# Implementation of Priority 1, Priority 2, and Priority 3 Recovery Tasks for Giant Garter Snake (*Thamnophis gigas*) – Status and distribution of giant garter snakes at the eastern Delta's White Slough Wildlife Area, San Joaquin County, CA


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## Abstract

This study addressed Priority 6 the CVPCP and HRP Fiscal Year 2009 Funding Opportunity Announcement, which emphasized status surveys for listed species, particularly those that will be the subject of 5-Year reviews in 2010, including giant garter snake. Further emphasis was placed on populations or occurrences that have not been visited in the past 10 years. Prior to this study, the White Slough/Caldoni Marsh population, identified as one of 13 presumably extant populations range-wide (USFWS 1999), had not been surveyed since 1994. This study confirms the persistence of the White Slough/Coldani Marsh GGS population after more than 14 years without reported sightings. However, while previous surveys indicate a relatively broad distribution throughout this portion of the eastern Delta, this survey suggests that GGS at WSWA are now mostly confined to the wetland area west of Pond 9, referred to hereafter as Coldani Marsh. GGS were not captured or observed in any of the ponds or in any of the emergent tidal marshes at WSWA despite the close proximity and ample connectivity amongst habitats. Among the desired work products described in Priority 6, this study provided species status information including numbers of individuals, size of occupied area, and reproductive status, which have never been provided for the species at this location. Finally, tissue samples collected as a part of this study were examined as part of a genetic examination of GGS. Results suggest that the White Slough/Coldani Marsh population of GGS is most closely related to that of Badger Creek, which is genetically unique amongst all others in the species' range.

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# INTRODUCTION

## Background

This document summarizes the results of the project entitled **Implementation of Priority 1, Priority 2, and Priority 3 Recovery Tasks for Giant Garter Snake (*Thamnophis gigas*) – Status and distribution of giant garter snakes at the eastern Delta's White Slough Wildlife Area, San Joaquin County, CA**. Funded by the Central Valley Project Improvement Act Habitat Restoration Program (HRP) during Fiscal Years 2009 and 2010, the project was completed in accordance with the terms and conditions of Fish and Wildlife Service Agreement No. 802709G514.

## Project Goals and Objectives

The project goals and objectives are:

- To determine presence-absence of giant garter snakes within the eastern Delta, with emphasis on the White Slough Wildlife Area;
- To establish control sites needed to evaluate the potential effects of seasonal variability in giant garter snake activity and distribution on sampling results;
- To more thoroughly assess the current status of giant garter snakes and potential habitat within the Mid-Valley Recovery Unit;
- To provide a demographic and methodological foundation for future research;
- To formulate and provide recommendations for water and habitat management.

## Species Description

The giant garter snake (*Thamnophis gigas*) (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, 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 overwintering. Where these canals are not regularly maintained, lush aquatic, emergent, and streamside vegetation develops prior to the spring emergence of GGS. 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. Emergent rice provides dense, shallow-water habitat during and after GGS parturition (birth), typically occurring from mid-July into August.

GGS feed on small fishes, tadpoles, and small frogs (Fitch 1941, Hansen 1980, USFWS 1999), specializing in ambushing prey underwater (Brode 1988). Historically, GGS 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 snake's current range, as well as the pacific treefrog (*Pseudacris regilla*) and Sacramento blackfish (*Orthodox microlepidus*), (Cunningham 1959; Rossman *et al.*

1996; USFWS 1999).  GGS now utilize introduced species, such as small bullfrogs (*Lithobates catesbeianus* [=*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 cinereoargentius*), 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 GGS (USFWS 1999). In areas near urban development, GGS may also fall prey to domestic or feral house cats (G. Hansen pers. comm.).  In permanent waterways, introduced predatory game fishes, such as bass (*Micropterus* spp.), sunfish (*Lepomis* spp.), and channel catfish (*Ictalurus* spp.), likely prey on GGS and compete with them for smaller prey (Hansen 1998, 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 subspecies of the western terrestrial garter snake, where the range of *T. e. elegans* 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.  For wetlands in California, draining and conversion to cropland and urban development have reduced the once vast expanses of marshland to less than 10% of their extent prior to European settlement (Dahl *et al.*, 1991).  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.

## Project Area Description and History

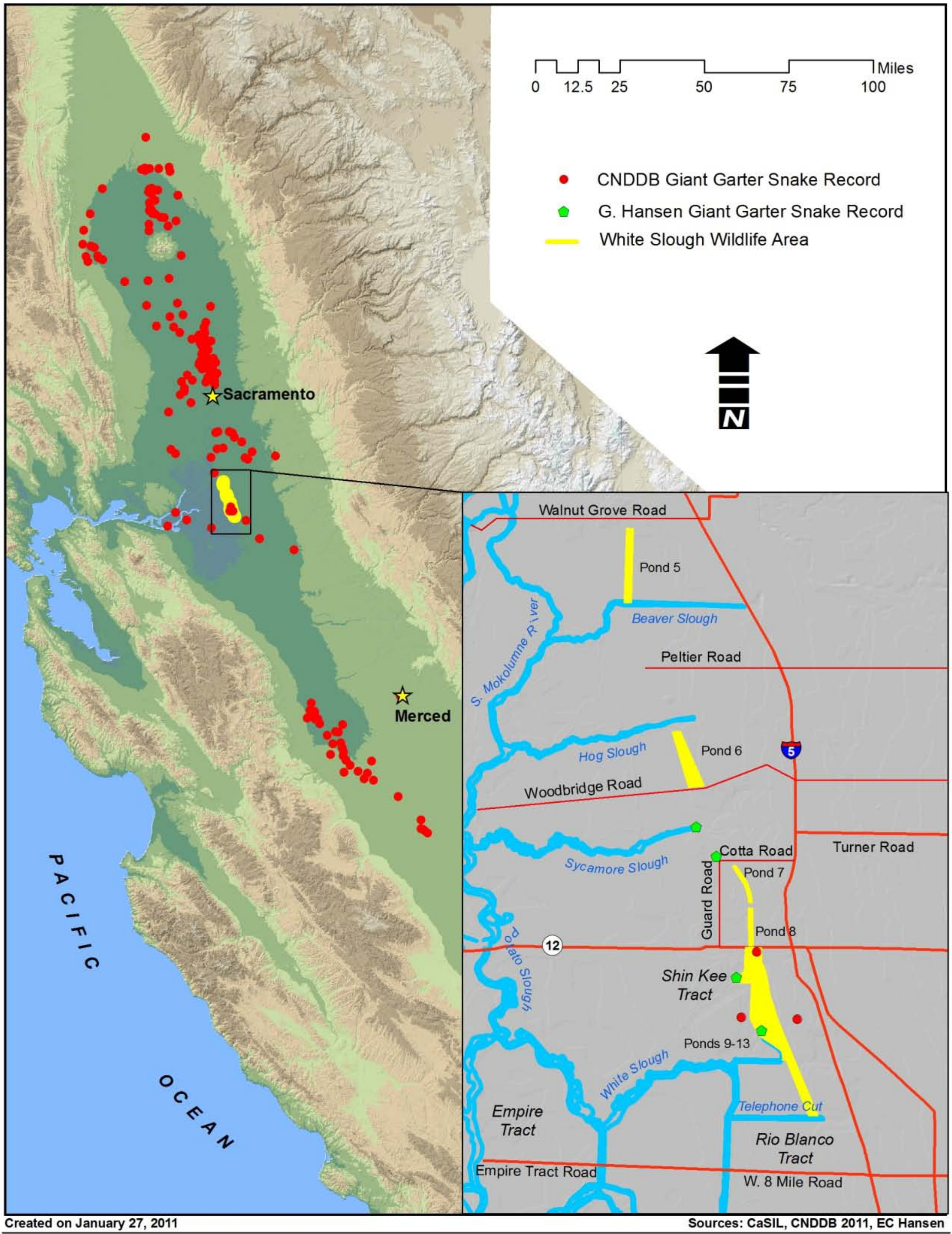
White Slough Wildlife Area (WSWA) is located in northwestern San Joaquin County on the eastern fringe of the Sacramento-San Joaquin River Delta (Figure 1). WSWA falls within the U.S. Geological Survey's Thornton and Terminous 7.5-minute Topographic Quadrangles in Township 3 North, Range 5 East, Mount Diablo baseline and meridian (sections are not designated in the corresponding portion of the township). The portion of WSWA that we studied is situated west of Interstate 5, east of Guard Road and the Shin Kee and Rio Blanco Tracts, north of Telephone Cut, and south of Cotta Road.

