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Transcontinental Introductions of Watersnakes (*Nerodia*) into California

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ABSTRACT: The watersnakes (*Nerodia*) are a group of semi-aquatic snakes native to North America, primarily east of the Rocky Mountains. Five populations of 3 watersnake species have become established in California. In the northern Sacramento area, more than 100 southern watersnakes (*N. fasciata*), including numerous gravid females, have been captured since their discovery in 1992. Thus far, this population is known from two tributaries of the American River. In southern California, another southern watersnake population is known from Harbor Park Lake, a semi-isolated urban lake in Los Angeles County. A population of northern watersnakes (*N. sipedon*) has become established in Roseville, CA, and until the mid-1990s a dense population of diamondbacked watersnakes (*N. rhombifer*) flourished at Lafayette Reservoir in Contra Costa County. These are potentially worrisome introductions because watersnakes share numerous traits with other invasive aquatic species, including a wide breadth of physiological tolerances, large native distributional ranges, and they occur in many different freshwater types. Watersnakes can be highly fecund, are viviparous, and readily disperse. They are generalist predators that coevolved with many of the aquatic vertebrates now inhabiting western waters. As such, introduced *Nerodia* pose potential threats to native wildlife, including special status species such as the federally-listed threatened giant gartersnake. To address issues surrounding the management, eradication, or control of *Nerodia* populations in the western states, concerned biologists formed the multi-agency *Nerodia* Working Group. Short-term goals of the group include experimental eradication/control of the southern California population, listing *Nerodia* as a restricted genus under Section 671 of Title 14 of California's Code of Regulations, and conducting outreach to the pet trade and other groups to raise awareness about these potentially invasive species.

KEY WORDS: California wildlife, giant gartersnake, invasive species, *Nerodia*, *Thamnophis gigas*, watersnakes

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INTRODUCTION

Snakes are generally ineffective at establishing as invasive species (Williamson and Fitter 1996a, Rodda et al. 1999), with notable exceptions being the brown treesnake (*Boiga irregularis*) in Guam and Burmese python (*Python molurus*) in Florida's Everglades. This is particularly true in temperate regions. However, watersnakes (*Nerodia* spp.), a group whose natural distribution is almost entirely east of the Rocky Mountains of North America, are proving to be an exception to the pattern. Watersnakes are large (to 1.7 m for *N. rhombifer*), active-foraging, semi-aquatic snakes that are closely related to gartersnakes (*Thamnophis* spp.) (Gibbons and Dorcas 2005). In their native range, watersnakes are often the most abundant snakes in an ecosystem and can reach very high population densities. Most watersnakes are generalist predators whose diet consists largely of aquatic ectothermic vertebrates (i.e., fish and frogs) (Gibbons and Dorcas 2005).

WATERSNAKES IN CALIFORNIA

Four watersnake populations consisting of three species have become established at localities throughout California. Reproduction is known or suspected at all populations. The southern watersnake (*N. fasciata*) has been established in the Folsom region of northern California since at least 1992 (Balfour and Stitt 2002, Stitt et al. 2005). One of the authors (P. Balfour) notified California Department of Fish and Game (CDFG) of the snake's presence in 1992, and department biologists subsequently captured 8 adult snakes in 1992 and 2

snakes in 1993 (CDFG unpubl. report). No additional capture effort was expended between 1993 and 1999. Collection attempts started again in 1999. In total, more than 100 snakes have been captured and dissected since 1992. Copulation has been observed in the wild, as has one "breeding ball" of numerous males swarming around a sexually active female. Twenty-seven of 29 (93%) known females were found to have ova, and the mean number of ova was 23.5 (range = 12 to 55). Five snakes gave birth while held in captivity. Southern watersnakes occupy small streams and ponds near Lake Natoma, an impounded portion of the American River which, in turn, connects with the Sacramento River, a major waterway in California's Central Valley. The pattern of *Nerodia* spread in the Folsom area appears to have been along stream courses upstream and downstream of the original locality. American bullfrogs (*Lithobates catesbeianus*), introduced into California, are often observed in close proximity, and two native gartersnake species (*Thamnophis elegans* and *T. sirtalis*) have been observed in sympatry in low numbers. Introduced fish (e.g., *Lepomis* spp., *Gambusia affinis*) and very high densities of crayfish (*Procambarus clarkii*) also occur at these sites. Mitochondrial DNA testing has confirmed that these snakes originated from one of three counties in Gulf Coast Florida (Balfour et al. 2007b, Stitt et al. 2005).

