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Assessment of Trap Modifications to Increase Capture and Detection Probabilities of the Giant Gartersnake (*Thamnophis gigas*)

Data Summary of Field Observations
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Abstract. We evaluated the efficacy of trap modifications for increasing detection and capture probabilities of the giant gartersnake (*Thamnophis gigas*). In evaluating trap efficiency, remote videography corroborated previous results that many individual gartersnakes pass traps without entering them, and that individuals that enter traps frequently escape them. Video observations of giant gartersnakes were not obtained at all modified trap types, so the efficacy of trap modifications could not be assessed by videography. Analysis of capture rates indicated that both trap modifications (cable ties used to construct a one-way valve in the small end of the funnel and hardware cloth extensions to increase the area sampled by individual traps) increased giant gartersnake capture rates, and that traps constructed of galvanized hardware cloth were more effective than traps constructed of vinyl-coated expanded steel. Because the effects of modifications on capture rates were independent of one-another, galvanized traps modified with valves and funnel extensions increased capture rates to 5.55 (2.45 – 10.51) times those of unmodified vinyl traps and 3.43 (1.79 – 5.87) times those of unmodified galvanized traps. This trap modification will increase giant gartersnake detection and capture probabilities and enable better estimation of demographic parameters for this species in future studies.

Introduction

Background

The California Department of Water Resources (DWR) has the responsibility of ensuring a reliable supply of water throughout much of California. Water supply reliability can be a difficult goal to achieve, given the large population in California (particularly in arid regions of the state), the extent and importance of agriculture to the California economy, and the dry Mediterranean and desert climates of much of the state. The high demand of water for urban, residential, industrial, and agricultural uses can deplete water resources necessary for plants and wildlife, particularly aquatic and wetland-dependent species. The giant gartersnake (*Thamnophis gigas*) is an obligate wetland species precinctive to marshes and marsh-like habitats in the Central Valley of California. Because of the loss of nearly all of its native tule marsh habitat, the giant gartersnake is listed under the federal and state endangered species acts as Threatened (California Department of Fish and Game Commission 1971, U.S. Fish and Wildlife Service 1993). Although it has been extirpated from the southern portion of its former range, the giant gartersnake persists in the Sacramento Valley in rice agricultural habitats (Halstead et al. 2010). Because of the intensive water use of rice, it's water supply is often targeted as a potential source for water during dry years. The effects of riceland idling and water transfers on the giant gartersnake are unknown, and studies evaluating the effects of riceland idling on the distribution and demography of the giant gartersnake are hindered by low detection and capture probabilities (Halstead et al. 2011b). The purpose of this study was to evaluate modifications to commercially-available traps for their effectiveness at sampling the giant gartersnake. The goal of this research is to increase detection and capture probabilities to levels that will allow quantitative assessment of the effects of water management practices on the distribution, demography, and behavior of this rare snake.

Goals and Objectives

The primary objective of this project was to evaluate alternative trap designs to increase the detection and capture probabilities of giant gartersnakes. This objective is an important early step for the goal of establishing a long-term programmatic assessment of the relationship of giant gartersnakes with rice agriculture in the Sacramento Valley. Low capture rates make estimation of demographic parameters difficult, and it is important to increase detection and capture rates to be able to more precisely estimate giant gartersnake occurrence, abundance, survival, recruitment, and population growth rates, and detect differences in these demographic rates in different habitats and experimental treatments. We evaluated the success of alternative trap designs by two methods: motion-triggered videography of traps and analysis of capture rates in each trap type.

Biology of the Giant Gartersnake

The giant gartersnake is precinctive to wetlands in California's Central Valley. It was first described in the southern San Joaquin Valley by Fitch (1940) as a subspecies of the aquatic gartersnake (at that time, *Thamnophis ordinoides*). Further taxonomic revisions resulted in the consideration of the giant gartersnake as a subspecies of the sierra gartersnake (*Thamnophis* *couchii*). Because the giant gartersnake is morphologically distinguishable from and allopatric with its most closely related species, the aquatic gartersnake (*Thamnophis atratus*) and the sierra gartersnake, it was recognized as a full species in 1987 (Rossman and Stewart 1987).

The giant gartersnake is highly aquatic and historically occurred in marshes, sloughs, and other habitats with slow-moving, relatively warm water and emergent vegetation, especially tules (*Schoenoplectus* [*Scirpus*] *acutus*). Although conversion of wetlands to agriculture has nearly extirpated the giant gartersnake from the San Joaquin Valley, this species persists in rice agriculture in the Sacramento Valley (Halstead et al. 2010). Canals associated with rice agriculture can provide marsh-like habitat conditions throughout the giant gartersnake active season (late March – early October; Wylie et al. 2009), and rice fields themselves are emergent wetlands for a portion of their active season. The quality of rice agricultural habitats relative to natural or restored marshes is an area of active research.