WSWA is owned by the California Department of Water Resources and managed by the California Department of Fish and Game. WSWA consists of 880 acres of man-made ditches, canals, and freshwater marshes with associated grassland/upland habitats. Between 1974 and 1978, 13 rectangular borrow pits were excavated from one to five miles west of Interstate 5 to provide fill for freeway construction (DWR 1995). The pits are fed by groundwater and periodic runoff from precipitation, irrigation, and high canal flows, creating a series of ponds characterized by vegetated sloping or vertical banks and open water with adjacent uplands and high ground. As a management area, WSWA comprises a discontinuous series of properties encompassing ponds 5-13, which occur along a roughly 11-mile stretch between Thornton and Stockton (Figure 1).

Access to the White Slough WA from the northern edge of Pond 7 (at Cotta Road) south to Pond 13 was provided through an entry agreement with California Department of Water Resources. Due to legal constraints, this access was limited to 60 visits per year. Additional access was provided by adjacent landowner Steve Coldani, allowing us to enter WSWA from Guard Road, and to access portions of the Upland Canal without entering WSWA. This access allowed us to extend our survey duration in key areas during 2010.

Efforts to sample additional features such as Sycamore Slough, Hog Slough, and Beaver Slough were infeasible due to routine public access rendering trapping unsafe. Private access to remote portions of these features was not obtained in large part because of heightened sensitivity stemming from the proposed Bay Delta Conservation Plan and concerns that resulting species protection would adversely affect land or facilities management. Efforts were made to broker entry agreements with Reclamation District 548 (Upland Canal) and Reclamation District 2029 (Empire Tract), but these were not obtained.

**Figure 1. White Slough Wildlife Area Location Map**



## Historical and Recent Species Occurrence within the Project Area

WSWA supports the preponderance of the Coldani Marsh/ White Slough GGS population, one of 13 GGS populations described in the USFWS 1999 Draft Recovery Plan for the Giant Garter Snake. First identified on site in 1974 (CNDDB 2011), GGS were observed at WSWA by George Hansen from the time he began surveying for them in 1976 (G. Hansen and J. Brode 1980; G. Hansen 1988, 1996) until the mid-1990's. Among two GGS populations recognized in San Joaquin County, the White Slough population is perhaps the only locality still supporting a viable snake population. After failing to detect GGS east of Stockton during surveys conducted in the 1980's and 1990's, George Hansen speculated that the other population in San Joaquin County (Stockton Diverting Channel/Duck Creek population) was likely extirpated by extensive urban development occurring since the 1970's (G. Hansen 1988, 1996).

Most GGS observations at WSWA are concentrated at the section labeled Pond 9 (referred to hereafter as Coldani Marsh to distinguish it from the pond created by the actual borrow pit), but surveys conducted by George Hansen in 1994 yielded additional sightings near Ponds 7 and 11, and at a site between Ponds 6 and 7 (CNDDB 2011; DWR 1995). Although channels and drainages including Telephone Cut, Sycamore Slough, Hog Slough, and Beaver Slough were surveyed by Hansen, observations were made only at or near the ponds (M. Green *pers. comm.*). Each of the locations where snakes were observed are characterized by slow moving water with mud banks and bottoms, vegetative cover, and access to high ground (DWR 1995).

Potential threats to the WSWA GGS population include introduced species and diminished water quality. In the 1970's, DFG stocked large-mouth bass, channel catfish, and red-eared sunfish in at least Ponds 7 and 8: each of these species probably prey on GGS and compete with them for smaller prey (Hansen 1988, USFWS 1993). Fish kills have been noted in the ponds on multiple occasions (DWR 1995). Although the kills may be attributed to insufficient levels of dissolved oxygen (DWR 1995), it is also possible that treated effluent and sludge dispersed on adjacent agricultural lands by the White Slough Water Pollution Control Plant leeched into the ponds (DWR 1995; J. Martin *pers. comm.*). Contaminants introduced by effluent or agricultural chemicals could prove detrimental to fish populations (DWR 1995) as well as GGS and their prey base.

To the best of our knowledge, prior to the current study, no efforts have been made to survey for GGS on or near WSWA since George Hansen's work in the mid-1990's.

## METHODS and MATERIALS

### Sampling

Sampling entailed a combination of visual encounter and trapping surveys to assess giant garter snake presence, distribution, and demographic profiles.

In 2009, surveys were initiated in early July—immediately following receipt of the grant award and the right of entry—and were conducted periodically for the remainder of the 60-visit right of entry allowance. Because sampling in 2009 was limited due to the shortened sampling season resulting from the timing of the grant award, funds for which were not obligated until June 25, 2009, we sought and received approval from CVPIA HRP to apply unused funding from 2009 to achieve the level of sampling effort outlined in the original scope during the spring of 2010. In 2010, surveys were initiated in early May following the snakes' emergence from winter refuge, and continued throughout the spring portion of the active season. Taken together, the two sampling years encompassed all months of the May-September peak of the GGS active season.

Visual encounter surveys entailed 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, including beneath surface cover and debris, such as boards or litter found near aquatic habitat. Incidental searches for snakes were also conducted while driving along the numerous paved, gravel, and dirt roadways occurring throughout the study area and during all trap checking activities.

Aquatic trapping was conducted following methods described by Casazza *et al*. (2000). As many as 350 traps were simultaneously deployed as seven, 50-trap transects and distributed throughout the study area. Traps were placed along the open water/terrestrial or open water/emergent vegetation interface within aquatic features (i.e., edges of channels, ponds, and associated marshland) and spaced approximately 10 meters (33 feet) apart, resulting in traplines approximately 500 meters (1,640 feet) long. UTM coordinates and environmental characteristics such as vegetation and substrate types were recorded at each trap. On occasions when traps were temporarily disabled to accommodate low water levels or to facilitate repair, trap numbers were recorded and reported survey effort (i.e., total trap days) was adjusted accordingly.

Although traps were not purposely baited, prey items such as frogs, tadpoles, and fish were routinely caught within traps, likely serving as attractants for GGS. At the end of each rotation, prey items within the traps were identified and counted in order to compare prey composition and abundance between traplines. All traps were checked daily.

