, bonytail could become an effective biological control agent for crayfish.

The tendency of berried female and young crayfish to hide also presents a serious problem to

Table 2. Percent and (number) of food items consumed by 3 juvenile bonytail (125 - 141 mm TL) over a two-hour period. Food items were available either separately or in combination. Three replicates were performed for each condition (12 pellets only (3 mm each), 60 crayfish only (mean 6.04 mm CPL), 12 pellets and 60 crayfish combined). The * indicates means that differ significantly: t (2 df) = 5.0, p = 0.02, other means do not differ significantly: t (2 df) = -0.66; P = 0.29.

<table>
<thead>
<tr>
<th>Food items presented separately</th>
<th>Food items presented simultaneously</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate Pellets (12) Crayfish (60)</td>
<td>Pellets (12) Crayfish (60)</td>
</tr>
<tr>
<td>1</td>
<td>100 (12)</td>
</tr>
<tr>
<td>2</td>
<td>75 (9)</td>
</tr>
<tr>
<td>3</td>
<td>58 (7)</td>
</tr>
<tr>
<td>Mean</td>
<td>78 (9.3)*</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>(2.5)</td>
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</tbody>
</table>
removal efforts. Our simulated cover experiment indicated that young crayfish are susceptible to bonytail predation when they move away from cover, and that they do not always remain hidden. Rearing ponds will always provide ample escape cover for crayfish, but with a population of bonytail it appears likely that crayfish will be eaten when they leave that cover.

Our data suggest there may be significant advantages to integration of bonytail and razorback sucker rearing programs. Crayfish populations, and therefore the intensity of predation from this exotic species is likely to be reduced by bonytail predation. As a consequence survival of young razorback sucker is likely to be increased. On the other hand, Johnson and Hines (1999) suggest that in clear backwater rearing ponds there is the possibility that bonytail may prey on razorback larvae. The current practice of rearing razorback larvae to approximately 150 mm TL prior to releasing them into rearing ponds coupled with the nocturnal habits of larval razorback (Bozek et al. 1991) should obviate that potential problem. Furthermore, since the two species evolved in sympathy, it is unlikely that bonytail would pose a more serious threat to razorback survival than would the exotic crayfish.

ACKNOWLEDGMENTS
We would like to express our sincere thanks to the management and staff of Willow Beach National Fish Hatchery for providing equipment, space, expertise, and hospitality throughout the duration of this study. Kevin Morgan with Arizona Game and Fish provided crayfish for use in this study. The Bureau of Reclamation field crew provided an outstanding working environment and learning experience for the senior author.

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