Western North American Naturalist

Volume 62 | Number 2 Article 7

5-2-2002

Movement, distribution, and predation: *Lepidomeda vittata* and nonnative salmonids in eastern Arizona

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Western North American Naturalist 62(2), © 2002, pp. 197–205

MOVEMENT, DISTRIBUTION, AND PREDATION: *LEPIDOMEDA VITTATA* AND NONNATIVE SALMONIDS IN EASTERN ARIZONA

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ABSTRACT.—Nonnative rainbow trout (*Oncorhynchus mykiss*) are stocked into several reservoirs in the range of federally threatened Little Colorado spinedace (*Lepidomeda vittata*), and so have the opportunity to negatively impact Little Colorado spinedace populations. We examined rainbow trout escapement from Nelson Reservior into Nutrioso Creek, critical habitat for *L. vittata.* We also examined movements of *L. vittata* and incidence of predation by rainbow trout on *L. vittata.* We detected no movement of rainbow trout out of Nelson Reservoir over 4 years of study. *Lepidomeda vittata* marked in 3 streams did not move much; but sample sizes were too small to make any meaningful conclusions regarding movement. Most *L. vittata* we captured during surveys subsequent to marking were unmarked, suggesting movement out of the study area, low tag retention, mortality, or failure to capture marked fish. *Lepidomeda vittata* co-occurred with *O. mykiss, Salmo trutta,* and *Salvelinus fontinalis* and were typically less than half the size of the sympatric nonnative salmonids. Consequently, they are potential prey fish for these species. We found fish remains in stomachs of 33% of *S. trutta*, 6% of *O. mykiss* and 25% of *S. fontinalis* examined, but remains of *L. vittata* were found only in a single *S. trutta.* Because *S. fontinalis* are rare in the streams examined, they probably do not pose a great threat to *L. vittata. Salmo trutta,* which are no longer stocked, had the highest piscivory level and may thus pose more of a threat to *L. vittata* than *O. mykiss.*

Key words: Lepidomeda vittata, *Little Colorado spinedace, salmonids, distribution, movement, predation.*

Native southwestern fishes have declined in part due to negative interactions with introduced species (Meffe 1984, Moyle 1986, Minckley and Deacon 1991). Other factors that contribute to declines (Minckley 1973) include drought, habitat loss and degradation, pollution, and poisoning (Miller 1961, 1963, Minckley and Carufel 1967). Little Colorado spinedace (*Lepidomeda vittata*), a cyprinid endemic to the Little Colorado River basin in eastern Arizona, is an example of a native fish that has declined since Europeans settled the area in the late 1800s (Miller 1963, Minckley and Carufel 1967, Minckley 1973).

Nonnative trouts likely impact *L. vittata* since these nonnatives are predaceous and have been extensively stocked. Rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*) have been stocked into the Little Colorado River basin since the early 1900s (Miller 1961, Rinne and Janisch 1995), but only *O. mykiss* still is stocked. *Oncorhynchus mykiss* and *S. trutta* prey on *L. vittata* in stream enclosures (Blinn et al. 1993, Rinne and Alexander 1995), but the extent of predation in the wild is unknown. Distributions of *L. vittata* and *O. mykiss* overlap, and historic distribution of *L. vittata* likely overlapped with native Apache trout (*O. apache*). However, *O. mykiss* may be more aggressive and piscivorous than *O. apache*, and stocking may result in higher trout densities than naturally occurred.

Lepidomeda vittata was federally listed as threatened, and critical habitat was designated in 1987 (USDI 1987). Critical habitats include Nutrioso Creek between Nelson Reservoir and the Little Colorado River, and East Clear Creek from Blue Ridge Reservoir downstream to Leonard Canyon. Because of suspected impacts of *O. mykiss* stocking on *L. vittata*, Arizona Game and Fish Department (AGFD) began section 7 consultation with U.S. Fish and Wildlife Service in 1994. As a consequence of that consultation, AGFD altered its *O. mykiss* management in the upper Little Colorado River basin; stockings within *L. vittata* range were restricted to reservoirs and limited to spring–summer after dams ceased to spill from spring runoff. Fishing regulations were changed in 1998 to allow unlimited take of *O.*

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mykiss and *S. trutta* from 1 September through 1 May in streams designated as critical habitat for *L. vittata* (including Nelson Reservoir, Blue Ridge Reservoir, and Knoll Lake).

