**Figure 1**. Narrow-headed Garter Snake *(Thamnophis rufipunctatus)* Photo by Robert L. Bezy and Kathryn Bolles

# Distribution, Ecology, and Management Recommendations for the Narrow-headed Garter Snake (*Thamnophis rufipunctatus*) in Oak Creek, Arizona- part II of II

Adapted from an unpublished final report to Arizona Game and Fish Department in fulfillment of Heritage Grant I99007
Continued from part I, *Sonoran Herpetologist 16:86-89*

**Erika M. Nowak and Manuel A. Santana-Bendix,** Northern Arizona University, USGS Colorado Plateau Field Station

No snake was found to have a spiny-bodied fish in its gut. We found a total of 12 snakes with prey in their stomach and palped these items out through induced regurgitation. Of these, eight were brown trout, two were Gila suckers, and two were fish that could not be identified. For comparison, Rosen and Schwalbe (1988) found the following prey species during their surveys of narrow-headed garter snakes in Oak Creek: speckled dace (n=7), Gila suckers (n=4), brown trout (n=1), and red shiner (*Notropis luternsis*) (n=1). The latter is a non-native species of fish that we did not observe during our surveys in Oak Creek.

It is extremely interesting that the major food item detected in narrow-headed garter snakes during this study was a non-native trout species. It is likely that brown trout closely resemble in body form and ecological niche a native trout species (Apache trout, *Salmo apache*, or a similar species) that formerly occurred in Oak Creek (Minckley 1973), so the evolutionary leap to a new food source may not have been too problematic for the snakes. Brown trout were first introduced into Oak Creek in the early 1900's (L. Luedecker, pers comm.) and breeding populations have become established, as evidenced by the presence of fingerling trout in traps and snake bellies at three locations during this study.

**Habitat Use.** The cluster analysis of habitat variables resulted in the grouping of all plots in three distinctive clusters, consistent with their distribution along the altitudinal gradient along the creek and the distinctive vegetation types in the area. Cluster 1 is sites from Cave Springs to Slide Rock State Park, located among ponderosa pine/oak forest in the upper middle areas of the canyon. Cluster 2 is composed of those plots from Manzanita Crossing to Midgely Bridge, in the lower canyon within pinyon-juniper habitat. Cluster 3 is comprised of plots from Chavez Crossing to Lower Oak Creek Estates, located below Sedona outside of the canyon within mesquite-grassland habitat. We found narrow-headed garter snakes in Clusters 1 and 2, but none in Cluster 3.

Each habitat cluster shares similar habitat features. Cluster 1 comprises the highest elevation in the canyon, has steeper and closer canyon walls, and tends to have the narrowest channel width and has significantly shallower water depth. The channel is often braided and there is

minimal silt in the main stem of the creek. Plots in this cluster had good canopy coverage, vegetated islands, and abundant streamside and significantly more aquatic vegetation to provide cover for snakes. Because the canyon walls are closer together and the trees taller, this area receives less insolation during the day than other clusters. We found the most narrow-headed garter snakes in this cluster, suggesting that this combination of habitat features (and perhaps the lack of crayfish plus the absence of spiny rayed fishes) is currently the most favorable to their distribution. However, these plots also had the fewest non-native and spiny-rayed fish, so it is likely that a combination of factors influences snake distribution.

Cluster 2 comprises mid-canyon elevations. Here the channel and canyon walls open up and get wider, and the water is deeper, with some pools over two meters in depth. The channel is less often braided and there is increased silt in the creek, especially in the pools, likely as a result of heavy recreation near these areas. This cluster was sunnier than Cluster 1, due to canyon walls being farther apart and to the dominant tree species being shorter. The cluster had the highest streamside canopy coverage and high vegetation cover, although there was significantly less vegetation growing in the stream. Some areas contained abundant aquatic vegetation. The number of non-native and spiny-rayed fish species increase in this cluster. We detected the remaining snakes in this cluster, in slightly lower numbers than in Cluster 1. These results are in contrast to those of Rosen and Schwalbe (1988), who found by far the most narrow-headed garter snakes in the area of Cluster 2. We suspect that this difference may be due to channel-altering (and thus habitat-altering) scouring flood events (also suggested by L. Luedecker, pers. comm.) and/or to an increase in the proportion of non-native fish species (P. Rosen, pers. comm.).

