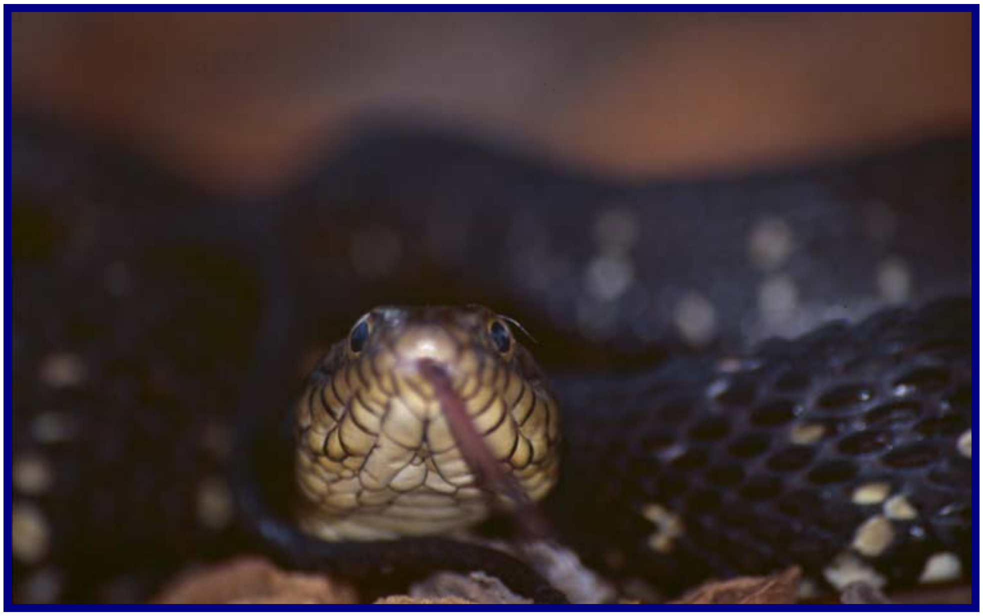
THE SOUTHERN WATERSNAKE (*NERODIA FASCIATA*) IN FOLSOM, CALIFORNIA: HISTORY, POPULATION ATTRIBUTES, AND RELATION TO OTHER INTRODUCED WATERSNAKES IN NORTH AMERICA



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U. S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

UNDER COOPERATIVE AGREEMENT #11420-1933-CM02

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"The brown treesnake* (Boiga irregularis) *is the only dramatic example of an artificially introduced snake causing widespread ecological damage, but clearly the potential exists for other such incidents."
-Herpetologist Harry Greene, in *Problem Snake Management* (page xvi)

"Only after most of the birds had been extirpated…" (on Guam) "…was the first crude snake population estimate undertaken (Fritts 1988), and by then it was impossible to observe the conditions under which the demise of the birds occurred."
-Rodda et al., in *Problem Snake Management* (page 8)

"Snakes seem to be unusually resistant to translocation; certain snake introductions have been spectacularly successful [e.g., the brown tree snake* (Boiga irregularis) *on Guam (Fritts 1988) and a blind snake* (Rhamphotyphlops bramina) *throughout the coastal tropics (McDowell 1974)], but other examples are few (Burke 1991)..."
-*Recovery Plan for the Giant Garter Snake* (Draft; page 164)

INTRODUCTION

The North American watersnakes (genus *Nerodia*) are currently recognized as ten species and 15 subspecies (Crother et al. 2001), all found east of the Rocky Mountains south into Mexico. As their name suggests, all are primarily aquatic, foraging and carrying out most other aspects of their life history in water (Gibbons and Dorcas 2004). Closely related to garter snakes (*Thamnophis* spp.) (Lawson 1985, Alfaro and Arnold 2001), all occasionally leave water to bask or move between water features. In their natural ranges, watersnakes sometimes reach high population densities and may be the most common snake in an aquatic community. Watersnakes play an important role in such communities as mid-level carnivores, eating aquatic amphibians, their larva, and fish, and taken as prey by mesocarnivores, wading birds, and birds of prey (Gibbons and Dorcas 2004 and references therein). Neonate and young watersnakes may be eaten by predaceous birds, mammals, fish, frogs, insects, and crayfish.

The Southern watersnake (*Nerodia fasciata*) has been introduced into the Folsom, California region, where it has reached high local densities (Balfour and Stitt 2002; Appendix A). The introduction of *N. fasciata* into Folsom is not an isolated occurrence: the same species was released and established outside its native range into the Brownsville, Texas area (Conant 1977). Further, there are unsubstantiated reports of individual watersnakes being captured in other areas of California (Bury and Luckenbach 1976), and of an established population of diamond-backed watersnakes (*N. rhombifer*) in Lafayette Reservoir, Contra Costa County (Mark Jennings pers. comm., WCT 1997).

The purpose of this report is to summarize our current state of knowledge regarding the Folsom *N. fasciata* population. Here, we summarize population attributes and the current range occupied by Folsom watersnakes and we compare the efficacy of different capture methodologies. Also, we present results of a preliminary radio telemetry study designed to determine behavioral traits and movement ecology of these introduced snakes.

In the course of our research, we found that although introduced snake populations are exceedingly rare (see epigraphs), watersnakes appear to be over-represented by introduced populations. Thus, we use this opportunity to summarize what is known regarding other introduced watersnake populations and to provide a context for future research. Also, because some aspects of *Nerodia* biology apparently allow these snakes to more readily establish extralimital populations than other snake genera, we strongly recommend that all *Nerodia* species be added to watch lists of possible noxious invasive species, and suggest that importation of these snakes into California be curtailed.

The Southern Watersnake (*Nerodia fasciata*)

The southern watersnake is a relatively large (to 152 cm), heavy-bodied aquatic snake. The coloration and pattern differs greatly both between and within populations, but most individuals have an earth-tone background coloration with lighter-colored crossbands running the length of the snake (Figure 1a; Conant and Collins 1998, Gibbons and Dorcas 2004). Most individuals feature a dark stripe from eye to angle of jaw (Figure 1b) and may possess worm-like red, orange, yellow, or black markings across the ventral surface (Figure 1c; Conant and Collins, 1998). Melanism is common in *N. fasciata*, and larger individuals may be completely black.

The southern watersnake is currently recognized as three subspecies (Crother et al. 2001 and references therein). The nominate subspecies is found in the southeastern United States along the Atlantic Coast in eastern North Carolina, South Carolina, and Georgia, south into northern Florida, and west to southern Alabama and eastern Mississippi (Gibbons and Dorcas 2004). *N. f. confluens* is found from eastern Mississippi west along the Mexican Gulf to southeastern Texas (see map in Gibbons and Dorcas 2004). This subspecies follows the Mississippi River north through Arkansas to southern Illinois. The third subspecies, *N. f. pictiventris* occurs only in peninsular Florida.

Figure 1. Diagnostic features of *Nerodia fasciata* include a.) light-colored crossbands on a darker background, b.) dark line from the corner of the eye to the angle of the jaw, and c.) "worm-like" red, orange, yellow and black markings across the ventral surface.

The taxonomic history of *N. fasciata* is convoluted and is not settled to date (Lawson et al. 1991, Crother et al. 2001, Gibbons and Dorcas 2004, Stephen Karl pers. comm.). One source of confusion is that hybridization zones occur both within *N. fasciata* and with other species. Intraspecific hybrid zones occur in northern Florida where *N. f. pictiventris* meets *N. f. fasciata*, and in eastern Mississippi where *N. f. fasciata* meets *N. f. confluens*. *N. fasciata* hybridizes with *N. sipedon* (northern watersnake) in several states where they co-occur, which is thought to be facilitated by anthropogenic and natural habitat modification (e..g., hurricanes). *N. fasciata* also hybridizes with *N. clarkii* (salt-marsh watersnake) in parts of Florida. To date, some molecular genetic studies fail to discriminate between these two species, indicating how closely related the (presumed) species are (Stephen Karl pers. comm.).

N. fasciata is a habitat generalist throughout its range and occurs in any freshwater aquatic habitat available, including lakes, ponds, reservoirs, creeks, canals, swamps, and small wetlands (Gibbons and Dorcas 2004 and references therein). Although one worker found *N. fasciata* to be associated only with ponds (Seyle 1980 in Gibbons and Dorcas 2004), another study found this snake in every available aquatic microhabitat (Hebrard and Mushinsky 1978). In general, *N. fasciata* does not occur in saline environments (H_2O salinity content >1.0 ppt; citation). Laboratory experiments have shown that *N. fasciata* will drink saline water (i.e., cannot discern saline from non-saline water) but will die if kept in salt water for one or two days (Pettus 1956 in Gibbons and Dorcas 2004).

N. fasciata is a dietary generalist. Prey items include aquatic vertebrates such as fish (17 genera) and amphibians (24 species), with crayfish (*Procambarus*) represented in low numbers (Gibbons and Dorcas 2004 and references therein). In a well-studied population in Louisiana, researchers observed an ontogenetic shift in dietary preference from being primarily piscivorus as juveniles to taking a mixture of fish and frogs as adults (Mushinsky et al. 1982), with 71% of the overall diet consisting of fish (Mushinsky and Hebrard 1977). Endothermic prey (squirrels and birds) have been reported in one paper (Clark 1949), a finding that remains unconfirmed 50 years later and the accuracy of which is now questioned (Gibbons and Dorcas 2004). Reptiles have not been reported as prey items (Gibbons and Dorcas 2004).

As with many reptiles in the southern United States, activity has been reported for *N. fasciata* throughout most of the year (Gibbons and Dorcas 2004). In Louisiana, *N.*

fasciata is a diurnally active snake early in the year, becoming more nocturnal as daytime temperatures increase into summer (Mushinsky et al. 1980). Seasonal activity patterns are bimodal, with activity peaks in spring and fall (Mushinsky et al. 1980).

Population biology for *N. fasciata* is relatively unknown and no life-tables have been constructed for any population. However, in Michigan, the closely related *Nerodia sipedon* (northern watersnake) is short-lived with complete population turnover every 2.8 years (Feaver 1977 in Gibbons and Dorcas 2004). Female *N. sipedon* there live a maximum of eight years and reproduce yearly. There is high variability in survivorship between sexes and age classes. Females first reproduce at two years of age and those females contribute a higher proportion of offspring to the population than other age classes. In all watersnakes, fecundity increases with female body size (Gibbons and Dorcas 2004). Watersnakes are sometimes very abundant and populations may reach very high densities in unnatural settings (e.g., fish hatcheries) (Bauman and Metter 1975).

Study Area

Folsom, California is a town of approximately 54,000 people, situated in northeastern Sacramento County, in Northern California (Figure 2) (Folsom city webpage: http://www.folsom.ca.us/). Established as a mining town at the advent of the California gold rush, the town encompasses an area of approximately 24 square miles. Throughout most of the 1900's, Folsom Prison was the area's largest employer; however, since the

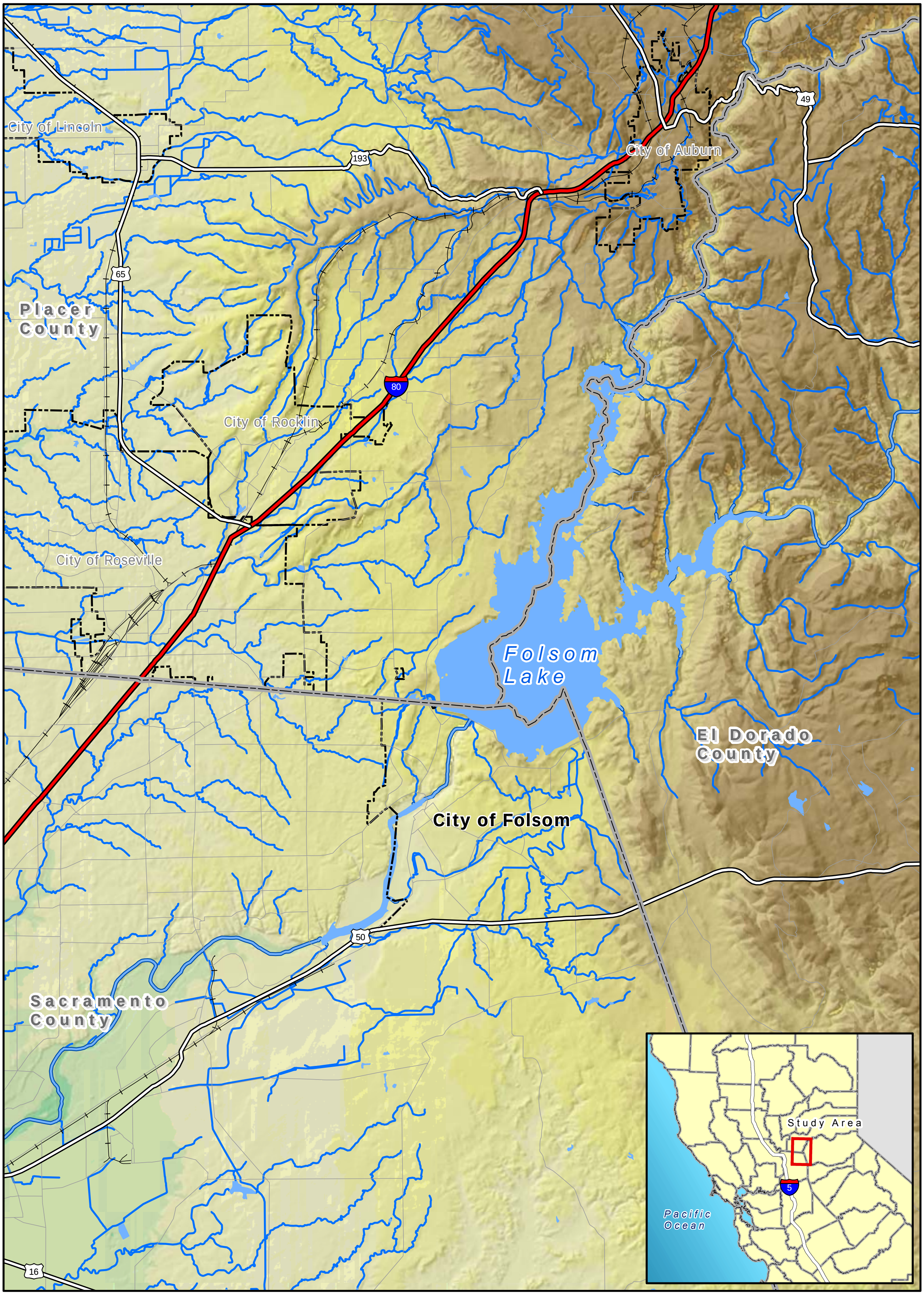

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Figure 2. Map of Folsom, California Study Area

1:200,000

2 1 0 2 Miles

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middle 1990's technology and research jobs have surpassed the prison in importance. Residential development has greatly increased since 1990, with the population growing at a rate of 5-9% per year.

The climate at Folsom is Mediterranean, with cold, wet winters and hot, dry summers. The area receives an average of 23.3 inches of rainfall annually, which is distinctly unimodal. Seventy-three percent of annual rainfall occurs in December through March. The average January minimum low temperature is 37.6°F and average July maximum temperature is 94.1°F (data from: http://www.worldclimate.com/cgi-bin/grid.pl?gr=N38W121). The elevation of Folsom is approximately 450 feet above sea level.

Vegetation in the area is a composite of introduced annual grasslands and oak woodlands, with chaparral present in small proportion. A dominant landscape feature is Folsom Lake (actually a reservoir), formed in 1956 by the construction of Folsom Dam in the American River. The 1,010,000 acre-foot reservoir provides water to all of the Sacramento area, and provides recreation opportunities (boating, fishing, and swimming) for nearby residents. Surrounding uplands are maintained for recreational and residential uses. Small tributaries (Humbug and Willow Creeks) braid from northeast to southwest through Folsom, emptying into the American River (Lake Natoma) below Folsom Dam.

Historically, these creeks were likely ephemeral or intermittent and flowed only after winter rains, drying completely during the hot, dry summers. With increased residential development, however, the creeks are now largely perennial, due to excess urban runoff draining into them year-round. Perennial ponds and marshes now dot the landscape where runoff is especially persistent, including areas where basins have been constructed for stormwater runoff containment. Marshes have also developed in old dredger tailing areas or have been augmented by placement of beaver (*Castor canadensis*) dams along streams.