Giant gartersnakes feed primarily on small fish, frogs, and tadpoles (Rossman et al. 1996). Specific prey items may include tadpoles and small adults of the American Bullfrog (*Lithobates catesbeianus*) and tadpoles and adults of the Sierran Treefrog (*Pseudacris sierrae*). Fish prey items include but are not limited to mosquitofish (*Gambusia affinis)* and small Cyprinid and Centrarchid fishes. Little is known about the diet of juvenile giant garternakes.

The giant gartersnake is the longest species of gartersnake (Rossman et al. 1996). Like most natricine snakes, the giant gartersnake is sexually dimorphic for size, with females the larger sex (Wylie et al. 2010). Smaller giant gartersnakes grow faster than larger giant gartersnakes (Coates et al. 2009). Males and females exhibit differing patterns of seasonal growth, with males forgoing foraging (and growth) for reproductive opportunities in the early spring (Coates et al. 2009). Similarly, male body condition is much lower than female body condition during the spring mating season, but males and females enter hibernation in similar condition (Coates et al. 2009). Body condition might be related to the thermal ecology of the giant gartersnake. Female giant gartersnakes exhibit elevated body temperatures during June, July, and August (Wylie et al. 2009), which is the period during which they are gravid. In contrast, males elevate body temperature in the winter and early spring (Wylie et al. 2009), likely to prepare for the spring mating season. The elevated body temperature of males might be metabolically costly, causing decreased body condition for male snakes in spring.

Although some aspects of giant gartersnake demography are difficult to determine, detailed study of populations in the Sacramento Valley has yielded some insight into their population ecology. Giant gartersnakes in the Sacramento Valley tend to produce smaller litters than those historically observed in the San Joaquin Valley. In the San Joaquin Valley, mean litter size was 23 (Hansen and Hansen 1990). In the Sacramento Valley, mean litter size was 17 (95% CI = 13 – 21; (Halstead et al. 2011a). Mean parturition date was 13 August, though parturition can occur from early July through early October (Halstead et al. 2011a). Neonates in the Sacramento Valley are born at approximately 209 mm snout-vent length (SVL) and 4.9 g mass (Halstead et al. 2011a). Litter size varies temporally, potentially with resources, and larger females produce more, rather than larger, offspring (Halstead et al. 2011a).

Survival of adult female giant gartersnakes in the Sacramento Valley varies among sites and years. The annual survival probability of adult females greater than 180 g in mass was 0.61 (95% CI = 0.41 – 0.79) at an average site in an average year (Halstead et al. 2012). Individuals are at 2.6 (1.1 – 11.1) times greater daily risk of mortality when in aquatic habitats than in terrestrial habitats (Halstead et al. 2012), likely because most terrestrial locations occur when snakes are in subterranean refugia. The effect of linear habitats on daily risk of mortality varied with context: in rice agricultural systems, daily risk of mortality was less in canals than away from canals, but in systems with natural or restored marshes, risk of mortality was less in these two-dimensional habitats than in simple linear canals (Halstead et al. 2012). Overall survival was greatest in a site with a relatively large network of restored marshes (Halstead et al. 2012).

Abundance, density, and body condition of giant gartersnakes vary by site, presumably as a result of site differences in habitat. Abundances and densities were greatest in a natural wetland, less in a natural wetland modified for agricultural uses, less still in rice agriculture, and least in seasonal marshes managed for waterfowl (moist soil management in summer, flooded in winter; (Wylie et al. 2010). Body condition of females followed a similar pattern (Wylie et al. 2010). Habitats that most closely approximate natural marshes are therefore most likely to support dense populations of healthy giant gartersnakes.

Prior to settlement, the range of the giant gartersnake extended from Butte County in the north to Kern County in the south (Fitch 1940, Hansen and Brode 1980). The draining of wetlands and subsequent urban and agricultural development have contributed to the loss of over 95% of the giant gartersnake's original habitat (Frayer et al. 1989). The few remaining natural wetlands are fragmented and the natural cycle of seasonal valley flooding by high sierra snowmelt has been limited and the waters diverted by a network of dams and levees. As a result, giant gartersnake populations have become fragmented with only small isolated populations remaining in the San Joaquin Valley. These factors precipitated the listing of the giant gartersnake by the State of California (California Department of Fish and Game Commission 1971) and later by the U.S. Fish and Wildlife Service as a threatened species with a recovery priority designation of 2C: full species, high degree of threat, and high recovery potential (U.S. Fish and Wildlife Service 1993, 1999). The recovery of the giant gartersnake will require the restoration and protection of marsh habitats, a reliable supply of water to these habitats throughout the year, and further research into the most effective conservation practices for this species.

Trap Videography

Purpose

Greater detection and capture probabilities result in less uncertainty about the values of demographic parameters and a greater ability to evaluate the effects of covariates on the demographic processes of interest. Detection and capture probabilities for giant gartersnakes are exceedingly low (Halstead et al. 2011b), and successfully evaluating the effects of covariates or experimental treatments on their demography will require greater detection and capture probabilities. Remote videography offers the opportunity to continuously monitor objects of interest while minimizing observer effects. We monitored giant gartersnake traps with remote videography to examine the interactions of giant gartersnakes (and other animals) with the traps to suggest mechanisms for improving detection and capture probabilities for trapping surveys for this species.

