Implementation of Priority 1 Recovery Tasks for the Giant Garter Snake (*Thamnophis gigas*) in Merced County, California

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Abstract

We investigated the potential presence of giant garter snakes north and east of the San Joaquin River and the current status of declining historical populations south and east of the San Joaquin River in the Grassland Ecological Area in Merced County, California. We also provided tissue samples for a parallel genetic study conducted by Dr. Tag Engstrom, CSU Chico. By establishing current baseline data through the implementation of a standardized, repeatable sampling protocol, it is our intention to provide an elementary foundation for long-term monitoring of giant garter snake populations in the San Joaquin Valley. Trapping began on May 10, 2006 and continued through August 19, 2006. Fifty traplines were established totaling 35,970 accrued trap days. Eight giant garter snakes were captured within the Grasslands Ecological Area and, although suitable habitat was observed, no giant garter snakes were encountered north and east of the San Joaquin River. Resulting population estimates did not exceed seven individuals, and snakes observed during this study displayed a skewed size distribution, in that all giant garter snakes observed were sexually mature adults. In addition, none of the females observed were perceptibly gravid. Giant garter snakes were not encountered at the majority of historical localities surveyed despite the presence of seemingly suitable habitat, suggesting that variables such as water quality and water management may play a significant role in the species' regional decline. Standardized surveys should continue to further assess regional distribution and to collect the long-term mark-recapture data required to analyze demographic parameters such as survivorship, age structure, and fecundity, and should expand to include historic populations near Mendota in Fresno County. Additional studies should target the interactions between water quality, water management, and pathology to assess the reasons for the precipitous decline of giant garter snakes in the San Joaquin Valley.

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INTRODUCTION

Background

This document summarizes the results of the project entitled **Implementation of Priority 1 Recovery Tasks for the Giant Garter Snake (*Thamnophis gigas*) in Merced County, California**. Funded by the Central Valley Project Conservation Program (CVPCP) and Central Valley Project Improvement Act Habitat Restoration Program (HRP) during Fiscal Year 2006, the project was completed in accordance with the terms and conditions of Fish and Wildlife Service (FWS) Agreement No. 802706G120.

Project Goals and Objectives

The project goals and objectives are:

- To investigate the presence of giant garter snakes north and east of the San Joaquin River in Merced County, including, but not limited to the East Side Canal and Drainage Management Area within the Stevinson Management District and Merquin County Water District (SMWD), and the Merced National Wildlife Refuge Complex;
- To assess the current status of giant garter snake populations within the Grasslands Ecological Area, including, but not limited to Federal- and State-managed refuges and wildlife areas and private lands along the Santa Fe Grade corridor south and west of the San Joaquin River;
- To contribute tissue samples for the parallel genetic study proposed by Dr. Tag Engstrom, CSU Chico;
- To provide a methodological foundation for future research.

Species Description

The giant garter snake (GGS) is an aquatic snake endemic to the Great Central Valley of California. Described as among California's most aquatic garter snakes (Fitch 1940), GGS are historically associated with low-gradient streams and valley floor wetlands and marshes and, more recently, with areas supporting rice agriculture (G. Hansen and J. Brode 1993; G. Hansen 1998; USFWS 1999; Wylie *et al*. 1997). GGS once ranged throughout the wetlands of California's Central Valley from Buena Vista Lake near Bakersfield, Kern County, north toward the vicinity of Chico in Glenn and Colusa Counties (Hansen and Brode 1980). Due mainly to loss or degradation of aquatic habitat resulting from agricultural and urban development, GGS has been either extirpated or else suffered serious declines throughout much of its former range. The current known distribution of GGS is patchy, and extends from near Chico in Butte County, south to Mendota Wildlife Area in Fresno County. GGS was listed by DFG as rare on June 27, 1971 and was designated as threatened following the passage of the California Endangered Species Act in 1984 (California Fish and Game Code §2050-2116). The U.S Fish and Wildlife Service listed GGS as threatened under the Federal Endangered Species Act on October 20, 1993 (58 FR 54053). GGS is considered vulnerable by the World Conservation Union (IUCN) (Baillie 1996).

GGS emerge in March and are generally active (foraging and breeding) from April through September, seeking winter refuge during the onset of cooling temperatures in the fall (Brode 1988; E. Hansen 2005; G. Hansen and J. Brode 1993; USFWS 1999; Wylie *et al*. 1997). Particularly in the Sacramento Valley Valley, rice fields have become important habitat for giant garter snakes. Irrigation water typically enters the rice lands during April along canals and ditches. GGS use these canals and their banks as permanent habitat for both spring and summer active behavior and winter hibernation. Where these canals are not regularly maintained, a lush aquatic, emergent and streamside vegetation develops prior to the spring emergence of giant garter snakes. This vegetation, in combination with cracks and holes in the soil, provides much needed sheltering cover during spring emergence and throughout the remainder of the summer active period.

GGS feed on small fishes, tadpoles, and small frogs (Fitch 1941, Hansen 1980, USFWS 1999), specializing in ambushing prey underwater (Brode 1988). Historically, giant garter snakes probably preyed on native species such as the thick-tailed chub (*Gila crassicauda*), the California red-legged frog (*Rana aurora draytonii*), which have been extirpated from the giant garter snake's current range, as well as the pacific treefrog (*Hyla regilla*) and Sacramento blackfish (*Orthodox microlepidus*), (Cunningham 1959; Rossman *et al.* 1996; USFWS 1999). GGS now utilize introduced species, such as small bullfrogs (*Rana catesbeiana*) and their larvae, carp (*Cyprinus carpio*), and mosquitofish (*Gambusia affinis*). While juveniles probably consume insects and other small invertebrates, GGS are not known to consume prey such as small mammals or birds.

Large vertebrates, including raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoagentius*), river otters (*Lutra canadensis*), opossums (*Didelphis virginiana*), harriers (*Circus cyaneus*), hawks (*Buteo* spp.), herons (*Ardea herodius, Nycticorax nyctycorax*), egrets (*Ardea alba*, *Egretta thula*), and American bitterns (*Botaurus lentiginosus*) prey on giant garter snakes (USFWS 1999). In areas near to urban development, giant garter snakes may also fall prey to domestic or feral housecats (G. Hansen pers. comm.). In permanent waterways, introduced predatory game fishes such as black basses (*Micropterus* spp.), striped bass (*Morone saxatilis*), sunfish (*Lepomis* spp.), and channel catfishes (*Ictalurus* spp.) probably prey on giant garter snakes and compete with them for smaller prey (Hansen 1988, USFWS 1993).

GGS coexist with the valley garter snake (*Thamnophis sirtalis fitchi*) and, in limited instances, both may be found together with the mountain garter snake

(*Thamnophis elegans elegans*), a western terrestrial garter snake subspecies, where this species' range extends to the Central Valley floor. The extent of competition among these species is unknown, but it is likely that differences in habitat use and foraging behavior allow their coexistence (Brode 1988, USFWS 1999).

Continued loss of wetland or other suitable habitat resulting from agricultural and urban development constitutes the greatest threat to this species' survival. The conversion of Central Valley wetlands for agriculture and urban uses has resulted in the loss of as much as 95% of historical habitat for the GGS (Wylie *et al.* 1997). In areas where GGS has adapted to agriculture, maintenance activities such as vegetation and rodent control, bankside grading or dredging, and discharge of contaminants may also threaten their survival (Hansen and Brode 1980, Brode and Hansen 1982, Hansen and Brode 1993, USFWS 1999, Wylie *et al.* 2004). In developed areas, threats of vehicular mortality are also increased. Paved roads likely have a higher rate of mortalities that dirt or gravel roads due to increased traffic and traveling speeds.

Project Area Description and History

Overview

Access for this study was limited to the San Luis National Wildlife Refuge complex (SNLNWR), the consortium of privately owned properties situated within Grasslands RCD, the privately owned Klamath Club encompassing Mud Slough east of the City of Los Banos between Highway 152 and Henry Miller Road, the Merced National Wildlife Refuge complex (MNWR), the privately owned Modesto Properties situated west of MNWR's Snobird Unit south of Highway 140, and the core of Stevinson Water District along with its associated rights-of-way along the East Side Canal corridor (Figures 1 and 2).

SSNLNWR lies south of the San Joaquin River, encompassing wetlands east and west of Highway 165 south to the City of Los Banos. GWD lies to the west of SNLNWR, extending from Highway 140 south to the Merced/Fresno County line (Figure 3). Encompassing privately managed lands adjacent to SNLNWR through the Los Banos Creek and Santa Fe Grade corridor, North Grassland Water District (GWD) extends to Highway 152 in the City of Los Banos. South GWD continues through the Santa Fe Grade corridor south of Highway 152.

The Stevinson and Merquin Water Districts are located on the Stevinson and Gustine U.S. Geological Survey 7.5-Minute topographic quadrangles, east of the confluence of the Merced and San Joaquin Rivers in Merced County, California (Figure 1). The East Side Canal bisects these quadrangles passing from east to west through the Districts. The Big Bottom Lake region lies upon the southern portion of the Gustine Quadrangle at the northern edge of the San Joaquin River (Figures 1-3). The East Side Canal corridor extends southeast from SMWD through the Arena Plains and Snobird Units of the Merced National Wildlife Refuge Complex (MNWR) to the Mariposa Bypass, East Side Bypass, and

Merced Unit of the MNWR (Figure 3). Intersecting the East Side Canal in this reach are Bear Creek and Atwater Drain.

Prior to the outset of the study, efforts were made to establish access to the expansive lands managed by California Department of Fish and Game (DFG) in the Los Banos area. Access to DFG lands for direct sampling in conjunction with this study was not granted. Ultimately, it was determined that DFG scientists would conduct sampling autonomously in a parallel effort, and that resulting data and tissues collected would be shared to benefit this study and the study conducted by Dr. Tag Engstrom. Results are to be reported separately. Efforts engaged by DFG focused largely on previously sampled areas primarily for the purpose of acquiring tissue samples. Accordingly, this study was limited to regions outside the jurisdiction of DFG. Results of the DFG surveys are not included as part of this report.

Stevinson and Merquin Water Districts

The Stevinson Water District provides water to 7,560 acres of irrigated land within its service area and 1,340 acres of neighboring land. Stevinson Water District also delivers surface water to the Merquin County Water District, pursuant to contractual obligations, to serve 6,000 acres of agricultural land. In the combined districts, water is distributed through approximately 66,900 feet of open ditch laterals.

At the southern edge of the Stevinson and Merquin water Districts (SMWD), Big Bottom Lake was created in the 1960s to contain agricultural drain water and now provides shallow open water habitat for waterfowl and other aquatic species. Turner Slough, which contained flowing water during this study and reportedly flows year round (R. Kelley, *pers. comm.*), supports dense patches of cattail (*Typha* sp.) and bulrush (*Scirpus* sp.) and scattered willows and cottonwoods overhanging its banks. The lower Borges area, adjacent to Big Bottom Lake, is choked with cattail and contains only isolated patches of standing water. Water is pumped into the lower Borges area from Big Bottom Lake for storm water storage; it also serves as a groundwater percolation basin.

Habitat within the Drainage Management Area resembles that of a perennial marsh, meeting all criteria associated with the giant garter snake's biological needs. The wetlands are characterized by sinuous open-water channels and pools interspersed with dense patches of emergent vegetation dominated by cattail and bulrush. Established populations of aquatic prey species, including bullfrogs, sunfish, and mosquitofish are present in densities comparable to those observed throughout the giant garter snake's range. Upland habitat is characterized by a mixture of grassland and ruderal vegetation accompanied by stands of cottonwood and willow that are also scattered throughout the wetlands. Topography is variable, providing ample high ground for overwintering giant garter snakes.

Merced National Wildlife Refuge Complex

Merced NWR totals 10,228 acres, including the 2,464-acre Arena Plains Unit and 1,904-acre Snobird Unit. Programs regulating activities such as grazing, burning, and farming are in place for managing avian species as well as the native grasslands and associated wildflower fields. Water piped belowground from the Merced Irrigation District provides 15,000 acre feet of water to refuge wetlands annually.