Another response to the consultation was research to evaluate effects of *O. mykiss* on *L. vittata*. We report on 4 elements of that research. Objectives were to (1) determine if *O. mykiss* stocked into Nelson Reservoir move into Nutrioso Creek, (2) document *L. vittata* movements, (3) determine incidence of predation by trouts on *L. vittata*, and (4) document *L. vittata* and trout distributions in Nutrioso Creek critical habitat and adjacent study reaches.

STUDY SITES

Nutrioso Creek, Rudd Creek, and Little Colorado River in east central Arizona (Fig. 1) were sampled from 1996 through 2000. Sampling was on U.S. Forest Service and AGFD lands. Nutrioso Creek heads in coniferous forest and flows through a meadow from the town of Nutrioso to Nelson Reservoir, approximately 20 km from the headwaters. Nelson Reservoir is managed by AGFD as a put-and-take *O. mykiss* fishery. The coniferous forest reach of Nutrioso Creek is occupied by *O. mykiss, S. fontinalis,* and speckled dace (*Rhinichthys osculus*). Fishes in the meadow portion are *L. vittata, R. osculus,* bluehead sucker (*Pantosteus discobolus*), *O. mykiss, S. trutta,* fathead minnow (*Pimephales promelas*), and green sunfish (*Lepomis cyanellus;* AGFD unpublished data). Nutrioso Creek is canyon-bound below Nelson Reservoir, and the fish assemblage is *L. vittata, R. osculus, P. discobolus, P. promelas, O. mykiss, S. trutta,* and *S. fontinalis* (AGFD unpublished data). The study area extends 11.5 km below and 8.3 km above the reservoir (Fig. 1).

Rudd Creek is approximately 13 km long and joins Nutrioso Creek about 2 km downstream of Nelson Reservoir. A man-made fish barrier (culvert through a cement dam with a 3-m-high waterfall) is 4.5 km above the confluence. The upper reach is occupied by *O. mykiss* and *S. fontinalis,* while *L. vittata, R. osculus, P. discobolus, O. mykiss,* and *S. fontinalis* occupy the lower (AGFD unpublished data). We sampled only the lower 4.5 km (Fig. 1).

Also sampled was 3.3 km of Little Colorado River within AGFD's Wenima Wildlife Area, northwest of Springerville, Arizona (Fig. 1). Fishes here are *L. vittata, R. osculus, P. discobolus,* Little Colorado sucker (*Catostomus* sp.), *P. promelas, O. mykiss, S. trutta,* and *L. cyanellus* (AGFD unpublished data).

METHODS

Oncorhynchus mykiss were marked with coded-wire tags (snout or below the adipose fin; 1996 and 1997) or tetracycline (1997 to 2000) and stocked into Nelson Reservoir each spring immediately after reservoir overflow ceased (typically in May). Creel surveys were conducted 1996 through 1999 on Nelson Reservoir to estimate percentage of salmonids removed by angling.

Nelson Reservoir was sampled with gill nets (45-m; experimental) set overnight (April/May 1997 to 2000) to determine holdover rates from the previous year's stocking. To determine if *L. vittata* occupied the lake, we set 4 trap nets (122 cm × 122 cm, 6-m middle wing) perpendicular to and opening toward shore in random locations at Nelson Reservoir for 2 nights in summer 1997.

We sampled Nutrioso Creek twice each year (spring = pre-stocking, late summer to early autumn = post-stocking) using a backpack electrofisher to assess escapement of *O. mykiss* from Nelson Reservoir. Fish captured were identified, measured (TL, mm), and weighed (g); location of capture (m below dam or above reservoir) also was recorded. All trouts were sacrificed and scanned for a coded-wire tag or tetracycline mark.