Methods

Field Methods.—We conducted video monitoring on established trap transects at Gilsizer Slough from 10 August 2012 – 27 September 2012. We used motion-triggered cameras that allowed us to capture video of snakes and other wildlife interacting with the traps. We deployed eight cameras to monitor four individual traps (2 per trap) within a transect of 24 total traps positioned along a drainage canal. We selected the individual traps for video monitoring based on our observation of previous snake captures at these trap locations. We did not monitor traps in wetlands because of difficulties associated with long distances from dry land and difficulty placing cameras in secure locations.

We set up the cameras to initiate recording when they detected motion. The level of motion sensitivity necessary to capture the movement of a snake on or in the water was determined experimentally prior to deployment. Once triggered, the camera was set to record video for 20 seconds or until it no longer detected motion and then remain on continuous standby. We changed the batteries every two days to avoid any lapses in motion capture.

We attached cameras 0.5 m above the ground on stakes 0.5-1.0 m from the entrance funnels at both ends of the trap. Cameras were powered by two 12 V marine batteries and digital video files were recorded on a flash card. The batteries and camera control electronics were placed in the ground and covered with burlap. The cameras were camouflaged with natural vegetation.

Analytical Methods.—We viewed the video recordings and documented the species observed, the date and time of the trap encounter, and the nature of the encounter. For giant gartersnakes, encounters were categorized as: swam by trap without entering, attempted to enter trap, entered trap, or exited (escaped from) trap. We tabulated the results and summarized the activity times of the snakes.

Results

Snakes.—We captured 15 video clips of snakes. Ten of these clips were multiple video clip captures of the same individual within a trap. It was often impossible to identify individuals to species in digital video camera images, but all observed snakes can be confidently identified as one of two congeners: the giant gartersnake or the common gartersnake (*Thamnophis sirtalis*). Based upon habitat and behavior, recorded individuals were much more likely to be giant gartersnakes than common gartersnakes. Snake activity was unimodal and peaked in the early afternoon; all snake observations occurred between 11:04 and 16:17 (Fig. 1).

The only trap types at which we captured video of snakes were unmodified galvanized traps and galvanized traps with valves (see "Trap Modifications" below). We captured a giant gartersnake in a video-monitored galvanized trap with funnel extensions, but the camera malfunctioned.

Similarly, images from cameras placed at a vinyl trap were too blurry and distorted to interpret. We captured 4 instances (67% of video clips with snakes, not counting multiple videos of a single individual in sequence) in which individual snakes swam near the trap without interacting with it. In two cases, the snake was captured, but escaped before traps were checked. In both cases, the camera failed prior to escape of the captured individual. In one of these cases, the snake was trapped in an unmodified galvanized trap for at least 2 hours and 52 minutes prior to camera failure.

Other animals.—The observed activity patterns of mammals and birds were spread throughout the day (Fig. 1).

The only observed mammal (38 video captures) was the American mink (*Neovison vison*). We have observed few mink while conducting field activities at Gilsizer Slough. Mink often used the trap to haul out and preen, and occasionally exhibited interest in the traps and the video cameras themselves.

We obtained 13 video captures of birds, with 5 video captures of great blue herons (*Ardea herodias*), 3 video captures of pied-billed grebes (*Podilymbus podiceps*), two video captures each of belted kingfishers (*Megaceryle alcyon*) and Anna's hummingbirds (*Calypte anna*), and one video capture of an American bittern (*Botaurus lentiginosus*). Birds did not appear to interact with the traps.

Discussion

Videography showed the relatively large proportion of observations in which individual snakes completely bypassed and ignored the trap. Indeed, if the video captures are truly representative, trap bypass was the most common interaction of gartersnakes with traps. Unfortunately, no video interactions of traps modified with funnel extensions, which were designed to address the problem of trap by-pass, were obtained.

Although we observed video of snakes captured in the traps, we captured only one snake in a video monitored trap. Unfortunately this capture event did not appear on video. This suggests that even when snakes enter the traps, a large proportion (both of the video recorded captures in this study) exit the traps before they are routinely checked. One of the two snakes observed within a trap, but that later escaped, was captured in a galvanized trap with valves intended to prevent escape. Although the valves were found to be effective (see "Trap Modifications" below), they are not perfect at preventing escape.

Videography suggests that giant gartersnakes most frequently interact with the traps during the early afternoon. Concentrating trap checks in the mid-late afternoon would decrease the time available for captured individuals to escape. Indeed, one individual was in the trap for nearly three hours before the camera failed. This individual had escaped by the time technicians arrived to check the trap. Thus, the timing of trap checks is important, even for traps modified in an attempt to prevent escape of captured individuals.