METHODS

Surveys and Hand Capture

We examined several aerial photographs of the Folsom, California area to determine the location of ponded areas, creeks, and streams in which to conduct visual encounter surveys (Crump and Scott 1994), and performed surveys in 2003 and 2004 under ideal conditions (cloudless days with high ambient temperatures; conditions under which watersnakes actively forage or bask on emergent objects). Upon approaching an area we scanned the surface of water and adjacent upland areas, often with binoculars, to identify foraging, basking, and/or swimming watersnakes. We then searched the margins of waterbodies by walking slowly along a perimeter while searching exposed banks and emergent or streamside vegetation (Figure 3). When possible, we walked through dense streamside vegetation in order to flush otherwise hidden snakes into the open or into water. During surveys, snakes were captured by hand or with snake tongs.

One goal of our study was to determine the current range of the southern watersnake. Thus, special attention was given to surveying beyond previously known areas that support the snake. To the southwest, this involved surveying Lake Natoma in the American River. Due to logistical problems (limited access, large expanse of water), we relied on help from others to alert us to sightings of watersnakes south of Lake Natoma (see Public Input, below). We also inspected several residential ponds and a small portion of Folsom Lake in the vicinity of "Beals Point".

Figure 3. Hand capture at the Kelly Moore ponds. Author Peter Balfour slowly walking around the southeast edge of the pond to catch watersnakes fleeing from the bank into water. Notice the upland vegetation on the bank, which is completely dominated by Himalayan blackberry. At places like this, when watersnakes were encountered on the bank they either fled into the water or retreated deep into the blackberry.

Trapping

We evaluated several trap methods for their efficacy at capturing *N. fasciata*. Aquatic funnel traps (Casazza et al. 2000), developed for trapping giant garter snakes (*Thamnophis gigas*) were deployed at several ponds and steams (Figure 4). These passive traps are modified minnow or crayfish traps with Styrofoam blocks attached laterally so they float half in/half out of the water. Aquatic funnel traps were placed parallel to the water margin and attached to emergent vegetation with large plastic cable ties (Figure 5). To the extent possible, traps were placed along areas most likely to be used by swimming snakes.

We also used aquatic mist nets (Figure 6, Lutterschmidt and Schaefer 1996), which were constructed of avian exclosure netting that is commonly placed over fruit trees as protection from frugivorous birds. These traps were constructed with lengths of netting (ca. one meter long) folded along its long axis three times, and stapled to a wooden stakes at each end. The mist nests were then staked perpendicular to the water/land interface such that netting emerged from the water's surface. Snakes were then trapped as they tried to pass through the netting.

We placed cover boards (Fellers and Drost 1994) at several localities (Figure 7). Snakes and other ectotherms use cover items as a means by which to thermoregulate and to stay hidden from predators. We thought that by increasing the number of artificial cover items available in the environment, the chances of capturing snakes under these items would increase.

Figure 4. An aquatic funnel trap, designed originally to capture giant gartersnakes (Cassaza et al. 1999).

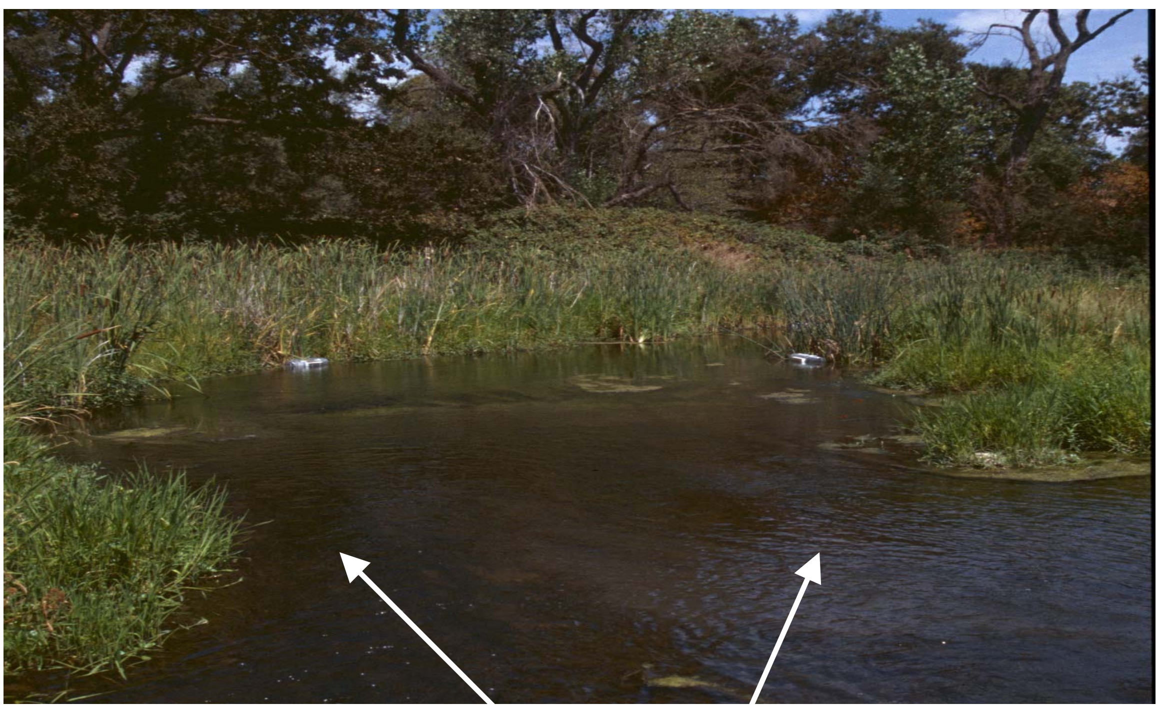

Figure 5. Aquatic funnel traps *in situ*. We used cable ties to anchor traps to emergent vegetation parallel to a shoreline.

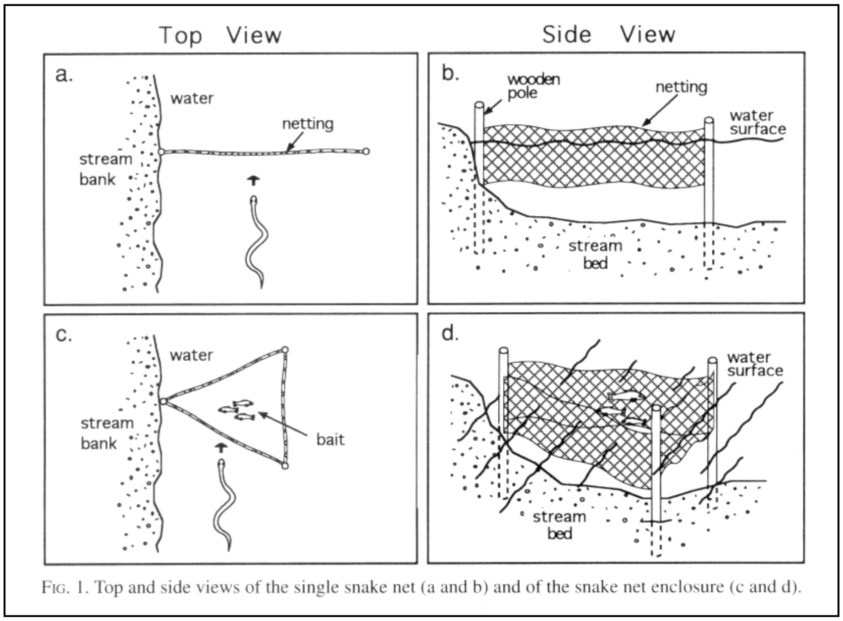

Figure 6. Snake "mist net" used to capture southern watersnakes (Lutterschmidt and Schaefer 1996).

Figure 7. Coverboard at California Department of Fish and Game restoration site.

Public Input

We contacted agency biologists in the Folsom/Sacramento/Lake Natoma area and explained the existence of the Folsom *N. fasciata* population. We described the snake and provided fliers to aid in identification. We asked that any observances of this snake by biologists be reported to us at ECORP Consulting, Inc.

We distributed fliers to the California Parks Department, San Juan Water District, Bureau of Land Management, and California Department of Fish and Game, and posted fliers in and around Folsom Lake at informational kiosks located at picnic and camping areas (Appendix B). We also posted fliers at Folsom/Granite Bay area boating and marine supply stores. We discussed the introduced population with California Department of Fish and Game biologists at the Nimbus branch office, and asked that any positive sightings of the snake at the Nimbus Fish Hatchery be reported to us. During field efforts we approached utilities workers, SWPPP inspectors, fish and game enforcement officers, and local residents and explained the presence of introduced watersnakes, the potential damage they might have on the environment, and asked to be contacted if any snakes were observed.

Dissections

All snakes captured, except those implanted with transmitters and released (see below), were humanely euthanized (induced hypothermia) and dissected (Figure 8). Sex was determined by cloacal probing or by determining proportion of tail length to body length (a qualitative approach: snakes that were sexed by assessing proportional tail length were not included in analyses between sexes). We dissected stomachs in order to determine diet but very few snakes had food in their stomachs so we do not report results here. We also determined fecundity of females by counting ova or embryos (Figure 9). We did not differentiate between size classes or stage of development for ova and embryos.

Figure 8. Dissection of southern watersnake.

Figure 9. Ova from dissected female. Developing snakelets are visible within several ova.

Statistical Analyses

For all snakes captured, we summarized snout-vent length, mass, sex (if determined) and age class. We considered adults to be all snakes over 350 mm and juveniles to be all snakes between 250 and 350 mm. Neonates were defined as all snakes born in captivity. We determined whether snakes had prior injuries (usually missing/partial tails). We then conducted inferential tests to determine whether 1) size (snout-vent length) varied between males and females, 2) injuries varied according to body size, and 3) there was a relationship between female body size and fecundity.

We summarized the number of snakes captured by hand or in different traps, and determined the efficiency of different capture methods according to unit effort. If necessary, we $\log_e$-transformed response variables to meet assumptions required by parametric tests, and we used non-parametric tests when response variables were categorical. We used JMP ver. 4.0 (SAS Institute Inc.) for all non-movement related statistical tests (see below).

Radio Telemetry

To determine patterns of habitat use and provide insight into seasonal behaviors, we implanted snakes with radio transmitters and relocated them with radio telemetry. Two males and two females were implanted with transmitters (Wildlife Track CRM110 for females, 30.0 g; Holohil SI-2T for males, 8.8 g) by Dr. Ray Wack (Sacramento Zoo) in October, 2003. Transmitters were implanted using standard methods (Reinert and Cundall 1982). Transmitter-equipped snakes were released at their point of capture and relocated weekly from October 2003 though June 2004 with a receiver and directional antenna (Communications Specialists R-1000 and Telonics RM-14, respectively). Snakes were tracked between 0700 and 1800 hr; care was taken to track at different times during daylight to obtain data relevant to all daylight habitat use and movement.

On each subsequent telemetry occasion, we determined as closely as possible, the location of each snake and recorded GPS coordinates of its position with handheld GPS receivers. GPS coordinates were recorded as UTM's (NAD-27 Conus datum), accurate to approximately 5 m. We visually confirmed each snake's position when possible and determined whether it was active or inactive. For each telemetry location we described behavior (unknown, swimming, land moving toward water, land moving from water, not moving, courting/mating, other, moving but not observable, and found dead), substrate (unknown, bare ground, veg/debris on ground, veg/debris on or over water, underground, extending from burrow, on water surface, below water surface, rock/rip rap, other), position (unknown, coiled, partly coiled, stretched, moving), percent of snake in sun (<10%, 10 – 25%, 25 – 50%, 50 – 75%, 75 – 100%, 0%), and distance to water or land (<1 m, 1 – 3 m, 3 – 10 m, 10 – 20 m, >20 m, at margin, at impediment to H_2O). We determined vegetation type (unknown, bulrush, cattails, grass, brush, weedy dicots, blackberry, primrose, other, no veg), categorized vegetation cover (unknown, 0 – 5%, 5 – 25%, 25 – 50%, 50 – 75%, 75 – 100%, 0%), and vegetation height (unknown, <15 cm, 15 – 50 cm, 50 – 100 cm, >100 cm). We also determined general habitat type (natural channel, freshwater marsh, marsh edge, fallow field, perennial grassland, levee, railroad grade) and microhabitat association (bare ground, rock/rip rap, terrestrial vegetation, litter, water, submergent vegetation, emergent vegetation, other). We recorded ambient temperature (shaded air temperature at 1.5 m above ground surface), substrate temperature (shaded ground temperature), and water temperature (10 cm below water surface approximately 20cm from water margin). We also recorded other environmental variables including wind speed and percent cloud cover. Transmitters implanted in male snakes included a temperature-sensitive module, with the rate of transmitter pulses being proportional to the snake's body temperature. Thus, transmitter pulse rate was counted for each sighting of a male.

Statistical Analyses-Movement

The movement ecology of southern watersnakes in Folsom is of great interest, with behaviors such as dispersal ability, site tenacity, overwintering behaviors, and intraspecific interactions having bearing on future eradication efforts. Thus, we assessed several different measures of movement. We determined the mean distance moved and the maximum distance moved by snakes between two successive telemetry dates. We determined the average and maximum rates of speed between successive locations. To determine home ranges we used two different methods. We determined 100% minimum convex polygon (Mohr 1947), which defines the total area used by an animal as a polygon with no interior angle greater than 180º. To determine home-range use with a degree of probabilistic certainty, we also determined space-use patterns as 50%, and 95% fixed kernel home range estimates (Worton 1989). We used BIOTAS ver. 1.03.1 alpha (Ecological Solutions Software), and the Animal Movements extension (Hooge and Eichenlaub 1997) in ARCview GIS ver. 3.3 (ESRI, Redlands, CA) to model snake movements resulting from UTM-derived data.

Genetics

We wanted to determine as closely as possible the source population for the Folsom *N. fasciata*. Determining the source locale for these snakes may provide insight into means by which they may be controlled in the future, or may indicate physiological constraints to be exploited during future eradication efforts. Further, if the source for the Folsom population is the same as that for the Brownsville population (see below), then it may be that the source population features especially "adaptable" individuals.

We obtained blood, scale clippings, and/or skin shed from seven specimens captured throughout the range of the Folsom population. Tissue was stored in lysis buffer and brought to the Genomic Analysis and Technology Core (GATC) at the University of

Arizona. We isolated total DNA by overnight lysis with proteinase K at 55°C, followed by extraction using phenol/chloroform and isopropanol/sodium acetate precipitation (Goldberg et al., 2002). We resuspended the DNA in low TE (10 mM Tris pH 8.0, 0.01 mM EDTA) and quantified it using a FLx 800 Microplate Fluorescence Reader (Bio-Tek Instruments, Inc.). We diluted working stock solutions to 5 ng/µl. We used standard methods of polymerase chain reaction (PCR) to amplify four regions of the mitochondrial genome (mtDNA) in our samples (Table 1). We used a PTC-100™ Programmable Thermal Controller (MJ Research, Inc.) and allowed PCR to run for 35 cycles.

Table 1. Primer sequences and PCR conditions for four regions of the mitochondria in *Nerodia fasciata*.

mtDNA region	Primer Sequence	Citation	MgCl (mM)	PCR Denature	PCR Anneal	PCR Extension	Amplicon size (bp)
ND4	Nap 2 5'-TGGAGCTTCTACGTG(GA)GCTTT-3' NewGly 5'-ATAAGTACAATG(AC)(CT)TTCCA-3'	Arévalo et al., 1994	35	94°C 1:00 min	50°C 2:00 min	73°C 3:00 min	911
ND2	CE2330 5'-CTAATAAAGCTTTCGGGCCCATAC-3' H5051 5'-TCGGTGCTATTTTTAGTGTTGCTA-3'	Janzen et al., 2002	25	94°C 0:30 min	54°C 0:30 min	72°C 1:30 min	630
Cyt b	LGlu 5'-TGATCTGAAAAACCACCGTTGTA-3' H15544 5'-AATGGGATTTTGTCAATGTCTGA-3'	Janzen et al., 2002	25	94°C 0:30 min	54°C 0:30 min	72°C 1:30 min	649
	L15446 5'-CCAACCCTAACACGATTCTTTGC-3' Hpro 5'-TTAAGTTAAAATACTGGCTTTGG-3'	Alfaro & Arnold, 2001	20	94°C 0:30 min	57°C 0:30 min	72°C 1:30 min	685
Control Region	Haplo1 5'-ATACCTGTTCTCCCTCATTT-3' Haplo2 5'-GGTGGAACTGGCATACG-3'	Luckau & Edwards (this report)	25	94°C 0:30 min	55°C 0:30 min	72°C 0:30 min	369

Parentheses indicate heterologous primers.