During 1996, 1999, and 2000, we surveyed Nutrioso Creek below Nelson Reservoir by electrofishing, making one pass through the reach. During 1997 and 1998, 18 random 50-m sites were sampled: 9 pre- and 9 post-stocking. Block nets (3.2-mm mesh) were placed at up- and downstream boundaries, and 3 passes were made. We similarly sampled twelve 50-m sites in Nutrioso Creek above Nelson Reservoir, 1998 through 2000.

To assess movements of *L. vittata*, we marked fish (42–128 mm TL) prior to spring runoff in selected reaches of each stream and subsequently surveyed there as well as up- and downstream (Table 1). Marking reaches had greater *L. vittata* densities than other reaches as indicated by previous sampling. Reaches were separated by a distance equal to

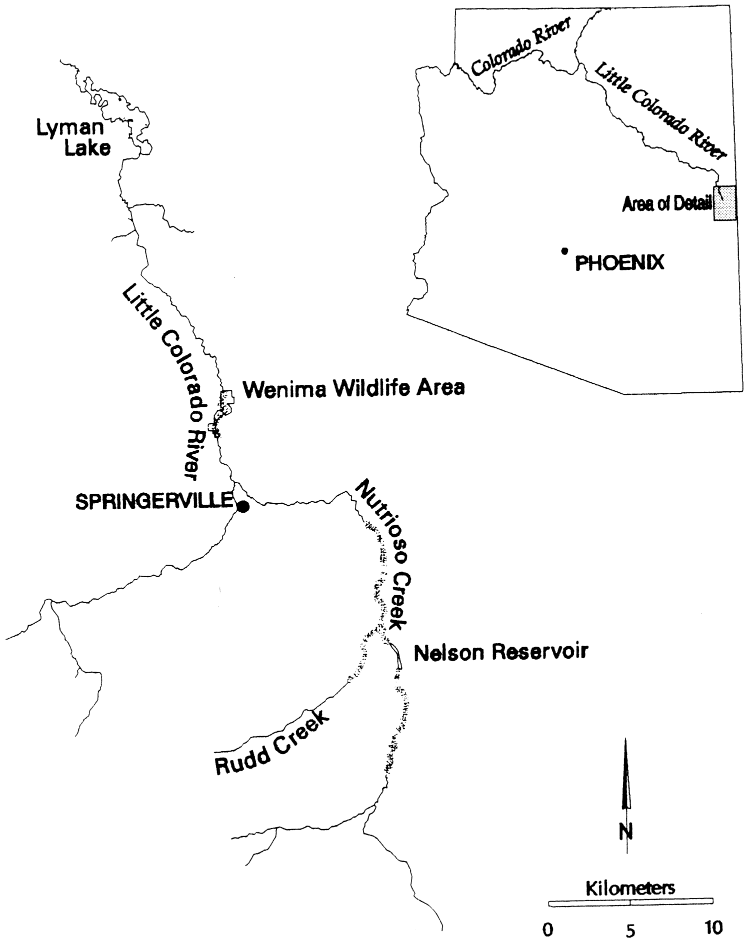

Fig. 1. Map of the study area in east central Arizona. Shaded portions indicate reaches sampled.

Table 1. Stream reaches where *L. vittata* were marked (April). Surveys were conducted during May, July, and September 1998; May and September 1999; and September 2000. Reaches are kilometers above Nelson Reservoir for upper Nutrioso, below Nelson Reservoir dam for lower Nutrioso, above the mouth for Rudd Creek, and above downstream property boundary of Wenima Wildlife Area for the Little Colorado River.

	Stream			
Year/reach type	Upper Nutrioso	Lower Nutrioso	Rudd	Little Colorado
1998				
Marking reach	7.1–7.6		3–3.5	
Survey reach	6.6–8.1	1.5–2.5	0–4.5	
1999				
Marking reach	6.3–6.8		3–3.5	0.997–1.047
	7.3–7.8		5–5.5	2.184–2.234
			7–7.5	2.734–2.784
				3.181–3.231
Survey reach	5.8–8.3	0–11.5	0–4.5	0–3.3
2000				
Survey reach	5.8–8.3	0–11.5	0–4.5	0–3.3

their length. *Lepidomeda vittata* were marked with coded-wire tags in 1998 and with fluorescent elastomeres in 1999. Elastomeres were used so fish could be identified individually and movements could be approximated more accurately. Both types of tags have high, short-term retention rates (Blankenship and Tipping 1993, Bonneau et al. 1995, Hale and Gray 1998). During 1998 through spring 2000, we surveyed for marked fish in May after spring runoff, in July during summer monsoons, and in September after summer monsoons,