Acquired in June of 1992, the Arena Plains Unit of the Merced NWR consists of 2,464 acres south of Highway 140 and contains the San Joaquin Valley's largest block of undisturbed sand dunes, perched wetlands, and vernal pool habitat. Backing up to the East Side Canal at its southern end, Arena Plains supports a mosaic of seasonal, perennial, and permanent wetlands and is bisected in part by Atwater Drain. Light grazing is applied by special permit to manage vegetation.

Southwest and contiguous with Arena Plains, the Snobird Unit of the Merced consists of 1,904 acres acquired in February of 2004. Extending south from the edge of the East Side Canal, Snobird includes the terminus of Atwater Drain and is bisected by Bear Creek and Deep Slough. Federal managers are awaiting a final assessment of the property's infrastructure and surface water is not currently applied (R. Albers, *pers. comm.*).

San Luis National Wildlife Refuge Complex

This 26,609-acre refuge is a mixture of managed seasonal and permanent wetlands, riparian habitat associated with 3 major watercourses, and native grasslands/alkali sinks/vernal pools. The refuge is primarily managed to provide habitats for migratory and wintering birds.

The Refuge is a remnant of San Joaquin bottomland/floodplain habitat. Marsh basins and riparian channels are natural in topography, but must be artificially flooded by distributing 30,000 acre-feet of CVPIA water supplies.

The Kesterson Unit of San Luis NWR consists of 10,621 acres and is located 4 miles east of Gustine and approximately 18 miles north of Los Banos in Merced County, California. It is a mixture of seasonal and permanent wetlands, riparian habitat associated with 3 watercourses, native grasslands, and vernal pools. Originally established in July 1970 as Kesterson NWR, the unit now consists of the original Kesterson Unit, the newly acquired adjacent Freitas Ranch, and the Blue Goose property.

The original 5,700-acre unit was originally developed by U.S. Bureau of Reclamation (USBR) as a series of holding ponds (approximately 1,283 acres) known as Kesterson Reservoir for agricultural drain water which had been transported via the San Luis Drain. The delivery of the selenium-laden drainwater from San Luis Drain officially ceased on June 9, 1986. Portions of the ponds were filled with 18" of clean, off-site dirt in 1988 to reduce wildlife exposure to selenium contamination.

The Kesterson Unit of San Luis NWR is within the historic floodplain of the San Joaquin River. The lands consist of native grasslands, wetlands, riparian habitat, and vernal pool and floodplain habitat. The Kesterson Unit is bisected by Mud Slough.

Grassland Water District and Grasslands RCD

Formed under Section 34000 of the State Water Code, the Grassland Water District (GWD) comprises approximately 51,537 acres of primarily wetland habitat. The District maintains approximately 110 miles of canals in order to execute its primary function of delivering water to the landowners within its boundaries.

The approximately 75,000-acre Grasslands RCD comprises private hunting clubs and other privately owned wetland areas, as well as all or portions of several state and federal refuges (such as Kesterson NWR, Volta WA, Los Banos WA, Freitas Unit, Salt Slough Unit, Blue Goose Unit, Gadwall Unit). To achieve a goal of sustaining waterfowl habitat, the management objectives of the Grassland RCD include encouraging natural food plant production (such as swamp timothy, smartweed, and wildlife millet) and habitat protection. Land uses include seasonally flooded wetlands, moist soil impoundments, permanent wetland, irrigated pasture, and croplands.

The Grassland RCD contains most of the 51,530-acre GWD, which is a legal entity established to receive and distribute CVP water. GWD delivers CVP water to the wetland areas within its boundaries. GWD contains approximately 165 separate ownerships, most of which are hunting or duck clubs. Perpetual easements have been purchased by the Service to help preserve wetland-dependant migratory bird habitat on approximately 31,000 acres serviced by the GWD.

Historical Species Occurrence within the Project Area

Extant GGS populations within the San Joaquin Valley are represented by three unique management areas; North and South Grasslands (Grasslands Ecological Area), Mendota Area, and the Lanare/Burrel Area (Tulare Lake Basin and Kern-Wasco Area populations are presumed extirpated). With one exception (CNDDB # 144), all reported occurrences of GGS in the San Joaquin Valley originate south and west of the San Joaquin River where large wetland complexes remain (Figure 1). None are known from SMWD. The closest known occurrence of GGS (CNNDB #27) to the SMWD is in Kesterson National Wildlife Refuge (in Los Banos Creek approximately 0.5 mile north of Highway 140, 3 miles northeast of Gustine). This occurrence is approximately 3.8 miles southwest of the Big Bottom Lake and lower Borges area (collectively known by the SMWD as the Drainage Management Area). Other occurrences (#184 - south of Carnation Road, 1.5 miles east of Gustine, west of the sewage treatment facility; #135 - east of Gustine in vicinity of Los Banos Creek and Santa Fe Grade; and #26 – vicinity of Los Banos Creek and Gun Club Road) are within 5 miles of the southern boundary of SMWD.

Most of these locality records were established by George Hansen during a range-wide status and distribution survey conducted for DFG during 1976 and 1977. This study determined that GGS were potentially extirpated from wetland regions of Buena Vista and Tulare Lake basins near Bakersfield in Kern County that had been drained for agriculture. However, populations near Mendota and Los Banos were described as widespread, occurring in densities comparable to those found in the rice growing regions of the Sacramento Valley (G. Hansen and J. Brode 1980).

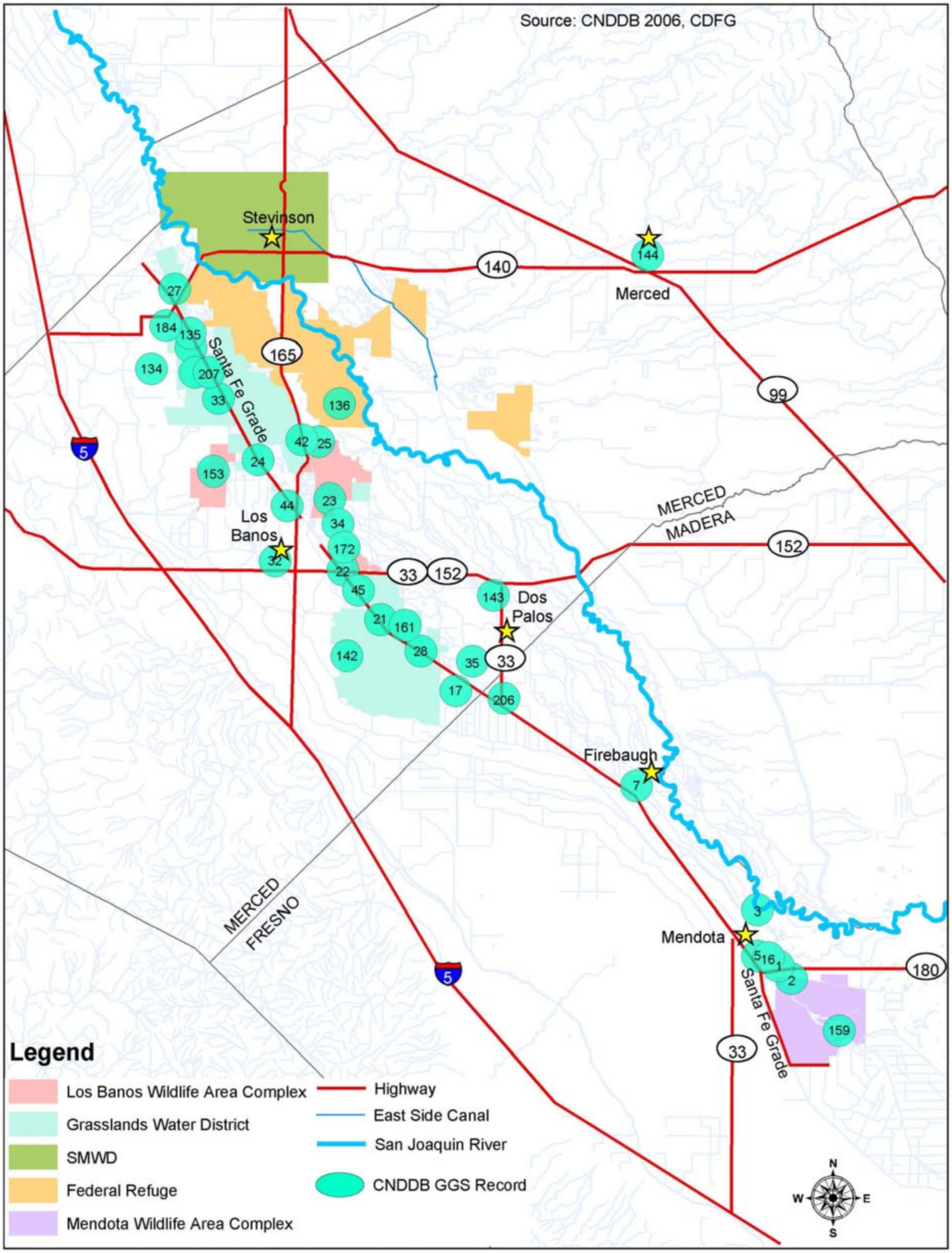
During a second status and distribution survey conducted from 1986-1987, George Hansen did not find GGS in areas where they had been found ten years prior (G. Hansen 1988). Hansen found that although much of the available habitat had deteriorated significantly since the 1970's, suitable habitat remained throughout the region. Hansen speculated that GGS present along the railroad bed at the northern boundary of MWA in the 1970's may have suffered declines due to flooding which overtopped this winter refugia in 1985 (G. Hansen 1988). This did not account for declines observed throughout the Los Banos area.

Due to the poor results of the 1986-1987 surveys, a study was engaged in 1995 to revisit all the locations shown to support the species during 1976-1977. With the exception of one road-killed individual at MWA and two potential GGS in South GWD that eluded capture, Hansen observed no GGS south of San Joaquin County (G. Hansen 1996). Hansen found that many or most of the sites established in the 1970's had deteriorated in quality and that many features were either maintained without water or without ample vegetative cover during the spring and summer GGS active season (G. Hansen 1996). Hansen noted that although many sites had deteriorated, suitable aquatic habitat was still present region-wide, leading him to observe that GGS appeared to have declined more rapidly and to a greater extent than had suitable habitat. This discordance suggests that factors other than habitat loss may contribute to the decline of GGS in SJV.

Extensive trapping was conducted by the U.S. Geological Survey and California Department of Fish and Game in the Grasslands Wetlands and Mendota Wildlife Areas of the San Joaquin Valley from 1999 through 2004. These surveys resulted in the capture and identification of 88 GGS over the five-year period (J. Sloan, pers. comm.). Thirty-one snakes were captured in 2003, with a reduction to13 snakes in 2004 (Dickert 2003, Sloan 2004). A parallel trapping effort conducted throughout the San Luis NWR complex during 2004 did not detect GGS (Williams *et al.* 2004). Trapping was conducted again by DFG in 2006 at Mud Slough and Volta, resulting in 7 GGS captured within the Volta Wasteway: none were captured at Mud Slough (J. Sloan, pers. comm.).

Trapping efforts in Mendota were last engaged in 2001 (Dickert 2005). Of the five sites sampled, one produced 18 GGS captures (NDDB # 159) (Figure 1). No population estimates are available for this region and no tissue samples are available for genetic analyses.

Figure 1. Historical Distribution of Giant Garter Snakes in the Central San Joaquin Valley



METHODS and MATERIALS

Sampling

Sampling entailed a combination of visual encounter surveys and trapping methods to assess giant garter snake presence.

Visual encounter surveys were initiated following the snakes' emergence from winter refuge and continued throughout the spring portion of the active season. Beginning in April, we conducted visual encounter surveys by walking or kayaking along channels, wetlands, and nearby upland areas to search for basking and mating snakes. Primary searching areas included the vegetated banks of channels and drainages, marshland edges, and potential upland basking and refuge sites. We also checked beneath surface cover and debris, such as boards or trash, found near aquatic habitat. Extensive searches were also made for snakes while driving along the numerous paved and gravel roadways occurring throughout the aquatic habitat present within the study area. Visual encounter surveys were conducted incidental to all trap checking activities.