Cluster 3 comprises plots that are outside the canyon proper. There are no canyon walls close to the stream, and the channel is significantly wider and deep. There are fewer areas of rocky run-riffle sequences; pool-run sequences are much more common. The channel is rarely braided and there is much silt throughout the creek, resulting in significantly lower water visibility. This cluster was very sunny with significantly less canopy coverage and streamside vegetation, especially grasses (graminoids) and sedges. Few areas contained abundant aquatic vegetation. We detected no native fish in our sampling area, and postulate that in lower Oak Creek the proportion of non-native and spiny-rayed fish species greatly outnumbers that of natives. We also detected no narrow-headed garter snakes in this cluster although they formerly occurred here.

When random plots were compared to non-random plots within Clusters 1 and 2, results were similar to those described above. That is, many of the same habitat variables that were significant between clusters were also important factors in snake locations. As expected, narrow-headed garter snakes were more likely to be found in locations without crayfish. Snakes were more likely to be found in areas without silt. They were also more likely to be found in shallower areas, but this may be an artifact of our increased ability to detect them in such areas, or to the overwhelming use by neonates of this habitat. In Cluster 1, snakes were more likely to be found in narrower areas of the stream.

In Cluster 2, significantly more snakes were found in plots that had abundant streamside grass/sedge cover, and correspondingly less unvegetated cover (bare soil or rock). We found several snakes in both clusters on islands created by tussocks of a large vase-shaped *Carex* sp., or underneath these plants if they overhung the water's edge. The overhanging plants serve a similar ecological function to the undercut banks favored by narrow-headed garter snakes in the San Francisco River in New Mexico (C. Painter, pers. comm.).

Different habitat variables were significant for adults, juveniles, and neonates. Neonate narrow-headed garter snakes appear to favor shallow backwaters or edges (with less current) with abundant aquatic vegetation, especially watercress. The juveniles and neonates tended to be found in shallower water in both clusters. On several occasions when we released neonates into deep water ($\geq$ 0.5 m), they tried to swim to the shore or to a shallower area. Neonates in Cluster 2 were found more often in areas of higher in-stream vegetation cover. Juveniles were less likely to appear in plots with a high percentage of unvegetated bank surface. Subadult and adult narrow-headed garter snakes appear to favor sections of Oak Creek Canyon with overhanging vegetation and/or vegetated islands that provide protection from predators.

We found all age classes of snakes either in the water or immediately adjacent to it during our surveys. Narrow-headed garter snakes across their range apparently spend most of their lives in or immediately adjacent to perennial streams, only emerging to bask, gestate young, and hibernate (Rossman et al. 1996, Rosen 1991, Tanner 1990, Rosen and Schwalbe 1988, Fowlie 1965). Changes in stream or bank microhabitat condition, therefore, might affect population trends and distribution of these snakes.

It is possible that recreation, especially high densities of visitors in localized areas along the creek (e.g. Slide Rock Park), may be one factor in any narrow-headed garter snake population declines because of its effects on habitat. During the 1990's, recreational use and private development in the Sedona area and along Oak Creek increased greatly. In 1995, 1.3 million people visited the Red Rock Ranger District, a 48% increase from 1974 (USDA Forest Service 1996 unpubl.). In 1999, the district received approximately six million visitors. Increased visitation has led to terrestrial and nearshore stream habitat degradation, siltation, and episodic outbreaks of coliform bacteria,

We found the most narrow-headed garter snakes in this cluster, suggesting that this combination of habitat features (and perhaps the lack of crayfish plus the absence of spiny rayed fishes) is currently the most favorable to their distribution.

particularly near Slide Rock State Park (Southam 1996, Burns et al. 1998).

Recreation in the form of heavy human foot traffic compacts the banks, removing suitable growing conditions for terrestrial and emergent vegetation. This recreation removes suitable cover for the snakes as well as physically destroying shallow backwater areas that neonate snakes favor. Scouring of the stream edges and removal of edge debris from some areas (e.g. Slide Rock State Park) by large spring flood events in 1993 and 1995 may also have locally impacted habitat for narrow-headed garter snakes by removing cover (L. Luedecker, pers. comm.).

Such recreation also increases silt load. This leads to decreased dissolved oxygenation of interstitial areas where fish normally lay their eggs (as well as physically covering the habitat) (Minckley 1973). Siltation affects the interstitial spaces between rocks used for foraging by narrow-headed garter snakes. Rosen and Schwalbe (1988) suggest that heavy siltation will negatively affect narrow-headed garter snake populations due to this loss of prey microhabitat. Heavy siltation likely also lowers water visibility as silt is stirred up by water currents or vertebrate use of the creek. The work of de Queiroz (2002) suggests that increased silt loading in the water column could negatively affect garter snake foraging efficiency and success (A. de Queiroz, pers. comm.). We have also observed that crayfish appear to become more abundant during periods of heavy silt load after flash flood events (pers. obs.), and over time these conditions could negatively affect snake populations.