We used Oligo Primer Analysis Software, version 6.68 (Molecular Biology Insights, Inc.) to design amplification primers for the mtDNA control region (see Table 1) and to design internal primers for sequencing the ND4 region (Nap2In_NeFa 5'-ATAAAGTATGTTCCTGCGGT-3' and NewGlyIn_NeFa 5'-CACCCTATGAGTGCGCA-3'). We sequenced all samples at the GATC DNA Sequencing Laboratory at the University of Arizona.

We examined concatenated sequences using Sequence Navigator version 1.0.1 (Applied Biosystems, Inc.). For the cytochrome b region, we sequenced 1,249 continuous base pairs using 2 overlapping primer sets. The ND2 and ND4 regions yielded 630- and 911-bp lengths, respectively. We then compared our samples to published sequences (GenBank accession # AF402910 and # AF384829; Alfaro and Arnold 2001). We also examined the control region of the mitochondria and assigned a "haplotype" to our individuals based on eight published GenBank sequences (Haplotype A, accession # AY269791; Haplotype B, accession # AY269792; Haplotype C, accession # AY269793; Haplotype D, accession # AY269794; Haplotype E, accession # AY269795; Haplotype F, accession # AY269796; Haplotype G, accession # AY269797; Haplotype H, accession # AY523573).

Brownsville, Texas *Nerodia fasciata*

The *Nerodia fasciata* population introduced into Folsom, California is not an isolated occurrence. This same species was introduced into the Brownsville, Texas area, south of its native range (Conant 1977). Here, we summarize literature records regarding that population, discussions regarding the current status of the population with acknowledged experts on Texas herpetology, and provide information gathered during a collecting trip to the study area in April, 2004. We wanted to know if 1) the Brownsville population was still viable, 2) whether the population had expanded its boundaries, and 3) whether there were any reported negative consequences attributed to its establishment.

Lafayette, California *Nerodia rhombifer*

While conducting our work we realized that another watersnake population was established in Lafayette, California, when, as we consulted other biologists, many thought we were referring to the Lafayette population instead of the Folsom population. To date there is little written record of that introduction and no information regarding its present status. Thus, we here summarize all known information regarding the Lafayette population based on written documents (including newspaper articles), interviews with knowledgeable individuals, and site-visits.

Vertebrate Museum Queries

We contacted curators of local academic vertebrate museums and gathered information regarding watersnakes collected from the wild in California. Museum records are listed in Appendix C.

RESULTS

***Nerodia fasciata* in Folsom, California**

History and Population Attributes

The first record that a population was established was summer, 1992 (P. Balfour pers. obs.). At that time, watersnakes were first observed in one pond ("Lyons Pond"; now near a Sizzler Restaurant on the corner of Blue Ravine and Bidwell Roads). The observer notified California Department of Fish and Game (CDFG) of the snake's presence (P. Balfour *in litt.* to CDFG). Department biologists subsequently captured eight adult snakes in 1992 and two snakes in 1993 (CDFG unpub. report). Snakes were initially misidentified in reports as *N. rhombifer*, and no additional capture effort was expended between 1993 and 1999.

In June, 1999, a biologist for ECORP Consulting, Inc. encountered several “very big, fast, black snakes” while monitoring vegetation at a pond at Prairie Oaks subdivision. That same day, an ECORP herpetologist (author E. Stitt) revisited the Prairie Oaks site and collected six large *Nerodia fasciata* while observing at least 10 more. All snakes observed were 50 cm or larger, on the upland slope of the pond, and quickly retreated to standing water when encountered. Subsequent trips to the Prairie Oaks site and to the original Lyons Pond indicated that the population was not extirpated in 1993, and had, in fact, increased considerably.

We alerted CDFG and the U.S. Fish and Wildlife Service (USFWS) of the snake’s presence. We learned that CDFG had been working independently from us, and that they had hired a worker to survey and capture as many snakes as possible (Kathy Hill pers. comm., Brown 1999) in another set of ponds (Kelly Moore Ponds). We joined forces and continued opportunistic (haphazard) collection attempts in 1999, 2000, 2001, and 2002. Funding provided through the Central Valley Project Improvement Act (CVP1A; (b)(1) “other”) allowed us to greatly increase the effort in 2003 and 2004, and to explore several different trap methods.

Using data reported by Brode (1993), Brown (1999), and gathered by us (1999 - 2004), we have data on 100 captured or captive-born snakes. Eight snakes were collected by

Brode in 1992-1993, and 61 were collected by us (including Brown 1999) between 1999 and 2004. Figure 10 illustrates the original point of capture as well as the current known distribution of southern watersnake in Folsom. Sixty-six were adults, two were juveniles, and 32 were neonates born in captivity. Of adults that we sexed, 37 were female and five were male. Most neonates born in captivity were not sexed.

The mean size (snout-vent length) of 68 juvenile and adult snakes was 71.5 cm (range = 25.0 – 103.3 cm) (Figure 11), and there was a strong allometric relationship between body mass and snout-vent length (Figure 12). We found a difference in snout-vent length between males and females ($t_{39} = 2.95$, $p = 0.005$) but given the small number of males captured, our results must be treated with caution.

Thirty of 35 females (85%) were gravid, three were not (9%), and two (6%) were not assessed for reproductive status. There was a strong positive relationship between female body size and fecundity (Figure 13). Gravid females had an average of 23.1 embryos (range = 12.0 – 55.0 ova; Figure 14), and a total of 693 developing ova were taken from gravid females.

Location: J:\GIS_Maps\2003-080_Watersnake_study\Figure10_Snake_Distribution.mxd

Figure 10. Map of *N. fasciata* distribution in Folsom

1:45,000

0.5 0.25 0 0.5 Miles

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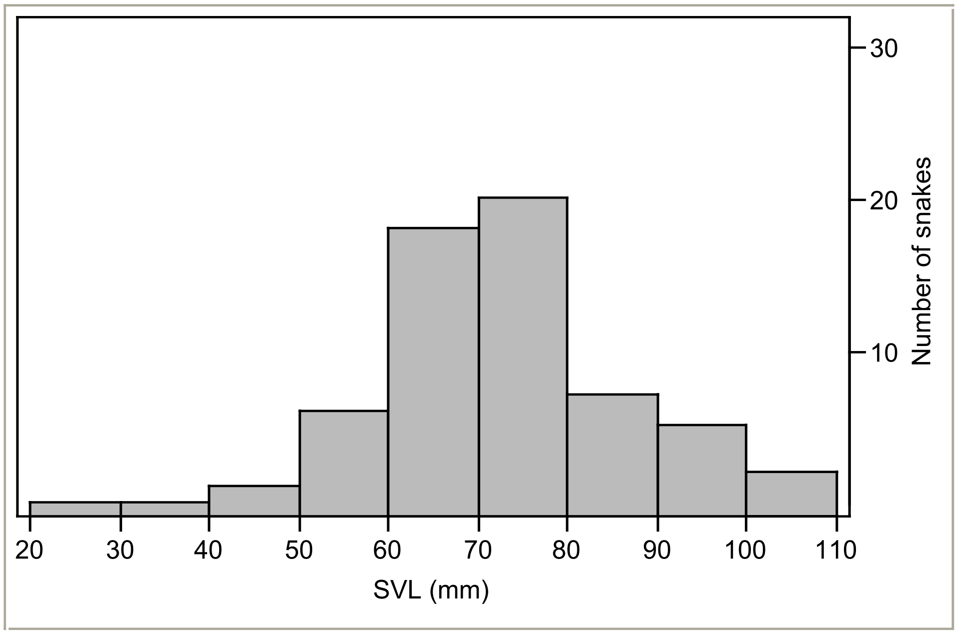

Figure 11. Snout-vent lengths of 68 adult and juvenile southern watersnakes from Folsom, California.

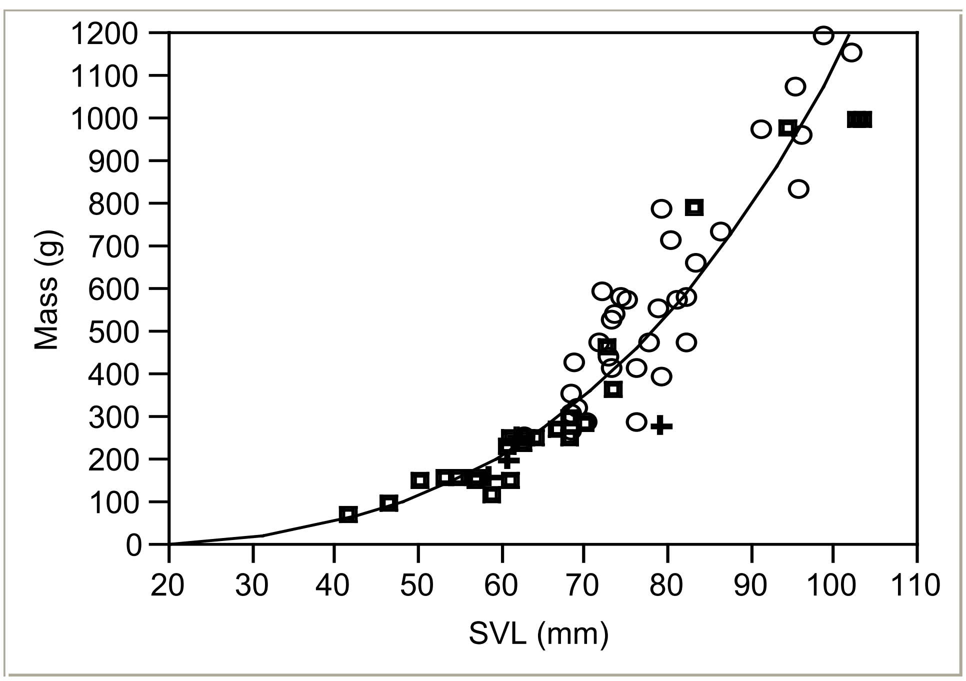

Figure 12. Log_e – log_e relationship of mass to snout-vent length for 61 southern watersnakes, Folsom, California ($Log_{Mass} = -7.997951 + 3.2620679\ Log_{SVL}$; $F_{1, 59} = 496.05$, $p<0.0001$, $r^2 = 0.893$).

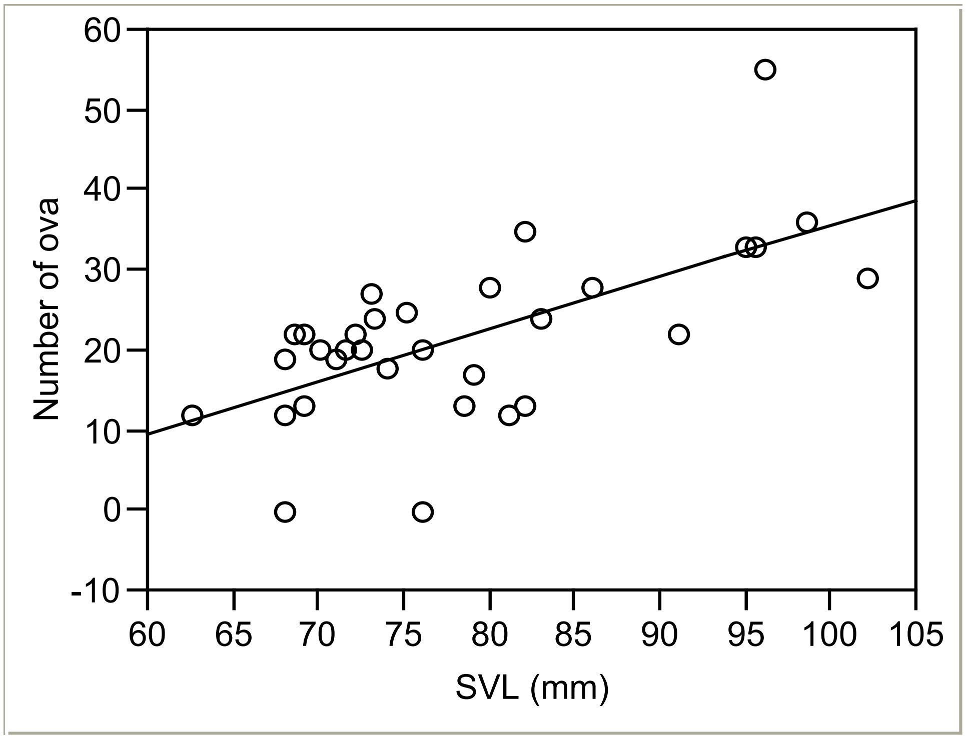

Figure 13. Relationship of snout-vent length to number of ova for 32 female southern watersnakes, Folsom, California (# ova = -29.137 + 0.648 SVL; $F_{1, 30} = 20.37$, $p<0.0001$, $r^2 = 0.404$).

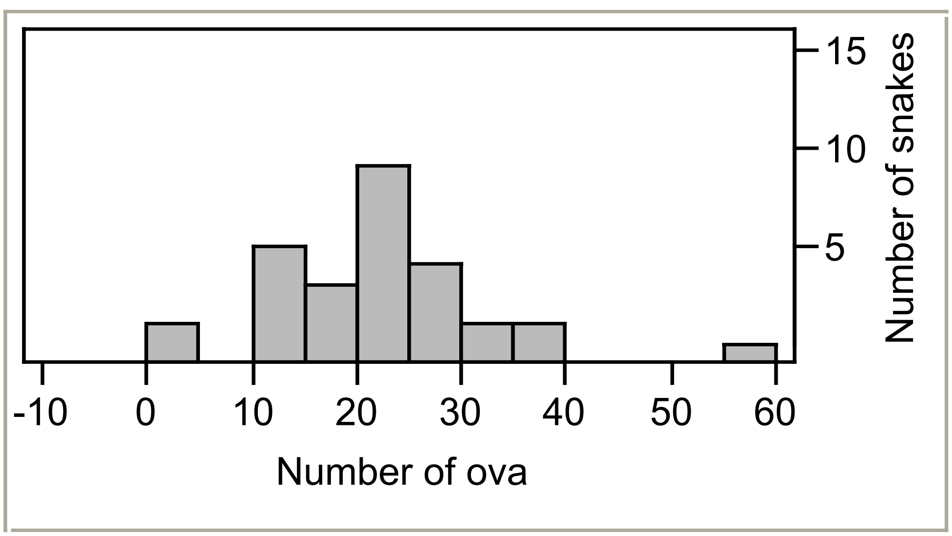

Figure 14. Number of ova for all dissected gravid watersnakes collected from Folsom, California (n = 32).

Five females gave birth in captivity. Brood size averaged 16.6 neonates (range = 12 – 22 neonates). The average size for neonates was 15.2 cm (range = 8.5 – 20.1 cm, n = 31), and the average mass was 3.7 g (range = 1.7 – 7.0 g, n = 19). Tail injuries occurred in 21 snakes, and larger snakes had a higher incidence of tail injuries that smaller snakes ($F_{1, 63}$ = 4.21, p = 0.04).

Seasonality of Captures

There was a strong seasonal component to our capture and sighting success (Figure 15); however, survey effort was not equal throughout a year or between years. Survey effort was increased approximately 7-10 fold in 2003 and 2004 relative to 1999 – 2002.