Floating modified minnow traps were placed along the edges of channels, streams, and associated marshland. Traps were not purposely baited, but captured numerous frogs, tadpoles, and fish that undoubtedly served as attractants to GGS. As many as 500 traps were deployed as 50-trap transects for minimum 14-day intervals between May 10 and August 19, when giant garter snakes are typically most active (G. Hansen and J. Brode 1993, E. Hansen 2004). GPS units were used to record the UTM coordinates of each unique trap location, and environmental characteristics, such as vegetation and substrate types, were noted for each point. Traplines were arranged with traps set at 10-meter (32.8-foot) intervals, resulting in traplines approximately 500 meters (1640 feet) long. Trap design and placement were modeled after methods refined by USGS (Casazza et al. 2000). Where traps remained in place without interference, organisms within the traps were identified and counted at the end of each rotation in order to compare prey densities between regions. Traps were checked daily.

One reference trapline was established where GGS were detected at Los Banos Creek (Figure 4). Reference traplines are by definition left in place throughout the snakes' active season, and are useful for several reasons. Permanent reference sites increase the probability of recapturing individuals through time, resulting in better estimates of survival and recruitment. Reference sites can also provide better information regarding species response to changing habitat conditions over time than do non-reference traplines, thereby developing information to inform the adaptive management process. Finally, reference sites provide information on seasonal variation in giant garter snake activity that short-term traplines cannot.

A second set of 50 traps was deployed in conjunction with permeable silt fencing placed in managed marsh habitats. Trapping in shallow wetlands can be ineffective without a well-defined interface between terrestrial or vegetative and open water habitats. The purpose of these traplines was to test the hypothesis that drift fences would improve capture success by providing a foraging boundary similar to the boundary present in linear water conveyance features. These traplines were set in areas of open or densely vegetated shallow (≤ 1.5 meters [4.9 feet]) water without a naturally occurring foraging boundary that would direct snakes toward the traps. The resulting *drift fence* traplines were arranged with traps set on alternating sides of the fencing material at 5-meter (16.5-foot) intervals, resulting in traplines approximately 250 meters (820 feet) long deployed in two rotations.

Traps used for drift fence traplines were constructed of eight-mesh hardware cloth (64 squares per square inch) rather than the standard four-mesh hardware cloth (16 squares per square inch) typically used. Little is known of newborn or juvenile GGS due to their low visual detectability and their ability to pass through coarser four-mesh traps. Newborn GGS may also die after becoming ensnared in the larger mesh (Wylie *et al.* 2004). Because newborn giant garter snakes cannot pass through the smaller eight-mesh cloth, this material was selected in an effort to sample for this smaller size class and to reduce the risks of mortality associated with four-mesh traps. Traps used for rotating and reference traplines were made of standard four-mesh hardware cloth for the durability needed to withstand extended periods in water, frequent transport, and resetting. All traps were checked daily.

In addition to traplines, one line of 50 plywood cover boards was set along the bank margin adjacent to the reference line. Set late in the season and remaining in place for approximately 3 weeks, the cover boards did not become well established (i.e., vegetation did not flatten to the extent needed to provide adequate cover). Cover boards were checked periodically through a full range of day-time periods.

Weight, total length, snout to vent length, sex, scale counts and measurements on head and midbody, and other physical features such as scars and tumors were noted for all snakes captured. Captured snakes were implanted with passive integrated transponder (PIT) tags for permanent identification. Tissue and/or blood was collected and archived for genetic analyses. All snakes were released at their point of capture after recording data.

Tissue was collected by clipping 1-2 scales from the terminal end of the tail using either surgical scissors or a scalpel. The tail was then sealed using surgical glue. Instruments were sterilized with hydrogen peroxide (H_2O_2) and isopropyl alcohol ($CH_3CHOHCH_3$) at the time of each use to prevent cross contamination. Tissue was stored in 70% ethanol (ETOH) until it was delivered to Dr. Tag Engstrom, CSU Chico for an examination of genetic variation amongst extant subpopulations of GGS. These tissues as well as all of those that we have collected during various studies conducted in the Sacramento Valley since 2001 were turned over to Dr. Engstrom's laboratory on October 25, 2006.

Population Estimates

The Fortran software program CAPTURE was used to estimate population size based on capture histories of marked individuals. Statistical models used to estimate density assume the population is closed, i.e., that no immigration or emigration occurs during the time period for which density is being estimated. To meet this assumption, estimates of density are typically based on a 2-week sampling period (E. Hansen 2004; Jones and Stokes 2005, Wylie *et al.* 2003). For consistency in the case of this analysis, data from the reference line was analyzed for three two-week periods and then averaged.

For comparison, data was pooled for the entire sampling period. Although the area surrounding the reference trapline was saturated with traplines over the course of the study, GGS were only captured or observed within traps in the core of this concentration of traplines. Because each GGS was captured multiple times and because surrounding traplines produced no captures, it is likely that most local GGS were accounted for. In such a case, pooling data collected over a period of more than two weeks is unlikely to violate the closed model assumption.

Spatial Analysis

All spatial-data analysis, including the estimation of parcel area, trap line distance, and the preparation of all figures was accomplished using the Environmental Systems Research Institute, Inc. (ESRI) Geographic Information Systems program ArcMap Version 8.2.

RESULTS

Overview

Trapping began on May 10, 2006 and continued through August 19, 2006. Fifty traplines were established with 35,970 trap days accrued – all within Merced County. Eight GGS were captured in all. Of these eight giant garter snakes, seven were captured multiple times, resulting in 32 capture events. Seven GGS were encountered along the Los Banos Creek corridor between the San Joaquin River and the City of Los Banos and one was encountered south of the City of Los Banos (Figure 2). Captures were limited to standard aquatic traplines: no GGS were observed during visual encounter surveys, within drift fence arrays, or beneath cover boards, and no GGS were found dead on or along roadways. No GGS were encountered north and east of the San Joaquin River.

Regions North and East of the San Joaquin River

Twenty traplines were established north and east of the San Joaquin River (Figure 2, 3). Traplines were established within Stevinson Water District at Big Bottom Lake, Turner Slough, and within the East Side Canal from the Stevinson Ranch golf course/Lake Honda southeast to the Mariposa Bypass near Merced National Wildlife Refuge (MNWR). At MNWR's main unit, traplines were established encompassing drainages and wetlands both north and south of Sandy Mush Road. At MNWR's Arena Plains and Snobird units, traplines were established within Bear Creek, Atwater Drain, and within and along the margins of perennial wetlands. One trapline was established in Drake Ditch, connecting the East Side Canal and Bear Creek at the privately owned Modesto Properties situated west of MNWR's Snobird Unit south of Highway 140. Although 22 captures of Valley garter snakes (*Thamnophis sirtalis fitchi*) were recorded throughout the region (10 of 20 sites), no GGS were encountered. The majority of areas trapped appeared suitable for GGS, and, with the exception of Big Bottom Lake, which dried entirely while traps were set, all possessed water throughout the summer active season.

Figure 2. Overview of Trapping Effort and Capture Results in SJV During 2006

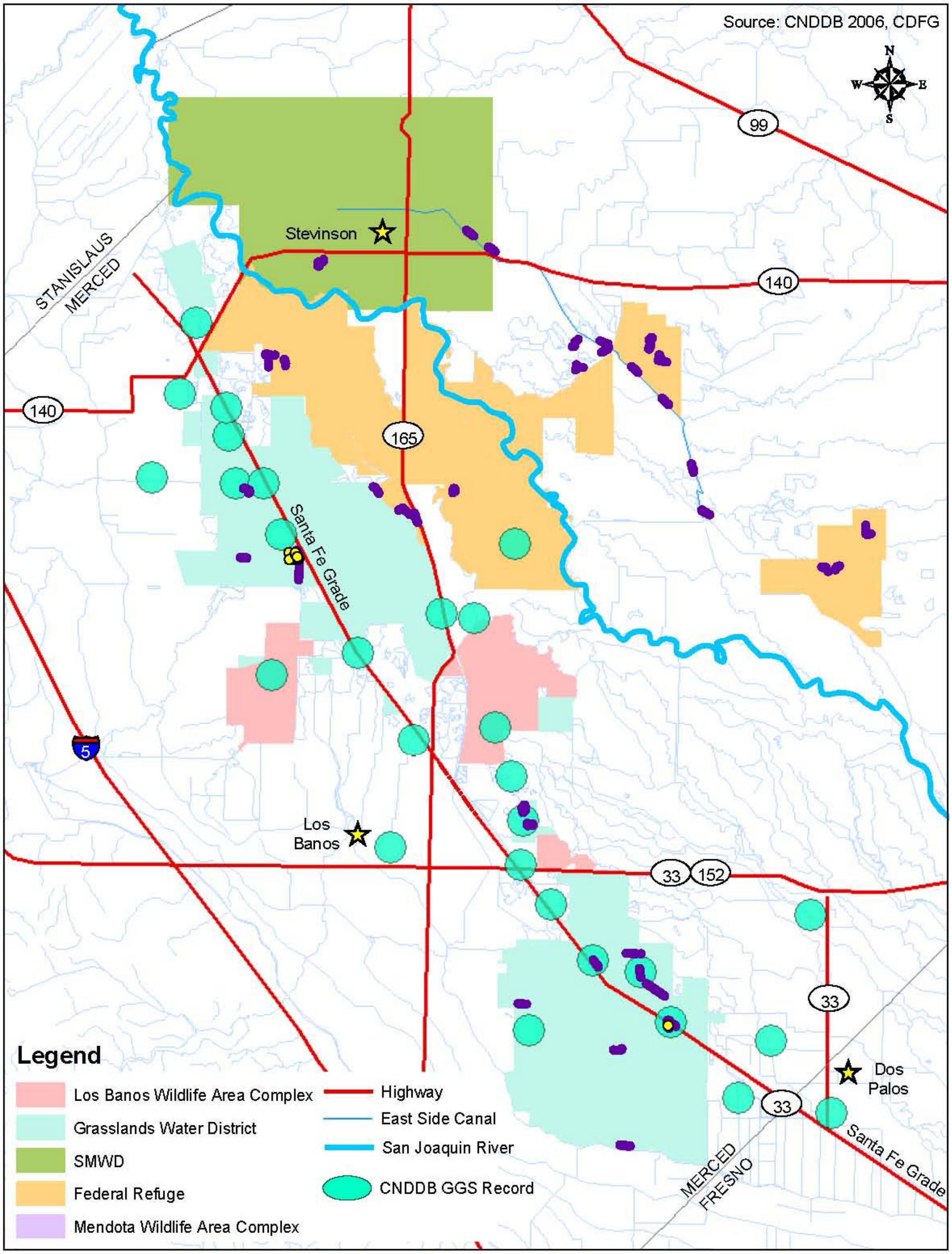
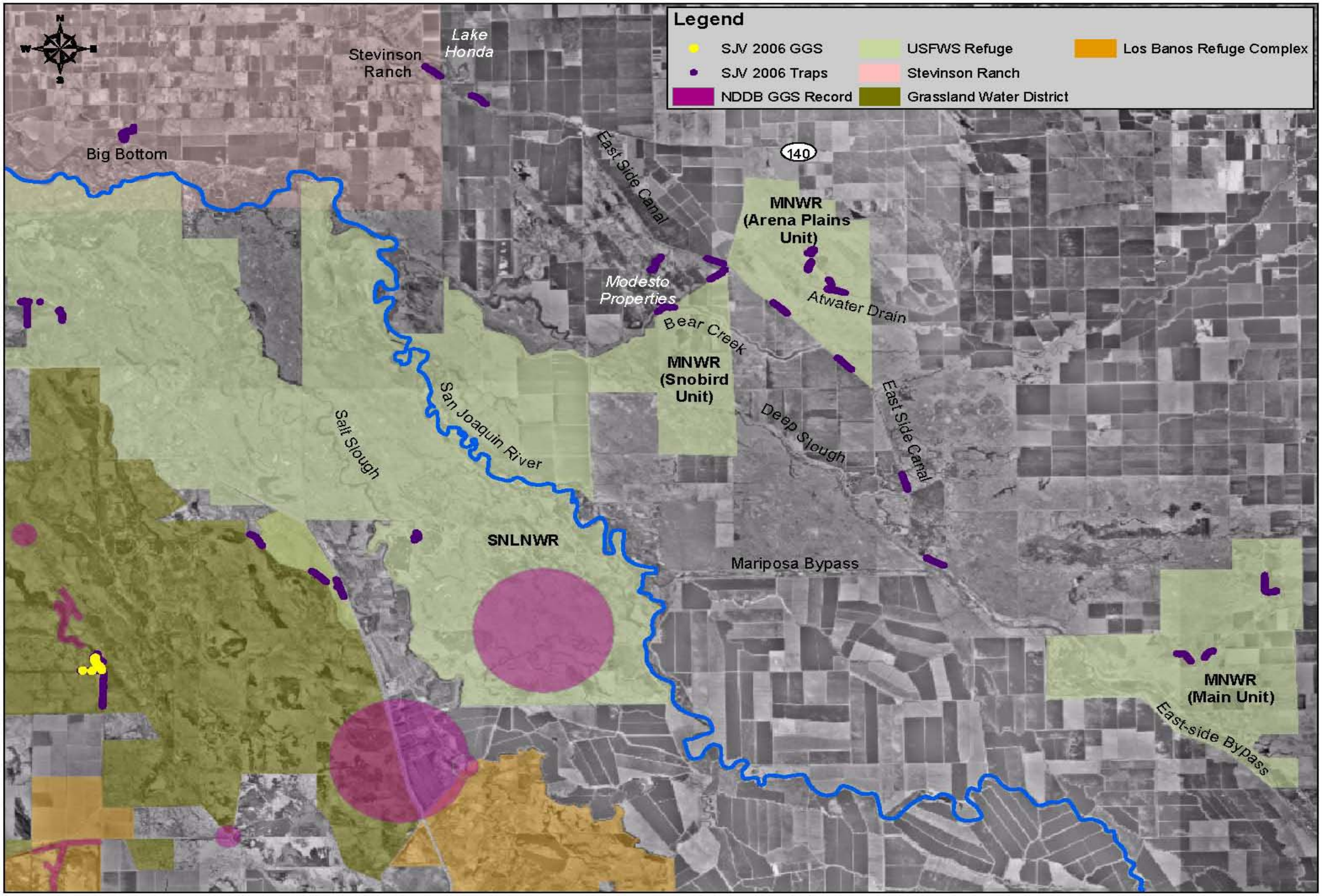