Localized higher mortality occurs due to direct killing of snakes by humans at heavily-used recreation areas, e.g. Slide Rock State Park. One reason this species is killed in particular by humans is that it is confused with venomous "water moccasins" by visitors from other parts of the country due to its triangular head shape and propensity to be seen in the water. Juvenile and neonate snakes are also commonly killed by cars at stream crossings, probably as they bask on the shallow water flowing over the roads at these points.

## Conclusions and Management Recommendations.

Even taking potential observer biases into consideration, Rosen and Schwalbe (1998 and unpubl. data) detected many more individual garter snakes than we did. In the Midgley Bridge area, they found about six times more garter snakes than we did when combining trapping and walking surveys. We feel that the large differences in overall numbers of narrow-headed garter snakes detected between the two surveys suggest population declines, especially in the Midgley Bridge area and south of the canyon. Despite several historic records of the species occurring outside of Oak Creek Canyon at Chavez Crossing, in Sedona, and other (Rosen and Schwalbe 1988, Fowlie 1965, George Bradley and John Schreiber, pers. comm.), we did not find any snakes in those areas. For that matter, neither did Rosen and Schwalbe during their earlier surveys. We feel it is likely that populations of the species are either very low south of the canyon or have been extirpated.

With one exception, in the north-middle reaches of Oak Creek Canyon we feel that there is no evidence of decline based on comparison to earlier surveys; population numbers appear stable in these areas. Based on anecdotal evidence from long-time residents of the area, however, it is possible that there have been substantial population declines at Slide Rock State Park. Bob Kittredge, Rich Gasaway, Brian Hubbs, and James O'Reilly (pers. comm.) all state that narrow-headed garter snakes were formerly easy to find at Slide Rock, yet we only found one there in over 13 person-hours of surveying.

The factors most likely implicated in narrow-headed garter snake population declines in Oak Creek are increases in populations of non-native and spiny-rayed fish, habitat destruction and modification due to increased recreation and siltation, and localized mortality due to channel-altering flood events, direct predation by humans, and roadkills.

## Management Recommendations

We recommended the following to the Arizona Game and Fish Department. First, monitoring of populations at four sites in the upper canyon with the most animals individually marked (permanently PIT-tagged). This recommendation has been adopted by the Department and by the US Forest Service and will be implemented starting in 2003!

Second, continue monitoring fish populations within the creek, with an emphasis on the distribution of natives (established or reintroduced) and non-natives, especially spiny-rayed species. As well, monitor bullfrog and crayfish populations, and develop a plan to eradicate them, especially within the canyon.

Third, protect known habitat, especially in the north-middle reaches between Cave Springs campground and Midgely Bridge. We recommended that no further developed sites be constructed in this area of the canyon along the water, and that dispersed recreation be better monitored and localized in that area between developed sites. New trails should be placed in areas that would minimize loss of microhabitats such as shallow edges and overhanging vegetation, and in such a way that social trails are minimized in suitable open shoreline habitat. If new stream crossings are constructed, make sure that they minimize snake mortality, i.e. do not construct low-water crossings, but raise the road level above the normal summer water level. Research methods of decreasing siltation caused by heavy recreation at developed sites- this seems like a hard issue to control,

but perhaps there are some diversion features that could be installed.

And finally, but perhaps the most immediately effective idea, increase public, landowner, US Forest Service staff, and outfitter awareness of narrow-headed garter snakes to decrease human direct predation. Signs at developed areas with pictures of the snakes and information about their status and biology would be helpful. Meetings with outfitters and local landowners and personal contacts with anglers at known fishing sites would also decrease snake mortality.

## Acknowledgements

The Arizona Game and Fish Heritage Fund provided funding for this research (Heritage Grant # I99007). Janie Agyagos and Cavetta Green of the US Forest Service Red Rock Ranger Station provided invaluable assistance. We are am indebted to George Bradley, Phil Rosen, Charlie Painter, Lee Luedecker, Alan de Queiroz, and Tim Hoffnagle for sharing their data. John Schreiber of Red Rock State Park and Bob Kittredge of Forest Houses Resort allowed access to their properties. Shawn Knox, Matthew Spille, Robert Feinsinger, and Trevor Persons assisted with fieldwork. John Coons, Robert Emerson, Erik Enderson, Marty Feldner, Rich Gasaway, Andy Holycross, Brian Hubbs, Katie Medina, Susan MacVean, Jay Meyers, Chad Montgomery, James O'Reilly, Roger Repp, and Mark and Chris Sogge provided additional assistance. Trevor Persons, Robyn Beck, and Janie Agyagos reviewed the original manuscript.