In addition to suggesting improvements to trapping protocols, videography provided information on potential predators' interactions with the traps. Although we observed several potential snake predators, only the mink attempted to access trap contents, and did not appear to do so with much success. Potential avian predators completely ignored the traps. We therefore do not expect trapping the giant gartersnake to increase predator-induced mortality.

Trap Modifications

Purpose

Low detection and capture probabilities result in increased uncertainty about the values of occupancy, abundance, survival, recruitment, and other demographic parameters, and make uncertain any evaluation of the effects of covariates on the demographic processes of interest. Detection and capture probabilities for giant gartersnakes are exceedingly low (Halstead et al. 2011b), and successfully evaluating the effects of covariates or experimental treatments on the demography of this species will require greater detection and capture probabilities. We therefore evaluated the effects of eight different trap modifications in an attempt to improve detection and capture probabilities for giant gartersnakes.

Methods

Rationale.—We evaluated capture success based on the material (vinyl coated mesh or galvanized hardware cloth) used to make the standard eel traps used to survey for giant gartersnakes (Casazza et al. 2000) and various modifications to those traps and their placement. The first modification we made to the traps was adding 5 cable ties to extend beyond the small opening of the funnel to meet and form a one-way valve (Fig. 2). The cable ties were flexible enough so as not to impede snakes from entering the trap, but when pressed from inside the trap, would lie across the opening or each other and inhibit escape. The cable ties also had the added benefit of visually obstructing the funnel opening when viewed from inside the trap. We used cable ties that most nearly matched the color of the traps; black for the vinyl-coated traps, and white for the galvanized hardware cloth traps. The second modification we made was to add hardware cloth funnel extensions to the large opening of the funnel (Fig. 3). The funnel extensions increased width of the funnel opening along the water's surface, and acted as small drift fences to increase the effective area sampled by each trap.

Field Methods.—We deployed four transects of 24 traps each at Gilsizer Slough and Colusa National Wildlife Refuge (NWR) to examine the effects of trap material and modifications on the number of giant gartersnake captures. At each site, we placed two transects in canals and two in created wetlands to sample habitats representative of the majority of sampling conditions in the Sacramento Valley. Within each transect, we deployed three replicates of each trap material and modification and placed traps in a random sequence with respect to trap type. We deployed traps at Gilsizer Slough on 19 April 2012, and checked them daily until 27 September 2012, when all traps were removed. At Colusa NWR, we deployed traps on 9 May 2012 and checked them daily until they were removed on 16 August 2012. We recorded the identity of the trap, including the trap type, for each giant gartersnake capture. We marked each captured giant gartersnake with a unique microbrand (Winne et al. 2006) and passive integrated transponder (PIT) tag, and measured and determined the sex of each individual prior to releasing it at its location of capture.

Analytical Methods.—We analyzed the number of giant gartersnake captures in each trap type using Bayesian analysis of log-linear models (Poisson regression with a log-link function) on the sums of captures in each trap type x habitat x site combination. We fit six models to the data, each representing a different hypothesis about the effects of trap modifications. All models contained an interaction of site with habitat to account for differences in abundance or capture probability in different habitats at different sites. Because of poor model fit of even highly parameterized models, we also added a log-normal random effect at the level of summation to each model to account for overdispersion of the observed counts (relative to the Poisson assumption of equal mean and variance). The null model represented the hypothesis that all trap types would have the same number of giant gartersnake captures, the main effects model represented the hypothesis that all variation in number of giant gartersnake captures was purely additive (the effectiveness of a modification was independent of which other modifications were applied to the trap), a two-way interactive model (combinations of trap modifications affected the number of captures in each trap type), and a three-way interactive model (each modification was affected by every other modification to that trap type). In addition to these models, we also expanded the main effects and two-way interaction models to include habitat type interacting with each of the trap modification effects and, if applicable, the modification interactions. These latter models evaluated the hypotheses that the effectiveness of trap modifications varied by habitat and that the effects of modifications on each other varied by habitat, respectively. We did not consider a four-way interactions model because our data were too sparse to fit a model of this complexity.

In addition to model coefficients, we also calculated several derived parameters. We compared the observed number of captures to that predicted (using the posterior predictive distribution) from the null model to examine which modifications performed better or worse than expected if trap modifications did not affect capture rates. We also calculated the pair-wise ratios between the predicted number of captures for all trap types in canals at Gilsizer Slough (the site and habitat combination with the greatest number of captures), and examined the 95% credible interval (CRI) of each ratio to see if it contained one. We considered posterior distributions that did not contain one to be evidence for statistical differences in capture rates between trap types. We also examined the range of snout-vent lengths (SVL) of captured snakes in each trap type to examine evidence for bias in the size of individuals sampled by each trap type.