All trouts captured in Nutrioso Creek (all years) and in Rudd Creek (2000 only) were sacrificed to assess predation on *L. vittata*. In addition, Little Colorado River on Wenima Wildlife Area was sampled during spring, summer, and autumn from 1997 through spring 2000. We captured fish with a single pass of backpack and canoe electrofishers, recorded location of capture, and sacrificed and eviscerated trout for diet analysis. Stomach contents were analyzed in the laboratory, and fish remains were identified to the lowest taxonomic level.

Availability of *L. vittata* as prey was based on the percentage of predator locations with *L. vittata* present (number of sympatric locations divided by total number of locations where the predator was captured). Species were considered sympatric at a location if they were collected within 10 m of each other in the same habitat (i.e., pool, run, riffle).

Distributions of trouts and *L. vittata* within critical habitat and nearby study reaches were assessed with data from all surveys. To assess species ranges and overlap within the study streams, only data from surveys of the entire study reaches are addressed within this paper (because Nutrioso Creek above the reservoir was sampled in its entirety only during 2000, data distributions are not presented).

Flow data were obtained from the U.S. Geological Survey gauging station (09384000) on the Little Colorado River above Lyman Lake and from an AGFD gauge on Rudd Creek at the fish barrier. Overflow of Nelson Reservoir dam was determined by observation.

RESULTS

Seven marked *O. mykiss* were captured in Nutrioso Creek, 2 with coded-wire tags in 1998 and 5 with tetracycline marks in May 2000. One (365 mm TL) coded-wire tagged *O. mykiss* was captured in July, 5.7 km below Nelson Reservoir, and another (248 mm TL) was captured in April, where Nutrioso Creek enters Nelson Reservoir. The 5 *O. mykiss* (198–230 mm TL) marked with tetracycline were caught approximately 250 m above Nelson Reservoir. No marked trout were captured in Rudd Creek or Little Colorado River.

Approximately 75,500 *O. mykiss* were stocked into Nelson Reservoir from 1996 to 2000. Anglers removed 48–85% of these trout (Table 2). Nelson Reservoir spilled in spring 1997 (April 12 through 1st week of May), 1998 (March 29 through May 23), summer 1999 (August), and periodically from winter 1999 through spring 2000, generally reflecting spikes in Little Colorado River discharge (Fig. 2).

We gill-netted 3 *O. mykiss*/8 net nights in 1997, 4 *O. mykiss*/8 net nights in 1998, 6 *O. mykiss*/4 net nights in 1999, and 18 *O. mykiss*/4 net nights in Nelson Reservoir during 2000. Nonnative black crappie (*Pomoxis nigromaculatus*) were more prevalent than *O. mykiss* (29/8 net nights, 1997; 7/8 net nights, 1998; 7/4 net nights, 1999; and 30/4 net nights, 2000). Over 1000 nonnative *P. promelas* and a few nonnative *L. cyanellus*, but no *L. vittata*, were caught in the trap nets set in 1997.

We marked 210 *L. vittata* and recaptured 71 (54–134 mm TL; Table 3); some fish may have been caught more than once. Typically (13 of 17 surveys), more than 80% of the fish captured during a survey in a given stream did not have a mark. Sixteen fish moved, 10 downstream and 6 upstream (Table 3). Timing and direction of movement did not appear related to flow. Base flow occurred during the marking period each year (Fig. 2). Three flow spikes were evident in Rudd Creek, 2 of which (May 1998 and August 1999) were also evident in the Little Colorado River (Fig. 2).