Weight, total length, snout to vent length, and sex were recorded for all GGS captured. Other physical features such as scars and tumors, as well as identifying characteristics such as scale counts and measurements on head and midbody were also noted. Captured snakes were implanted with passive integrated transponder (PIT) tags for permanent identification. For snakes that were too small to implant with PIT tags (≤ 30 grams), medical cautery units were used to microbrand caudal scutes in a pattern consistent with established scale-clip marking techniques (Brown and Parker 1976, Winne et al. 2006). Marking snakes is essential for estimating population size, density, male to female ratios, and fecundity of the species (E. Hansen 2004, USFWS 1999, Wylie et al. 1997). All snakes were released at their capture location immediately following data recordation.

Relative abundance of GGS at WSWA was evaluated on the basis of the number of individual snakes caught, standardized by the amount of survey effort (i.e., catch per unit effort). The software program CAPTURE (White *et al*. 1978, White *et al*. 1982), an extension of Program MARK (White 2004), was used to estimate population size in discrete habitat segments on the basis of capture histories of marked individuals.

As part of a separately funded study investigating GGS fecundity (e.g., number of young born per adult female per year), three of the female GGS captured in 2009 were transported to the Sacramento Zoo upon capture and radiographed by Dr. Raymond F. Wack, DVM, ACZM, Staff Veterinarian. Developing fetuses were identified and counted for each female snake. All GGS were handled and transported according to the protocols stipulated in Eric C. Hansen's USFWS RECOVERY PERMIT 10(a) (1) (A) ESA TE-018177-5 and released at the point of capture as soon as possible following completion of the radiograph.

Contributing to a separately funded study analyzing GGS genetics, tissue samples were obtained from all captured GGS 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 (cyanoacrylate) 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 samples were stored in individual vials containing 70% ethanol (ETOH). Samples collected in 2009 were submitted to Dr. Tag Engstrom, California State University, Chico, for genetic analysis (Engstom 2010); samples collected in 2010 have been archived for future analysis.

Water metrics including electrical conductivity (EC) (mS/cm) and pH were measured periodically at five sampling stations distributed throughout the study area using a portable YSI 556 Multi-Probe unit.

Traplines and water sampling stations in 2009 and 2010 are depicted in Figures 2 and 3, respectively. Trapline location descriptions, UTM coordinates, and survey dates are reported in Appendix A.

**Figure 2. White Slough Wildlife Area Survey Locations, 2009**

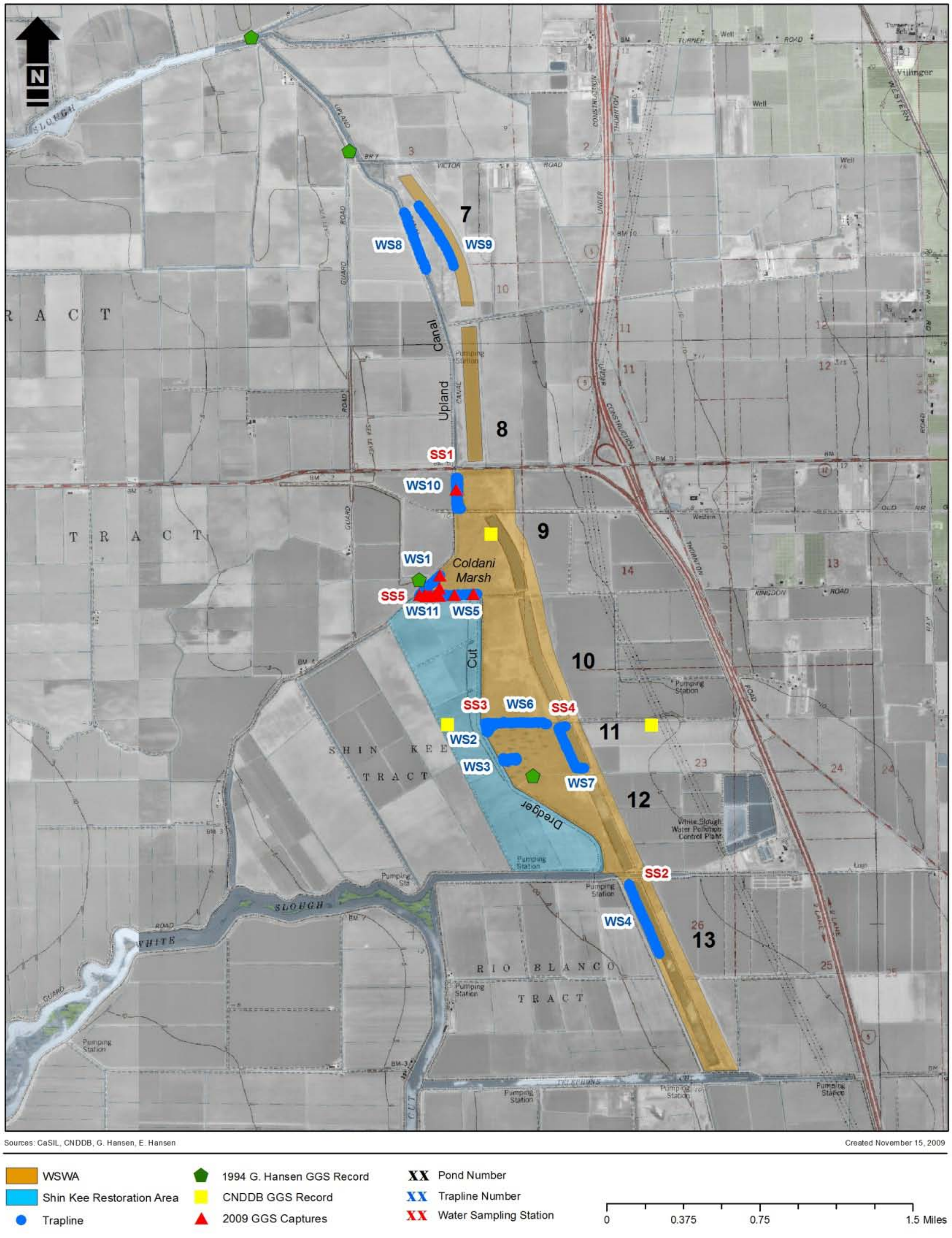
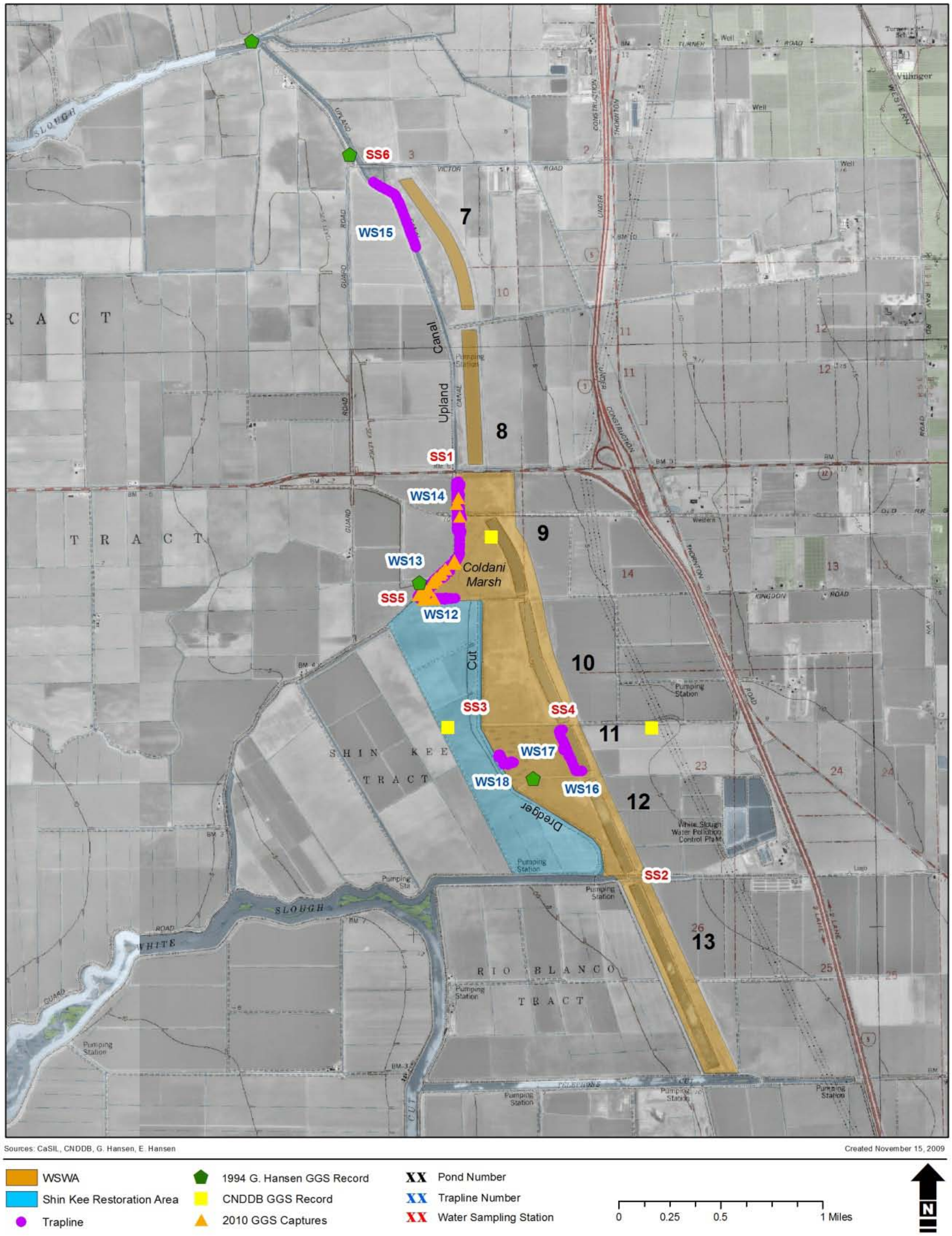