We used standard Markov-chain Monte Carlo (MCMC) techniques to obtain posterior inference from the models. We assessed model fit with a Bayesian p-value (Kéry 2010), and compared models with the Deviance Information Criterion (DIC; Spiegelhalter et al. 2002)). We used uninformative N(mean=0, SD=100) priors for all model coefficients and a U(min=0, max=10) prior for the standard deviation of the log-normal random effect. Each model was run on five chains of 100,000 iterations each after a burn-in period of 10,000 iterations; each chain was thinned by a factor of five, resulting in posterior inference based upon 100,000 samples from the posterior distribution. We assessed convergence with history plots and the Gelman-Rubin

Statistic (Gelman and Rubin 1992), and found no evidence for lack of convergence (all R-hat < 1.06). We analyzed each model by calling OpenBUGS 3.2.2 (Lunn et al. 2009) from R 2.15.1 (R Core Team 2013) with the R package R2OpenBUGS (Sturtz et al. 2005). Unless otherwise indicated, results are presented as the posterior mean and 95% CRI.

Results

We captured 75 individual giant gartersnakes 142 times (133 in canals, 9 in wetlands) at Gilsizer Slough, and 56 individual giant gartersnakes 65 times (33 in canals, 32 in wetlands) at Colusa NWR, for a total of 207 captures of 131 individual giant gartersnakes. The best model based on DIC was the main effects model, indicating that the effects of trap modifications were independent of each other (Table 1). In canals at Gilsizer Slough, vinyl traps with valves and unmodified galvanized traps had fewer captures than expected if all trap types were equal in their ability to capture giant gartersnakes, and galvanized traps with funnel extensions (both with and without valves) had more captures than expected (Fig. 4). In wetlands at Colusa NWR, unmodified vinyl traps had fewer captures than expected if all traps types were equal (Fig. 4). Galvanized traps with funnel extensions and valves performed better than all other traps except galvanized traps with funnel extensions (but without valves; Table 2, Fig. 4). Galvanized traps with funnel extensions and without valves performed better than all other traps except galvanized traps with extensions and valves, vinyl traps with extensions and valves, and unmodified galvanized traps (Table 2, Fig. 4). Galvanized traps with extensions and valves were 5.55 (2.45–10.51) times more effective than unmodified vinyl traps (Table 2). Captured individuals ranged in size from 228–924 mm SVL, with small and large individuals represented in each trap type except unmodified galvanized traps (neither small nor very large individuals captured) and galvanized traps with valves (no very large individuals captured).

Discussion

The most successful traps were galvanized traps with funnel extensions and valves. The next most successful trap design was galvanized traps with funnel extensions. We suspect that the mechanism leading to increased capture rates in traps with funnel extensions was an increase in the probability that a giant gartersnake enters the trap because of the greater distance of the water's surface intersected by the trap. In contrast, the mechanism leading to the effectiveness of valves was likely a decrease in the probability that an individual, once captured, escaped. This could have been caused either by the physical barrier the valves were intended to provide, or by the visual obstruction the valves created at the small funnel opening. Regardless of the mechanisms by which the trap modifications increased capture rates, they did so independently of one another. Including funnel extensions or valves on traps increased capture rates by the same amount, regardless of whether the other modification was present. Therefore, traps with both modifications resulted in the highest capture rates.

Both galvanized and vinyl traps were enhanced by all modifications. Unmodified traps had the lowest capture rates, a result that is encouraging because it indicates that none of the modifications was detrimental to capturing giant gartersnakes. Based upon our results, we recommend that surveys employ modified galvanized traps, rather than modified vinyl traps, to obtain the highest possible capture rates.

Because we sampled the two main habitat types occupied by the giant gartersnake throughout the Sacramento Valley at two sites, we are confident that our results will be transferable to studies of the giant gartersnake throughout the Sacramento Valley. We do not know, however, what the realized detection or capture probabilities will be using transects composed entirely of galvanized traps with funnel extensions and valves. We suspect that daily detection probabilities will increase approximately six-fold, from 0.18 (0.14–0.22; with 50 traps, 25°C water, 1 June) to 0.63 (0.36–0.88; under the same sampling conditions). A similar proportional increase in capture probabilities, which are generally an order of magnitude lower than daily detection probabilities, is also expected. These expected results await testing with field trials.

Summary

- Because of technical difficulties, remote videography provided few new insights into the interaction of giant gartersnakes with traps.
- All trap modifications evaluated increased giant gartersnake capture rates.
- The effectiveness of trap modifications did not depend on trap material or habitat in which the traps were deployed.
- Galvanized traps modified with funnel extensions and valves had the highest capture rates.
- Using galvanized traps with funnel extensions and valves is predicted to increase detection and capture probabilities by approximately 5.6 times those of unmodified traps.
- These results are incorporated into the manuscript, "Efficacy of trap modifications for increasing capture rates of aquatic snakes in floating aquatic funnel traps," by Brian J. Halstead, Glenn D. Wylie, and Michael L. Casazza (Appendix A).

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Figure Captions

Fig. 1. Dates and times of video captures for different vertebrates. Green circles indicate gartersnakes (*Thamnophis* spp.), yellow triangles represent birds, red squares represent mammals, and blue diamonds represent amphibians.