Thirty-three percent of *S. trutta* ($N = 24$), 6% of *O. mykiss* ($N = 54$), and 25% of *S. fontinalis* ($N = 4$) had fish in their stomachs (Table 4). Remains of one *L. vittata* were found in an individual *S. trutta* from Little Colorado River during 1997. *Lepidomeda vittata* was not in any other salmonid examined.

Sixty-three percent of the sites with *O. mykiss* ($N = 19$), 60% with *S. trutta* ($N = 10$), and 50% of the sites with *S. fontinalis* ($N = 2$) had *L. vittata* present (Table 4). At sites where

Table 2. Estimates of stocking and harvest (based on creel census) for *O. mykiss* in Nelson Reservoir, AZ.

	Year			
Information	1996	1997	1998	1999
Number stocked	16,042	19,897	20,000	19,546
Census period	April 1996–April 1997	May 1997–April 1998	May 1998–April 1999	May 1999–Dec. 1999
Estimated harvest	7,723	13,943	11,956	16,529
Percent harvested	48	70	60	85

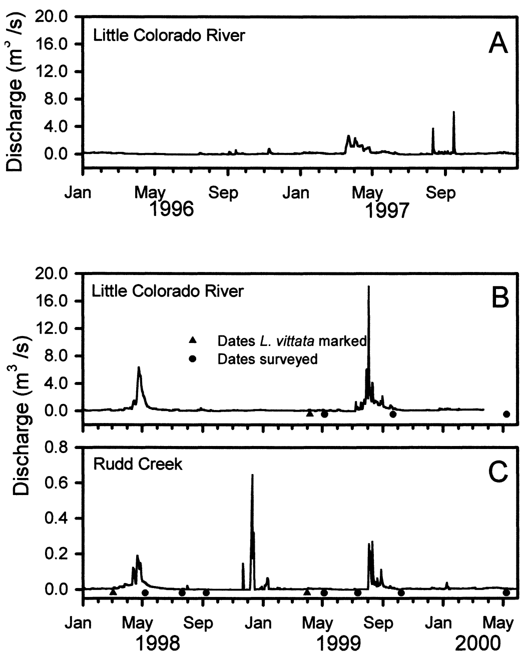

Fig. 2. Flows in Little Colorado River, AZ, above Lyman Lake, 1996 through 1997 (A) and 1998 through May 2000 (B); Rudd Creek, AZ, 1998 through May 2000 (C). Dates when *L. vittata* were marked and surveyed are shown.

trout and *L. vittata* were captured, all trout were more than twice as long as *L. vittata*, except at 4 sites where *O. mykiss* were larger than, but not twice as large as, *L. vittata.*

Lepidomeda vittata was throughout Nutrioso Creek (below Nelson Reservoir), Rudd Creek, and Little Colorado River (Figs. 3–5). Range in Nutrioso Creek and Little Colorado River was greater (Figs. 3–5) in 1999 and 2000 than in 1996 (Nutrioso Creek) or 1997 and 1998 (Little Colorado River). Distribution overlapped on broad scales with salmonids in each stream (Figs. 3–5). Other native species were *P. discobolus, R. osculus,* and the Little Colorado River sucker (*Catostomus* sp.; only in the Little Colorado River). Nonnative *P. promelas* was typically the most abundant or 2nd most abundant species captured in Nutrioso Creek and Little Colorado River, but was rare in Rudd Creek. The other nonnative species (only in Nutrioso Creek and the Little Colorado River), *L. cyanellus,* typically comprised less than 1% of the catch.

Unmarked trout were captured in all 3 streams, most during the 1st year (Figs. 3–5). Though not ample in numbers, *Oncorhynchus mykiss* was the most abundant and widely distributed trout in Nutrioso and Rudd creeks, whereas *S. trutta* was the most abundant trout captured in the Little Colorado River.