**Figure 3. White Slough Wildlife Area Survey Locations, 2010**



## Analysis

Relative abundance of GGS at WSWA was evaluated on the basis of the number of individual snakes caught, standardized by the amount of survey effort (i.e., catch per unit effort). The software program CAPTURE (White *et al*. 1978, White *et al*. 1982), an extension of Program MARK (White 2004), was used to estimate population size in discrete habitat segments on the basis of capture histories of marked individuals. The statistical models used to estimate population size in this statistical framework assume the population being sampled is a *closed* population; that is, that neither immigration nor emigration occurs during the sampling period. Characterized by interconnected aquatic features, the closed population assumption is violated at WSWA.

Though population size estimates are used as a means of comparison amongst studies of other GGS populations and are reported here for this purpose, the reliability of these estimates remains dubious due to the lack of population closure required for the modeling framework. Despite these imperfections, this method is frequently used for estimating population size for GGS throughout their range (e.g., E.C. Hansen 2005, 2007; Jones & Stokes 2005, 2006, 2007; USFWS 1999; Wylie *et al*. 1997; Wylie *et al.* 2004) and is subsequently applied here. We anticipate that limiting the sampling sessions to 15 calendar days reduces the degree of individual immigration and emigration, thereby increasing the model's reliability. However, because CPUE is based simply on the number of individual snakes captured per unit effort expended, it is likely the more reliable metric to use for comparison.

# RESULTS

## Giant Garter Snake Surveys

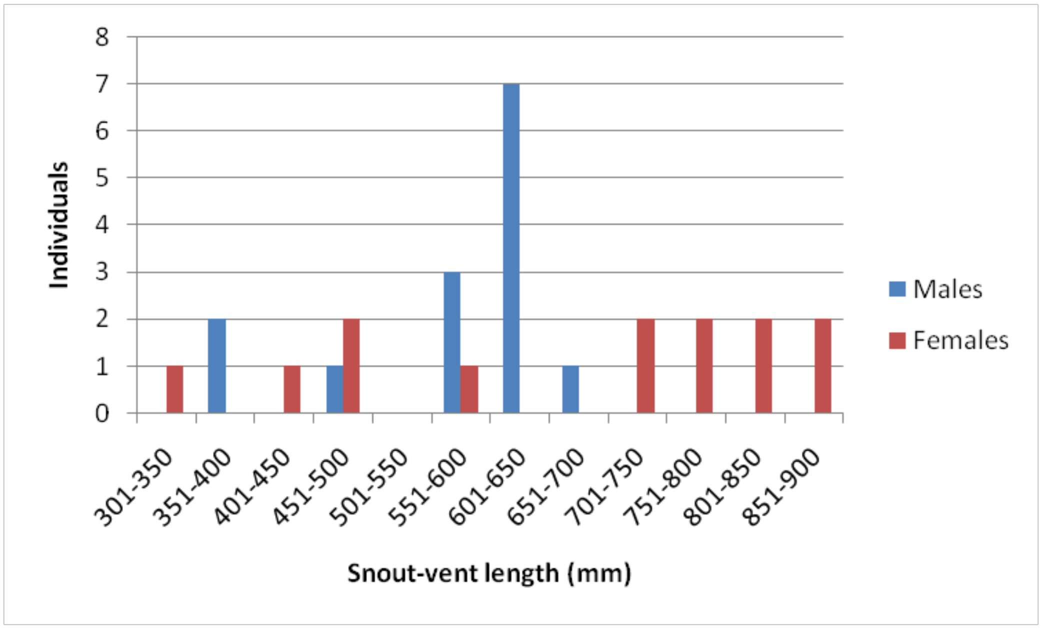
Eleven traplines were deployed in 2009, resulting in 19,793 accrued trap days. Eight traplines were deployed in 2010, resulting in 24,326 accrued trap days. In total, 27 individual GGS were captured in 49 trap-capture events during the two year study. GGS were also observed twice during visual encounter surveys. Of the 27 captured individuals, 14 were males and 13 were females, suggesting a male:female ratio of approximately 1:1. Five of the thirteen individuals captured during 2009, were recaptured during 2010. An additional 14 individuals were captured during 2010. In both years, GGS captures and observations were concentrated in the Upland Canal along the west and southwest edges of Coldani Marsh, which is an emergent tule marsh situated to the west of WSWA Pond 9 (Figures 2 and 3). Trapping efforts and results at each trapline are reported in Appendix B.

Capture success per unit effort (CPUE), calculated as the number of individuals trapped per trap day, was 0.0006 when pooling survey efforts and results across the two year study. CPUE within years was 0.0007 in 2009 and 0.0008 in 2010 (2010 calculation includes the five individuals recaptured from 2009).

Population estimates obtained through the software program CAPTURE were based on results pooled from adjacent traplines simultaneously deployed on opposite banks of the Upland Canal at the southwest corner of Coldani Marsh (traplines WS1 and WS5 in 2009; traplines WS12 and WS13 in 2010). In 2009, population estimates based on the first 14-day period in which the number of captures was sufficient for running the model (July 9 to July 23) and for the entire season pooled (July 9 to September 16) were 21 (SE=17; 95% CI=10–95) and 20 (SE=6; 95% CI=10–95), respectively. In 2010, the respective estimates were 6 (SE=2; 95% CI=6–14) (June 8 to June 22) and 22 (SE=4; 95% CI=18–36).