Fig. 2. Example of cable ties creating a one-way valve permitting giant gartersnake (*Thamnophis gigas*) entry into the trap, but preventing escape.

Fig. 3. Hardware cloth funnel extensions to expand the wide funnel opening on floating aquatic funnel traps. (a) View of the trap as constructed, and (b) example of trap deployed along a canal bank.

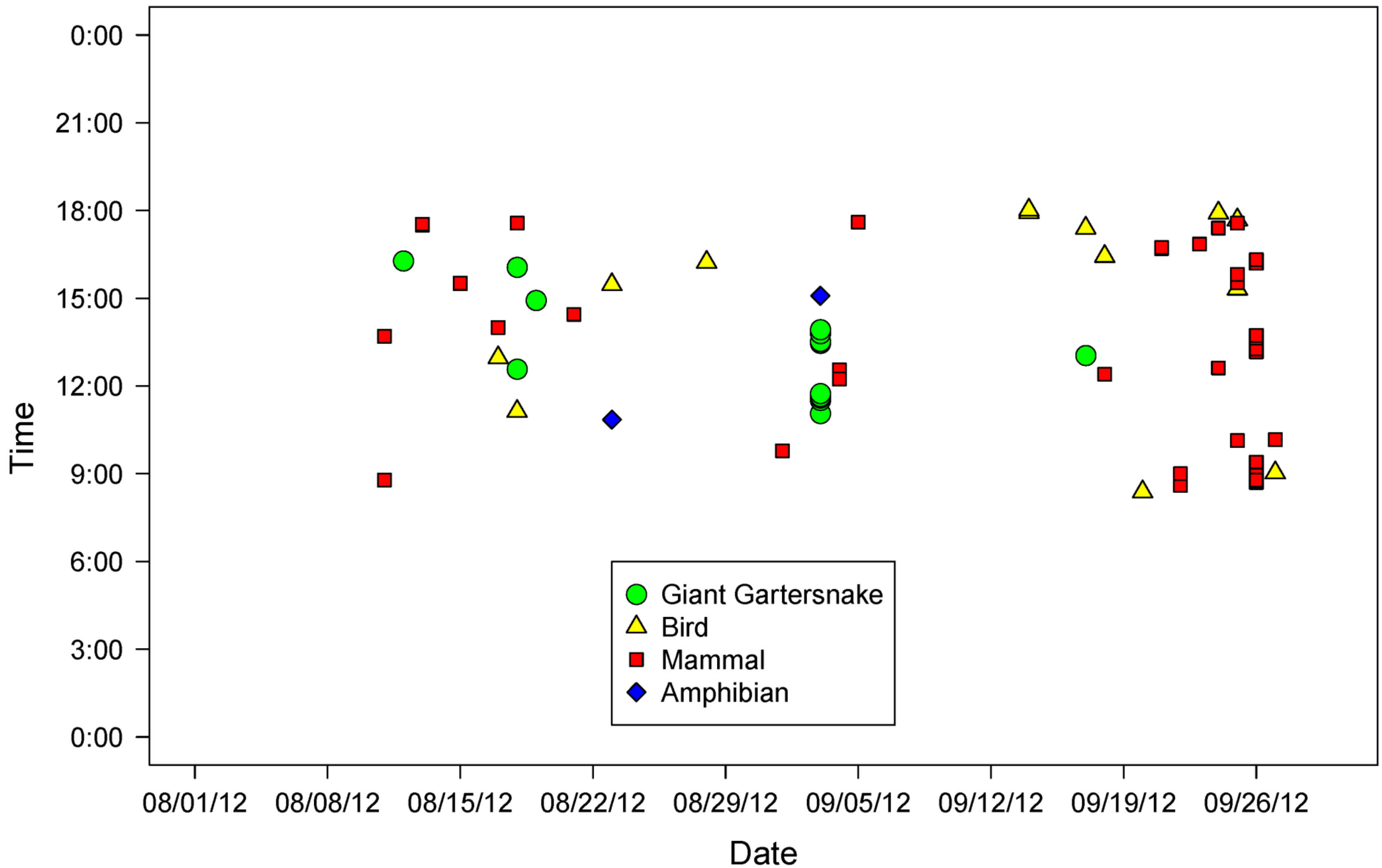
Fig. 4. Observed number of giant gartersnake (*Thamnophis gigas*) captures (bars) in each trap type in canals and marshes at Gilsizer Slough and Colusa National Wildlife Refuge, 2012. Black dots and error bars represent the mean (95% credible interval) expected number of captures for each trap type based upon the best supported model. Trap codes are as follows: Vi = Vinyl, G = Galvanized, O = Open, Va = Valve, S = Standard, E = Extensions.

Table 1. Measures of model fit for capture rates of the giant gartersnake (*Thamnophis gigas*) at Gilsizer Slough and Colusa National Wildlife Refuge, 2012. Models are listed in order of decreasing support. All models include an intercept and modification × site × habitat random effect; models with interactions also include main effects. pD is the effective number of parameters in the model; DIC is the deviance information criterion.