Discussion

Movement of *O. mykiss* out of Nelson Reservoir is minimal, reducing the chance of negative effects on *L. vittata* by nonnative trout. Despite reservoir spills every year (except 1996), post-spill sampling yielded only 1 marked *O. mykiss* below the dam and 5 marked *O. mykiss* above the mouth. Downstream escapement may have been minimal because few *O. mykiss* were in the reservoir prior to spring runoff each year, as indicated by creel-take estimates and spring sampling efforts. However, no escapement was detected after an extensive summer spill in August 1999, when *O. mykiss* numbers in the reservoir should have been relatively high. Escapement upstream is probably limited by an extensive cattail-sedge bed at the mouth of Nutrioso Creek. Aside from that, the 5 marked *O. mykiss* obtained above the reservoir were smaller than *O. mykiss* (335–445 mm TL) concurrently captured in Nelson Reservoir and were also relatively smaller than *O. mykiss* (average size approximately 230 mm TL) stocked in spring 1999 (AGFD unpublished data). We therefore believe that these trout came from a private pond upstream of Nelson

TABLE 3. Number of *L. vittata* marked and captured in subsequent surveys (numerator = total fish captured, denominator = number of recaptures), number of recaptures that moved, and distances moved (negative numbers indicate downstream and positive indicate upstream movement) by recaptured fish in 3 eastern Arizona streams, April 1998 through May 2000. Fish were marked with coded-wire tags (April 1998) or fluorescent elastomeres (April 1999).

		Year and month of survey						
		1998			1999			2000
Tag type and stream	Marked	May	July	Sep	May	July	Sep	May
CODED-WIRE TAGS								
Rudd Creek (*N* fish)	66	40/12	45/17	90/12	20/2	8/1	41/0	81/1
No. marked that moved		1	0	0	1	1	0	0
Reaches moved (500 m)		–2			–1	–3		
Upper Nutrioso (*N* fish)	37	25/1	30/0	24/2	42/0	7/0	38/0	147/3
No. marked that moved		0	0	0	0	0	0	3,
Reaches moved (500 m)								–2, –3, –3
ELASTOMERE TAGS								
Rudd Creek (*N* fish)	22				20/3	8/3	41/1	81/3[a]
No. marked that moved					3	1	1	0[a]
Distance moved (m)					–272, 268, 98	313	554	
Upper Nutrioso (*N* fish)	13				42/2	7/2	36/1	147/0
No. marked that moved					1	1	1	
Distance moved (m)					599	–190	–381	
Little Colorado (*N* fish)	72				137/5		157/0	127/0
No. marked that moved					2			
Distance moved (m)					–115, 77			

[a]Fish were recaptured in reach they were marked in; actual meter where they were marked is unknown since complete mark could not be discerned upon recapture.

TABLE 4. Incidence of piscivory (number of and percentage [in parentheses] of individuals with fish in their gastrointestinal tracts) by 3 salmonid species captured in Rudd and Nutrioso creeks and Little Colorado River, AZ, 1996–2000. Number of sites where salmonids were captured and number and percentage (in parentheses) of those sites with *L. vittata* are also given.

	Salmonid species		
	O. mykiss (*N* = 54)	*S. trutta* (*N* = 24)	*S. fontinalis* (*N* = 4)
Range of total length (mm)	105–495	212–552	162–302
Trout with fish in GI tract	3 (6)	7 (33)	1 (25)
Trout with *L. vittata* in GI tract	0	1 (4)	0
Trout with other cyprinids in GI tract	3 (6)	7 (33)	1 (25)
Number of sites with trout	43	17	4
Number of trout sites where presence-absence of *L. vittata* was recorded	19	10	2
Number of trout sites with *L. vittata*	12 (63)	6 (60)	1 (50)

Reservoir (at least one private pond upstream of the reservoir is known to be stocked with *O. mykiss* from private hatcheries that are generally known to use tetracycline-treated feed), indicating that there was no *O. mykiss* movement upstream from Nelson Reservoir. Injecting all AGFD-reared trout with coded-wire tags before they are stocked would be a more precise method of detecting movement out of the reservoir.

Lepidomeda vittata were not found within Nelson Reservoir, but sampling was limited and not a primary objective. *Lepidomeda vittata* are probably rare in Nelson Reservoir because of the presence of nonnative piscivorous fishes and the fact that *L. vittata* generally occupy stream habitats.