## Literature Cited

Arizona Game and Fish Department. In prep. Wildlife of special concern in Arizona. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix, Arizona.

Burns, J., K. Farr, S. Hurlocker, J. Bishop, and K. Anderson. 1998. Decision notice and finding of no significant impact for an amendment to the Forest Plan for the Sedona area: Amendment 12 to the 1987 Coconino National Forest Plan. Unpublished report of the USDA National Forest Service, Coconino National Forest, Sedona Ranger District, Sedona Arizona: 274 pp.

Crump, M.L., and N.J. Scott, Jr.1994. Visual encounter surveys. pp. 84-92 *In* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, eds. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington, D.C.: 364 pp.

De Queiroz, A. 2002 in press. From interspecific variation to individual context-dependence: Effects of water depth on foraging behavior in three species of garter snakes. Manuscript. submitted to Animal Behaviour.

Fagerstone, K.A., and B.E. Johns. 1987. Transponders as permanent identification markers for domestic ferrets, black-footed ferrets, and other wildlife. Journal of Wildlife Management 51: 294-297.

Fitch, H.S. 1986. Collecting and life-history techniques. Chapter 5 *In* R.A. Seigel, J.T. Collins, and S.S. Novak, eds. Snakes: Ecology and evolutionary biology. Macmillan Publishing Co., New York, New York.

Fowlie, J.A. 1965. *Thamnophis rufipunctatus* Cope, Spotted garter snake. pp. 125-126 *In* The Snakes of Arizona. McGraw-Hill, Inc., New York, New York: 164 pp.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical Ecology: a primer on methods and computing. John Wiley & Sons Inc., New York. 337pp.

McMahon, T.E., A.V. Zale and D.J. Orth. 1996. Aquatic habitat measurements. Pages 83-120 *In* B.R. Murphy and D.W. Willis, eds. Fisheries Techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona, USA: 293 pp.

Nowak, E.M., T.B. Persons, and S.C. Knox. 2002 unpublished. Results for first-year herpetofauna inventories of southern Colorado Plateau National Parks. Report to the National Park Service Southern Colorado Plateau Inventory and Monitoring Network.

Reinert, H.K. 1993. Habitat selection in snakes. Chapter 6 *In* R.A. Seigel and J.T. Collins, eds. Snakes: Ecology and behavior. McGraw-Hill, Inc., New York, New York: 414 pp.

Rosen, P.C. 1991. Comparative field study of thermal preferenda in garter snakes (*Thamnophis*). Journal of Herpetology 25(3): 301-312.

——, and C.R. Schwalbe. 1988. Status of the Mexican and narrow-headed garter snakes (*Thamnophis eques megalops* and *Thamnophis rufipunctatus rufipunctatus*) in Arizona. Unpublished report from Arizona Game and Fish Department (Phoenix, Arizona) to US Fish and Wildlife Service, (Albuquerque, New Mexico).

——. 2002. Widespread Effects of Introduced Species on Aquatic Reptiles and Amphibians in the Sonoran Desert Region. pp. 220-240 *In* B. Tellman, ed. Invasive exotic species in the Sonoran region. University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson, Arizona.

Rossman, D.A., N.B. Ford, and R.A. Seigel. 1996. *Thamnophis rufipunctatus*, Narrow-headed garter snake. pp. 241-488 *In* The garter snakes: Evolution and ecology. University of Oklahoma Press, Oklahoma, USA.

Schuhardt, S. 1989. Stream Survey Report: Verde River, Oak Creek, and tributaries. Unpublished report to Arizona Game and Fish Department.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry: The principles and practice of s tatistics in biological research. Second Edition. W.H. Freeman and Co. New York: 859 pp.

Tanner, W. 1990. *Thamnophis rufipunctatus* (Cope). Catalogue of American Amphibians and Reptiles. Society for the Study of Reptiles and Amphibians. pp. 505:1-2.

USDA Forest Service. 1996 unpublished. Characteristics and Condition: Executive Summary and Supplemental Information for the Sedona / Oak Creek Ecosystem. Report by USDA Forest Service, Coconino National Forest, Sedona Ranger District: 29 pp.