Model	Bayesian p-value	pD	Mean deviance	DIC
Material + valve + extension + habitat × site	0.336	14.4	132.3	146.7
Material × valve + material × extension + valve × extension + habitat × site	0.339	17.0	131.7	148.7
Material × habitat + valve × habitat + extension × habitat + habitat × site	0.290	16.8	132.5	149.3
Material × valve × extension + habitat × site	0.286	17.0	132.8	149.8
Habitat × site	0.447	19.9	130.0	149.9
(Material × valve + material × extension + valve × extension) × habitat + habitat × site	0.341	21.3	129.5	150.8

Table 2. Pair-wise posterior mean ratios of the expected number of giant gartersnake (*Thamnophis gigas*) captures in canals at Gilsizer Slough based upon the best supported model. Ratios in **bold** are statistically different from one. Trap codes are as follows: Vi = Vinyl, G = Galvanized, O = Open, Va = Valve, S = Standard, E = Extensions.

	Numerator Trap Type							
Denominator Trap Type	ViOS	ViOE	ViVaS	ViVaE	GOS	GOE	GVaS	GVaE
ViOS	1.00	**2.38**	1.44	**3.43**	**1.62**	**3.86**	**2.33**	**5.55**
ViOE	**0.42**	1.00	0.58	1.44	0.71	**1.62**	1.02	**2.33**
ViVaS	0.69	1.72	1.00	**2.38**	1.18	**2.80**	**1.62**	**3.86**
ViVaE	**0.29**	0.69	**0.42**	1.00	**0.52**	1.18	0.71	**1.62**
GOS	**0.62**	1.41	0.85	**1.92**	1.00	**2.38**	1.44	**3.43**
GOE	**0.26**	**0.62**	**0.36**	0.85	**0.42**	1.00	0.58	1.44
GVaS	**0.43**	0.98	**0.62**	1.41	0.69	1.72	1.00	**2.38**
GVaE	**0.18**	**0.43**	**0.26**	**0.62**	**0.29**	0.69	**0.42**	1.00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Date
Giant Gartersnake
Bird
Mammal
Amphibian

Fig. 1.

