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G. Gary Scoppettone

*Biological Resources Division, U.S. Geological Survey, Reno, Nevada*

J. Antonio Salgado

*Biological Resources Division, U.S. Geological Survey, Reno, Nevada*

M. Bridget Nielsen

*U.S. Fish and Wildlife Service, Reno, Nevada*

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## BLUE TILAPIA (*Oreochromis aureus*) PREDATION ON FISHES IN THE MUDDY RIVER SYSTEM, CLARK COUNTY, NEVADA

G. Gary Scopettone<sup>1</sup>, J. Antonio Salgado<sup>1</sup>, and M. Bridget Nielsen<sup>2</sup>

*Key words:* blue tilapia, predation, Muddy River, Moapa dace, Moapa White River springfish.

Blue tilapia (*Oreochromis aureus*), native to North Africa and the Middle East (Courtenay and Robins 1973, Fuller et al. 1999), has been introduced around the world as a human food source, for vegetation control, and as a game fish (Costa-Pierce and Riedel 2000). Blue tilapia has been particularly successful in establishing and spreading in North American waters where it has been reported to change fish community structure and cause native fish decline (Courtenay and Robins 1973, Fuller et al. 1999). Because of these detrimental effects, it is now generally considered an unwelcome introduction into North American waters (Dill and Cordone 1997, Fuller et al. 1999).

The 1st known introduction of blue tilapia in Nevada was in the Muddy River (a.k.a. Moapa River), Clark County, Nevada, and its arrival was followed by a decline in populations of native fishes (Scopettone et al. 1998). The Muddy River is a 40-km-long tributary to the Colorado River system harboring 4 native fishes, 2 of which are endemic. Moapa dace (*Moapa coriacea*) and Moapa White River springfish (*Crenichthys baileyi moapae*) are known only from the headwaters of the Muddy River, referred to as the Warm Springs area. The river originates from over 20 thermal springs feeding 6 primary tributaries (Fig. 1). The native Virgin River chub (*Gila seminuda*) also occurs in the Warm Springs area but is considered thermal tolerant with greater abundance downstream, while native speckled dace occurs downstream from the Warm Springs area (Deacon and Bradley 1972, Cross 1976, Scopettone 1993).

Blue tilapia was first observed in the Muddy River in 1991 immediately downstream from

the Warm Springs area (Don Sada, Desert Research Institute, personal communication). It did not have access to the area, however, until February 1995 when a 1.5-m-high diversion dam was removed. Within 2 years of dam removal, blue tilapia had invaded 90% of the Warm Springs area, and there was a marked decline in native fishes (Scopettone et al. 1998). By February 2001, snorkel surveys indicated that native fishes had been virtually eliminated from sections of the Warm Springs area accessible to and inhabited by blue tilapia (James Heinrich, Nevada Department of Wildlife, personal communication). Most of the remaining population of Moapa dace and Moapa White River springfish occurred in a tributary (Refuge Springs outflow) upstream of a natural barrier that had been enhanced to prevent blue tilapia movement upstream (Fig. 1). Endemic fish habitat was reduced from about 5.9 km of stream in the Warm Springs area prior to tilapia invasion to <600 m (upstream of a barrier) post-invasion. This development provides strong circumstantial evidence that blue tilapia was responsible for the decline of native fishes in the Warm Springs area.

In its native habitat blue tilapia is described as a filter-feeder, consuming zooplankton and phytoplankton as well as aquatic vegetation and some invertebrates (Spataru and Zorn 1978). In the Warm Springs area we observed aquatic vegetation declining after the blue tilapia invasion, following which tilapia persisted in robust numbers and native fishes declined. We hypothesized that after blue tilapia began to deplete aquatic vegetation, they switched to fish consumption, which would be extraordinary since piscivory has not been previously

<sup>1</sup>Biological Resources Division, U.S. Geological Survey, 1340 Financial Boulevard, Suite 161, Reno, NV 89502.

<sup>2</sup>U.S. Fish and Wildlife Service, 1340 Financial Boulevard, Reno, NV 89502.

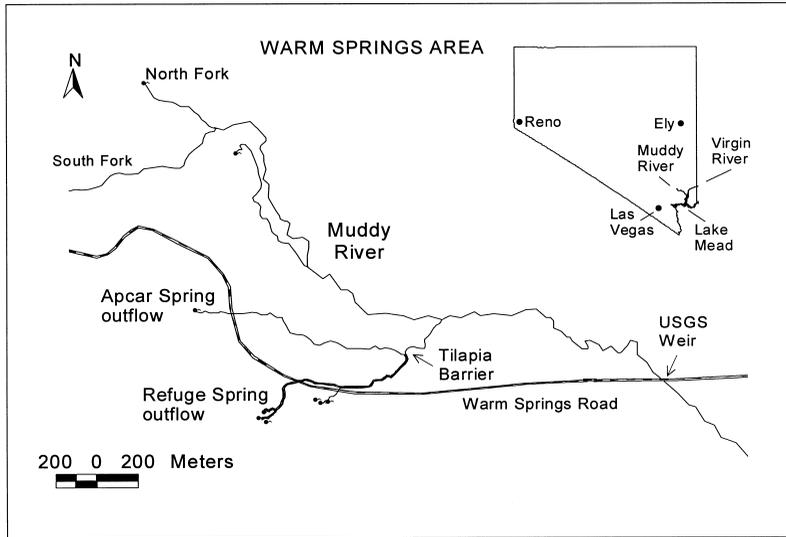


Fig. 1. Map of the Warm Springs area showing the Apcar Spring outflow and the Muddy River. Also shown is the Refuge Spring outflow and tilapia barrier. In bold is the 600 m of stream habitat harboring virtually all remaining Moapa dace and Moapa White River springfish in 2001. Inset shows the Muddy River system in relationship to State of Nevada and Lake Mead.