Figure 3. Trapping Effort and Capture Results North and East of the SJV River During 2006



Regions South and West of the San Joaquin River

Thirty traplines were established south of the San Joaquin River along the Los Banos Creek and Santa Fe Grade corridors where giant garter snakes have occurred historically (Figures 4-5). Sampling was restricted to the San Luis National Wildlife Refuge complex (SNLNWR), the consortium of privately owned properties situated within Grassland Water District (GWD), and the privately owned Klamath Club encompassing Mud Slough east of the City of Los Banos between Highway 152 and Henry Miller Road. In South GWD (south of Highway 152), traplines were established in Atwater Drain, Poso Canal, Big Water Drain, Helm Canal, and a series of smaller roadside ditches linking these features; one giant garter snake was captured in a historically occupied locality at the junction of Agatha Canal and Poso Drain. Within North GWD (north of Highway 152), traplines were established within Los Banos Creek, Mosquito Ditch (northern end of the Volta Waste Way), and San Luis Creek (drainage along Ingomar Grade); seven giant garter snakes were captured multiple times at the junction of these three features. Traplines established within the San Luis, Blue Goose, and Kesterson units of SNLNWR and those established at Mud Slough at the Klamath Club did not result in GGS encounters despite their proximity to historical occurrences. Similarly, concurrent trapping surveys conducted by DFG at Mud Slough within the Los Banos Refuge Complex failed to detect GGS where they were documented in 2001 (Dickert 2005)

A control site was established at the northern terminus of Mosquito Ditch, resulting in 29 captures among 7 individual snakes. Capture frequency was fairly regular throughout the study (Figure 6) and recaptures were sufficient to estimate the local population at 7 ± 0.4932 (95% C.I. not estimable) (Table 2). Visual encounter surveys were unusually unproductive. At Mud Slough and at the junction of Los Banos Creek and Mosquito Ditch, aquatic drift fences were established in backwaters and areas of dense vegetation where standard trapping was impractical. Cover boards were also placed along bank margins at the Mosquito Ditch control site. Despite abundant vegetative cover and aquatic prey, and in the case of Mosquito Ditch, the immediate presence of GGS in adjacent features, none were captured in adjacent drift fence transects or beneath cover boards. In comparison, drift fence transects deployed in the Sacramento Valley during the same time resulted in as many as 15 captures of GGS per transect with an associated capture per unit effort ratio of 0.0052. Although no GGS were captured in two SJV drift fence arrays, both resulted in captures of adult and neonate valley garter snakes.

Figure 4. Trapping Effort and Capture Results Near Los Banos Creek During 2006

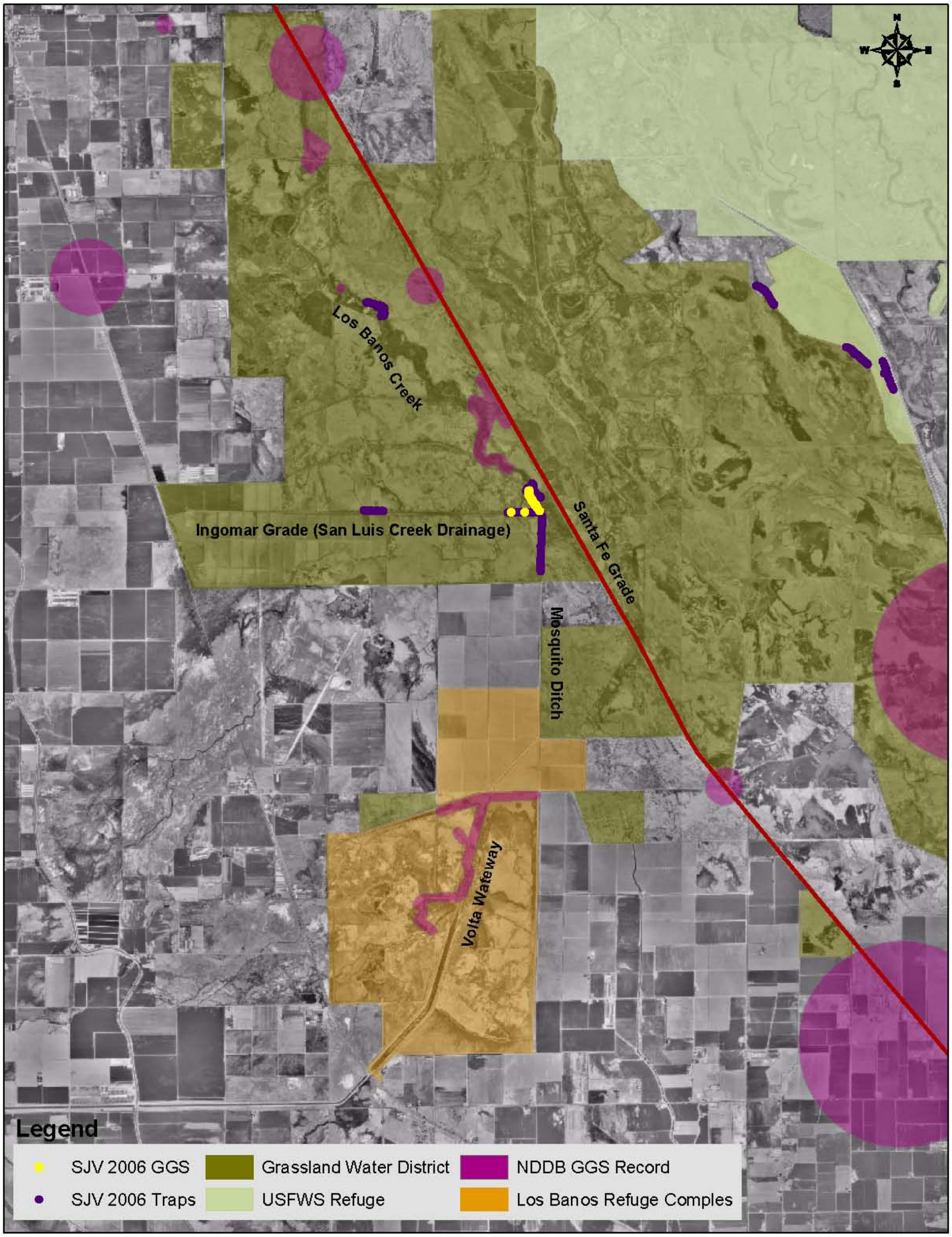


Figure 5. Trapping Effort and Capture Results in South Grasslands During 2006

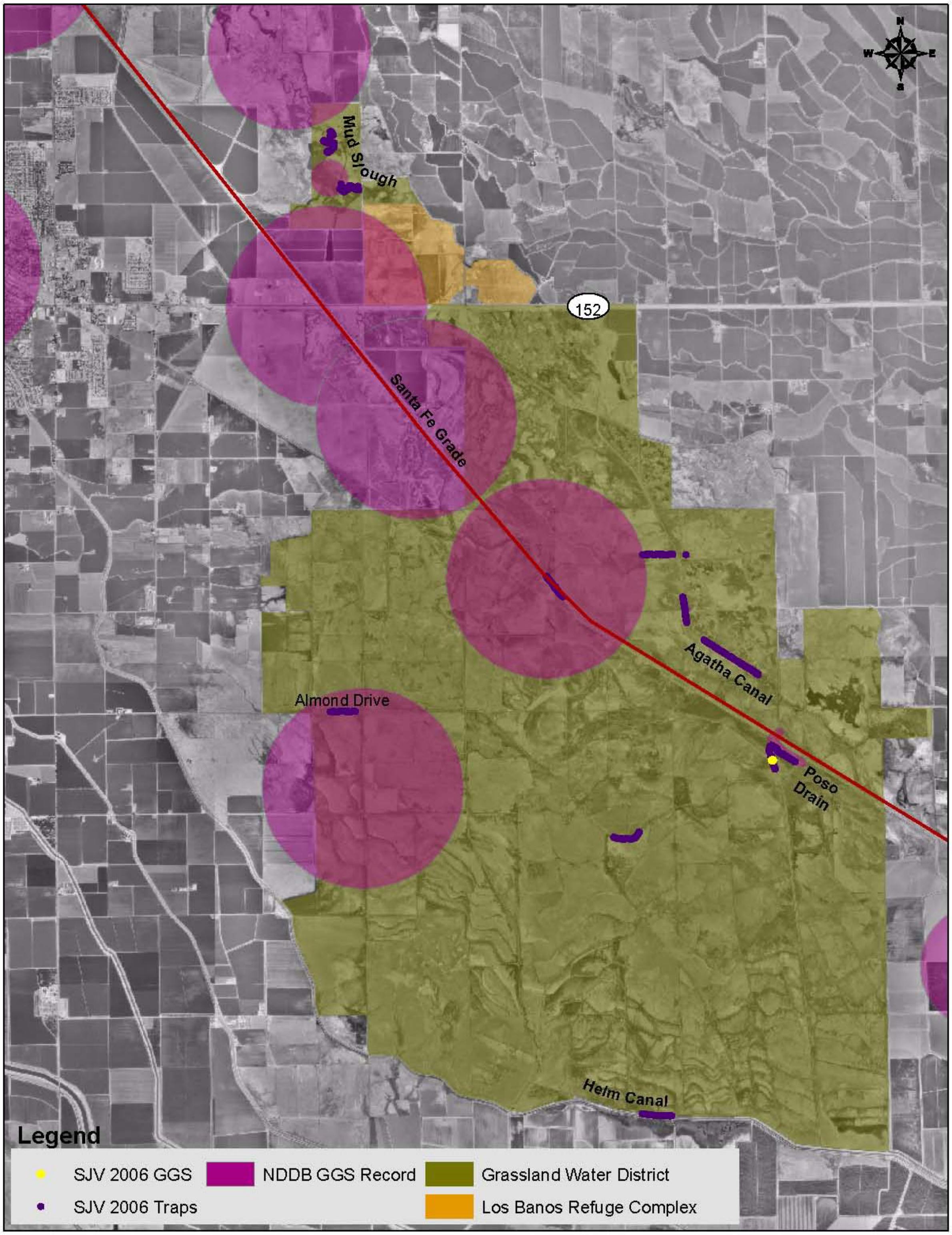


Figure 6. Capture Frequency Distribution of Giant Garter Snakes in SJV During 2006