The size (snout-vent length) of male GGS captured over the two year study ranged from 376 to 678 millimeters (mean=572, SE=25, SD=94), respectively. Female GGS size (snout-vent length) ranged from 336 to 898 millimeters (mean=669, SE=55, SD=197), respectively. The size frequency distributions for male and female GGS are depicted in Figure 4.

**Figure 4. Length frequency distribution of GGS captured at WSWA 2009-2010**



Size/age distribution for the Coldani Marsh GGS concentration was biased toward larger/older individuals in 2009, and distribution among genders was distinctly bi-modal. Pooled results following early season trapping in 2010 indicate a more normal size distribution overall. As part of a separately-funded project investigating GGS demography, three of the five female giant garter snakes captured were transported to the Sacramento Zoo for full-body radiographs to detect and count (if present) developing embryos. Developing embryos (14) were detected in one of three snakes, indicating that at least some reproduction is occurring. Young of the year were not detected, so whether offspring are being successfully recruited into the population remains unclear.

In addition to GGS, 30 valley garter snakes were captured and identified/marked as individuals over the two year study. Of the 30 individuals captured, 21 were captured in association with GGS at Coldani Marsh (six in 2009 and sixteen in 2010), four were captured in the Upland Canal west of Pond 7 (all in 2010), four were captured in Pond 11 (all in 2010), and one was captured in at the northwest corner of the wetland west of (behind) Pond 11 in 2009. None of the valley garter snakes captured in 2009 were recaptured in 2010. Valley garter snakes were also observed on 11 occasions, nine of which occurred near Coldani Marsh; the other two were observed on dirt roads near Ponds 9 and 11.

## Habitat Variables

### *Prey Samples*

Vertebrates collected in traps over the two year study included adult and larval American bullfrogs (*Lithobates catesbeianus* [=*Rana catesbeiana*]), mosquitofish (*Gambusia affinis*), black bass (*Micropterus* spp.), other Centrarchids (*Lepomis* spp.), carp (*Cyprinus carpio*), silversides (*Menidia* sp.), and prickly sculpin (*Cottus asper*). Centrarchids (excluding bass) (n=487) were the most abundant prey species detected, followed by larval bullfrogs (n=158), black bass (n=105), mosquitofish (n=69), adult bullfrogs (n=57), carp (n=45), silversides (n=7), and prickly sculpin (n=4). Raw counts and catch per unit effort at each trapping location during 2009 and 2010 are reported in Appendix C, Tables 1 and 2.

### *Water Samples*

Water metrics were periodically measured in both years at five locations resulting in 90 samples of each metric (50 in 2009 and 40 in 2010). After the first round of measurements in 2010, sampling station 2 (SS2) (Figures 2 and 3) was replaced with SS6 (Figure 3) after frequent access by the public precluded continued surveys at Pond 13. Over the two year study, pH measurements ranged from 7.66 (SS5) to 9.59 (SS1) (mean=8.48, SE=0.04, SD=0.34) and EC measurements ranged from 0.062 (SS1 and SS5) to 2.328 (SS2) (mean=0.461, SE=0.072, SD=0.688).

In 2009, pH measurements ranged from 7.66 (SS5) to 9.14 (SS4) (mean=8.50, SE=0.05, SD=0.37) and EC measurements ranged from 0.062 (SS1 and SS5) to 2.328 (SS2) (mean=0.624, SE=0.119, SD=0.848). All pH and EC measurements obtained at WSWA during 2009 are reported in Appendix D, Tables 1 and 2.

In 2010, pH measurements ranged from 7.96 (SS3) to 9.59 (SS1) (mean=8.46, SE=0.05, SD=0.30) and EC measurements ranged from 0.095 (SS5) to 2.115 (SS2) (mean=0.257, SE=0.050, SD=0.314). All pH and EC measurements obtained at WSWA during 2010 are reported in Appendix D, Tables 3 and 4.

## SUMMARY and CONCLUSIONS

### Overview

This study confirms the persistence of the White Slough/Coldani Marsh GGS population after more than 14 years without reported sightings. However, while previous surveys indicate a relatively broad distribution throughout this portion of the eastern Delta, this survey suggests that GGS at WSWA are now mostly confined to the wetland area west of Pond 9, referred to here as Coldani Marsh. GGS were not captured or observed in any of the ponds or in any of the emergent tidal marshes at WSWA despite the close proximity and ample connectivity amongst habitats.

### Distribution and Habitat

Though reasons for the observed distribution remain unclear, Coldani Marsh differs from surrounding features in several ways. First, it differs from the ponds in that it is relatively shallow with mud bottoms and is characterized by the dense, emergent vegetation that typically characterizes perennial marsh on the Central Valley floor. The ponds, on the other hand, are deep, often sand- or gravel-bottomed, and are characterized by expansive open water supporting high concentrations of predatory fishes. Coldani Marsh also differs from other densely vegetated perennial marsh at WSWA in that tidal influence is strongly muted. Unlike surrounding features, water inputs to Coldani Marsh are controlled, limiting both tidal influence and access by large aquatic predators.

In order to explore whether water characteristics provides a potential explanation for the observed GGS distribution, we conducted comparisons of mean water metrics between Coldani Marsh and the Pond 11 marsh, which is less than 1 km distant and directly connected via Dredger Cut and separates WSWA from Shin Kee Tract (see figure 2). The results, though significant, were not remarkable. In two-sample t-tests assuming equal variances ($H_0$: mean water metrics at both locations are equal; $\alpha=0.05$), statistically significant differences were observed in mean pH between Coldani Marsh and the Pond 11 marsh during 2009 (respective means were 8.05 and 8.60, df=18, two-tailed p-value=0.0008), and in mean EC during 2009 (respective means were 0.122 and 0.251, df=18; two-tailed p-value<<0.0001) and 2010 (respective means were 0.152 and 0.241, df=14; two-tailed p-value=0.0001). While statistically significant, the differences in mean water metrics between the two sites were marginal. These values are within ranges reported for habitats supporting GGS in other regions (e.g., Hansen 2008) and are likely not biologically significant. Representative photographs of Coldani Marsh and Pond 11 marsh are depicted in Figures 6a and 6b.

**Figure 5a. Coldani Marsh**

**Figure 5b. Pond 11 marsh**

## Implications for Recovery

With the exception of the Badger Creek/Willow Creek population on the Cosumnes River Preserve, GGS in southern Sacramento County have declined notably since the 1970's and are perhaps now extirpated from much of their former range (G. Hansen 1986,1988; USFWS 1993, 1999, 2006). GGS have experienced a similar decline and likely extirpation in eastern San Joaquin County at Duck Slough and Stockton Diverting Canal (G. Hansen 1988, 1996; USFWS 1993, 1999, 2006). As such, the White Slough Wildlife Area (Coldani Marsh/White Slough) population of giant garter snakes is potentially the southernmost extant population in the Sacramento Valley, and is the only known extant population in San Joaquin County.

The White Slough/Coldani Marsh GGS population is characterized by a size/age distribution containing both adults and young (Figures 4-5), and the results of radiographed females suggest that reproduction is occurring. As such, this population appears to be a suitable candidate as an anchor population for expansion and recovery within the eastern Delta.