reported for blue tilapia. In this study we investigate blue tilapia fish predation in the Warm Springs area of the Muddy River.

The Warm Springs area spring systems and river channel had been greatly altered and were inhabited by nonnative mosquitofish (*Gambusia affinis*) and shortfin molly (*Poecilia mexicana*) for decades prior to blue tilapia (Hubbs and Miller 1948, Hubbs and Deacon 1964, Scopettone et al. 1998). This was the case for the Apcar Spring outflow and the mainstem Muddy River, source locations for fish used in this investigation. The Apcar Spring outflow was 1.1 km in length and flowed at  $0.06 \text{ m}^3 \cdot \text{s}^{-1}$ , half of which was diverted for municipal and agricultural use at the upstream end. The stream channel was partially shaded by ash (*Fraxinus* sp.), cottonwood (*Populus* sp.), nonnative fan palm (*Washingtonia filifera*), and tamarisk (*Tamarix* sp.). Before blue tilapia introduction, approximately 90% of the stream bottom was covered with the macrophyte *Vallisneria*. In the Warm Springs area the Muddy River flowed in a deeply incised channel, and the predominant riparian vegetation was tamarisk and fan palms. Prior to tilapia entering the Warm Springs area, *Vallisneria* carpeted the main river channel almost 1 km upstream of

Warm Springs. A 0.6-m-high weir (USGS weir) at Warm Springs Road approximated the beginning of the Warm Springs area (Fig. 1). Immediately upstream of the USGS weir, there was a 1.5-m-high gabion dam that served to divert water to the Reid-Gardner Power Plant until it was replaced with a no-head diversion system in February 1995.

We collected blue tilapia from the Apcar Spring outflow ( $n = 161$ ) on 10 December 1998 following rotenone treatment for tilapia eradication (Fig. 1). Several weeks prior to treatment, we minnow-trapped Apcar Spring outflow to capture and relocate native fishes; 34 Moapa dace and several hundred Moapa White River springfish were relocated. We also collected blue tilapia ( $n = 35$ ) along the Muddy River upstream of Warm Springs Road to the junction of the north and south forks, on 6 August 2000 using a 6.3-mm-mesh, 10.1-m-long, 1.2-m-wide seine. Captured blue tilapia were slit with a scalpel ventral to the digestive tract, fixed in 10% formalin, and stored in 45% ethanol. The Apcar blue tilapia were placed in formalin within 20 minutes of their exposure to rotenone, and Muddy River blue tilapia were placed in formalin immediately after seining. For each fish we measured standard length

TABLE 1. Items ingested by blue tilapia (*Oreochromis aureus*) in 2 tributaries of the Warm Springs area by frequency of occurrence (f) and percent by volume.

Food item	Apcar Spring 2/10/98 (n = 128)		Muddy River 8/16/00 (n = 16)	
	f	% volume	f	% volume
Mosquitofish	42	19.42	5	23.75
Shortfin molly	1	0.79	—	—
Moapa dace	5	1.25	—	—
Moapa White River springfish	9	2.89	1	3.75
Blue tilapia	—	—	1	5.63
Unidentified fish	44	19.52	—	—
Aquatic invertebrates	31	3.28	2	4.69
Terrestrial invertebrates	2	0.80	—	—
Plant	58	32.97	11	61.56
Digested matter	35	19.07	1	0.62

(SL) and total length (TL) to the nearest mm. Standard length was also taken of prey fishes retrieved from the gut that were sufficiently intact to obtain an approximate measurement. Stomach contents were examined and identified using a dissection microscope. Items consumed were quantified by frequency of occurrence and mean percent by volume (Windell 1971). Invertebrates were categorized as aquatic or terrestrial and fishes were identified to species. For those fishes that had been extensively digested, we used pharyngeal teeth, otoliths, and scales for identification. We correlated predator (i.e., blue tilapia) SL with SL of prey fish consumed. Significance of resulting correlation coefficients was tested using Table R in Rohlf and Sokal (1995).