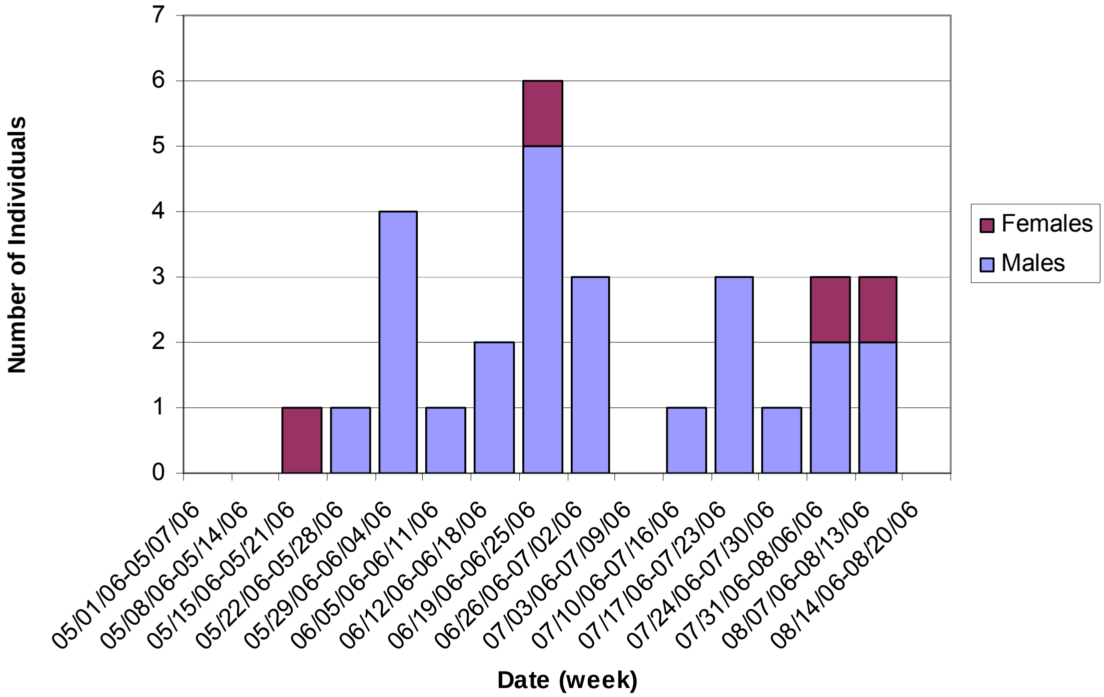


Figure 7. Length Frequency Distribution of Giant Garter Snakes in SJV During 2006

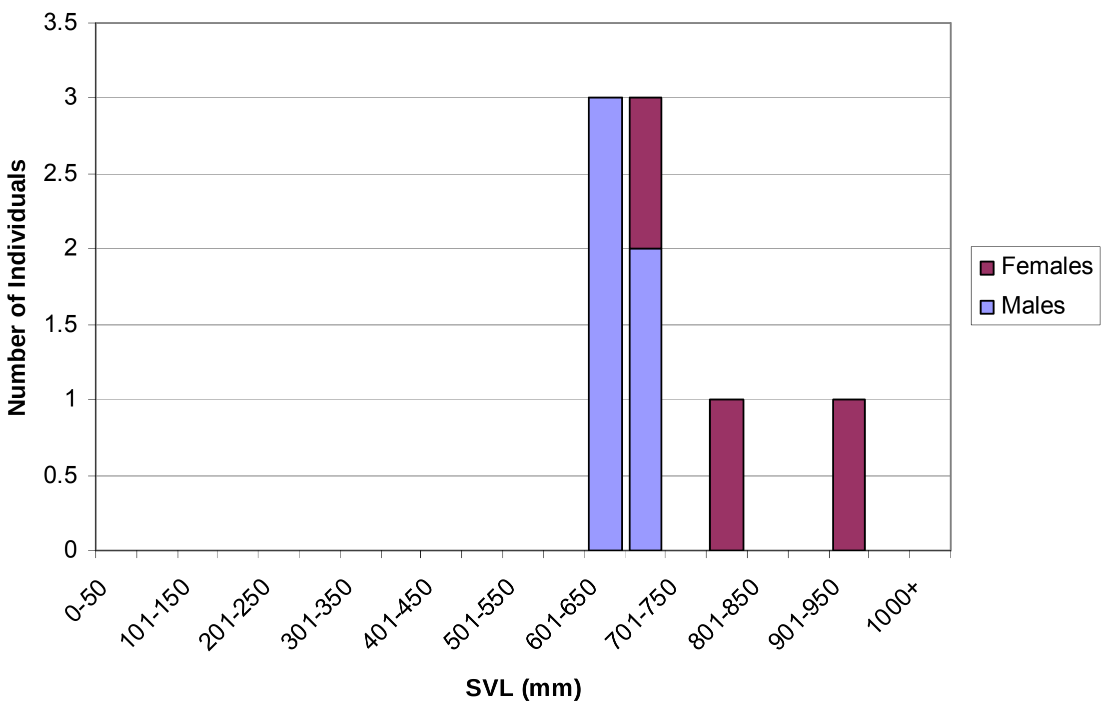
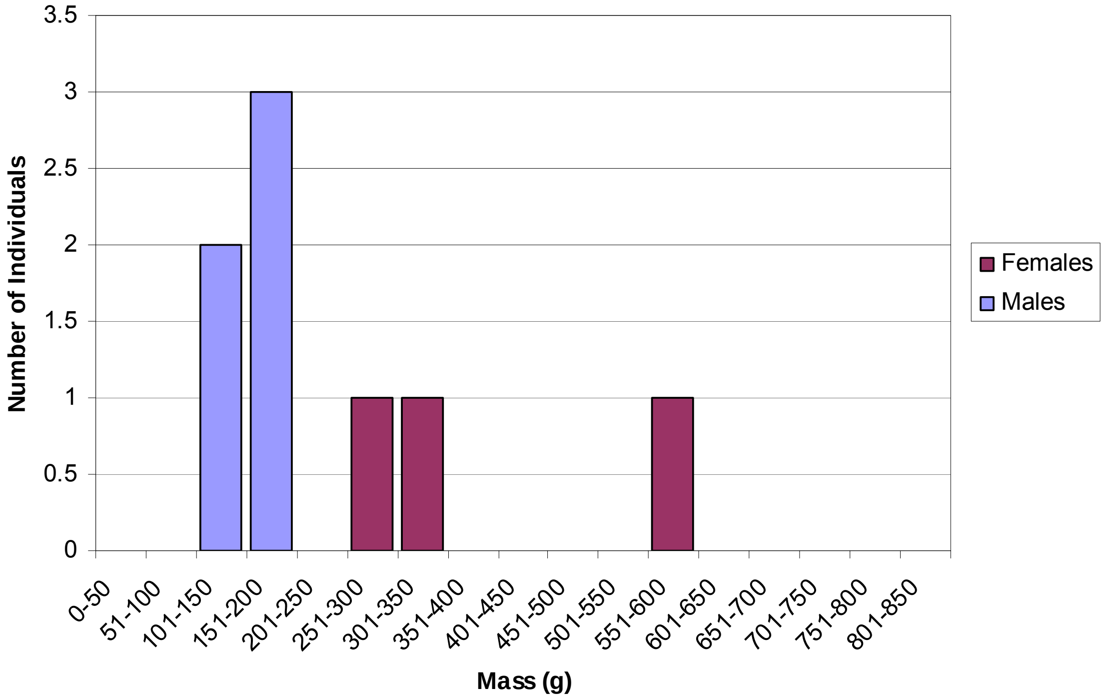


Figure 8. **Mass Frequency Distribution of Giant Garter Snakes in SJV During 2006**



Of the eight GGS captured, five were male and three were female (M:F gender ratio of 2.5:1 in North GWD, 1.67:1 overall). All were large, sexually mature adults, with females averaging 365.7 grams and 790 millimeters snout-to-vent length (SVL) and males averaging 133 grams and 647.4 SVL. No young were observed, and, unlike snakes observed in the Sacramento Valley during the same time, females were not perceptibly gravid (E. Hansen, unpublished data). Though all snakes displayed the lumps caused by the parasitic nematode infection now associated with this species throughout its range, each appeared otherwise healthy and robust.

Table 1: Statistical attributes of San Joaquin Valley giant garter snake size parameters in 2006

SJV Male GGS SVL	
Mean	649.98
Standard Error	3.371558
Median	647.5
Standard Deviation	7.539032
Sample Variance	56.837
Skewness	0.275629
Range	16.9
Minimum	641.6
Maximum	658.5
Sum	3249.9
Count	5
Confidence Level (95.0%)	9.360944

SJV Female GGS SVL	
Mean	796.2333
Standard Error	63.16134
Median	800
Standard Deviation	109.3986
Sample Variance	11968.06
Skewness	-0.15475
Range	218.7
Minimum	685
Maximum	903.7
Sum	2388.7
Count	3
Confidence Level (95.0%)	271.7613

SJV Male GGS Mass	
Mean	148.4
Standard Error	7.0025
Median	152
Standard Deviation	15.65807
Sample Variance	245.175
Skewness	-1.49486
Range	38.5
Minimum	122.5
Maximum	161
Sum	742
Count	5
Confidence Level (95.0%)	19.44206

SJV Female GGS Mass	
Mean	390.6333
Standard Error	69.44956
Median	348.6
Standard Deviation	120.2902
Sample Variance	14469.72
Skewness	1.380447
Range	229.3
Minimum	297
Maximum	526.3
Sum	1171.9
Count	3
Confidence Level (95.0%)	298.8173

Table 2: Sampling effort and capture results

Transect	Traps	Days	Trap Days	Captures	Success/Unit Effort (snakes/trap day)	Population Estimate
SJV1	50	15	750	0	0	N/A
SJV2	50	14	700	0	0	N/A
SJV3	50	15	750	1	.0013	N/A
SJV4	50	15	750	0	0	N/A
SJV5	50	15	750	0	0	N/A
SJV6	50	15	750	7	.0093	See SJV17*
SJV7	50	15	750	0	0	N/A
SJV8	50	2	100	0	0	N/A
SJV9	50	15	750	0	0	N/A
SJV10	50	15	750	0	0	N/A
SJV11	49	15	735	0	0	N/A
SJV12	50	14	700	2	.0029	See SJV17*
SJV13	50	14	700	0	0	N/A
SJV14	50	15	750	0	0	N/A
SJV15	50	5	250	0	0	N/A
SJV16	50	15	750	0	0	N/A
SJV17	50	68	3400	22	.0065	7 ± 0.4932 (95% C.I. not estimable)*
SJV18	50	29	1450	0	0	N/A
SJV19	50	14	700	0	0	N/A
SJV20	50	7	350	0	0	N/A
SJV21	50	15	750	0	0	N/A
SJV22	50	15	750	0	0	N/A
SJV23	50	15	750	0	0	N/A
SJV24	50	8	400	0	0	N/A

SJV25	50	2	100	0	0	N/A
SJV26	50	15	750	0	0	N/A
SJV27	50	14	700	0	0	N/A
SJV28	50	14	700	0	0	N/A
SJV29	50	14	700	0	0	N/A
SJV30	50	14	700	0	0	N/A
SJV31	50	15	750	0	0	N/A
SJV32	50	15	750	0	0	N/A
SJV33	50	15	750	0	0	N/A
SJV34	50	14	700	0	0	N/A
SJV35	50	14	700	0	0	N/A
SJV36	50	15	750	0	0	N/A
SJV37	50	15	750	0	0	N/A
SJV38	50	8	160	0	0	N/A
SJV39	50	15	750	0	0	N/A
SJV40	50	15	750	0	0	N/A
SJV41	50	15	750	0	0	N/A
SJV42	50	15	750	0	0	N/A
SJV43	50	15	750	0	0	N/A
SJV44	50	15	750	0	0	N/A
SJV45	50	14	700	0	0	N/A
SJV46	50	15	750	0	0	N/A
SJV47	25	28	700	0	0	N/A
SJV48	50	14	700	0	0	N/A
SJV49	25	13	325	0	0	N/A
SJV50	50	2	100	0	0	N/A

*Density estimates are based upon pooled data from contiguous traplines. Estimates from individual traplines and estimates from two-week time periods within the reference line resulted in population estimates below that which is reported for SJV17. All estimates utilized the same pool of 7 snakes captured multiple times near Los Banos Creek.