Because the GGS population at WSWA is genetically unique, maintaining it would help to preserve genetic diversity. Of only five tissue samples analyzed to date, four represent genetic types consistent with those found only within the Badger Creek GGS population, and one genotype appears entirely unique to White Slough/Coldani Marsh (Engstrom 2010). Although the sample size is small, results suggest that the White Slough/Coldani Marsh population of GGS is most closely related to that of Badger Creek, which is genetically unique amongst all others in the species' range (Paquin et al. 2006, Engstrom 2010). This population is genetically unique and represents a large proportion of the total giant garter snake genetic diversity. Although results represent neutral variation in the population, there is a strong possibility that this population harbors unique adaptive genes (Engstrom 2010). In recognition of their genetic value it is important to continue managing Badger Creek and White Slough as separate and distinct population segments.

Potential threats to the White Slough Wildlife Area GGS population include introduced species, diminished water quality, and water conveyance / infrastructure projects. In the 1970's, DFG stocked large-mouth bass, channel catfish, and red-eared sunfish in at least Ponds 7 and 8: each of these species probably prey on giant garter snakes and compete with them for smaller prey (Hansen 1988, USFWS 1993). Fish kills have been noted in the ponds on multiple occasions (DWR 1995). Although the kills may be attributed to insufficient levels of dissolved oxygen (DWR 1995), it is also possible that treated effluent and sludge dispersed on adjacent agricultural lands by the White Slough Water Pollution Control Plant leeched into the ponds (DWR 1995; J. Martin *pers. comm.*). Contaminants introduced by effluent or agricultural chemicals could prove detrimental to fish populations (DWR 1995) as well as giant garter snakes and their prey base. Finally, the proposed development of water conveyance infrastructure associated with the Bay Delta Conservation

Plan / Peripheral Canal could directly impact or fragment giant garter snakes within the eastern Delta.

## Recommendations

While our study suggests that GGS are highly localized within the WSA, the reasons are not entirely clear. The most obvious difference between this feature and others surrounding it is the muted tidal influence and apparent separation from mobile aquatic predators such as largemouth and striped bass. A priority for ensuring the persistence of this population should be safeguarding the integrity of Coldani Marsh by preserving this separation until the factors driving this distribution become clear.

Though we did not observe GGS at the majority of sites that we sampled at WSWA, there are a significant number of other locations at this latitude along the eastern Delta that may also harbor concentrated populations. While public access and tidal fluctuations confound trapping in many of the larger waterways, several possess backwaters that are sheltered by private lands. Among these features, eastern Sycamore Slough, Dredger Cut (northwest of Cotta Road), and Hog Slough contain the most promising habitat, characterized by the turbid water, vegetated banksides, and emergent vegetation supporting GGS at Coldani Marsh. We recommend continued attempts to gain access to these features, and to explore other sites for the potential presence of GGS in the eastern Delta.

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Appendix A. 2009-2010 WSWA trapline location descriptions, UTM coordinates (NAD83, Zone 10S), and survey dates

| Transect ID | Location Description | Start Easting | Start Northing | End Easting | End Northing | Start Date | End Date |
|---|---|---|---|---|---|---|---|
| **WS1** | Upland Canal - South and West of Coldani Marsh | 639114 | 4218894 | 638968 | 4219047 | 7/06/2009 | 9/18/2009 |
| **WS2** | Wetland West of Pond 11 - NW Corner | 639324 | 4217881 | 639347 | 4217873 | 7/07/2009 | 8/29/2009 |
| **WS3** | Wetland West of Pond 11 - West Central | 639468 | 4217586 | 639466 | 4217608 | 7/08/2009 | 8/29/2009 |
| **WS4** | Pond 13 - West Edge | 640460 | 4216613 | 640698 | 4216067 | 7/09/2009 | 7/23/2009 |
| **WS5** | Upland Canal - South of Coldani Marsh | 639262 | 4218902 | 638809 | 4218885 | 7/10/2009 | 9/18/2009 |
| **WS6** | Pond 11 - North Channel | 639813 | 4217874 | 639343 | 4217886 | 7/11/2009 | 8/28/2009 |
| **WS7** | Pond 11 - West Edge | 640106 | 4217529 | 639959 | 4217858 | 7/23/2009 | 8/28/2009 |
| **WS8** | Upland Canal - West of Pond 7 | 638859 | 4221458 | 638688 | 4221909 | 8/23/2009 | 8/25/2009 |
| **WS9** | Pond 7 - West Edge | 639076 | 4221487 | 638800 | 4221960 | 8/23/2009 | 9/04/2009 |
| **WS10** | Upland Canal - West of Coldani Marsh (So. of HWY 12) | 639110 | 4219818 | 639094 | 4219818 | 8/28/2009 | 9/17/2009 |
| **WS11** | Coldani Marsh - SW Corner (Drift Fence) | 638834 | 4218898 | 638874 | 4218898 | 8/30/2009 | 9/16/2009 |
| **WS12** | Upland Canal at Coldani Marsh SW (Marsh Side) | 639107 | 4219210 | 639088 | 4218893 | 5/11/2010 | 9/24/2010 |
| **WS13** | Upland Canal at Coldani Marsh SW (Levee Side) | 639093 | 4219207 | 639057 | 4218890 | 5/11/2010 | 9/24/2010 |
| **WS14** | Upland Canal at Coldani Marsh NW (1) | 639113 | 4219811 | 639112 | 4219221 | 5/12/2010 | 8/05/2010 |
| **WS15** | Upland Canal West of Pond 7 | 638441 | 4222177 | 638776 | 4221662 | 6/04/2010 | 8/02/2010 |
| **WS16** | Pond 11 - West Edge | 639935 | 4217856 | 640087 | 4217530 | 8/02/2010 | 8/31/2010 |
| **WS17** | Wetland West of Pond 11 - (Pond 11 Inlet) | 639943 | 4217693 | 639941 | 4217711 | 8/05/2010 | 8/31/2010 |
| **WS18** | Wetland West of Pond 11 - (Dredger Cut Inlet) | 639440 | 4217660 | 639548 | 4217596 | 8/05/2010 | 8/31/2010 |
| **WS19** | Upland Canal at Coldani Marsh NW (2) | 639094 | 4219805 | 639102 | 4219427 | 8/31/2010 | 9/24/2010 |