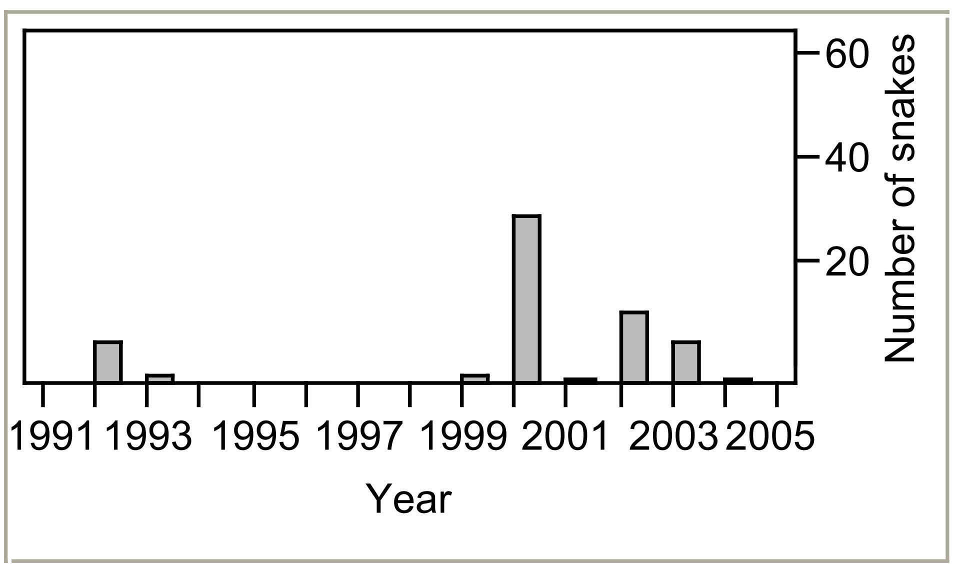

Figure 15. Number of snakes collected and born in captivity per year in Folsom, California (n = 98; data from Brode 1993, Brown 1999, and the authors). Note the 5-year period when no collections were made, and the diminishing number of captures from years 2000 to 2004, despite much-increased effort.

Agencies Contacted, Fliers Distributed

In response to our fliers, we were contacted four times by private individuals who reported suspect snakes. Based on descriptions and/or photographs of observed snakes, all sightings were attributed of other species (i.e., garter snakes, king snakes, and gopher snakes). Work crew members taking part in a water hyacinth removal effort provided several credible observation records, from an area known to support the species (Ken Davis, pers. comm.).

Snake Captures By Method

Prior to 2003, all snakes were captured by hand or snake tongs (a hand-capture method; n = 54). In 2003, 13 additional watersnakes were captured with a variety of methods (Table 2). Of these, it appears that hand capture is still the most efficient method; this method is highly biased, however, with most snakes captured by hand being females. Although the sex of 26 adult snakes was not determined, it is highly unlikely that many among these were males, given that only five of the 41 (14%) sexed snakes were males, and four of those were captured by another method (see below). Alternative capture methods were discontinued in late 2003.

Table 2. Numbers and methods used for snakes captured in 2003.

	Male	**Female**	**Effort**	**#/unit effort**	**Total**
Hand	0	7, 1*	388 hrs.	0.021 (1/48 hr)	8
Minnow traps	0	0	1940 trap nights	0	0
Cover boards	0	1*	85 boards	--	1
Drift fences	4**	0	269 trap nights	0.015 (1/67 tn)	4
*unexed juvenile		**2 dead in trap			13

Aquatic mist nets were another effective method for capturing watersnakes. This method was also biased in that only adult males were captured (n = 4). Also, there was mortality associated with aquatic drift fences. Although we checked these traps approximately every 12 hrs, two snakes were found dead (50% mortality rate), raising possible non-target animal-welfare concerns. Also, the method by which this trap type works (entanglement) poses possible bycatch-related problems, and may lead to entanglement other animals such as birds, beavers, turtles, and fish.

Modified minnow traps were completely ineffective at capturing watersnakes, with no captures in 1,940 trap-nights. Coverboards were only slightly more productive, with one capture among the 85 boards. Coverboards may become more effective as they become seasoned and accepted by watersnakes as a resource available to them.

Distribution

We have found watersnakes distributed from the ponded dredger tailing ponds beside Creekside Oaks retirement community, at the corner of Blue Ravine Road and Oak Avenue Parkway, southwest to Lake Natoma at its confluence with Willow Creek (see Figure 10). We have not observed *N. fasciata* in Willow Creek northeast of its confluence with Humbug Creek (see Figure 10). Native pond turtles (*Actinemys marmorata*) and non-native pond sliders (*Trachemys scripta*, Appendix D) were often observed during surveys (Stitt et al 2004).

Radio Telemetry

We implanted four snakes (two males, two females) with transmitters in October 2003. The small number of implanted snakes and the late date of implantation were unfortunate results of the difficulty we had finding and capturing watersnakes later in the study (see above).

Males

Two adult males, numbers 724 and 823, were released at their point of capture on October 16, 2003. Number 724 was tracked 52 times before the snake stopped moving and we were unable to determine the exact location of the snake (the transmitter signal appeared to emanate from a nest in a stand of large oaks, thus we believe #724 was preyed upon by a raptor. The transmitter was never recovered).

Over 258 days, male #724 moved an average of 30.9 m per day and a maximum distance of 491.2 m between successive telemetry locations (Table 3). Over the same time period, the average speed of this snake was 6.1 m/day, and the maximum speed was 61.4 m/day. Male #724 had a minimum convex polygon home range size of 4.37 ha (Table 3; Appendix E). The core use area (50% fixed kernel estimate) for this snake was 0.01 ha, and 95% of locations were predicted to be within 0.13 ha.

Table 3. Movements and home ranges of two male and two females southern watersnakes.

#	Sex	AvgD (m)	MaxD (m)	AvgS (m/day)	MaxS (m/day)	MCP	50%	95%
724	M	30.9	491.2	6.1	61.4	4.37	0.01	0.13
823	M	35.0	259.0	6.9	102.4	13.7	0.01	0.13
128	F	--	40.5	--	--	--	--	--
455	F	17.6	49.6	0.8	49.6	0.20*	0.008*	0.10*

* Female 455 was located only 14 times, as such these home range estimates are uncertain.

Male #823 was tracked 52 times between October 16, 2003 and June 30, 2004 when the snake was assumed dead. Over 258 days, #823 moved a maximum distance between successive telemetry sessions of 259.0 m, a mean distance of 35.0 between sessions, and a total (cumulative) distance of 1.783 km (see Table 3). The snake moved at a mean daily speed of 6.9 m/day, and a maximum speed of 102.4 m/day. This snake had a relatively large minimum convex polygon (MCP) home range of 13.7 ha. The core use area for #823 was 0.01 ha, and 95% of locations were predicted to be within 0.13ha.

Interestingly, both males overwintered within 2 m of each other. The overwintering site in 2003 – 2004 was at the southwestern edge of a pond at Creekside Oaks, underground, and possibly below water-level. The two males moved very little in December 2003 and not at all in January and February 2004, indicating that hibernation did occur. They became increasingly active in March and April, and were completely active from May through June. Movements and MCP home ranges for both males are presented in Appendix E.

Females

Two females, numbers 128 and 455, were released at their point of capture. Number 128 was a large melanistic snake with a partial tail (resulting from a previous unsuccessful capture attempt by us in July, 2003). She was released on October 17, 2003 and tracked only three times before she was found dead on October 24, 2003 (total of seven days). Over that time, she moved a minimum of 8.1 m and a maximum of 40.5 m between telemetry sessions (see Table 3). Because we had so few telemetry locations for this snake we did not analyze home range data.

Female number 455 was released on October 17, 2003, and tracked 14 times until November 23, 2003, when she was observed giving birth. During those 37 days, she moved an average of 17.6 m between telemetry locations, and a maximum of 49.6 m (see Table 3). She moved a minimum speed of 0.8 m/day, and a maximum of 49.6 m/day (straight-line distance between successive locations). This snake established a short-term minimum convex polygon home range of 0.19 ha. Ninety-five percent of locations were within 0.10 ha (95% kernel estimate), and the core use area (50% fixed kernel) for this snake was 0.008 ha. Both estimates are obviously underestimated.

On November 23, 2003 number 455 was located at 1330 hr in the process of giving birth. Several neonates were collected from the near vicinity still in their embryonic sacs. The female was also collected at this time. All were euthanized.

Behavior, Habitat, and Temperature

Telemetered snakes were hidden most of the time (88% of telemetry occasions; n = 106), and visible 12% of the time (n = 15). The activities for telemetered snakes were unknown for 84% of observations (n = 91). Of the other 16% of observations, snakes were either not moving (11%; n = 12), swimming (2%; n = 2), on land moving toward water (2%; n = 2), or found dead (one snake; 1% of observations). For 52% of locations, the substrate could not be determined (n = 58), 30% of snake locations were underground (n = 33), 7% of locations were in rock or cobble (n = 8), 6% were in vegetation or debris on the ground (n = 7), 2% were on vegetation on or over water (n = 2), 2% were below water (n = 2), and one snake was in open water (1% of observations). The body position of snakes could not be determined for 86% of locations (n = 95); recorded positions were stretched out (n = 6), coiled (n = 4), partially coiled (n = 4), or moving (n = 2). Also, for 86% of snake locations, the proportion of snake in the sun could not be determined. The other 14% of locations were in deep shade (n = 5), <10% sunlight (n = 4), 10 – 25% sunlight (n = 3), 50 – 75% sunlight (n = 2), or 75 – 100% sunlight (n = 2). Snakes kept close to water, with 34% of observations being within one meter of water's edge (n = 39) and another 41% being within one – three meters (n = 47).

At the broad habitat scale, 91% of watersnake telemetry sightings were in freshwater marsh (n = 108), 8% were at a marsh edge (n = 10), and one was within a natural marsh. Watersnakes were most often found in Himalayan blackberry (56% of sightings; n = 62), followed by cattails (24% of sightings; n = 26), grass (n = 9), and water primrose (n = 8). Due to their use of blackberry, snakes were most often found in dense vegetation: 49% of locations were in vegetation with 25 to 75% cover. Seventy-two percent of locations were in vegetation greater than 100 cm in height, and 16% were in vegetation 50-100 cm in height.

For the telemetry-tracked males, body temperatures were dependent on the snake's distance to water, the temperature of the substrate (ground temperature) and water temperature, but did not vary according to ambient temperature (multiple regression: H_20 temp $F_{1, 81} = 3.86$, $p = 0.053$; substrate $F_{1, 81} = 9.49$, $p = 0.003$; air $F_{1, 81} = 0.58$, $p = 0.45$). Excluding body temperatures during hibernation, the mean body temperature for snakes during our telemetry sessions was 20.4°C, which did not vary between snakes ($t_{74} = 0.47$, $p = 0.64$). Daylight body temperatures during hibernation averaged 14.5°C, which also did not vary between snakes ($t_{74} = 0.59$, $p = 0.56$). The difference in body temperature between the active season and hibernation was statistically significant ($t_{74} = 4.22$, $p = 0.0001$).

Other Incidental Observations

An unsolicited report from workers at the Kelly Moore paint center (overlooking the "Kelly Moore ponds") described a "mass of snakes" they observed in June 2003 in the pond directly north of the establishment. Five to eight snakes were observed swimming in a writhing mass, seemingly concentrated on one snake at the center of the ball. An exact count of the number of snakes was not made, nor was a determination of the sexes involved. This sighting is consistent with reports for other watersnakes that describe "mating balls" of males concentrated around reproductive females (Tinkle and Liner 1955, Mushinsky 1979).

We observed courtship behavior between two (presumed male and female; one noticeably larger than the other) snakes at the Creekside Oaks ponds on June 26, 2003, at 0930 hr (Figure 16). We watched two melanistic snakes for approximately 20 minutes. Both were situated primarily out of water, draped across an exposed log. The smaller of the two was the more active, and appeared to be nose- and chin-rubbing the larger snake. The snakes' tails were not visible so we cannot conclude that copulation or intromission occurred. However, the observed behavior is consistent with courtship rituals observed by us in closely related coast range garter snakes (*Thamnophis atratus*; Eric Stitt, pers. obs.).

Figure 16. Two adult *N. fasciata* engaged in (presumed) courtship ritual, June 26, 2003, at Creekside Oaks study site. The male (lower right) engaged in tongue-flicking and tactile chin-rubbing of the female (upper left).

Genetics

In total, we examined 2,790 base pairs of sequence for each of 6 individuals. Nucleotide diversity and polymorphism statistics were zero among our sample set and there were no differences among the individuals sampled. However, our sequences did show differences in comparison to GenBank sequences in the ND2, and cytochrome b regions. For the control region, we examined 369 base pairs of sequence for 7 individuals. The Folsom samples matched exactly that of "Haplotype A" (accession # AY269791; Jansen & Karl, unpublished data), associated with samples collected from Volusia, Pinellas, and Hillsboro Counties in Florida, and therefore represent individuals of *Nerodia fasciata pictiventris.* Volusia County is along the eastern (Atlantic) coast, and encompasses St. Augustine. Pinellas and Hillsboro Counties are along the western (Gulf) coast, and correspond to the St. Petersburg area.

Other *Nerodia*

Brownsville Nerodia fasciata

Conant (1977) reported an introduced, breeding population of *Nerodia fasciata pictiventris* from Brownsville, Texas, located approximately 200 km southwest of its native range. The snake was likely introduced through intentional and accidental releases by a commercial reptile dealer (The "Snake King") over a period of years from approximately 1910 to the mid-1950's (Conant 1977, Patrick Burchfield pers. comm.). The population was formerly most numerous in the resaca system (old oxbow formations associated with the Rio Grande River) adjacent to Gladys Porter Zoo, and apparently remained localized. Several other non-native reptile species were liberated by the same dealer over several decades, with Conant (1977) attributing the establishment of a non-native population of *Ctenosaura pectinata* (spiny-tailed iguana) to the same dealer.

To our knowledge *Nerodia fasciata* has not been collected from the Brownsville area since the mid-1970's, despite several informal surveys by Drs. Jim Dixon and Glenn Tipton (Texas A and M, Arlington) and Dr. Patrick Burchfield (Gladys Porter Zoo, Brownsville). One individual may have been observed crossing a street between resacas in August 2001 (Maxwell Pons pers. comm., The Nature Conservancy's Southmost Preserve). The observer was certain of its identification based on characteristic "wormlike" markings observed on the venter of the snake as it raised its anterior body while lunging across the road. However, that snake was not collected, thus the identity can not be verified.

Despite approximately 30 person/hours of survey effort by us in that aquatic system in April, 2004, no *N. fasciata* were confirmed. Several of the native *N. rhombifer* were captured and photographed, and one very dark snake, possibly *N. fasciata*, was observed foraging. Again, positive identification could not be made and it remains unknown whether the introduced watersnake still exists in Brownsville. If *N. fasciata* persists, it appears to be much less abundant than the native *N. rhombifer*, and seems to have not spread in distribution. We cannot conclude whether *N. fasciata* had any detrimental impact on the ecosystem, but researchers in the area feel that its impact was probably benign (Jim Dixon pers. comm., Patrick Burchfield pers. comm.).

Lafayette Nerodia rhombifer

Diamond-backed watersnakes were first observed in Lafayette Reservoir in the late 1980's (Contra Costa Sun, July 3, 1996). Two watersnakes, collected June 2, 1990, were accessioned from this population into U. C. Berkeley's Museum of Vertebrate Zoology (see Appendix C); whether these represent original releases or later-generation individuals is unknown. Presumably, the original propagule consisted of released captives, probably unwanted pets. By the early 1990's the snakes had reached high densities, with as many as 5-10 snakes observed at once basking on piers, tules (*Scirpus* spp.), and sunny, exposed banks of the reservoir (Contra Costa Sun, July 3, 1996, WCT 1997).

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 aggressive and incidents may have occurred where fishermen reeled in their catch only to realize that a watersnake was also at the end of the hook (Contra Costa Sun, July 3, 1996). Concerned about recreational and liability issues, EBMUD solicited proposals in 1992 to learn more about the introduced snake population. In 1996, EBMUD awarded a contract to Wildlife Control Technology, Inc. (WCT) to evaluate capture methods and summarize the pertinent literature regarding the Diamond-backed watersnake (Contra Costa Sun, July 3, 1996; WCT 1997). Also, EBMUD posted signs around the reservoir alerting visitors to the presence of the watersnakes and asking for sightings to be reported to EBMUD employees.