The southern watersnake was also recently documented as established in Harbor City (Los Angeles Co.) in southern California (Fuller and Trevett 2006). Although demographic studies have not yet been conducted, a preliminary investigation of parasites in the Harbor City

population has identified non-native trematodes in collected watersnakes (Jamie Bettaso, USFWS, unpubl. data).

Diamond-backed watersnakes (*N. rhombifer*) were first reported from Lafayette Reservoir (Contra Costa Co.) circa 1988 (Hicks 1996). By the early 1990s, the snakes had reached high densities, and 5-10 might be observed at once basking on piers, bulrush (*Scirpus* spp.), cattails (*Typha* spp), and sunny, exposed banks of the reservoir (Hicks 1996). By 1992, East Bay Municipal Utility District (EBMUD) began receiving complaints from fishermen and other user groups at the reservoir and started considering an eradication effort (WCT 1997). The snakes were described as aggressive, and incidents were reported where fishermen reeled in their catch only to realize that a watersnake was also at the end of the hook (Hicks 1996). In 1996, a consulting company was hired to determine the feasibility of eradicating or controlling the introduced population (Hicks 1996). During an initial 1996 site visit, many watersnakes were observed in "a couple of hours" (WCT 1997). From June 1996 to May 1997, biologists used hand capture techniques and traps to capture snakes. The resultant project report concluded that a population estimate of 200 snakes in the reservoir, as determined by park staff, was "possibly conservative" (WCT 1997). Regardless of the exact population size, at times densities were high and many snakes could be observed in an hour's time (Hicks 1996).

The eradication effort in 1996-1997 was unsuccessful at removing diamond-backed watersnakes from Lafayette Reservoir, and another biological consultant was retained by EBMUD to again try to eradicate the population (Cuff 1999). However, as surveys were commenced, dead and dying *N. rhombifer* were found throughout the reservoir in high numbers (Cuff 1999). Unfortunately, no snakes were salvaged during this time, and neither necropsies nor histological exams were performed. Disease signs at the time indicated that perhaps a respiratory infection was a contributing factor in the die-off (Cuff 1999). The die-off was severe and may have been complete. No watersnakes have been collected at Lafayette Reservoir since late 1998 (Roger Hartwell, EBMUD, pers. commun.). However, occasional "watersnakes" have been reported to reservoir staff in recent years by visitors or park personnel. To date, no sightings have been confirmed by a herpetologist, and no vouchers have been collected. The time of persistence for the population was at least 10 years.

Even more recently, a population of northern watersnakes (*N. sipedon*) has been documented from Roseville, CA (Balfour et al. 2007a). Two female northern watersnakes were collected in April, 2007 from the margin of a large freshwater marsh. One of the females was copulating with a male that subsequently escaped. Additional individuals of undetermined sex were also observed but not captured. The presence of numerous individuals and observed copulation suggest that reproduction is occurring at the site. Genetic analyses (mitochondrial DNA) confirms this species identification as *N. sipedon* (Taylor Edwards, University of Arizona, unpubl. data), thus confirming a third *Nerodia* species as established in California waters.

WATERSNAKES AS INVASIVE SPECIES

These are worrisome introductions, because as a group, watersnakes possess many traits in common with other aquatic or semi-aquatic harmful invasive species (Moyle and Light 1996, Williamson and Fitter 1996b). Watersnakes are habitat and dietary generalists, are highly fecund, and viviparous (live-bearing) (Conant and Collins 1998). The three species now present in California have large native distributional ranges throughout the eastern states, and possess a behavioral tendency to disperse in times of environmental stress. Additionally, they originate from regions where natural disturbances (e.g., hurricanes) are common, and thus may possess behavioral pre-adaptations to cope in human altered environs (such as urban waterways) (Gibbons and Dorcas 2005). Lastly, given the now primarily eastern-US origin of many aquatic vertebrates now found in California's waters, watersnakes, in effect, have "all the comforts of home" regarding potential prey species.