Marked *L. vittata* did not move much, but sample sizes were too small to make any meaningful conclusions regarding flood-induced

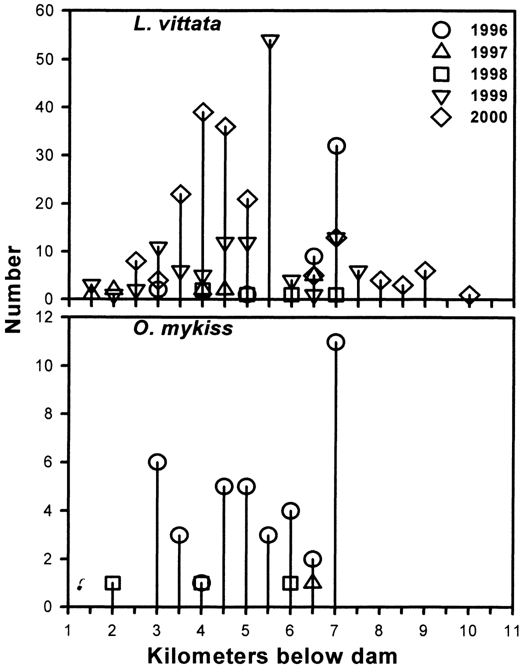

Fig. 3. Number of *L. vittata* and *O. mykiss* captured per 500 m below Nelson Reservoir in Nutrioso Creek, AZ, 1996–2000.

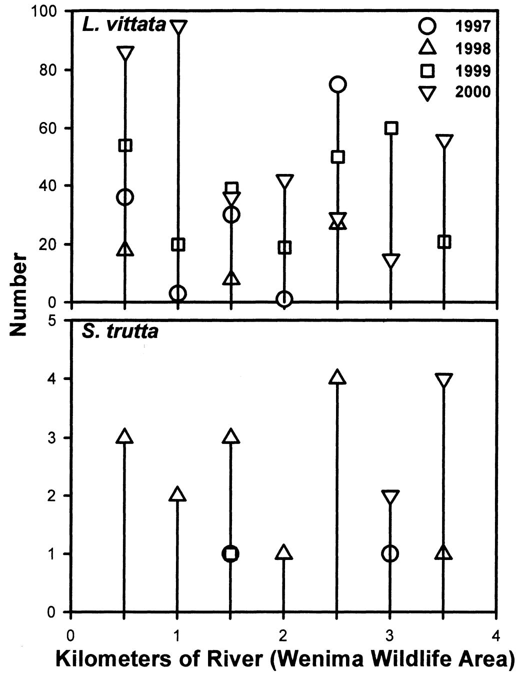

Fig. 4. Number of *L. vittata* and *S. trutta* captured per 500 m in Little Colorado River, AZ, within Wenima Wildlife Area, 1997–2000.

movement. Most *L. vittata* we captured during surveys subsequent to marking were unmarked, suggesting movement out of the study area, low tag retention, mortality, or failure to capture marked fish. We believe tag retention was high and our surveys extensive enough (particularly in 1999) to detect long-range movements. Unfortunately, we cannot rule out the possibility that fish moved outside our survey area or suffered mortality.

Lepidomeda vittata appear to be available prey fish for each salmonid species, and they co-occurred with each salmonid. All 3 salmonids consumed cyprinid fishes, and so they all may consume *L. vittata.* Because *Salmo trutta* were more piscivorous than *O. mykiss* or *S. fontinalis,* they may pose more of a threat to *L. vittata.* Fortunately, neither *S. trutta* nor *S. fontinalis* are still stocked into the Little Colorado River basin, although natural reproduction occurs within these waters.

Blinn et al. (1993), based on experiments in stream enclosures, suggested that *O. mykiss* limit the distribution of *L. vittata.* Our results lend little support for this contention; both