Using hand capture and three baited trap types, WCT captured 35 diamond-backed watersnakes between June 17, 1996 and January 28, 1997 (WCT 1997). They found that aquatic funnel traps were effective for capturing diamond-backed watersnakes, capturing 31 of 35 with this method (89%). Three snakes were captured by hand or modified tongs (9%), and one was apparently captured by hook-and-line (3% of captures; percentages sum to greater than 100 due to rounding error). Other trap types tested by WCT were completely ineffective. WCT determined that an "original estimate of 200 snakes made by park staff is realistic and possibly conservative" (WCT 1997, page 10). Fifty-nine percent (22/37) of snakes captured were females, with eight (36%) being gravid. WCT (1997) did not report the number of males captured; however, if the other 41% of snakes were male, then a 0.7:1.0 male:female sex ratio was indicated by their capture results. Only one of 31 snakes had any stomach contents, a blue gill (*Lepomis macrochirus*).

Biologists concluded that night-collection was ineffective, with only three snakes observed during spotlighting activities; however, 59% of trap-captures were made between 1800 and 2400 hr (WCT 1997). As many as five to ten snakes were observed at a time. Snakes were highly visible during diurnal surveys, with "several" snakes observed sunning and swimming on June 26, 1996, "multiple numbers of snakes sunning together on rafts of tules, tops of submerges trees and overhanging brush" on June 27, 1996, "multiple sightings of snakes sunning" on July 13, 1996, and "multiple snakes observed at various locations sunning" on January 28, 1997 (WCT 1997). The date of the latter observation is particularly noteworthy as it indicates winter activity by these snakes, suggesting that hibernation did not occur within this population. Apparently, no snakes were observed during surveys on other days throughout the study period.

Several recommendations were made in the final report as to how to better control the watersnake population, including the use of spot lighting and shooting with a small-caliber shotgun, modified 244-cm (8 ft) tongs (tried and determined to be "largely ineffective"), electro-shocking, habitat modification, water-level manipulation, Rotenone® application, and vegetation control (WCT 1997). A combination of trapping, shooting, and water-level reduction was suggested as the best strategy for complete eradication, but shooting and water-level reductions were dismissed as being unfeasible. Repeated attempts to contact the lead biologist on this study (David Chesemore, California State University, Fresno) to clarify several aspects of the report (e.g., locations of traps, body-size distribution, deposition of specimens captured) went unanswered.

In December, 1997, a biological consultant was hired to continue and increase the control effort. However, after the contract was awarded and as the work was beginning, that individual and others observed large numbers of dead watersnakes, together with dead red-eared sliders (*Trachemys scripta*; a non-native turtle species), throughout the reservoir (Gary Beeman, pers. obs.; Contra Costa Times, January 31, 1999). The cause of the die-off is unknown, but watersnakes that were dissected were found to contain a yellow "fungus" throughout the respiratory tract, leading to speculation that a fungal respiratory disease was responsible (Gary Beeman, pers. obs.; Contra Costa Times, January 31, 1999). Unfortunately, no snakes were saved or accessioned at museums during that time period. The die-off was severe and may have been complete. No watersnakes have been confirmed at Lafayette Reservoir since late 1999 (Gary Beeman, pers. obs.; Roger Hartwell, pers. comm.), although sightings are occasionally reported to reservoir workers. Speculation in a newspaper article from the time suggests that a wet El Nino pattern may have facilitated the pathogen outbreak (Contra Costa Times, January 31, 1999).

Incidental Reports of Nerodia

In California, one *N. fasciata* was collected in 1976 near San Pablo Reservoir in Contra Costa County. That specimen is now housed at the Museum of Vertebrate Zoology (U. C. Berkeley), and is thought to represent an isolated occurrence (see Appendix C). Also, Bury and Luckenbach (1976) report a specimen of *N. fasciata* collected in western Los Angeles County, also thought to be an isolated instance.

To our knowledge, two watersnakes have been collected from the wild in Arizona. First, a specimen of *Nerodia rhombifer* was collected by Arizona Game and Fish Department while conducting field work on ranid frogs on Fort Huachuca (Sredl et al. 2000). The authors believed this was a released pet, thus an isolated occurrence. Lastly, Dale DeNardo (ASU Dept. of Biology) collected an unidentified *Nerodia* in fall of 1998 while crossing Ahwatukee Road, which bisects two golf courses in Phoenix (Dale DeNardo pers. comm.). It is unknown whether a population exists at that locale, as surveys have not been conducted in the area.

DISCUSSION

As evidenced by the more than 100 southern watersnakes captured and born to captive watersnakes in Folsom, *N. fasciata* joins 12 other non-native amphibians and reptiles now established in California (Appendix F). Some evidence indicates that the population density is much lower now than when we started this project, but many data gaps and distributional questions remain. The following discussion, although speculative, outlines major concerns that should be addressed by future research on *N. fasciata* in northern California and serves to document our concern that, if left unchecked, this snake has the potential to seriously disrupt the already-altered aquatic ecosystems of the Sacramento region.

Beyond documenting population attributes for this snake, establishing a context for this invasion is another goal of this report. Thus, we assess the presence of southern watersnakes in Folsom in the context of our knowledge of invasive species biology. The success of species invasions can generally be attributed to the interaction of two broad categories. Species attributes are those aspects of a species' biology that facilitate dispersal, rapid population growth, or efficient utilization of resources. Site invasibility traits are features of a site that enable a species, given the opportunity, to establish and flourish in a new geographic area. Thus, the ideas raised here should be considered from both perspectives: those *intrinsic attributes* that allowed *N. fasciata* to establish and become successful, and *landscape features*, often facilitated by anthropogenic changes, that made Folsom suitable for the establishment of the southern watersnake.

Distribution and Habitat

A species' distributional range is determined by the distribution of habitat, defined here as a physical space with all the biotic and abiotic factors needed for a species to survive and reproduce (Morrison et al. 1998). Thus, physical areas for foraging, refugia, over-wintering, and thermoregulation need be present. Prey must be present and readily accessible. Temperatures and other environmental conditions (e.g., water quality, dissolved O_2 concentrations, humidity) must be within the range of physiological tolerances acceptable for a species, and densities of predators and parasites must be at acceptably low levels. Many of these factors may vary between life-stages and sexes for a species. What follows is a discussion of factors that may influence the distribution of *Nerodia fasciata* in northern California.

Present and Potential Distribution

The range of the southern watersnake has apparently expanded since it was first discovered in 1992, although wide-spread surveys were not conducted at that time. Southern watersnakes now occur upstream in the creek system from their original point of discovery, possibly occurring in Folsom Lake. The more troubling finding is that they now occupy at least a portion of the American River at Lake Natoma. Having had no reports of their occurrence from the Nimbus Fish Hatchery as yet, we cannot conclude how far downstream in the American River they occur. However, it is likely that snakes will disperse downstream: habitat is suitable and we suspect that high water events will aid dispersal.

The distribution of *N. fasciata* in northern California will always be closely tied to the availability of standing water. Their prey is aquatic and most aspects of *N. fasciata*'s ecology are related to water (e.g., foraging, mating, escape behavior). In their native range, *N. fasciata* is a habitat generalist and occurs in "rivers, streams, lakes, reservoirs, swamps, and small wetlands" (Gibbons and Dorcas 2004); virtually every type of water feature that occurs in California. Although in Folsom to date the snake has primarily been found in small creeks and ponds, we have documented it from Lake Natoma, a large, lotic water body northeast of the Sacramento/San Joaquin Delta. We must assume that most aquatic features from Folsom Lake south throughout the Central Valley are suitable, and that there will be no lack of habitat if *Nerodia fasciata* disperses downstream.

As stated previously, we have received unverified reports that the snake may occupy parts of Folsom Lake (e.g., Beals Point). If so, even if eradication/control efforts in Humbug and Willow Creeks are ultimately successful, the lake may serve as a source population for downstream dispersal. Surprisingly, given its commonness in its native range, few data are available regarding movements or dispersal patterns. Our limited movement data indicate that males move a maximum distance of 0.5 km at a time. It appears there were no dispersal-related movements during our study. However, limited evidence indicates that males occupy a rather large area over time, and in our study moved from one discrete pond to another.

Although we did not see dispersal, Holman and Hill (1961) documented a mass, unidirectional migration of *Nerodia fasciata pictiventris* in Florida. Over two nights, 128 of 130 snakes found crossing a road were oriented in the same direction. The authors speculated that the population-level movement was a response to unusually dry weather conditions. Applying this observation to Folsom, spread of the introduced population may be facilitated during dry years when snakes would disperse from drying habitats to inundated features. This argues against intentional drying-down of waters as an eradication method.

Our preliminary telemetry study confirmed, in part, what we already suspected regarding aspects of *N. fasciata*'s biology in Folsom. First, these snakes are infrequently seen: we obtained visual confirmation of a snake's location only 15% of the time (disregarding locations from December through February during which hibernation occurred), even though snakes were tracked to within 1-2 meters of their exact location. This observation has several implications.

First, although we have hand-captured approximately 70 snakes, there are undoubtedly many that we did not observe during every outing. In fact, if the 15% detection rate we observed for two radio-transmittered males can be generalized to all other adult males and females, then for every adult watersnake we saw there may be at least six that we did not observe. Such generalizations should not be taken as rigorous population indices however, as many variables undoubtedly influence the encounter rate, including habitat complexity, sex and size of the animal, and an individual snake's propensity to flee or stay put when disturbed. The fact that all hand-captured snakes for which we determined sex turned out to be females indicates that the encounter rate does differ between sexes, with females being encountered more often. With additional telemetry work, with a larger sample size and an emphasis on females, we should be able to better estimate encounter rate, and thus develop an index to population abundance.

Transmittered snakes were often not observed because they were underground in rip-rap (hibernation), under water, or in dense vegetation, primarily blackberry brambles. Most locations were within three meters of the water's edge. Future trapping efforts might be optimized by saturating waters near areas of dense vegetation with a variety of trap types. Indeed, much work will be needed to identify alternate trap types and optimal trap placement strategies. Future radio-telemetry data might provide more insight into space-use behaviors that could be exploited.

We documented that hibernation occurs in this population, and very limited evidence (n = 2) indicates that there might be winter aggregating behavior. If future radio telemetry confirms that communal hibernation occurs, then the use of a "Judas goat" might be employed as a management strategy. Using such a technique, one or more telemetered animals may lead researchers to winter aggregations at which snakes might be accessed and euthanized.

Prey

We have no information regarding diet of *Nerodia fasciata* in Folsom. Our captive specimens fed upon bullfrog tadpoles and various fishes (e.g., goldfish, frozen sardines). In its native range, *N. fasciata* is a dietary generalist, eating hylid, bufonid, and ranid frogs, and 17 genera of fish, including Centrarchids, Ictalurids, and Poeciliids (Gibbons and Dorcas 2004 and references therein). American bullfrogs (*Rana catesbeiana*) are the most commonly encountered amphibian in the study area, presumably having completely replaced the native California red-legged frog (*Rana draytonii*). Hylid frogs (*Hyla regilla*) and western toads (*Bufo boreas*), although present in Folsom, may not comprise a large proportion of *Nerodia fasciata*'s diet except, perhaps, when present in large breeding aggregations. Additionally, the latter species is highly toxic. Whether some life stages of *Bufo boreas* are palatable to southern watersnakes warrants future research. Introduced fish species including bass, catfish, and mosquitofish all reach high population densities in the study area, particularly in the ponds. Thus, regarding prey, the southern watersnake in northern California has "all the comforts of home" in the form of ample and familiar prey items.

Temperature

As expected for ectotherms, we found a difference in body temperatures between active and non-active seasons. Moreover, body temperatures were positively related to water and substrate temperatures, but interestingly, not to ambient temperature. It is unknown what (if any) temperature cues facilitate the start of hibernation in *N. fasciata* in Folsom, or whether the snakes hibernate every year. Because snake body temperatures were dependent on water and substrate temperatures, some lower threshold in one or both temperatures may have provided the cue(s) necessary to initiate hibernation.

Gibbons and Dorcas (2004) indicated that in North Carolina, the northern and western distributional limits for *N. fasciata* coincided with an average annual temperature isopleth of 16°C. Areas that had lower average annual temperatures were occupied by the closely related *Nerodia sipedon* (northern watersnake), with which *N. fasciata* hybridizes. In our area the average annual temperature for Folsom Dam is 16.5ºC (Western Regional Climate Center, http://www.wrcc.dri.edu/CLIMATEDATA.html, data collected at 38.70°N 121.16° W). We established that the Folsom *Nerodia* are most likely from peninsular Florida, in the southern part of their range. Although we might expect local adaptation of Floridian *N. f. pictiventris* to higher average annual temperatures, this snake has persisted for at least one decade in Folsom where the average annual temperature is only slightly higher than 16ºC, indicating that over the short-term local temperatures have not limited the population. Whether *Nerodia fasciata* is limited by temperatures over a longer time period remains to be seen.

Genetics

Although our sample size for the genetic analysis was small, the lack of any variability among samples suggests that the introduced population came from a single maternal lineage. Further testing of autosomal markers (microsatellites) may allow us to determine with more certainty whether the original introduction consisted of many different individuals or only a few (or if only a few snakes survived to establish the population). It is questionable how long a population can persist with low genetic diversity and consistent inbreeding, but there are natural and introduced populations (Wayne et al. 1991, Gray 1995) with low genetic diversity that show no adverse effects.

It has been proposed that invasives are commonly generalists that can easily adapt to new environments (Hänfling and Kollmann 2002), and from a molecular standpoint it might be expected that a species with the potential to become invasive would come from a population with high genetic diversity, thus increasing the likelihood that an individual would, by chance, have the necessary genetic make-up to survive in a new area (Hänfling and Kollmann 2002; Lee 2002). However, once established, the genetic diversity in the introduced population usually remains extremely low as a result of rapid population growth and inbreeding (Patti and Gambi 2001). How invasives survive over time with such a small pool of genetic diversity obviously warrants further study. In this larger context, further research of this population by using autosomal markers may give us a better understanding of how populations of invasive species can persist despite decreased genetic material. Also, with the above comments under consideration, it would be very informative to sample the Brownsville, Texas population of *N. f. pictiventris* (Conant 1977), if it persists, to see if snakes in the two populations share a common origin. We are currently pursuing plans to that end.

There are records of parthenogenesis for closely related gartersnakes (Schuett et al. 1997, Murphy and Curry 2000), suggesting the intriguing possibility that *N. fasciata* may occasionally reproduce via parthenogenesis. Parthenogenesis in otherwise sexually reproducing snake species is a recently documented phenomenon which could be investigated with a more detailed genetic study (Dubach and Sajewicz 1997, Groot et al. 2003). Two questions are immediately apparent given this possibility; first, can *Nerodia fasciata* reproduce via parthenogenesis under some conditions, and second, has parthenogenesis occurred in the Folsom population?

Habitat Alteration

In the previous 150 years, the Folsom/American River landscape has undergone drastic changes. Hydraulic and placer mining were used extensively in the area from 1849 through the early 1950's (Figure 17) (Orme 2002). These mining methods were environmentally destructive, involving the movement of massive amounts of material from rivers, creeks, and associated upland areas. The materials left behind after gold and ores were extracted (the tailings) were either dumped back into the streams and rivers, leading to massive siltation, or piled into high, nutrient-barren piles of cobble. The destructive nature of these activities led to severe alteration of both aquatic and terrestrial communities (Figures 18 and 19) (Orme 2002).