Table 3: Prey Densities

Transect ID	General Location	Trap Days	Ranid Larva	Density	Ranid Adult	Density	Centrar-chids	Density	Carp	Density	Mosquito -fish	Density	Catfish	Density
SJV1	Big Water Drain at Santa Fe Road	750	3	0.004	0	0	0	0	10	0.013333	14	0.01866	62	0.08266
SJV2	Atwater Drain at Arena Plains	700	31	0.044286	5	0.007143	11	0.015714	3	0.004286	23	0.03285	227	0.32428
SJV3	Agatha/Poso	750	1	0.001333	3	0.004	10	0.013333	6	0.008	10	0.01333	131	0.174667
SJV4	Los Banos Creek N	750	0	0	2	0.002667	0	0	0	0	134	0.17866	785	1.04666
SJV5	East Side Canal at Snobird	750	0	0	2	0.002667	0	0	47	0.062667	4	0.00533	54	0.072
SJV6	Los Banos Creek SW	750	0	0	1	0.001333	8	0.010667	27	0.036	5	0.00666	77	0.10266
SJV7	Turner Slough	750	0	0	3	0.004	5	0.006667	2	0.002667	0	0	100	0.13333
SJV9	Mud Slough at Klamath Club	750	1	0.001333	1	0.001333	13	0.017333	1	0.001333	6	0.008	59	0.07866
SJV10	East Side Canal at Hwy 140	750	22	0.029333	1	0.001333	13	0.017333	1	0.001333	8	0.01066	31	0.04133
SJV11	Agatha Canal at CLLCC	735	0	0	0	0	0	0	68	0.092517	10	0.01360	157	0.21360
SJV12	San Luis Creek East	700	54	0.077143	1	0.001429	1	0.001429	12	0.017143	8	0.01142	32	0.04571
SJV13	Atwater Drain at Snobird	700	2	0.002857	8	0.011429	5	0.007143	3	0.004286	1	0.00142	149	0.21285
SJV14	Arena Plains Wetland 2	750	0	0	2	0.002667	12	0.016	0	0	21	0.028	229	0.30533
SJV15	Los Banos Creek SE	250	0	0	0	0	8	0.032	6	0.024	28	0.112	359	1.436
SJV16	Mud Slough at Klamath Club 2	750	1	0.001333	7	0.009333	56	0.074667	5	0.006667	12	0.016	53	0.07066
SJV17	Los Banos Creek 2	3400	4	0.001176	6	0.001765	8	0.002353	0	0	0	0	123	0.03617
SJV18*	Drift Fence at Mud Slough/Klamath	1450	1	0.00069	3	0.002069	24	0.016552	2	0.001379	141	0.09724	8	0.00551
SJV19	East Side Canal at Stevinson Ranch	700	550	0.785714	9	0.012857	15	0.021429	4	0.005714	0	0	115	0.16428

Transect ID	General Location	Trap Days	Ranid Larva	Density	Ranid Adult	Density	Centrar-chids	Density	Carp	Density	Mosquito -fish	Density	Catfish	Density
SJV21	Blue Goose Interior 1	750	1	0.001333	1	0.001333	7	0.009333	3	0.004	16	0.02133	52	0.06933
SJV22	Bear Creek at Snobird	750	46	0.061333	46	0.061333	0	0	22	0.029333	0	0	110	0.14666
SJV23	Arena Plains Wetland 3	750	0	0	3	0.004	7	0.009333	2	0.002667	1	0.00133 3	566	0.75466 7
SJV25	Blue Goose at Hwy 165	100	1	0.01	12	0.12	15	0.15	0	0	5	0.05	0	0
SJV26	Blue Goose Interior 2	750	3	0.004	12	0.016	18	0.024	1	0.001333	1	0.00133	56	0.07466
SJV27	San Luis NWR Dead Man's Slough	700	500	0.714286	8	0.011429	25	0.035714	20	0.028571	3	0.00428	700	1
SJV28	Mosquito Ditch NE	700	69	0.098571	1	0.001429	8	0.011429	88	0.125714	4	0.00571	66	0.09428
SJV29	Santa Fe Canal at Kesterson	700	479	0.684286	2	0.002857	35	0.05	6	0.008571	12	0.01714	80	0.11428
SJV30	E3P Marsh at Kesterson	700	4	0.005714	3	0.004286	25	0.035714	4	0.005714	1	0.00142	148	0.21142
SJV31	Beaver Pond at Kesterson	750	244	0.325333	0	0	13	0.017333	0	0	1	0.00133	27	0.036
SJV32	Mosquito Ditch SW	750	95	0.126667	14	0.018667	11	0.014667	29	0.038667	1	0.00133	88	0.11733
SJV33	San Luis Creek W	750	52	0.069333	61	0.081333	2	0.002667	12	0.016	6	0.008	89	0.11866
SJV34	Poso Drain at Mallard Road	700	113	0.161429	8	0.011429	16	0.022857	44	0.062857	0	0	0	0
SJV35	Agatha Canal at CLLCC 2	700	138	0.197143	1	0.001429	8	0.011429	11	0.015714	0	0	4	0.00571
SJV36	Agatha Canal at CLLCC 3	750	92	0.122667	26	0.034667	0	0	9	0.012	0	0	0	0
SJV37	Merced NWR 1 Marsh	750	21	0.028	13	0.017333	0	0	0	0	17	0.02266	558	0.744
SJV39	Merced NWR 2 Ditch	750	0	0	1	0.001333	1	0.001333	0	0	3	0.004	183	0.244
SJV40	East Side Canal 4	750	0	0	0	0	2	0.002667	1	0.001333	0	0	151	0.20133

Transect ID	General Location	Trap Days	Ranid Larva	Density	Ranid Adult	Density	Centrar-chids	Density	Carp	Density	Mosquito -fish	Density	Catfish	Density
SJV41	East Side Canal 5	750	3	0.004	9	0.012	8	0.010667	4	0.005333	0	0	92	0.122667
SJV42	East Side Canal 6	750	0	0	4	0.005333	7	0.009333	4	0.005333	0	0	270	0.36
SJV43	Almaden Ditch	750	768	1.024	4	0.005333	14	0.018667	0	0	2	0.00266	47	0.06266
SJV44	Helm Canal at Frog Pond Club	750	19	0.025333	3	0.004	0	0	3	0.004	5	0.00666	3	0.004
SJV45	East Side Canal 7	700	1	0.001429	19	0.027143	2	0.002857	9	0.012857	0	0	102	0.14571
SJV46	Merced NWR 4 Dead Man Creek E	750	3	0.004	0	0	2	0.002667	0	0	0	0	11	0.01466
SJV47*	Los Banos Creek Drift Fence 1	700	0	0	1	0.001429	0	0	1	0.001429	55	0.07857	29	0.04142
SJV48	Modesto Properties Drake Ditch	750	64	0.085333	9	0.012	1	0.001333	0	0	0	0	17	0.02266
SJV49*	Los Banos Creek Drift Fence 2	325	0	0	1	0.003077	1	0.003077	2	0.006154	83	0.25538	59	0.18153
SJV50	Almond Drive Ditch	100	17	0.17	0	0	19	0.19	13	0.13	10	0.1	41	0.41

* Signifies traps with 16 holes per inch of mesh compared to the standard 4 holes per inch; these traps capture larger number of small prey such as mosquitofish.

Key: Tadpole = *Rana catesbeiana* or *Pseudachris regilla;* Bullfrog = *Rana catesbeiana;* Treefrog = *Pseudacris regilla;* Centrarchid Fish = Sunfish (*Lepomis* spp.); Black basses (*Micropterus* spp.); Carp (*Cyprinus carpio*); and Crappie (*Pomoxis* spp.); Mosquitofish = *Gambusia affinis;* Crayfish = *Procambarus clarkii*

SUMMARY AND CONCLUSIONS

Potential Reasons for Decline

While habitat loss is the primary threat to the survival of GGS, other factors, such as insufficient water supply during the snake's active season, degraded water quality, environmental contamination, and parasite infestation have been identified as potential contributors to the species' ongoing decline (G. Hansen *in litt*. 1992; G. Hansen 1993; USFWS 1999, 2006). These factors may be particularly significant in the San Joaquin Valley where recent surveys indicate an alarming decrease in GGS numbers despite the presence of apparently suitable habitat (Dickert 2003; E. Hansen *in litt.* 2006; G. Hansen 1996; Sloan 2004; Wylie 1999).

Water Management

Historic changes in wetland management practices on State, Federal, and private lands in the Grassland Wetlands of Merced County have coincided with significant declines of GGS populations in the area (Beam and Menges 1997; G. Hansen 1988, 1996; Paquin *et*. *al*. 2006; USFWS 2006). Wetland management for water fowl on several State and Federal wildlife refuges entails flooding the wetlands during winter and spring months, and draining them in the summer (Paquin *et*. *al*. 2006; USFWS 2006). In the past, private duck clubs maintained pastures for cattle during the summer, which provided sufficient water for giant garter snakes in sloughs, canals, and other water features throughout the basin (G. Hansen 1988; Paquin *et*. *al*. 2006; USFWS 2006). In the mid-1970's, however, duck clubs were encouraged to shift their focus from cattle grazing to moist soil management, which significantly reduced the amount of summer water in the area (G. Hansen 1988; Beam and Menges 1997; USFWS 2006). This shift in management coincides with the observed onset of GGS decline in SJV.

Water management may also affect the aquatic prey that GGS depend on. During this study, acute fluctuations of water levels in a number of sloughs, irrigation canals, ditches, drains, and wetlands occurred throughout the season and study area. On several occasions, water features that had appeared stable went completely dry within a day, killing numerous fish, frogs, and tadpoles. Fish kills were also periodically observed where water levels remained stable and of ample depth, suggesting that impaired water quality and/or contamination may play a role. Diminished water quality may also affect GGS directly.

Water Quality

Selenium contamination and impaired water quality have been identified as contributing factors in the decline of GGS, particularly in the southern portion of their range (USFWS 1993, USFWS 1999). Unfortunately, information regarding reptile toxicology is lacking, particularly for snakes (Burger *et al.* 2005; Campbell *et al*. 2005; Clark *et al.* 2000; Holem *et al.* 2006; Hopkins *et al.* 2002; Rainwater *et al.* 2005; USFWS 2003). No studies to date have specifically examined giant garter snake toxicology. One recent study used valley garter snakes (*Thamnophis sirtalis fitchi*) and western terrestrial garter snakes (*Thamnophis elegans elegans*) as surrogate species to determine the acute toxicity to giant garter snakes of select herbicides and a surfactant; no adverse effects were observed (Hosea *et al*. 2003). Research on other snake species, including eastern water snakes (*Nerodia* spp.), which occupy an ecological niche very similar to giant garter snakes (Rossman *et al*. 1996), have demonstrated that bioaccumulation of trace elements, pesticides, and other contaminants does occur in snakes (Bishop and Rouse 2000; Clark *et al.* 2000; Campbell *et al.* 2005; Hopkins *et al.* 2002; K. Campbell and T. Campbell 2001, Ohlendorf *et al.* 1988; Rainwater *et al.* 2005; Santos *et al.*1999) and can result in adverse biological effects, including increased standard metabolic rates (Hopkins *et al.* 1999; USFWS 2006) and impaired locomotion (Hopkins *et al.* 2005). Impaired reproduction, weakened immune systems, and a number of other harmful effects have been demonstrated in a variety of other organisms. While little data is available regarding the effects of specific contaminants, the bioaccumulative properties of selenium in the food web has been well documented in the Kesterson National Wildlife Refuge area (Ohlendorf *et. al.* 1986, Saiki and Lowe 1981, Saiki and May 1988, Saiki *et al.* 1991, USFWS 1993).