Appendix B. 2009-2010 WSWA GGS trapping effort and results

| Transect ID | Traps | Days | Theoretical Trap Days | Lost Trap Days | Actual Trap Days | Total Capture Events | Individuals Captured | Success/Unit Effort (Individuals/Trap day) |
|---|---|---|---|---|---|---|---|---|
| **WS1** | 50 | 74 | 3,700 | 0 | 3700 | 9 | 7 | 0.0019 |
| **WS2** | 50 | 53 | 2,650 | 0 | 2650 | 0 | 0 | 0 |
| **WS3** | 50 | 52 | 2,600 | 0 | 2600 | 0 | 0 | 0 |
| **WS4** | 50 | 14 | 700 | 0 | 700 | 0 | 0 | 0 |
| **WS5** | 50 | 70 | 3,500 | 46 | 3454 | 8 | 7 | 0.0020 |
| **WS6** | 50 | 48 | 2,400 | 10 | 2390 | 0 | 0 | 0 |
| **WS7** | 50 | 36 | 1,800 | 0 | 1800 | 0 | 0 | 0 |
| **WS8** | 50 | 2 | 100 | 1 | 99 | 0 | 0 | 0 |
| **WS9** | 50 | 12 | 600 | 0 | 600 | 0 | 0 | 0 |
| **WS10** | 50 | 20 | 1,000 | 0 | 1000 | 1 | 1 | 0.0010 |
| **WS11** | 50 | 17 | 850 | 50 | 800 | 0 | 0 | 0 |
| **2009 Total (all)** | | | **19,900** | **107** | **19,793** | **18** | **13** | **0.0007** |
| **2009 Total (successful)** | | | **8,200** | **46** | **8,154** | **18** | **13** | **0.0016** |
| **WS12** | 50 | 136 | 6,800 | 112 | 6,688 | 4 | 4 | 0.0006 |
| **WS13** | 50 | 136 | 6,800 | 125 | 6,675 | 22 | 14 | 0.0021 |
| **WS14** | 50 | 85 | 4,250 | 105 | 4,145 | 4 | 4 | 0.0010 |
| **WS15** | 50 | 59 | 2,950 | 43 | 2,907 | 0 | 0 | 0 |
| **WS16** | 50 | 29 | 1,450 | 15 | 1,435 | 0 | 0 | 0 |
| **WS17** | 12 | 26 | 312 | 6 | 306 | 0 | 0 | 0 |
| **WS18** | 38 | 26 | 988 | 9 | 979 | 0 | 0 | 0 |
| **WS19** | 50 | 24 | 1,200 | 9 | 1,191 | 0 | 0 | 0 |
| **2010 Total (all)** | | | **24,750** | **424** | **24,326** | **30** | **19** | **0.0008** |
| **2010 Total (successful)** | | | **17,850** | **342** | **17,508** | **30** | **19** | **0.0011** |
| **2009 – 2010 Total (all)** | | | **44,650** | **531** | **44,119** | **48** | **27** | **0.0006** |
| **2009 – 2010 Total (successful)** | | | **26,050** | **388** | **25,662** | **48** | **27** | **0.0011** |

Appendix C. 2009-2010 WSWA prey counts and catch per unit effort (CPUE)

### Table 1: 2009 prey counts and CPUE

| Transect ID | Count Number | Trap Days | Ranid Larva | | Ranid Adult | | Mosquitofish | | Black Bass | | Other Centrarchids | | Carp | | Silverside | | Prickly Sculpin | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE |
| WS1 | 1 | 1,400 | 1 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 1,600 | 4 | 0.0025 | 0 | 0 | 1 | 0.0006 | 1 | 0.0006 | 3 | 0.0019 | 1 | 0.0006 | 0 | 0 | 0 | 0 |
| WS2 | 1 | 1,400 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.0014 | 2 | 0.0014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 700 | 0 | 0 | 0 | 0 | 2 | 0.0029 | 2 | 0.0029 | 4 | 0.0057 | 1 | 0.0014 | 0 | 0 | 0 | 0 |
| | 3 | 550 | 0 | 0 | 0 | 0 | 2 | 0.0036 | 0 | 0 | 3 | 0.0055 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS3 | 1 | 1,400 | 0 | 0 | 0 | 0 | 1 | 0.0007 | 1 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 700 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 500 | 0 | 0 | 0 | 0 | 1 | 0.0020 | 2 | 0.0040 | 2 | 0.0040 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS4 | 1 | 700 | 1 | 0.0014 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 0 | 0 |
| WS5 | 1 | 1,400 | 1 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 650 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 1,404 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.0014 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS6 | 1 | 2,040 | 0 | 0 | 0 | 0 | 2 | 0.0010 | 1 | 0.0005 | 5 | 0.0025 | 1 | 0.0005 | 0 | 0 | 0 | 0 |
| | 2 | 350 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.0086 | 15 | 0.0429 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS7 | 1 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0.0143 | 81 | 0.1157 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 800 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0.0138 | 74 | 0.0925 | 5 | 0.0063 | 0 | 0 | 0 | 0 |
| | 3 | 300 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0.0367 | 50 | 0.1667 | 3 | 0.0100 | 0 | 0 | 0 | 0 |
| WS8 | 1 | 99 | 2 | 0.0202 | 12 | 0.1212 | 15 | 0.1515 | 0 | 0 | 8 | 0.0808 | 2 | 0.0202 | 0 | 0 | 0 | 0 |
| WS9 | 1 | 600 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.0033 | 1 | 0.0017 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS10 | 1 | 1000 | 0 | 0 | 9 | 0.0090 | 0 | 0 | 4 | 0.0040 | 17 | 0.0170 | 5 | 0.0050 | 0 | 0 | 0 | 0 |
| WS11 | 1 | 800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.0038 | 4 | 0.0050 | 0 | 0 | 0 | 0 |

**Table 2: 2010 WSWA prey counts and CPUE**

| Transect ID | Count Number | Trap Days | Ranid Larva | | Ranid Adult | | Mosquitofish | | Black Bass | | Other Centrarchids | | Carp | | Silverside | | Prickly Sculpin | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE | Count | CPUE |
| WS12 | 1 | 699 | 4 | 0.0057 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 5 | 0.0072 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 694 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 0 | 0 |
| | 3 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.0029 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0.0143 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 686 | 2 | 0.0029 | 1 | 0.0015 | 1 | 0.0015 | 0 | 0 | 11 | 0.0160 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6 | 622 | 0 | 0 | 0 | 0 | 5 | 0.0080 | 0 | 0 | 5 | 0.0080 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 699 | 0 | 0 | 5 | 0.0072 | 5 | 0.0072 | 2 | 0.0029 | 6 | 0.0086 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8 | 350 | 2 | 0.0057 | 2 | 0.0057 | 0 | 0 | 0 | 0 | 4 | 0.0114 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS13 | 1 | 700 | 6 | 0.0086 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.0043 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 700 | 0 | 0 | 2 | 0.0029 | 3 | 0.0043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 700 | 2 | 0.0029 | 1 | 0.0014 | 0 | 0 | 0 | 0 | 3 | 0.0043 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 699 | 6 | 0.0086 | 2 | 0.0029 | 2 | 0.0029 | 1 | 0.0014 | 16 | 0.0229 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 672 | 3 | 0.0045 | 4 | 0.0060 | 2 | 0.0030 | 0 | 0 | 11 | 0.0164 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6 | 620 | 1 | 0.0016 | 4 | 0.0065 | 0 | 0 | 0 | 0 | 15 | 0.0242 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 695 | 0 | 0 | 2 | 0.0029 | 2 | 0.0029 | 1 | 0.0014 | 24 | 0.0345 | 1 | 0.0014 | 0 | 0 | 0 | 0 |
| | 8 | 294 | 0 | 0 | 3 | 0.0102 | 0 | 0 | 1 | 0.0034 | 7 | 0.0238 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS14 | 1 | 750 | 19 | 0.0253 | 2 | 0.0027 | 0 | 0 | 2 | 0.0027 | 8 | 0.0107 | 1 | 0.0013 | 0 | 0 | 0 | 0 |
| | 2 | 660 | 0 | 0 | 3 | 0.0045 | 0 | 0 | 3 | 0.0045 | 4 | 0.0061 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 699 | 1 | 0.0014 | 2 | 0.0029 | 1 | 0.0014 | 0 | 0 | 7 | 0.0100 | 2 | 0.0029 | 0 | 0 | 0 | 0 |
| | 4 | 546 | 1 | 0.0018 | 3 | 0.0055 | 0 | 0 | 0 | 0 | 9 | 0.0165 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS15 | 1 | 699 | 0 | 0 | 3 | 0.0043 | 3 | 0.0043 | 0 | 0 | 0 | 0 | 1 | 0.0014 | 0 | 0 | 1 | 0.0014 |
| | 2 | 2075 | 0 | 0 | 3 | 0.0014 | 0 | 0 | 6 | 0.0029 | 1 | 0.0005 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 133 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS16 | 1 | 685 | 12 | 0.0175 | 0 | 0 | 4 | 0.0058 | 27 | 0.0394 | 11 | 0.0161 | 0 | 0 | 3 | 0.0044 | 1 | 0.0015 |
| | 2 | 750 | 18 | 0.0240 | 0 | 0 | 1 | 0.0013 | 8 | 0.0107 | 8 | 0.0107 | 0 | 0 | 3 | 0.0040 | 2 | 0.0027 |
| WS17 | 1 | 168 | 1 | 0.0060 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 138 | 4 | 0.0290 | 0 | 0 | 1 | 0.0072 | 2 | 0.0145 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WS18 | 1 | 532 | 9 | 0.0169 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.0019 | 5 | 0.0094 | 0 | 0 | 0 | 0 |
| | 2 | 447 | 26 | 0.0582 | 0 | 0 | 10 | 0.0224 | 0 | 0 | 0 | 0 | 9 | 0.0201 | 1 | 0.0022 | 0 | 0 |
| WS19 | 1 | 694 | 14 | 0.0202 | 2 | 0.0029 | 0 | 0 | 0 | 0 | 28 | 0.0403 | 2 | 0.0029 | 0 | 0 | 0 | 0 |
| | 2 | 497 | 6 | 0.0121 | 4 | 0.0080 | 2 | 0.0040 | 1 | 0.0020 | 15 | 0.0302 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1: 2009 pH measurements and statistics**