Prior to recent times, most aquatic features in the area were ephemeral in nature, flooding during winter and spring rains, and drying completely during the hot, rainless summer months (Moyle 2002). More recently, Sacramento County has been the focus of a massive population boom. The human population of Sacramento County has increased an average of 25% per decade from 1960 through 2000 (http://www.censusscope.org

/us/s6/c67/chart_popl.html). Urban development and associated infrastructure (roads, parking lots, and other hard surfaces) has led to once-ephemeral waters becoming increasingly perennial as a result of increased water run-off (Figure 20) (Moyle 2002). Thus, many historic depressions, seasonal ponds, and placer mining pits now contain water throughout the year. Combined, these changes served as prerequisites for the current invasion of non-native aquatic species, including crayfish, myriad fish species, and bullfrogs. The afore-mentioned species, like *N. fasciata*, all require perennial or near-perennial waters in which to carry out life history functions. It is very doubtful that bullfrogs, as one example, would have been so successful in northern California had the aquatic ecosystem remained unchanged (Moyle 1973). However, unlike the introductions of fish, crayfish, and bullfrogs, which were deliberately introduced by

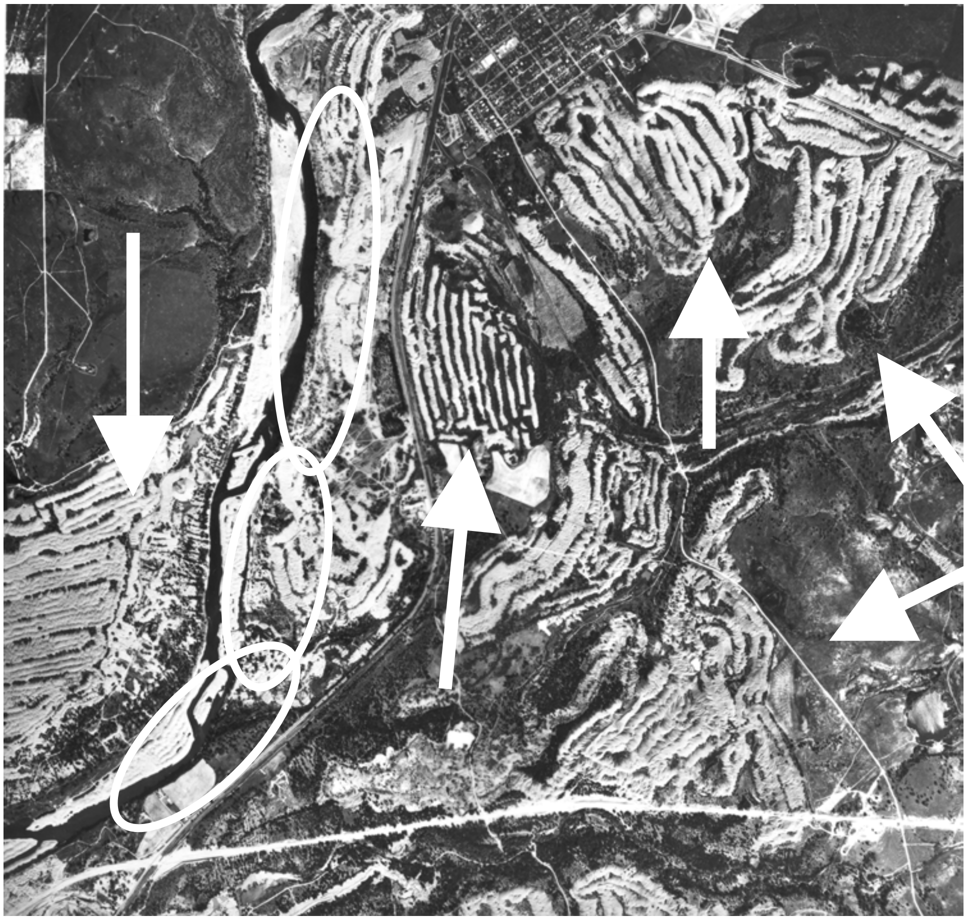

Figure 17. Folsom and the American River *circa* 1949 showing widespread damage due to hydraulic mining. Mine tailings are extensive throughout the area (arrows), and massive sand and cobble deposits are evident in the American River (circled).

Figure 18. Ponds at Creekside Greens. Scene here is typical of many waterways in Folsom and shows three levels of disturbance. First, the pond itself is the result of dredging and hydraulic mining. The linear waterway and high, piled cobble at the center of the picture are remnants of the extensive mining in the area early in the 20th century. Second, Himalayan blackberry (*Rubus discolor*) completely dominates the bank in the foreground. Lastly, the ponded water here is hypereutrophic. Dissolved oxygen levels are much reduced, and nutrient levels (nitrogen and phosphorus) have increased, feeding an algae bloom and favoring a warm-water, disturbance-adapted largely introduced aquatic fauna.

Figure 19. Invasive hyacinth (*Eichhornia crassipes*) near the California Department of Fish and Game restoration site (near Kikkoman factory). This site has been the target of a concentrated hyacinth eradication effort. Watersnakes have been captured here by hyacinth removal crews, but none have been observed by us during surveys (probably due to the dense growth of vegetation).

Figures 20a and 20b. Close-up of the east Bidwell Street/Blue Ravine Road section of the study area. Figure a is from 1994 and Figure b is from 2000. In the span of less than 10 years, Humbug Creek became much more perennial in nature and now supports such water-dependent species as bass, bluegill, and mosquitofish.

public agencies to provide game opportunities, the southern watersnake was an accidental introduction (i.e., not agency sponsored or condoned).

Potential Threats to Ecosystem

The federally threatened and state-protected giant gartersnake (*Thamnophis gigas*) occurs downstream in the American River/Natomas Basin, and portions of the Central Valley. The giant garter snake is considered an ecological analogue to eastern watersnakes (*Nerodia*) in that it is large-bodied, highly aquatic and has a diet that consists of fish and amphibians (USFWS 1999). Although studies showing invasive species outcompeting endemic species to the point of competitive exclusion are uncommon, we cannot rule out the possibility that *N. fasciata* could have negative consequences for our native, imperiled gartersnake.

The snake's introduction may also pose a threat to native fish. Interactions between southern watersnakes and native fish are impossible to predict, but are assumed to be a predator (watersnake) – prey (native fish) relationship. Although native fish are numerically less abundant than introduced game fish in this area (Moyle 2002), *N. fasciata* could potentially negatively impact native fish populations. Such threats should not be ignored: in fact, the Western Section of the Wildlife Society, a well-known society for wildlife biologists and managers, issued a statement of concern after it learned of the watersnake introduction in Folsom (Appendix G).

LAFAYETTE *NERODIA RHOMBIFER* AND BROWNSVILLE *N. FASCIATA*

The significance of the observed die-off of *Nerodia rhombifer* at Lafayette Reservoir should not be minimized. *Nerodia rhombifer* was an established invasive species, problematic to the point of requiring the EBMUD to allocate resources to its eradication. Before the die-off, snakes were very common, causing problems among lake users and raising insurance liability concerns among EBMUD staff. As a result of some unknown pandemic, the population that once numbered in the hundreds is now either extirpated or very rare. This "boom and bust" pattern has been observed in other introduced species (Simberloff and Gibbons 2004), but is unprecedented for snake populations (Dan Simberloff, University of Tennessee, pers. comm.; Jim Jarchow, Sonoran Animal Hospital, pers. comm.).

Even minor epizootics in snake populations have rarely been reported, but Cheatwood et al. (2003) described an outbreak of fungal dermatitis and stomatitis in *Sistrurus miliarius barbouri* (dusky pigmy rattlesnake). Dead and moribund individuals were found with severe legions in and around the mouth and eyes. Additional snakes were observed with less severe "multifocal subcutaneous masses or crusted scutes," and three individuals of two other species (ribbon snakes [*Thamnophis sauritis*] and common gartersnakes [*T. sirtalis sirtalis*]) were also found with similar disease signs (Cheatwood et al. 2003). Examination of legions indicated mixed-fungal infections. Four fungi species were subsequently isolated from tissues, and of those, the authors felt that three possibly contributed to the observed conditions (the fourth was not known to be pathogenic except to plants). The proportion of snakes showing signs of infection was as high as 6.3%, but there was no indication of a reduction in population size.

To some degree the die-off at Lafayette was similar to the outbreak described above for *Sistrurus*. However, acute respiratory distress was associated with the Lafayette die-off, with “fungal spores” (not verified as such by a qualified pathologist) found throughout the trachea and lungs of dead snakes (Gary Beeman pers. comm.). The effects of epizootics on a population are usually density dependent, with more drastic results manifested in more-dense populations. Recently, it has been suggested to us that the disease signs observed at Lafayette were consistent with paramyxoviral infection or parasitic trematode or nematode infestations (Jim Jarchow, Sonora Animal Hospital, pers. comm.). Unfortunately, a great opportunity has been lost as we will likely never be able to confirm the exact cause of the outbreak. Additionally, the cause for such rare, devastating pandemics, once identified, is often attributable to a new taxon (Jim Jarchow, Sonora Animal Hospital, pers. comm.).

We have much less information regarding the status of the Brownsville *Nerodia fasciata*, but we tentatively conclude that the population is extirpated due to the lack of recent confirmed sightings. In the years since the population was reported by Conant (1977), Gladys Porter Zoo personnel have made many informal collecting efforts in the area (although not specifically for *N. fasciata*) and have not documented any (Patrick Burchfield pers. comm.). Texas’ most eminent herpetologist, has visited the area on several occasions, often with groups, and has not observed the snake in many years (Jim Dixon pers. comm.).

Having no evidence of a die-off, we assume that *Nerodia fasciata* persisted for a while with recruitment equaling or surpassing mortality. However, at some point the rate of mortality likely passed some threshold beyond which the population could not recover. Whether the population decline was mediated by competition with the native *Nerodia rhombifer*, by predation or parasitism, disease, or an inability to cope with environmental conditions is unknown.

UNRESOLVED QUESTIONS

These questions are particularly important to address in future studies of *N. fasciata* in Folsom:

1) How far downstream in the American River does *N. fasciata* occur?

2) What constitutes the snake's diet? What proportion of prey is of introduced or native aquatic species?

3) Does *N. fasciata* occur in Folsom Lake? Does the snake occur *above* Folsom lake or in areas downstream of Lake Natoma?

RECOMMENDATIONS

Continued Monitoring

We recommend that the Folsom *Nerodia fasciata* population continue to be monitored. At the very least, repeated surveys should be conducted several times each year during favorable weather conditions. The number of snakes observed should be noted, and attempts should be made to capture and remove any that are accessible. Key areas that should be included in monitoring include the Nimbus Fish hatchery and river-side habitat upstream from the hatchery, Lake Natoma, Beals Point at Folsom Lake, and all occupied ponds and intervening stream reaches within the survey area. Environmental conditions at each location should be noted, and water levels, particularly at the ponds, should be recorded. A systematic method to quantify other invasive aquatic species (*Trachemys scripta*, *Rana catesbeiana*, non-native fish, crayfish) should be included in the monitoring effort. Systematic surveys for native garter snakes and breeding aggregations of native amphibians should also be considered.

Radio Telemetry

Another radio-telemetry study should be planned, particularly if numerous snakes continue to be captured. Data gathered from such a study will help address behaviors that researchers can use to further the eradication/control effort and may provide insight into population dynamics and detectability. With more rigorous estimates of detectability, population indices may be developed.

From a theoretical perspective, radio-telemetry may reveal differences in behaviors between the Folsom, California population and native populations, and may indicate local adaptation to climatic conditions, among other possibilities.

Development of More Effective Traps

A priority for future work should be the evaluation and testing of different trap types. We were surprised that floating minnow traps, developed for capturing giant gartersnakes (Casazza et al. 2000), were completely ineffective. However, Rodda et al. (1999) show that for brown treesnakes (*Boiga irregularis*), cues used during foraging can be complex, dictating a need for varied trapping techniques. For that species, a succession of 49 different trap types were evaluated over a period of approximately 12 years, for a total of more than 24,000 trap-nights. A "state-of-the-art" trap was developed for brown treesnakes that uses minnow traps as the foundation, altered with an internal mouse chamber, a black plastic sleeve around the outside of the trap, an inner tube made of small diameter black plastic, and a tilted entrance flap. This design was developed over 12 years, and it appears there is still room for improvement (Rodda et al. 1999). The same paper contains an appendix that includes information on 322 trap type/snake species combinations, many of which resulted in no captures for the entire effort, indicating that much more research is needed regarding the science of snake trapping.

Eradication Program

After more efficient traps are designed, a systematic eradication/control program should be developed and implemented. Landowner cooperation should be obtained for all areas within the currently occupied range, and all suitable areas should be saturated with traps.

Diet Analysis and Foraging Ecology

To date we have very little information concerning the diet of *Nerodia fasciata* in northern California. We suspect this is a matter of our capture procedures rather than of a food-limited diet. *N. fasciata* is an active snake, with a faster average metabolism than many other snakes with which we are familiar (Crotalids [rattlesnakes]; Boids [boas]; colubrids such as *Lampropeltus getula* [kingsnake], *Pituophis catenifer* [gophersnake]). Many watersnakes were not euthanized immediately after we captured them, but instead were held captive for one to three days. Over that short period of time, digestion appears to have been complete in almost all cases. Additionally, if American bullfrog tadpoles comprise a significant proportion of the diet (they are often the most conspicuous prey items at a locale), these soft-bodied organisms are probably digested very quickly. Future capture protocols should explicitly state that watersnakes be euthanized, and stomach contents preserved, within one hour of capture. An ice-filled cooler should be kept during any field work to facilitate this process.

Body Condition Index

A dissection protocol should be developed for future studies. Fat bodies for all snakes should be weighed so that a body-mass index can be developed, and questions regarding food limitation can be addressed and compared with other populations. Reproductive condition should be determined for all snakes (rather than only females), which would help determine 1) age at first reproduction for males and females, 2) seasonality of reproduction, and 3) whether the timing of reproduction differs in Folsom relative to natural populations. Presence of sperm in *vas deferens* should be determined microscopically.

Comparative Ecology of *Nerodia fasciata* and *Thamnophis gigas*

A study should be designed that addresses questions related to ecological similarities between *N. fasciata* and *T. gigas*, the degree to which resource use overlaps between the species, and potential interspecific competition. Collaboration with USGS biologists and graduate students and other experts currently studying aspects of *T. gigas* ecology may be very productive. Diet comparisons between sexes and age classes should be made, and space-use patterns should be compared. Microhabitat associations and activity periods should also be compared. Assays of parasites may reveal differences in susceptibility between the two species, and may contribute to the development of possible eradication strategies.

SUMMARY

It is apparent that *N. fasciata* possesses pre-adaptations that allow the snake to use resources found in the Folsom, California area. Specifically, in Folsom, this eastern U.S. snake faces 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 this introduction may be, in reality there is no way of knowing until the impacts are manifested. Such impacts may include predation on native fish or frogs, or competition with native snakes, particularly

Thamnophis gigas. 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.

Based on information from Conant (1977) and us (Balfour and Stitt 2002) the USGS now recognizes *Nerodia fasciata* as a nonindigenous aquatic species (http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=2271). Going further, we suggest that all *Nerodia* should be added to invasive species watch lists as possible invasive species. In the western United States, it is largely a biogeographical accident that *Nerodia* do not occur naturally. Certainly, California features an array of potentially suitable aquatic habitats. However, like many eastern aquatic vertebrates (*Rana catesbeiana*, *Trachemys scripta*, *Lepomis*), the Rocky Mountains were a barrier to dispersal, enabling *Thamnophis gigas* to occupy the "large aquatic snake" niche in California's Central Valley (and allowing *Thamnophis rufipuntatus* and *T. eques* to assume somewhat similar niches in Arizona). Now, facilitated by human means, watersnakes and other eastern aquatic herpetofauna can readily 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, we believe it is imperative to reduce the rate of introductions, through restricting importation of non-native aquatic species.

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LITERATURE CITED

Alfaro, M.E., and S.J. Arnold. 2001. Molecular systematics and evolution of *Regina* and the Thamophiine snakes. Molecular Phylogenetics and Evolution 21:408-423.

Arévalo, E., S.K. Davis, and J.W. Sites, Jr. 1994. Mitochondrial DNA sequence divergence and phylogenetic relationships among eight chromosome races of the *Sceloporus grammicus* complex (Phrynosomatidae) in central Mexico. Systematic Biology 43:387-418.

Balfour, P. S. and E. W. Stitt. 2002. Geographic distribution. *Nerodia fasciata fasciata* (banded watersnake). Herpetological Review 33:150.

Bauman, M. A. and D. E. Metter. 1975. Economics, feeding, and population structure of *Natrix s. sipedon* in a goldfish hatchery. Progressive Fish-Culturist 37:197 – 201.

Brode, J. 1993. Notes on an introduced population of diamondback water snake (*Nerodia rhombifera*) population at a beaver pond on Humbug Creek within the City of Folsom. Unpublished report to California Department of Fish and Game.

Brown, D. 1999. The *Nerodia rhombifera* problem. Unpublished report to California Department of Fish and Game.

Bury, R. B. and R. A. Luckenbach. 1976. Introduced reptiles and amphibians in California. Biological Conservation 10:1-14.

Casazza, M. L., G. D. Wylie, and C. J. Gregory. 2000. A funnel trap modification for surface collection of aquatic amphibians and reptiles. Herpetological Review 31:91 – 92.