Potential Threats

Of the many potential impacts resulting from these introductions, perhaps the most disconcerting is the possibility that introduced watersnakes could adversely affect native species, including those with special regulatory status. A notable example is the federal and state-threatened giant gartersnake (*Thamnophis gigas*). Considered an ecological analogue to the eastern *Nerodia* species (Rossman et al. 1996), giant gartersnakes evolved in isolation from watersnakes to fill a similar ecological niche in California's Central Valley (USFWS 1999). That is, they are relatively large, semi-aquatic snakes, which use lentic and slow-moving lotic freshwater habitats and eat aquatic, largely endothermic, prey.

Introduced watersnakes in northern California may potentially compete with the giant gartersnake for food, shelter, habitat, or other resources. Additionally, there is the possibility for chemical or pheromone interference with giant gartersnakes, and the possibility for the introduction of non-native parasites and pathogens. Although parasites tend to be taxa-specific, watersnakes and gartersnakes are very closely related, leading to the concern that non-native trematodes found in introduced watersnakes may potentially be transferred to giant gartersnakes.

To date, watersnake populations in northern California have not been documented within occupied giant gartersnake habitat. However, two populations (Roseville and Folsom, CA) are located immediately upstream of areas inhabited by giant gartersnakes. The Folsom population, at present, is known to occur in two drainages that are tributary to the American River, which in turn is contiguous with downstream giant gartersnake habitat (e.g., the American Basin and surrounding areas). The Roseville population is perhaps even more problematic, as it is located in western Placer County approximately 8 miles east of the Natomas Basin, situated within the American Basin of the Southern Sacramento Valley Recovery Unit for the giant gartersnake. If left unchecked, *Nerodia* from either or both populations may access downstream giant gartersnake habitats through active or passive downstream dispersal.

Concern from Ecologists

The potential for significant ecological (and economic) damage related to the establishment of non-native watersnakes has not gone unnoticed. In 1992-1993, following the discovery of the Folsom *Nerodia* population, the California Department of Fish and Game conducted removal efforts in that area. No further state monitoring or eradication efforts directed at that population occurred until 2001, when the Western Section of The Wildlife Society issued a letter of concern to the Director of the California Department of Fish and Game. The letter outlined numerous concerns regarding the Folsom *Nerodia* population and suggested that “the watersnake could potentially find (now altered) habitat more suitable than native species such as the giant gartersnake, which appears to be increasingly surrounded by non-native species” (Barrett Garrison, *in litt.*). Subsequently, a preliminary study was funded to assess aspects of the Folsom *Nerodia* population and to research potential eradication techniques (Stitt et al. 2005). In 1996, watersnakes at Lafayette Reservoir were recognized by park operators as pests, potentially negatively affecting visitorship (Hicks 1996).

Recently, a coalition of concerned biologists from state and federal agencies, academia, and private biological consulting companies has been formed to guide study and eradication strategies for all California *Nerodia* populations (the *Nerodia* Working Group). In 2008, the California Fish and Game Commission added *Nerodia* to the list of restricted species under Section 671 of Title 14 of California’s Code of Regulations. As well, the USGS now recognizes *Nerodia fasciata* as a nonindigenous aquatic species (<http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=2271>).

SUMMARY

It is apparent that watersnakes possess pre-adaptations that allow them to use resources found in California’s waters. Specifically, these eastern snakes face an abundance of similarly introduced aquatic prey and human-altered, now-perennial waters. What is unknown is whether climatic and other abiotic factors are within the realm of physiological tolerance for the snake over a long term. Also, although we can speculate as to what the potential impacts of these introductions may be, in reality there is no way of knowing until the impacts are manifested. Such impacts may include competition with native snakes, such as the giant gartersnake, or predation on native fish or frogs. Introduced predatory vertebrates have the potential to seriously alter an ecosystem, and for that reason alone, we believe that a continued eradication and monitoring program be developed and implemented.

In the western United States, it is largely a biogeographical accident that *Nerodia* do not occur naturally. Certainly, California features an array of potential aquatic habitats. However, as for many other eastern aquatic vertebrates, the Rocky Mountains were a barrier to dispersal, enabling giant gartersnakes to occupy the “large aquatic snake” niche in California’s Central Valley. Now, facilitated by human means, watersnakes and other eastern aquatic herpetofauna (e.g., American bullfrogs) can become established in areas historically

unavailable to them (e.g., Jennings 2004). In order to conserve what remains of California’s lower-elevation aquatic herpetofauna, it is imperative to reduce the rate of introductions through controlling importation of non-native aquatic species.

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