Fish were found in guts of blue tilapia collected in the Apcar Spring outflow and the Muddy River. In the Apcar Spring outflow, fish were the predominant diet by frequency of occurrence and percent by volume. Of 161 blue tilapia collected, 128 had food items in the gut. Of these, 101 had consumed a total of 345 fish, accounting for 44% of the volume consumed. Five had consumed a total of 11 Moapa dace, and 9 had consumed a total of 14 Moapa White River springfish (Table 1). Mosquitofish were the predominant fish taken, with 163 found in 42 stomachs; a 150-mm-SL blue tilapia had consumed 25 mosquitofish. Measurable fish prey ranged from 11.0 to 38.7 mm SL, with Moapa dace the longest (Fig. 2). There was a significant ( $n = 64$ ,  $r = 0.44$ ,  $P = 0.01$ ) positive correlation between blue tilapia SL and prey SL. Only 2 of 326 prey fish that could be identified were shortfin molly even

though they were judged to represent over 50% of the Apcar fish population.

In the Muddy River, 16 of 35 blue tilapia collected had stomach contents: 33% by volume of the items consumed were fishes, 75% of which were mosquitofish (24% by volume; Table 1). Moapa White River springfish as prey ranged from 17 mm to 19 mm SL. Two young blue tilapia were part of the prey, accounting for 6% by volume of the items ingested.

This study adds predation to the list of mechanisms (competition for space, competition for food, and change in energy flow) by which blue tilapia can cause native fish decline (Gu et al. 1997, Moyle 2002). The long gut of this species is characteristic of herbivory (Costa-Pierce and Riedel 2000), but herbivory does not preclude the ability to digest animal protein (Hofer and Schiemer 1981). Blue tilapia is apparently a successful fish predator, with several consuming numerous fish, including small adult Moapa White River springfish and Moapa dace. We also documented 2 occurrences of cannibalism by the species.

Blue tilapia adjusts its feeding strategy to reflect the relative abundance and composition of available food (Gu et al. 1997), and we found this adjustment may include fish consumption. In the Apcar Spring outflow we assume that blue tilapia switched its diet from *Vallisneria*, after it was depleted, to fish. When blue tilapia were first observed in the Apcar Spring system in May 1997, over 400 were counted. At that time much of the stream was covered with *Vallisneria*, and the Moapa dace population was extensive (>500), similar to what had been counted in previous surveys

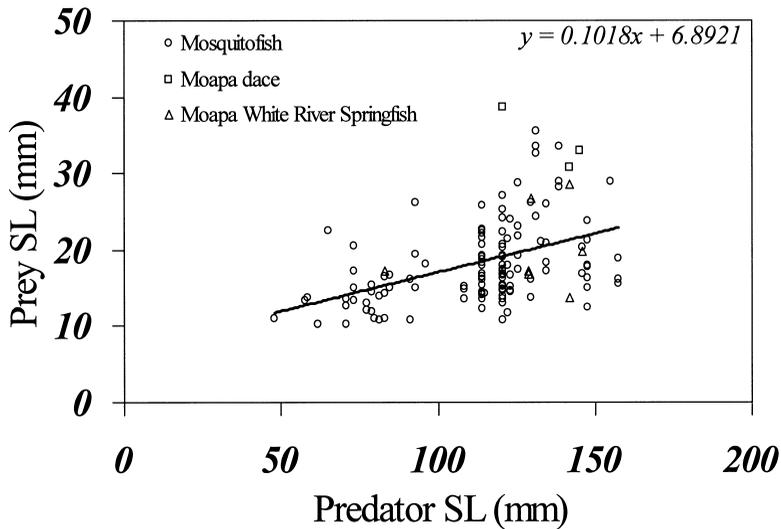


Fig. 2. Predator blue tilapia standard length (SL) in relation to SL of 3 prey species.

(Scoppettone et al. 1992, 1998). In June 1997, seven blue tilapia (140–240 mm fork length) were captured and were full of *Vallisneria* (James Heinrich personal communication), suggesting it was their primary food source. By 9 December 1998, the Aparc outflow was denuded and the Moapa dace population had collapsed from >500 to <70 (James Harvey personal communication). We collected fish samples from Aparc Spring outflow at a time when blue tilapia had switched diet but native fishes had not yet been extirpated. We were thus able to implicate blue tilapia piscivory as a contributor to native fish decline.

The high number of fish taken in the Aparc Spring outflow was not an artifact of rotenone application (i.e., blue tilapia taking dead and dying fish). First, with the application of rotenone, blue tilapia moved immediately to the water surface, gasping for air, with no indication of their preying on fish (James Heinrich personal communication). Second, many of the prey fish were in an advanced stage of digestion, indicating they had been taken before treatment. Lastly, blue tilapia seined from the Muddy River had also consumed fish, which was surprising since, other than blue tilapia and shortfin mollies, native fish were extremely rare when the Warm Springs area was snorkeled in February 2000 (James Harvey personal communication).

Blue tilapia has proven to be similar to Mozambique tilapia (*Oreochromis mossambicus*) in dietary plasticity (Maitipe and De Silva 1985) and ability to tolerate a broader range of temperature (Stauffer et al. 1988) than most tilapia. Since its introduction to the Muddy River system, it has spread from the warm water of the Muddy to seasonally cool waters of Lake Mead and the Virgin River (James Heinrich personal communication). Thus, its potential to spread into North American waters is greater than once believed. This study supports the suggestion that blue tilapia has had a detrimental effect in North American waters and the recommendation that its introduction and spread should be discouraged and existing populations extirpated whenever possible.

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