Selenium has been shown to cause hepatotoxicity and impaired embryo growth in contaminated American avocet (*Recurvirostra americana*) hatchlings collected from the Tulare Lake Basin (Hoffman *et al.* 2002). Lead intoxication caused increased kidney weight, altered mitochondrial structure and function, presence of renal intranuclear inclusion bodies, and depressed alanine dehydrogenase activity in the blood, liver, and kidneys of London pigeons (*Columba livia*) (Hutton 1980). Organophosphate pesticide exposure has been shown to significantly decrease cholinesterase activity in the kidney and liver of changeable lizards (*Calotes versiclor*) (Khan 2003) and impair sprint velocities in western fence lizards (*Sceloporus occidentalis*) (Holem *et al.* 2006). Organochlorine pesticides biomagnify in the food chain, and can disrupt the immune system (Grasman and Fox 2001) and endocrine processes (Tanabe 2002). While the effects of these contaminants on reptiles are not fully understood, it is expected that toxicity thresholds for reptiles would be similar to those of fish and birds (USFWS 1993, 1999).

Of eight giant garter snakes captured, all were sexually mature adults. No young were observed, and, unlike snakes observed in the Sacramento Valley during the same time, females were not perceptibly gravid. This suggests that reproductive output may be impaired. Bioaccumulation of selenium and organochlorine pesticides in fish, frogs, fish-eating birds (Hothem and Ohlendorf 1989; Ohlendorf *et al*. 1986, 1988; Saiki and Lowe 1987; Saiki and May 1988; Saiki and Schmitt

1986; Saiki *et al*. 1991, 1992; 1993; USFWS 1999, 2006), and gopher snakes (*Pituophis catenifer*) (Ohlendorf *et al*. 1988) has been well documented in the Grassland Ecological Area and surrounding areas of Merced County. As with other species, each of these compounds may impact reproductive success and population recruitment in San Joaquin Valley giant garter snakes.

Water quality in the east side of the San Joaquin Valley, where the SMWD is located, is considerably better than west side of the Valley. In the east side of the Valley, salinity of source water as well as drainage water is considerably lower, and SMWD does not have the problems with high selenium and salt concentrations. In fact, SMWD is mostly deficient in selenium and selenium supplements may be required for cattle operations (R. Kelley personal communication). Impaired water quality, therefore, may not provide an adequate explanation for the possible lack of GGS northeast of the San Joaquin River.

Predation

GGS are also threatened by the introduction of exotic species. Examinations of gut contents confirm that introduced bullfrogs (*Rana catesbeiana*) prey directly on juvenile GGS throughout their range (Dickert 2003, Treanor 1983, Wylie 2003). While the extent of this predation and its effect on population recruitment is poorly understood, estimates based on preliminary data from a study conducted at Colusa National Wildlife refuge suggests that 22% of neonate giant garter snakes may succumb to bullfrog predation (Wylie et al. 2003). Some suggest that bullfrog densities in SJV might exceed those in the Sacramento Valley by an order of magnitude (J. Beam, *pers. comm.*). Other studies of bullfrog predation on snakes have documented bullfrogs ingesting other species of garter snakes up to 80 cm (31.5 inches) long, resulting in a depletion of this age class within the population which experienced alternating resurgence and decline coinciding with fluctuations in the local bullfrog population (Bury and Wheelan 1984).

Introduced predatory game fishes such as black basses (*Micropterus* spp.), striped bass (*Morone saxatilis*), sunfish (*Lepomis* spp.), and channel catfishes (*Ictalurus* spp.) probably prey on giant garter snakes and compete with them for smaller prey (Hansen 1988, USFWS 1993). GGS appear absent from features supporting permanent populations of these species (USFWS 2006). Observations made during the fish kills and episodic drying of ditches and canals throughout the study area suggests that the composition and population structure of potential predatory fishes in SJV differ from those noted in the rice growing regions of the Sacramento Valley. Striped bass frequently exceeding 3-5 pounds were common to all permanent ditches and drains observed throughout the SJV study area. Striped bass are not observed where GGS persist in rice growing regions (E. Hansen 2005). In addition to striped bass, channel catfish and black basses from 2-8 pounds were not uncommon.

In rice growing regions, irrigation systems are dried down at the end of each growing season, preventing predatory fish from becoming large enough to consume GGS. Because much of the water conveyance infrastructure in SJV is also used to divert tile and surface drainage and to provide water for overwintering waterfowl, the water in SJV is more permanent. Subsequently, unlike their counterparts in rice growing regions, predatory fishes in SJV likely grow through multiple seasons and attain larger sizes. Because much of the available wetlands in SJV are drained for moist soil management during the GGS active season, GGS are likely forced to inhabit the permanent drainages and waterways that form the foundation of the irrigation system, perhaps exposing themselves to elevated rates of predation by these larger fish.

Pathology

The species' decline might also be attributed to pathological factors that may be exacerbated by diminished water quality and altered water management. In 1992, George Hansen (*in*. *litt*.) documented parasite infestations in GGS from the American Basin in Sacramento County. Unidentified filarial nematode worms, possibly of the genus *Eustrongylides* (G. Wylie. *pers. comm.*) that have been identified in San Francisco garter snakes (*Thamnophis sirtalis tetrataenia*) (USFWS 1999), were observed in several captive-held snakes. Affected snakes developed lumps under the skin from which worms exited after burrowing their way out. Several neonates exhibiting the lumps died after lingering malaise, and those that survived showed lower growth rates then their unaffected siblings. Older infected snakes appeared to have difficulty breathing 1 to 2 days prior to death. The worms appear to be transferred from mother to young in vitro, and may contribute to low survival rates among neonates (E. Hansen *unpublished notes*). At the time of the original report in 1992, George Hansen had not observed the parasites or the associated lumps in any giant garter snake populations outside of the American Basin (*in litt*. 1992). Since 1992, however, lumps consistent with the parasitic infestation have been increasingly observed in giant garter snakes throughout their range (Dickert *pers comm.*; Hansen *unpublished notes*; Wylie *pers*. *comm*.). Necropsies and surgeries have shown these parasites in a variety of organs and tissues (E. Hansen *unpublished notes*; G. Hansen *unpublished notes,* R. Wack, *pers. comm*.). Pathology and population health has not been studied in this species.

Implications for Recovery

Recruitment

Successful recruitment of young is required to maintain stable populations. GGS observed during this study displayed a skewed size distribution (Figures 6-7, Table 1). All GGS were sexually mature adults, and, as discussed above, none of the females were perceptibly gravid. Recaptured females also did not display the significant reduction in mass that follows parturition. Drift fence arrays set in areas of shallow water with dense vegetation where GGS were present did not result in captures of neonates or juveniles. Although this sample is small (n=8) and may not accurately reflect the population's true size distribution, a skewed size distribution was also apparent in the sample collected by USGS in 1998. Of the 11 snakes captured, males ranged from 84-140 grams (mean = 114 grams) and females ranged from 136-790 grams (mean = 446.9 grams) (Wylie 1999), all of which are sexually mature adults. Though size classes for GGS observed by DFG are unavailable for this analysis, it is known that at least some neonates and sexually immature snakes are present at Volta Wildlife Area (Sloan 2004, Sloan *pers comm.*). Regardless, the aforementioned studies may indicate that GGS population structure in SVJ differs from that which is typically observed in stable population in the Sacramento Valley (E. Hansen 2005; Jones and Stokes 2005, 2006; Wylie et al. 1997, 2002, 2004). If the observed results in fact suggest poor representation within the younger age classes, the potential reduction in population recruitment could hinder GGS recovery in SJV.

Recolonization and Repatriation

Recovery potential may increase with habitat and water quality improvements, allowing GGS to either recolonize or be reintroduced (repatriated) to portions of their former range. In 1996, drainage water containing high concentrations of selenium, salts, and other constituents from farms in the 97,000 acre Grassland Drainage Area formerly discharged into Salt Slough and other channels used to deliver water to GWD was diverted through a segment of the cement-lined San Luis Drain to Mud Slough, a tributary of the San Joaquin River. However, while it is true that water quality in Salt Slough and other wetland supply channels in the Grasslands has improved since the onset of the Grassland Bypass Project in 1996, there are several sources of selenium-tainted drainage still affecting water quality in these channels, especially in the south Grasslands. The sources of drainage in Grassland wetland channels include: unregulated runoff associated with heavy rainfall events, drainage flows from lands outside the Grasslands Bypass Project Area [DPA] (direct discharges into Almond and Poso Drains in the South Grasslands), and drainage discharges into source waters (discharges into the Delta Mendota Canal) (Eppinger and Chilcott, 2002). Discharges into the Delta Mendota Canal include those from sumps and check drains that discharge directly into the canal between O'Neil Forebay and Mendota Pool. These discharges cumulatively account for about 1,500 pounds of added selenium per year to the supply water (source: USBR, 2003-2005, Monthly data reports of the Delta-Mendota Canal Water Quality Monitoring Program for Selenium and Salinity. Mid-Pacific Region, Sacramento, and Fresno California).

During the closure and cleanup of Kesterson Reservoir in 1988, contaminated soil was buried under 18" of clean topsoil. Although elevated levels of selenium continue to persist in biota at the former Kesterson Reservoir (Ohlendorf and Santolo 1994) subsequent monitoring shows a significant improvement in water quality throughout Grasslands RCD (http://www.fws.gov/sacramento/ec/grassland.htm). The removal of contaminants, the creation of permanent wetlands throughout the San Luis NWR, and the application of untainted water to the numerous private wetlands in Grasslands RCD may provide an opportunity to recover populations of GGS where local extirpations have occurred. When provided with ample water during the active season, GGS are demonstrated using newly-constructed wetlands (E. Hansen, unpublished data; Jones and Stokes 2005; Wylie et al. 2002). Recolonization, however, will depend upon successful recruitment within source populations and compatible water management. As was noted in the section on Water Management, management of private wetlands in the Grasslands Area has shifted from irrigated pasture to moist soil management. This management regime would likely not provide adequate water during the hot summer months, forcing GGS to move to nearby less desirable or drainwater contaminated agricultural lands and ditches.

Although GGS were not detected north of the San Joaquin River, the habitat features appear largely suitable and prey is comparable to that found where GGS are documented (Table 3). Theoretically, GGS could access SMWD and areas northeast of the San Joaquin River by traveling through the system of interconnected wetlands, pools, and swales associated with the Mud Slough, Salt Slough, and San Joaquin River drainages to the south (CNDDB 2006). In fact, long-time residents interviewed during the course of this study described seeing snakes matching the description of GGS on a fairly regular basis prior to the 1970's. Because water here is described as superior – at least historically – to that found south of the San Joaquin River, and because the Merced NWR now manages regional wetland habitat specifically for species conservation, this region may provide opportunities for GGS recovery by either facilitating the growth of undetected populations or by relocating snakes from other locations. Once again, recolonization would likely depend upon successful recruitment within source populations and upon compatible water management.

In general, habitat within the interior of SMWD is poor with regard to giant garter snakes. SMWD does not possess the rice agriculture that provides the stable network of ditches and drains that support permanent populations of giant garter snakes throughout the Central Valley, nor do they possess the abundant pools, wetlands, and low gradient streams supporting giant garter snakes in state-managed areas south and west of the San Joaquin River or present within the East Side Canal and Drainage Management Area. Soils are sandy, allowing water to quickly percolate through to subsurface levels. As a result, the majority of ditches do not possess the permanent water needed to support the populations of aquatic prey and emergent vegetation required by giant garter snakes. Although some features, such as Lake Honda, the Drainage Management Area, East Side Canal, and select pipeline locations provide suitable habitat conditions year-round, the system is largely fragmented by both dry open-ditch and previously piped segments. The limited habitat that does exist is isolated, providing little or no opportunity for giant garter snakes to migrate throughout the system to reach viable habitat as local conditions deteriorate. As such, suitability and recovery potential is greatest within the East Side Canal and Drainage Management Area as compared to laterals within the core of SMWD.