Cheatwood, J. L., E. R. Jacobson, P. G. May, T. M. Farrell, B. L. Homer, D. A. Samuelson, and J. W. Kimbrough. 2003. An outbreak of fungal dermatitis and stomatitis in a free-ranging population of pigmy rattlesnakes (*Sistrurus miliarius barbouri*) in Florida. Journal of Wildlife Diseases 39:329 – 337.

Clark, R. F. 1949. Snakes of the hill parishes of Louisiana. Journal of the Tennessee Academy of Science 24:244 – 261.

Conant, R. 1977. The Florida water snake (Reptilia, Serpentes, Colubridae) established at Brownsville, Texas, with comments on other herpetological introductions in the area. Journal of Herpetology 11:217-220.

Conant, R. and J. T. Collins. 1998. Reptiles and Amphibians: Eastern /Central North America. Houghton-Mifflin Co, Boston.

Contra Costa Sun, July 3, 1996. Water snakes on last legs at Lafayette Reservoir *by* Tony Hicks Sun staff writer.

Contra Costa Times. January 31, 1999. Lake-invading snakes die off *by* Dennis Cuff, Times staff writer.

Crother, B. I., J. Boundy, J. A. Campbell, K. de Queiroz, D. R. Frost, R. Highton, J. B. Iverson, P. A. Meylan, T. W. Reeder, M. E. Seidel, J. W. Sites, Jr., T. W. Taggart, S. G. Tilley, and D. B. Wake. 2001. Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in Our Understanding. SSAR Circular # 29.

Crump, M. L. and N. J. Scott. 1994. Visual encounter surveys. Pages 84 – 92 *in* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians, W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster, eds. Smithsonian Institution Press, Washington, D. C.

Dubach, J. and A. Sajewicz. 1997. Parthenogenesis in the Arafuran filesnake (*Acrochordus arafurae*). Herpetological Natural History, 5:11-18.

Feaver, P. E. 1977. The demography of a Michigan population of *Natrix sipedon* with discussions of ophidian growth and reproduction. Ph. D. dissertation, University of Michigan, Ann Arbor.

Fellers, G. M. and C. A. Drost. 1994. Sampling with artificial cover. Pages 147 – 150 *in* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians, W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster, eds. Smithsonian Institution Press, Washington, D. C.

Gibbons, J. W. and M. E. Dorcas. 2004. North American Watersnakes: A Natural History. University of Oklahoma Press, Norman.

Goldberg, C. S., M. E. Kaplan, and C. R. Schwalbe. 2003. From the frog's mouth: buccal swabs for collection of DNA from amphibians. Herpetological Review 34(3):220-221.

Gray, E. M. 1995. DNA-fingerprinting reveals a lack of genetic-variation in northern populations of the western pond turtle (*Clemmys marmorata*). Conservation Biology 9:1244-1254.

Groot, T. V. M., E. Bruins, and J. A. J. Breeuwer. 2003. Molecular genetic evidence for parthenogenesis in the Burmese python, *Python molurus bivittatus*. Heredity 90:130-135.

Hänfling, B. and J. Kollmann. 2002. An evolutionary perspective of biological invasions. Trends in Ecology and Evolution 17:545-546.

Hebrard, J. J. and H. R. Mushinsky. 1978. Habitat use by five sympatric water snakes in a Louisiana swamp. Herpetologica 34:306 – 311.

Holman, J. A. and W. H. Hill. 1961. A mass unidirectional movement of *Natrix sipedon pictiventris*. Copeia 1961:498 – 499.

Hooge, P. N and B. Eichenlaub. 1997. Animal movement extension to Arcview. Alaska Biological Control Center, U. S. G. S., Anchorage, Alaska.

Janzen, F. J., J. G. Krenz, T. S. Haselkorn, E. D. Brodie, Jr., and E. D. Brodie. 2002. Molecular phylogeography of common garter snakes (*Thamnophis sirtalis*) in western North America: implications for regional historical forces. Molecular Ecology 11:1739-1751.

Jennings, M. R. 2004. An annotated check list of the amphibians and reptiles of California and adjacent waters. California Fish and Game 90:161 – 213.

Jennings, M. R. and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final report to California Department of Fish and Game.

Lawson, R. A. Molecular studies of thamnophine snakes. Ph.D dissertation, Louisiana State University, Baton Rouge.

Lawson, R. A., A. J. Meier, P. G. Frank, and P. E. Moler. 1991. Allozyme variation and systematics of the Nerodia fasciata-Nerodia clarkii complex of watersnakes. Copeia 1991:638 – 659.

Lee, C. E. 2002. Evolutionary genetics of invasive species. Trends in Ecology and Evolution 17:386-391.

Lutterschmidt, W. I. and J. F. Schaefer. 1996. Mist netting: adapting a technique from ornithology for sampling semi-aquatic snake populations. Herpetological Review 27:131 – 132.

Marchetti M. P., P. B. Moyle, and R. Levine. 2004. Invasive species profiling? Exploring the characteristics of non-native fishes across invasion stages in California. Freshwater Biology 49:646-661.

Mohr, C. O. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223 – 449.

Morrison, M. L. B. G. Marcot, and R. W. Mannan. 1998. *Wildlife – Habitat Relationships: Concepts and Applications*, second ed. University of Wisconsin Press, Madison.

Moyle, P. B. 1973. Effects of introduced bullfrogs, *Rana catesbeiana*, on native frogs of the San Joaquin Valley. Copeia 1973:18 – 22.

Moyle, P. B. 2002. *Inland Fishes of California*. University of California Press, Berkeley.

Murphy, J. C. and R. M. Curry. 2000. A case of parthenogenesis in the plains garter snake, *Thamnophis radix*. Bulletin of the Chicago Herpetological Society 35:17-19.

Mushinsky, H. R. 1979. Mating behavior of the common water snake, *Nerodia sipedon sipedon*, in eastern Pennsylvania (Reptilia, Serpentes, Colubridae). Journal of Herpetology 13:127 – 129.

Mushinsky, H. R. and J. J. Hebrard. 1977. Food partitioning by five species of water snakes in Louisiana. Herpetologica 33:162 – 166.

Mushinsky, H. R., J. J. Hebrard, and M. G. Walley. 1980. The role of temperature on the behavioral and ecological associations of sympatric water snakes. Copeia 1980:744 – 754.

Mushinsky, H. R., J. J. Hebrard, and D. S. Vodopich. 1982. Ontogeny of water snake foraging ecology. Ecology 63:1624 – 1629.

Orme, A. R. 2002. Human imprints on the primeval landscape. Pages 459 – 481 *in* The Physical Geography of North America, A. R. Orme, ed. Oxford University Press, New York.

Patti F. P. and M. C. Gambi. 2001. Phylogeography of the invasive polychaete *Sabella spallanzanii* (Sabellidae) based on the nucleotide sequence of internal transcribed spacer 2 (ITS2) of nuclear rDNA. Mariene Ecology-Progress Series 215:169-177.

Pettus, D. 1956. Ecological barriers to gene exchange in the common water snake (*Natrix sipedon*). Ph. D. dissertation, University of Texas at Arlington.

Rodda, G. H., Y. Sawai, D. Chizar, and H. Tanaka, eds. 1999. *Problem Snake Management: the Habu and the Brown Treesnake*. Cornell University Press, Ithaca, New York.

Reinert, H. K. and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982:702 – 705.

Rodda, G. H., T. H. Fritts, C. S. Clark, S. W. Gotte, and D. Chizar. 1999. A state-of-the-art trap for the brown treesnake. Pages 268 – 305 *in* Problem Snake Management: The Habu and the Brown Treesnake, G. H. Rodda, Y. Sawai, D, Chizar, and H. Tanaka, eds. Cornell University Press, Ithaca, New York.

Schuett, G. W., P. J. Fernandez, W. F. Gergits, N. J. Casna, D. Chiszar, H. M. Smith, J. B. Mitton, S. P. Mackessy, R. A. Odum, and M. J. Demlong. 1997. Production of offspring in the absence of males: Evidence for facultative parthenogenesis in bisexual snakes. Herpetological Natural History 5:1-10.

Seyle, C. W. 1980. The systematic relationship between the water snakes *Nerodia sipedon* and *N. fasciata* in Georgia. M. S. thesis, Auburn University, Auburn, Alabama.

Simberloff, D. and L. Gibbons. 2004. Now you see them, now you don't!-population crashes of established introduced species. Biological Invasions 6:161 – 172.

Sredl, M. J., J. E. Wallace, and V. Miera. 2000. Aquatic herpetofauna inventory of Fort Huachuca and vicinity. Arizona Game and Fish Department Technical Report #167.

Stitt, E.W., D. Brown, P.S. Balfour. 2004. Red-eared slider (*Trachemys scripta elegans*): Distribution. Herpetological Review 35:187.

Tinkle, D. W. and E. A. Liner. 1955. Behavior of *Natrix* in aggregations. Field and Laboratory 23:84 – 87.

USFWS. 1999. Recovery plan for the Giant Garter Snake (draft). U. S. Fish and Wildlife Service.

Wayne R. K., S. B. George, D. Gilbert, P. W. Collin, S. Kovach, D. Girman, and N. Lehman. 1991. A morphological and genetic-study of the island fox, *Urocyon-littoralis*. Evolution 45:1849-1868.

(WCT) Wildlife Control Technology, Inc. 1997. Diamondback Water Snake Management Feasibility Study, East Bay Municipal Utility District, Lafayette Reservoir. Unpublished report to EBMUD.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70:164 – 168.

LIST OF APPENDICES

APPENDIX A

Nerodia fasciata Geographic Distribution Record

NERODIA FASCIATA FASCIATA (Banded Water Snake). USA: CALIFORNIA: Sacramento Co: 100 m SE of intersection of Riley Street and Blue Ravine Road (38° 39' 35" N, 121° 09' 30" W). June 2000. Peter S. Balfour and Eric W. Stitt. California Academy of Sciences (CAS 215207-215214). Verified by Robin Lawson (CAS) and Rhonda Lucas (CAS). This introduced population was originally discovered by the senior author (PSB) in 1992. The accessioned specimens were collected from a constructed pond and adjacent watershed. Twenty seven additional captured individuals (many provided by the California Department of Fish and Game) have ranged in length between 63.5 and 130 cm. Seventeen females were dissected and found to contain between 12-55 developing ova (mean = 24). Several additional individuals, of all size classes, have been observed prior to and since this collection. This subspecies is native to southern Alabama, northeast through North Carolina (R. Conant and J. T. Collins 1991, Reptiles and Amphibians of Eastern/Central North America. Houghton Mifflin Co., Boston, New York. xiv + 450 pp.).

Submitted by **PETER S. BALFOUR**, ECORP Consulting, Inc., 2260 Douglas Blvd., Suite 160, Roseville, California, 95661, USA (e-mail: pbalfour@ecorpconsulting.com), and **ERIC W. STITT**, University of Arizona, School of Renewable Natural Resources, 125 Biological Sciences East, Tucson, Arizona, 85721 (e-mail: estitt@u.arizona.edu)

APPENDIX B

"Have You Seen This Snake?" Poster

Have You Seen This Snake?

This is a Southern watersnake (*Nerodia fasciata*) introduced into the Folsom area from the southeastern states (Georgia and Florida). The snake has become established here, and we are presently trying to determine the limits of its range in northern California. If you see this snake in the wild please call Peter Balfour or Adam Ballard at ECORP Consulting, Inc. Phone number is 916-782-9100, or email:pbalfour@ecorpconsulting.com.

There is a black stripe from eye to back corner of mouth. The body is usually black with orange bands, and no yellow stripes or blotches. Large individuals may be entirely black. This snake may be large (3.5-4.5 feet in length). It is thick-bodied, fast moving and will escape into water.

Should you catch one, the underside has a white background color with small bands of orange, red, and/or black (see photo to right).

APPENDIX C

California *Nerodia* Specimens Accessioned and Examined.

Species	Institution	Accession number	Collector(s)	County	Date of Collection	Notes
N. fasciata	CAS	215207	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215208	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215209	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215210	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215211	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215212	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215213	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. fasciata	CAS	215214	Balfour and Stitt	Sacramento County, CA	5 Jun 2000	
N. rhombifer	MVZ	217740	M. Young	Contra Costa County, CA	2 Jun 1990	
N. rhombifer	MVZ	217741	M. Young	Contra Costa County, CA	2 Jun 1990	
N. fasciata	MVZ	200782	None listed	Contra Costa County, CA	April 1976	Incorrectly listed as from Alameda County

APPENDIX D

Trachemys scripta Geographic Distribution Record

TRACHEMYS SCRIPTA ELEGANS (Red-eared slider). USA: CALIFORNIA: Sacramento CO.: 500 m NE of intersection of East Bidwell and Blue Ravine Road (38° 39’ N, 121° 09’ W). 22 May 2003. Eric W. Stitt, Dustin Brown, and Peter S. Balfour. Verified by Cecil R. Schwalbe. A voucher slide has been accessioned at the University of Arizona Collection of Amphibians and Reptiles (#UAZ 55579-PSB). Female, 218 mm midline carapace length, 1515 g. Captured on the bank of a man-made pond ca. 3 m from water’s edge, possibly preparing to lay eggs (although no eggs could be felt by palpation). Several other adult *Trachemys* have been observed here, together with the native *Actinemys marmorata*. This subspecies is native to eastern New Mexico through Louisiana, and has been widely introduced throughout the western states (Stebbins. 2003. Western Reptiles and Amphibians, Third Edition. Houghton Mifflin Co., New York, NY. 533 pp.). In northern California, the turtle occurs in the Sacramento-San Joaquin Delta, but the status of most populations is unknown (Stebbins, *op. cit.*). Also, although this species is occasionally recorded in local field guides (e.g., The American River Natural History Association. 1993. The Outdoor World of the Sacramento Region: A Local Field Guide. ARNHA, 214 pp.) specific locality data are lacking. Museum records exist from Putah Creek near Davis, Yolo County, California, ca. 60 km E-SE of this new locality (CAS 203705, 203706, 203710). This verifies the turtle’s presence in Sacramento County, in the vicinity of Folsom Lake and Lake Natoma.

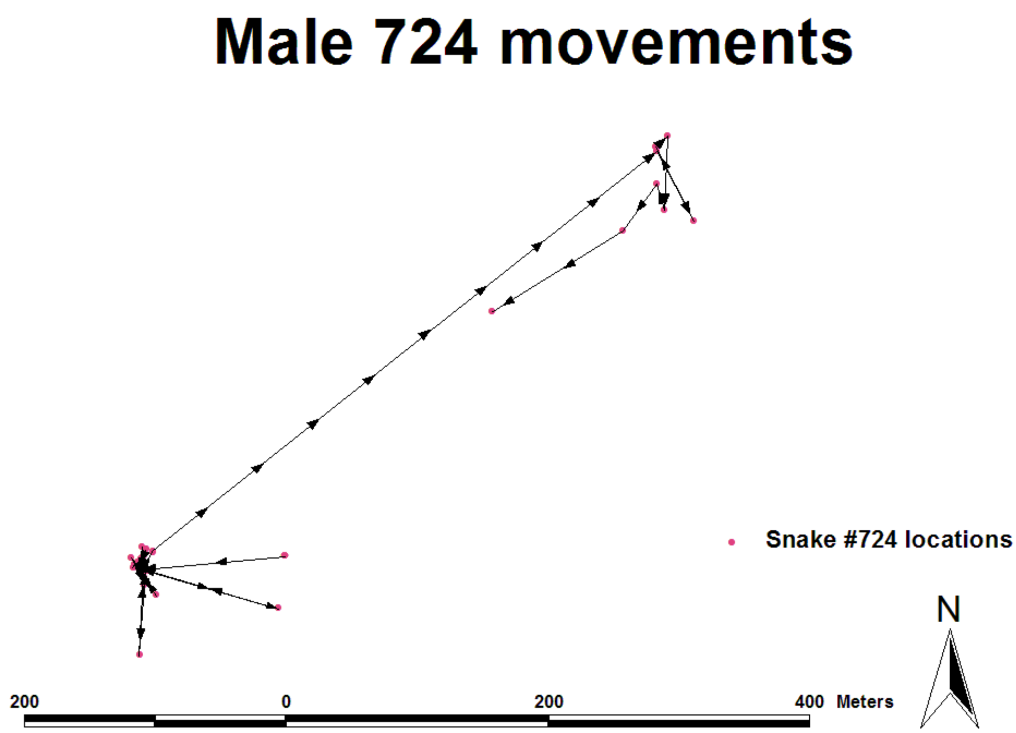
Submitted by **ERIC W. STITT**, University of Arizona, School of Renewable Natural Resources, 125 Biological Sciences East, Tucson, Arizona 85721, USA (e-mail: estitt@u.arizona.edu), **DUSTIN BROWN**, The Masters College, 21726 Placerita Canyon

Road, Santa Clarita, California 91321, USA, and **PETER S. BALFOUR**, ECORP Consulting, Inc., 2260 Douglas Blvd., Suite 160, Roseville, California 95661, USA.