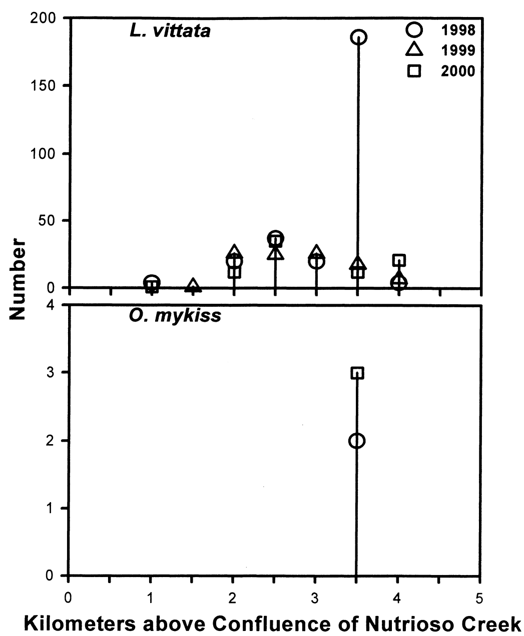

Fig. 5. Number of *L. vittata* and *O. mykiss* captured per 500 m in Rudd Creek, AZ, above the confluence of Nutrioso Creek, 1998–2000.

species were often caught within the same pools (during uninterrupted flow conditions), and no predation was detected by *O. mykiss* on *L. vittata*. However, *O. mykiss* will likely prey on larval fish when they are available, as suggested for other native-nonnative fish interactions (Marsh and Langhorst 1988, Johnson and Hines 1999). In laboratory settings they readily preyed on larval *L. vittata* and *P. promelas* (unpublished data). However, since *O. mykiss* tend to be largely insectivorous (Cada et al. 1987, Angradi and Griffith 1990, Metcalf et al. 1997), the impact of predation on larval stages on the overall population of *L. vittata* is unknown. Studies examining this interaction in natural situations (when various prey types are available) would be valuable, but difficult, since larvae are quickly digested.

Sample size was relatively small for all objectives within this study. Drought conditions likely affected the sample size of *L. vittata* and trouts during our study. Annual precipitation was below average each year during our study, particularly during 1996 and 1997 (data from the Western Regional Climate Center, Reno, NV). During summer and autumn months of 1996 and 1997, Rudd and Nutrioso creeks became intermittent. We estimated that 50–75% of Nutrioso Creek below Nelson Reservoir and >50% of lower Rudd Creek were dry in the summers of 1996 and 1997. Such large decreases in available habitat coupled with likely decreases in habitat quality (increased water temperatures and turbidity, and decreased dissolved oxygen due to nonexistent flows) may have had effects on *L. vittata* and trout populations. It is also possible that electrofishing contributed to these issues as well (Nordwall 1999).

Efforts to prevent nonnative salmonid impacts on *L. vittata* include cessation of nonnative salmonid stocking and nonnative fish removal from streams where *L. vittata* exist. Native *O. apache* could be stocked rather than nonnative *O. mykiss* (Rinne and Janisch 1995), since these waters are within historical range of *O. apache* (Carmichael et al. 1995). However, before converting lake fisheries to native *O. apache*, we recommend studies examining the effects of *O. apache* on *L. vittata* and other native fishes under a variety of habitat conditions and prey availability so these efforts would not be refuted in the event that *O.* apache are just as detrimental to *L. vittata* as *O. mykiss* are reported to be. Because *O. mykiss* impact *L. vittata* populations and the nonnative sport fishery is to be retained, efforts to further reduce impacts should include (1) stocking *O. mykiss* into lakes only, and only after dams cease to spill from spring runoff, (2) removing nonnative salmonids where *L. vittata* occur, and (3) removing nonnative salmonids and reestablishing *L. vittata* in areas they historically inhabited.

ACKNOWLEDGMENTS

This work was funded by a grant from Federal Aid in Sport Fish Restoration Program (Dingell-Johnson/Wallop-Breaux) and a matching state grant from the Arizona Game and Fish Department Heritage IIPAM Fund. We thank L. Avenetti, M. Lopez, R. Dryer, and G. Gonzales for their assistance in the field and their input of ideas. We also thank J. Novy, J. Burton, K. Young, and D. Blinn for their contributions to the study design and M. Brouder, T. McKinney, M. Childs, and M. Rabe for review of this manuscript. Finally, we thank the U.S. Fish and Wildlife Service Fishery Resource office in Pinetop, Arizona, for use of their laboratory facilities and equipment.

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Received 11 July 2000
Accepted 29 March 2001