| Station | 9/5 | 9/9 | 9/12 | 9/16 | 9/18 | 9/20 | 9/22 | 9/24 | 9/26 | 9/29 | Mean | SE | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS1 | 8.52 | 8.27 | 8.37 | 8.36 | 8.6 | 8.07 | 8.26 | 8.05 | 8.70 | 8.30 | 8.35 | 0.06 | 0.21 |
| SS2 | 8.46 | 8.66 | 8.57 | 8.71 | 8.69 | 8.92 | 8.78 | 8.53 | 8.72 | 8.86 | 8.69 | 0.05 | 0.14 |
| SS3 | 9.06 | 8.83 | 8.68 | 8.13 | 8.11 | 8.72 | 8.66 | 8.60 | 8.63 | 8.61 | 8.60 | 0.09 | 0.29 |
| SS4 | 8.73 | 9.14 | 9.03 | 8.25 | 8.42 | 8.93 | 8.8 | 8.93 | 8.90 | 8.90 | 8.80 | 0.09 | 0.27 |
| SS5 | 8.60 | 8.24 | 7.86 | 7.89 | 8.50 | 7.66 | 7.79 | 7.90 | 7.80 | 8.25 | 8.05 | 0.10 | 0.32 |

**Table 2: 2009 electrical conductivity (mS/cm) measurements and statistics**

| Station | 9/5 | 9/9 | 9/12 | 9/16 | 9/18 | 9/20 | 9/22 | 9/24 | 9/26 | 9/29 | Mean | SE | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS1 | 0.088 | 0.106 | 0.087 | 0.074 | 0.062 | 0.080 | 0.081 | 0.073 | 0.075 | 0.103 | 0.083 | 0.004 | 0.014 |
| SS2 | 2.294 | 2.266 | 2.281 | 2.264 | 2.278 | 2.278 | 2.297 | 2.312 | 2.328 | 2.295 | 2.289 | 0.006 | 0.020 |
| SS3 | 0.248 | 0.275 | 0.274 | 0.240 | 0.258 | 0.231 | 0.266 | 0.238 | 0.234 | 0.243 | 0.251 | 0.005 | 0.016 |
| SS4 | 0.374 | 0.384 | 0.382 | 0.372 | 0.376 | 0.380 | 0.375 | 0.377 | 0.374 | 0.374 | 0.377 | 0.001 | 0.004 |
| SS5 | 0.256 | 0.194 | 0.216 | 0.110 | 0.065 | 0.062 | 0.072 | 0.078 | 0.066 | 0.101 | 0.122 | 0.023 | 0.072 |

**Table 3: 2010 pH measurements and statistics**

| Station | 5/29 | 6/26 | 7/10 | 7/31 | 8/14 | 8/28 | 9/9 | 9/24 | Mean | SE | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SS1 | 9.59 | 8.41 | 8.33 | 8.86 | 8.26 | 8.26 | 8.38 | 9.05 | 8.64 | 0.17 | 0.48 |
| SS2 | 8.29 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| SS3 | 8.48 | 8.66 | 8.48 | 8.18 | 8.24 | 8.47 | 8.32 | 7.96 | 8.35 | 0.08 | 0.22 |
| SS4 | 8.39 | 8.59 | 8.35 | 8.78 | 8.16 | 8.46 | 8.72 | 8.19 | 8.46 | 0.08 | 0.23 |
| SS5 | 8.54 | 8.07 | 8.10 | 8.45 | 8.08 | 8.48 | 8.46 | 8.41 | 8.32 | 0.07 | 0.20 |
| SS6 | -- | 8.68 | 8.63 | 8.46 | 8.82 | 8.40 | 8.68 | 8.39 | 8.58 | 0.06 | 0.16 |

**Table 4: 2010 electrical conductivity (mS/cm) measurements and statistics**

| Station | 5/29 | 6/26 | 7/10 | 7/31 | 8/14 | 8/28 | 9/9 | 9/24 | Mean | SE | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SS1 | 0.106 | 0.119 | 0.123 | 0.132 | 0.142 | 0.155 | 0.174 | 0.177 | 0.141 | 0.009 | 0.026 |
| SS2 | 2.115 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| SS3 | 0.207 | 0.214 | 0.221 | 0.227 | 0.253 | 0.256 | 0.259 | 0.293 | 0.241 | 0.010 | 0.029 |
| SS4 | 0.327 | 0.330 | 0.335 | 0.336 | 0.337 | 0.370 | 0.386 | 0.431 | 0.357 | 0.013 | 0.037 |
| SS5 | 0.095 | 0.121 | 0.127 | 0.135 | 0.167 | 0.174 | 0.192 | 0.204 | 0.152 | 0.013 | 0.038 |
| SS6 | -- | 0.122 | 0.125 | 0.134 | 0.147 | 0.152 | 0.176 | 0.180 | 0.148 | 0.009 | 0.023 |

**Implementation of Priority 1, Priority 2, and Priority 3 Recovery Tasks for Giant Garter Snake (*Thamnophis gigas*) – Status and distribution of giant garter snakes at the eastern Delta's White Slough Wildlife Area, San Joaquin County, CA**

**PI - Eric C. Hansen**

| YEAR(S) | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009-10 | Principal Investigator | $ 72,31.68 | 25 | $ 9,039.60 | | | | | | | |
| | Field Manager | $ 17,423.77 | 25 | $ 21,779.71 | | | | | | | |
| | L2 Technician | $ 40,780.65 | 25 | $50,975.81 | | | | | | | |
| | L1 Technician | $ 4,139.06 | 25 | $5,398.83 | | | | | | | |
| | | | | | $11,376.95 | $2,500 | $6,400 | $107,470.15 | 15.000% | $ 16,120.52 | **$ 123,590.68** |
| | | | | | | | | | | | |
| TOTALS | | **$ 69,755.16** | | **$ 87,193.95** | **$11,376.95** | **$2,500** | **$6,400** | **$107,470.15** | | **$ 16,120.52** | **$ 123,590.68** |

**Approximate Hourly Breakdown by Task**

| | |
|---|---|
| Field Hours (Task 1) | 1593 |
| Project Management, Data Analysis, and Report Hours (Task 2) | 147 |