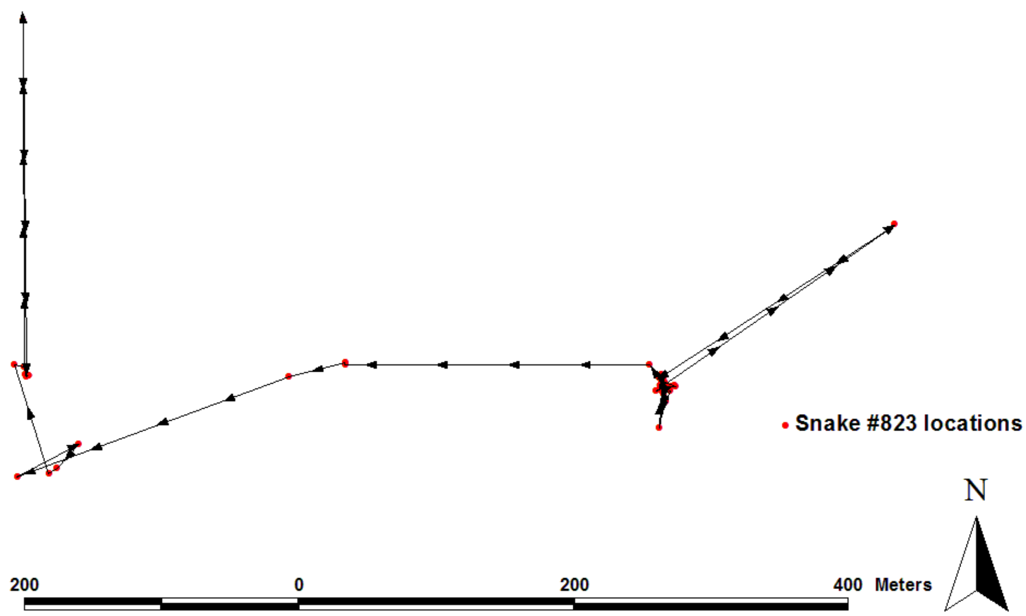
APPENDIX E

Movements and Minimum Convex Polygon Home Ranges of Two Male

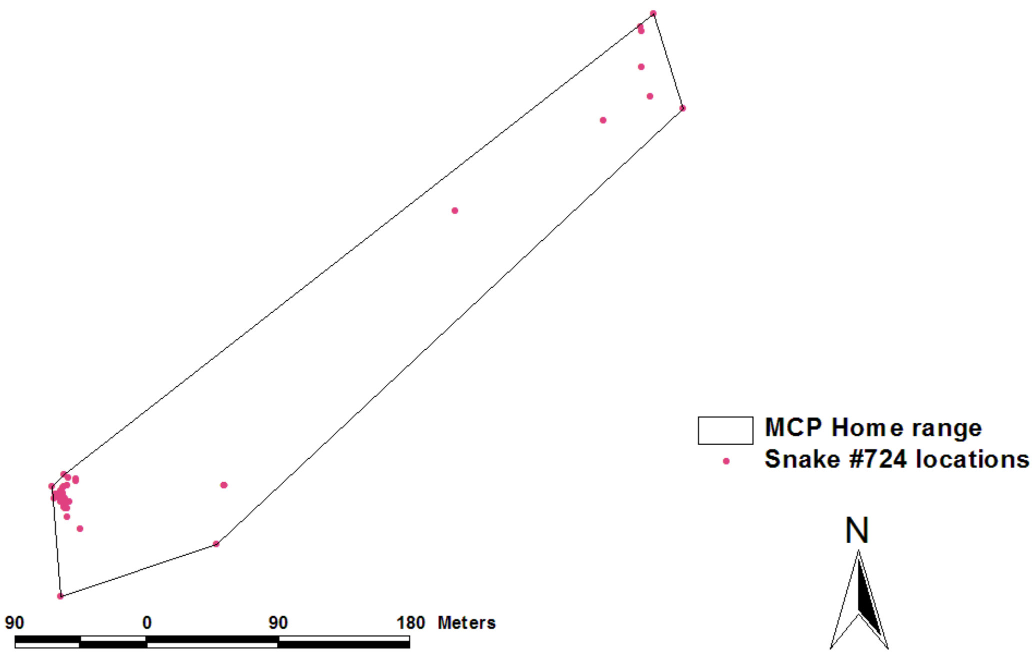
Nerodia fasciata, 2003 - 2004



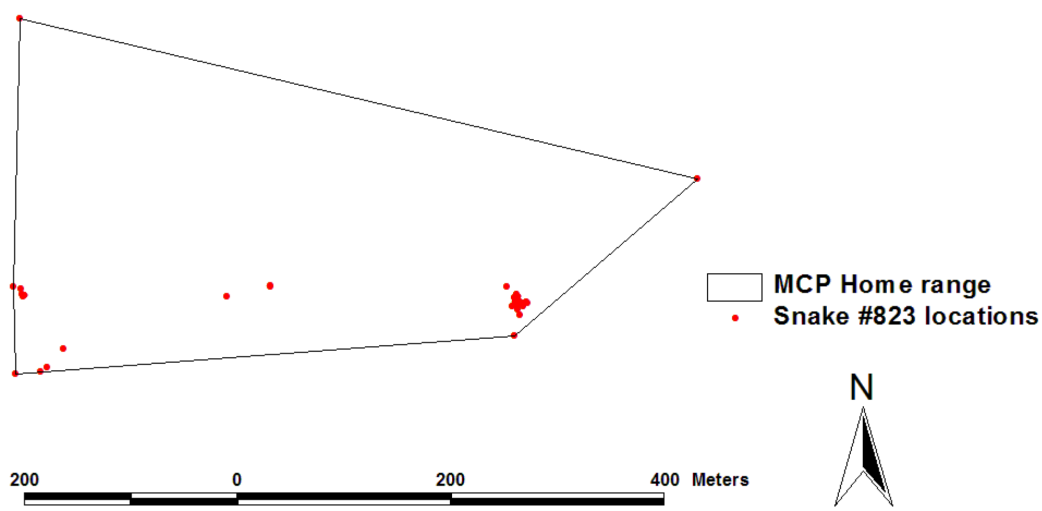
Male 823 movements



Male #724



Male #823



APPENDIX F

Introduced Reptiles and Amphibians Established in California

Common name[1]	Scientific name[1]	Amphibian/ reptile	Body form	Aquatic/ terrestrial[2]	Widespread/ localized[3]	Citation
Tiger salamander	*Ambystoma tigrinum*	A	salamander	A	W	Jennings and Hayes 1994, Jennings 2004
African clawed frog	*Xenopus laevis*	A	anuran	A	W	McCoid and Fritts 1980, Jennings 2004 and references therein
American bullfrog	*Rana catesbeiana*	A	anuran	A	W	Jennings and Hayes 1985 and references therein
Northern leopard frog	*Rana pipiens*	A	anuran	A	W	Bury and Luckenbach 1976, Jennings 2004, Jennings ad Fuller 2004
Rio Grande leopard frog	*Rana berlandieiri*	A	anuran	A	W	Jennings 2004
Southern leopard frog	*Rana sphenocephala*	A	anuran	A	W	Jennings and Fuller 004
Snapping turtle	*Chelydra serpentina*	R	turtle	A	W	Stebbins 2003
Red-eared slider	*Trachemys scripta*	R	turtle	A	W	Stebbins 2003
Spiny softshell	*Apalone spinifera*	R	turtle	A	W	Bury and Luckenbach 1976, Jennings 2004
Mediterranean gecko	*Hemidactylus turcicus*	R	lizard	T	W	DeListle 1989
Moorish wall gecko	*Tarentola mauritanica*	R	lizard	T	L	Mahrdt 1998
Jackson's chameleon	*Chameleo jacksonii*	R	lizard	T	L	Stebbins 2003, Gary Nafis pers. comm.
Southern watersnake	*Nerodia fasciata*	R	snake	A	L	Balfour and Stitt 2002, this report

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[1]Crother et al. 2000 [2]Obligate or facultative use of wetlands for one or more aspects of life history [3]widespread = established in more than one county, localized = established in only one county.

APPENDIX G

Letter to California Department of Fish and Game from The Wildlife Society

The Wildlife Society
Western Section
Barry Garrison
1613 Costa Verde Street
Davis, CA 95616
916-616-0693 phone
916-358-2912 fax
bagarris@dfg.ca.gov

July 9, 2001

Mr. Robert C. Hight, Director
California Department of Fish and Game
1416 Ninth Street Sacramento, CA 95814

Subject: A population of the southern (banded) watersnake (Nerodia fasciata) in Folsom, California

Dear Mr. Hight:

The purpose of this letter is to provide information about the status of an introduced population of the southern (banded) watersnake that has become established near Lake Natoma in Folsom and offer the support and assistance of the Western Section of The Wildlife Society (TWS-WS) to any efforts taken by the California Department of Fish and Game (DFG) to control this non-native species. The watersnake occurs at Lake Natoma in apparently substantial numbers, and it is possible this snake could adversely affect populations of native fish and wildlife in the Sacramento-San Joaquin Valley and San Francisco Bay Delta if its range expands from its current location. For example, the watersnake could adversely affect populations of the giant garter snake (*Thamnophis gigas*), a species listed as threatened under the Federal and California Endangered Species Acts.

Background Information

The TWS-WS has known these snakes occurred at Lake Natoma for several years. During 1992-93, several watersnakes were captured at a perennial marsh there by Dr. Peter Balfour, a TWS-WS member. He gave the captured individuals to the DFG, and a DFG biologist (recently retired) visited the site several times, collected more snakes, and produced an internal DFG report. Another TWS-WS member, Mr. Eric Stitt, visited the site last spring and found >25 watersnakes ranging between 0.5-1.3 m in length. In a subsequent visit this spring, Mr. Stitt and Dr. Balfour visited several sites in the area and saw more watersnakes; they collected five snakes which were given to the California Academy of Sciences. They determined that the population has dispersed upstream and downstream from its original location.

Dr. Balfour and Mr. Stitt informed the DFG and U.S. Fish and Wildlife Service about the population, and they asked how they should proceed with their work and to offer help in controlling these snakes which they felt represented a potential threat to native species. The DFG provided Mr. Stitt with two reports, one written by the DFG biologist and the other apparently written in June 2000 by a DFG volunteer who was working on this population too. The DFG authorized Mr. Stitt and Dr. Balfour to take as many snakes as they could, and the DFG provided them with frozen specimens that were collected in 1999 and 2000.

The southern watersnake occurs naturally throughout the Gulf States from Florida to Texas. It is a generalist predator which actively forages on fish, crayfish, frogs, and salamanders; it grows to lengths up to 1.5 m with a heavy body, and can escape quickly. The watersnake bears live young, and is apparently reproducing around Lake Natoma because all size classes (thus age classes) were observed and captured. Dr. Balfour and Mr. Stitt are currently attempting to determine the extent of the watersnake's dispersal and conducting a food habits study using analyses of stomach contents.

Possible Threats to Native Species

Introductions of non-native vertebrates in California have had substantial impacts to native species. For example, bullfrogs (*Rana catesbeiana*) have caused population declines of native frog species[1]. Non-native fish introductions into high-elevation lakes have reduced populations of native amphibians[2] and may be having effects at higher trophic levels[3]. European starlings (*Sturnus vulgaris*) have adversely affected populations of native cavity-nesting birds[4], and introduced non-native predators and herbivores are greatly affecting the flora and fauna of California's Channel Islands[5]. The adverse consequences of exotic species introductions resulted in the issuance on February 3, 1999 of Executive Order 13112 which takes a strong position against these introductions and encourages control of non-native species populations.

The watersnake is too large to be preyed upon by native garter snakes, which also generally do not eat other snakes. As far as can be discerned, the watersnake is not known to eat other snakes. It's unknown, however, if the watersnake has displaced native species; non-native species are well known to adversely affect populations of native species once the non-native species is freed from the ecological constraints of its native range. With the watersnake, we do not know if these impacts have occurred because an investigation has not been done to determine its relationships with native species since the watersnake was discovered. While working with the Lake Natoma population, TWS-WS members have found two native garter snakes - the western terrestrial garter snake (*T. elegans*) and common garter snake (*T. sirtalis*) - co-occurring with the watersnake. To date, however, watersnakes have been more frequently observed.

Recommended Actions

The TWS-WS is uncertain if the southern watersnake will displace native species through predation and/or competition. Several types of existing prey available to the watersnake (e.g., bass, sunfish, mosquitofish, crayfish, and bullfrogs) are what they prey upon in their native range. They could, however, potentially prey upon native and sensitive species such as California red-legged frogs (*Rana aurora draytonii*), Delta smelt (*Hypomesus transpacificus*), or Sacramento splittail (*Pogonichthys macrolepidotus*) because of their range and foraging and food habits. Because of the modified habitat conditions in the Sacramento-San Joaquin Valley, Delta, and surrounding foothills, the watersnake could potentially find habitat more suitable than native species such as the giant garter snake, which appears to be increasingly surrounded by non-native species.

The TWS-WS has concluded that the risk to native species from the watersnake is too great to wait for studies to unequivocally conclude that the watersnake is adversely affecting native species. We feel it is a prudent management decision to assume that the watersnake will adversely affect native species, and that more intensive and active control and management efforts are needed by the DFG and other agencies.

Therefore, the TWS-WS requests that the DFG direct more of its resources to controlling the southern watersnake through an intensive control program that should begin as soon as possible. If control efforts are delayed, costs will increase commensurate with the watersnake's range expansion. The TWS-WS is willing to assist with any control effort that the DFG pursues. The TWS-WS also supports the DFG's efforts to prepare and implement a non-native species control plan that we understand your staff are currently preparing. We have many members who are experts in the ecology and management of non-native species, and we are willing to assist the DFG in preparing this plan and establishing and implementing a statewide control program. I heartily encourage the DFG to contact me at 916-616-0693 if additional information or the assistance and support of the TWS-WS is needed. The TWS-WS thanks the DFG for its leadership with non-native species control and for the opportunity to provide this information and offer our assistance and support.

Sincerely,

Barrett A. Garrison, President

Literature Cited

[1] Moyle, P.B. 1973. Effects of introduced bullfrogs, *Rana catesbeiana*, on the native frogs of the San Joaquin Valley, California. *Copeia* 1973:18-22.

[1] Lawler, S.P., D. Dritz, T. Strange, and M. Holyoak. 1999. Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. *Conservation Biology* 13:613-622.

[2] Bradford, D.F. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implications of the negative impact of fish introductions. *Copeia* 1989:775-778.

[2] Bradford, D.F., F. Tabatabai, and D.M. Graber. 1993. Isolation of remaining populations of the native frog, Rana muscosa, by introduced fishes in Sequoia and Kings Canyon National Parks, California. *Conservation Biology* 7:882-888.

[2] Knapp, R.L. and K.R. Matthews. 2000. Non-native fish introductions and the decline of the mountain yellow-legged frog from within protected areas. *Conservation Biology* 14:428-438.

[3] Jennings, W.B., D.F. Bradford, and D.F. Johnson. 1992. Dependence of the garter snake Thamnophis elegans on amphibians in the Sierra Nevada of California. *J. Herpetology* 26:503-505.

[4] c.f. in Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. *The birder's handbook: a field guide to the natural history of North American birds.* Simon and Schuster, Inc., New York. 785 pp.

[5] Steinhart, P. 1990. *California's wild heritage: threatened and endangered animals in the Golden State.* California Department of Fish and Game, Sacramento, CA. 108 pp.