Recommendations

The rapid decline of GGS in the southern and Central San Joaquin Valley is well documented (G. Hansen and J. Brode 1980; G. Hansen 1988, 1996; Dickert 2003, 2005; Sloan, 2003, 2004; USFWS 1993, 1999, 2006; Williams 2004, Wylie 1999). Available data suggests that the structure of local populations may also be skewed (E. Hansen, unpublished data; Wylie 1999). To recover this species in SJV will require continued monitoring to seek unreported populations and to evaluate the continued existence and trends associated with those that are known. This study established current baseline data throughout much of the known range of GGS in the Grasslands RCD using a standardized, repeatable trapping protocol. Because trap number and duration are standardized, results of subsequent studies executed according to these protocols can be compared across years, with less of the bias associated with comparing data collected by varying methods. To adhere to a standardized protocol will allow accurate comparisons through time, providing the data needed to assess the status of recovery in the region.

Standardized sampling of extant populations should be conducted annually to facilitate analyses of demographic characteristics such as age structure, fecundity, and survivorship, each of which may bear significantly on the species' decline in SJV. Though intensive demographic analyses have not been conducted for giant garter snakes, several models have been recently developed for studying other species within the genus *Thamnophis* (Stanford and King 2004; Lind *et al.* 2005). These and similar models require the continual monitoring of marked individuals through time, necessitating a commitment to a stable, long-term monitoring program.

In conjunction with monitoring GGS presence and demographic characteristics, future studies should seek to examine potential causes for this species' regional decline. SJV GGS populations are in rapid decline despite the presence of seemingly suitable habitat, suggesting that causes other than habitat loss play a role. Studies should target the interactions between water quality, water management, and pathology, to better understand and potentially reverse the observed population declines.

Combined with previous research, this study provides only a foundation for future monitoring. Efforts to identify previously undocumented populations should continue in order to identify potential recovery opportunities. Standardized monitoring should continue in order to track GGS population trends and should include all known population clusters, including concentrations of GGS in Fresno County that have not been investigated since 2001 (Dickert 2005).

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SJV 2006 Traplines

Trap Line ID	Traps	Start Date	End Date	Trap Days	Start Location	End Location
SJV1						
Big Water Drain at Santa Fe Rd.	50	5/10/2006	5/25/2006	750	E. 700481 N. 4098720	E. 700339 N. 4098882
SJV2						
Atwater Drain at Arena Plains	50	5/13/2006	5/28/2006	700	E. 702484 N. 4126755	E. 702886 N. 4126663
SJV3						
Agatha at Poso	50	5/17/2006	6/ 1/2006	750	E. 703981 N. 4096155	E. 703970 N. 4095817
SJV4						
Los Banos Creek North	50	5/18/2006	6/ 2/2006	750	E. 683676 N. 4119996	E. 683632 N. 4119991
SJV5						
East Side Canal at Snowbird	50	5/19/2006	6/ 3/2006	750	E. 699760 N. 4127549	E. 700136 N. 4127412
SJV6						
Los Banos Creek SW	50	5/23/2006	6/ 7/2006	750	E. 685900 N. 4117306	E. 686096 N. 4116975
SJV7						
Turner Slough	50	5/25/2006	6/ 9/2006	750	E. 686613 N. 4130804	E. 686796 N. 4130925
SJV8						
Arena Plains Wetland 1	50	5/28/2006	5/30/2006	100	E. 702512 N. 4127001	E. 702592 N. 4126804
SJV9						
Mud Slough at Klamath Club	50	5/27/2006	6/11/2006	750	E. 697081 N. 4105105	E. 697362 N. 4105014
SJV10						
East Side Canal at Hwy 140	50	5/31/2006	6/15/2006	750	E. 694757 N. 4131514	E. 694431 N. 4131728
SJV11						
Agatha Canal at CLCC	49	6/ 1/2006	6/16/2006	735	E. 702504 N. 4098548	E. 702561 N. 4098140

Appendix A. 2006 SJV Trapline Dates and Locations (UTM Zone 10, NAD 1927)

SJV12						
San Luis Creek East	50	6/ 3/2006	6/17/2006	700	E. 686067 N. 4116972	E. 685587 N. 4116964
SJV13						
Atwater Drain at Snowbird	50	6/ 3/2006	6/17/2006	700	E. 699834 N. 4127013	E. 700171 N. 4127256
SJV14						
Arena Plains Wetland 2	50	6/ 4/2006	6/19/2006	750	E. 702104 N. 4127666	E. 702094 N. 4127674
SJV15						
Los Banos Creek SE	50	6/ 7/2006	6/12/2006	250	E. 685929 N. 4117309	E. 685958 N. 4117413
SJV16						
Mud Slough 2	50	6/11/2006	6/26/2006	750	E. 696798 N. 4105789	E. 696852 N. 4105620
SJV17						
Los Banos Creek 2	50	6/12/2006	8/19/2006	3400	E. 686075 N. 4116991	E. 685905 N. 4117297
SJV18						
Mud Slough Drift Fence	50	6/10/2006	7/10/2006	1450	E. 696914 N. 4105934	E. 696941 N. 4105910
SJV19						
E Side Canal/Stevinson Ranch	50	6/15/2006	6/30/2006	700	E. 693726 N. 4132219	E. 693381 N. 4132476
SJV20						
Clear Lake North	50	6/16/2006	6/23/2006	350	E. 701863 N. 4099225	E. 702346 N. 4099232
SJV21						
Blue Goose Interior 1	50	6/17/2006	7/ 2/2006	750	E. 690817 N. 4119518	E. 691151 N. 4119247
SJV22						
Bear Creek at Snowbird	50	6/18/2006	7/ 3/2006	750	E. 698648 N. 4126182	E. 699014 N. 4126294
SJV23						
Arena Plains Wetland 3	50	6/19/2006	7/ 4/2006	750	E. 702049 N. 4127249	E. 702131 N. 4127447
SJV24						
Big Bottom Lake	0	6/ 9/2006	6/22/2006	400	E. 686457 N. 4130831	E. 686529 N. 4130964
SJV25						
Blue Goose at Hwy 165	50	6/23/2006	6/25/2006	100	E. 691375 N. 4119299	E. 691545 N. 4118861
SJV26						

Blue Goose Interior 2	50	6/26/2006	7/11/2006	750	E. 689702 N. 4120166	E. 689429 N. 4120461
SJV27						
San Luis Refuge Dead Man Slough	50	7/ 2/2006	7/17/2006	700	E. 693146 N. 4120309	E. 693183 N. 4120508
SJV28						
Mosquito Ditch NE	50	7/11/2006	7/26/2006	700	E. 686106 N. 4116472	E. 686115 N. 4116915
SJV29						
Santa Fe Canal at Kesterson	50	7/ 7/2006	7/22/2006	700	E. 684387 N. 4125836	E. 684379 N. 4126333
SJV30						
E3P Marsh at Kesterson	50	7/ 8/2006	7/23/2006	700	E. 685176 N. 4125949	E. 685112 N. 4126180
SJV31						
Beaver Pond at Kesterson	50	7/ 9/2006	7/24/2006	750	E. 684413 N. 4126448	E. 684336 N. 4126454
SJV32						
Mosquito Ditch SW	50	7/12/2006	7/27/2006	750	E. 686092 N. 4116054	E. 686097 N. 4116449
SJV33						
San Luis Creek West	50	7/13/2006	7/28/2006	750	E. 683362 N. 4116995	E. 683552 N. 4116992
SJV34						
Poso Drain at Mallard Rd.	50	7/16/2006	7/30/2006	700	E. 703924 N. 4096169	E. 704283 N. 4095930
SJV35						
Agatha Canal at Clear Lake 2	50	7/17/2006	7/31/2006	700	E. 702840 N. 4097864	E. 703296 N. 4097574
SJV36						
Agatha Canal at Clear Lake 3	50	7/20/2006	8/ 4/2006	750	E. 703705 N. 4097315	E. 703311 N. 4097564
SJV37						
Merced NWR 1	50	7/22/2006	8/ 6/2006	750	E. 712389 N. 4119143	E. 712640 N. 4119006
SJV38						
Merced NWR 2 Dead Man Creek	50	7/23/2006	7/31/2006	160	E. 710705 N. 4117205	E. 710386 N. 4117412
SJV39						
Merced NWR 3	50	7/24/2006	8/ 8/2006	750	E. 712380 N. 4119406	E. 712381 N. 4119010

Appendix A. 2006 SJV Trapline Dates and Locations (UTM Zone 10, NAD 1927)

SJV40						
East Side Canal 4	50	7/26/2006	8/10/2006	750	E. 702712 N. 4124990	E. 703025 N. 4124696
SJV41						
East Side Canal 5 Mariposa	50	7/27/2006	8/11/2006	750	E. 704295 N. 4121609	E. 704171 N. 4122001
SJV42						
East Side Canal 6	50	7/28/2006	8/12/2006	750	E. 701253 N. 4126414	E. 701568 N. 4126134
SJV43						
Almaden Ditch	50	7/30/2006	8/14/2006	750	E. 701409 N. 4094738	E. 701813 N. 4094820
SJV44						
Helm Canal at Frog Pond Club	50	7/31/2006	8/15/2006	750	E. 701861 N. 4090354	E. 702323 N. 4090321
SJV45						
East Side Canal 7	50	8/ 4/2006	8/19/2006	700	E. 704724 N. 4119864	E. 704823 N. 4119802
SJV46						
Merced NWR 4	50	7/25/2006	8/ 9/2006	750	E. 711203 N. 4117480	E. 711012 N. 4117304
SJV47						
Los Banos Creek / Salinas Drift Fence	25	7/21/2006	8/18/2006	700	E. 685892 N. 4117318	E. 685887 N. 4117339
SJV48						
Modesto Properties Drake Ditch	50	8/ 2/2006	8/17/2006	750	E. 698479 N. 4127253	E. 698725 N. 4127585
SJV49						
Los Banos Creek Drift Fence 2	25	8/ 5/2006	8/18/2006	325	E. 685870 N. 4117297	E. 685889 N. 4117295
SJV50						
Almond Drive Ditch	50	8/ 6/2006	8/ 8/2006	100	E. 696915 N. 4096725	E. 697307 N. 4096725

SJV 2006 GGS Captures

Date	PIT	Sex	Mass (g)	SVL (mm)	Easting	Northing	USGS Topo Quad	Township	Range	Section	Quarter
5/19/2006	466C4D142C	F	297	685	E. 703925	N. 4095952	DOS PALOS	T. 11	R. 11 E.	12	NE
5/24/2006	466C594568	M	107	640	E. 685918	N. 4117242	INGOMAR	T. 9	R. 10 E.	6	NE
6/1/2006	466D191B02	F	331	790	E. 685921	N. 4117287	INGOMAR	T. 9	R. 10 E.	6	NE
6/1/2006	46730F6A25	F	469	895	E. 685923	N. 4117297	INGOMAR	T. 9	R. 10 E.	6	NE
6/4/2006	4851485A62	M	130	635	E. 685853	N. 4116965	INGOMAR	T. 9	R. 10 E.	6	NE
6/14/2006	46731F1732	M	114	640	E. 685642	N. 4116968	INGOMAR	T. 9	R. 10 E.	6	NE
6/22/2006	465B552149	M	169	665	E. 686040	N. 4117040	INGOMAR	T. 9	R. 10 E.	5	NW
6/26/2006	48312D3600	M	145	657	E. 685912	N. 4117280	INGOMAR	T. 9	R. 10 E.	6	NE

Appendix C. Summary of Expenditures

Implementation of Priority 1 Recovery Tasks for the Giant Garter Snake (*Thamnophis gigas*) in Merced County, California
PI - Eric C. Hansen

YEAR	Individual	Total Labor	% Benefits	Personnel total (salary + benefits)	Travel	Operating Expenses	Equipment	Total Direct Costs	Overhead Rate (% of Total Direct Costs)	Indirect Costs	Total by Task
2006	Project Manager	$ 11,964	25	$14,954							
	Principal Investigator	$ 38,885	25	$48,606							
	Technician	$ 22,835	25	$28,544							
					$8,836	$2,445	$0	$ 103,385	15.000%	$15,508	**$118,893**
TOTALS		**$ 73,237**		**$92,104**	**$8,836**	**$2,445**	**$0**	**$ 103,385**		**$15,508**	**$118,893**

Approximate Hourly Breakdown by Task

Field Hours (Task 1)	**1116.5**
Project Management, Data Analysis, and Report Hours (Task 2)	**209**

Timeline

Task 1	April 15 to August 19, 2006
Task 2	October 1 to April 15, 2007