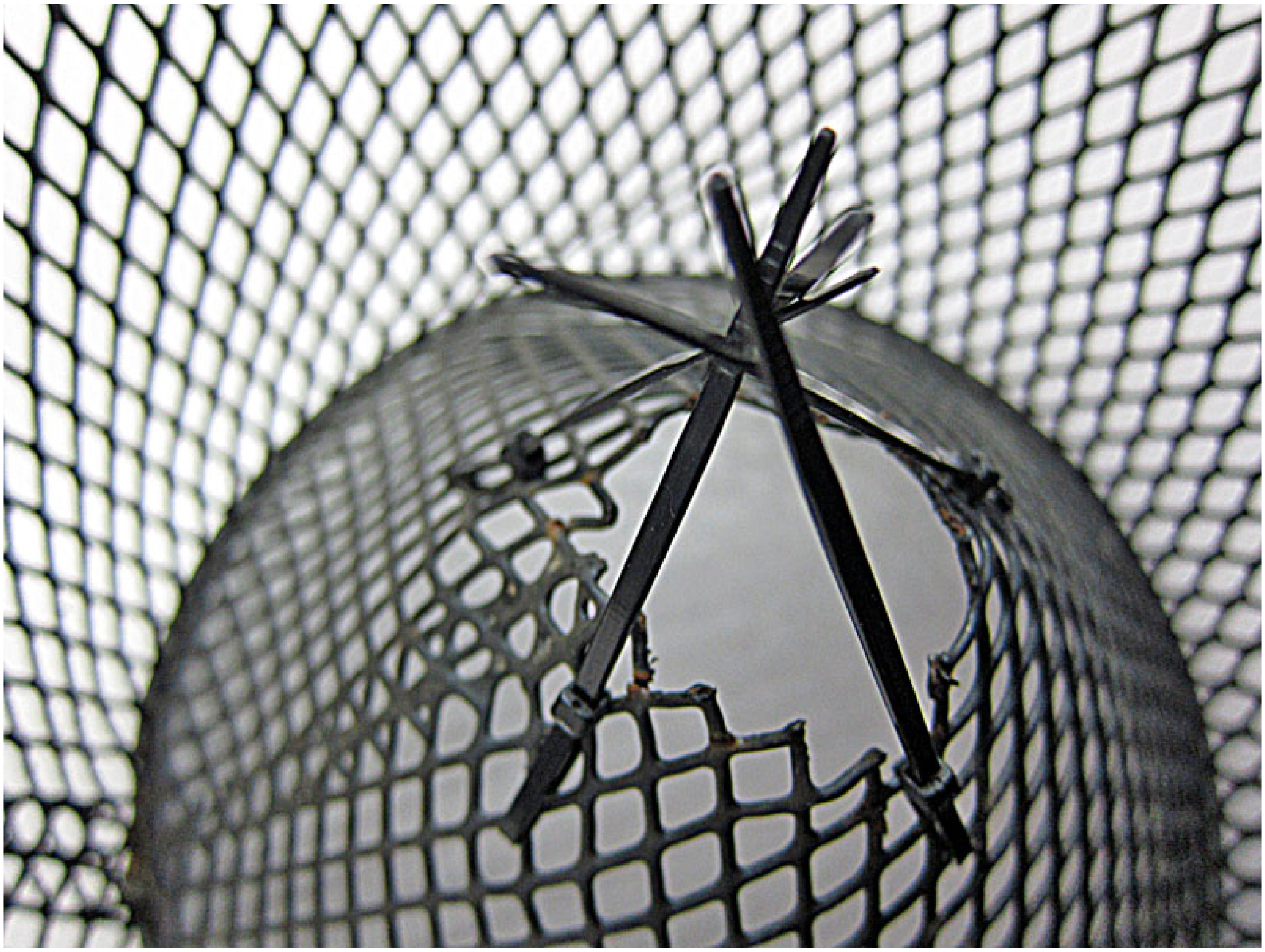


Fig. 2.

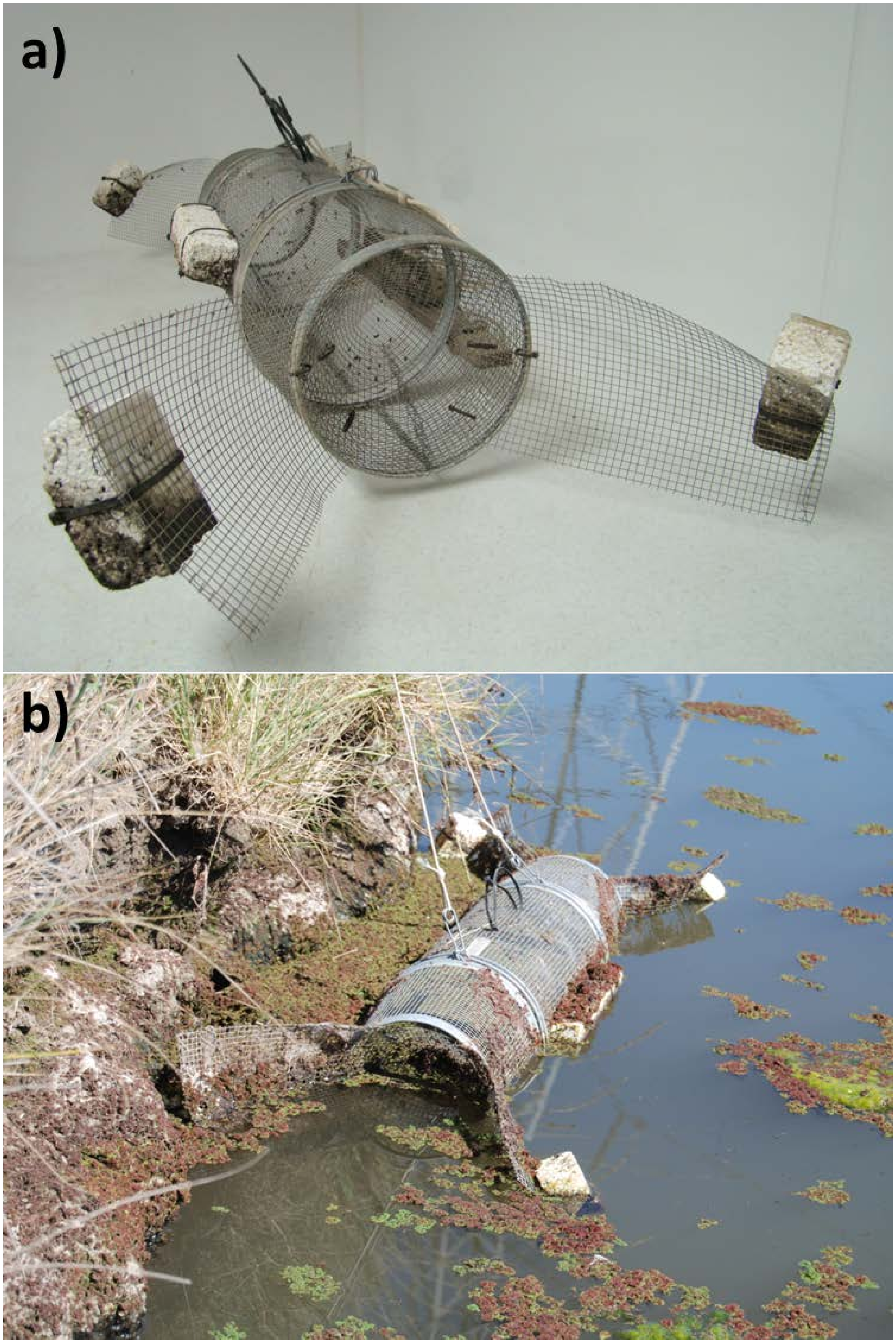
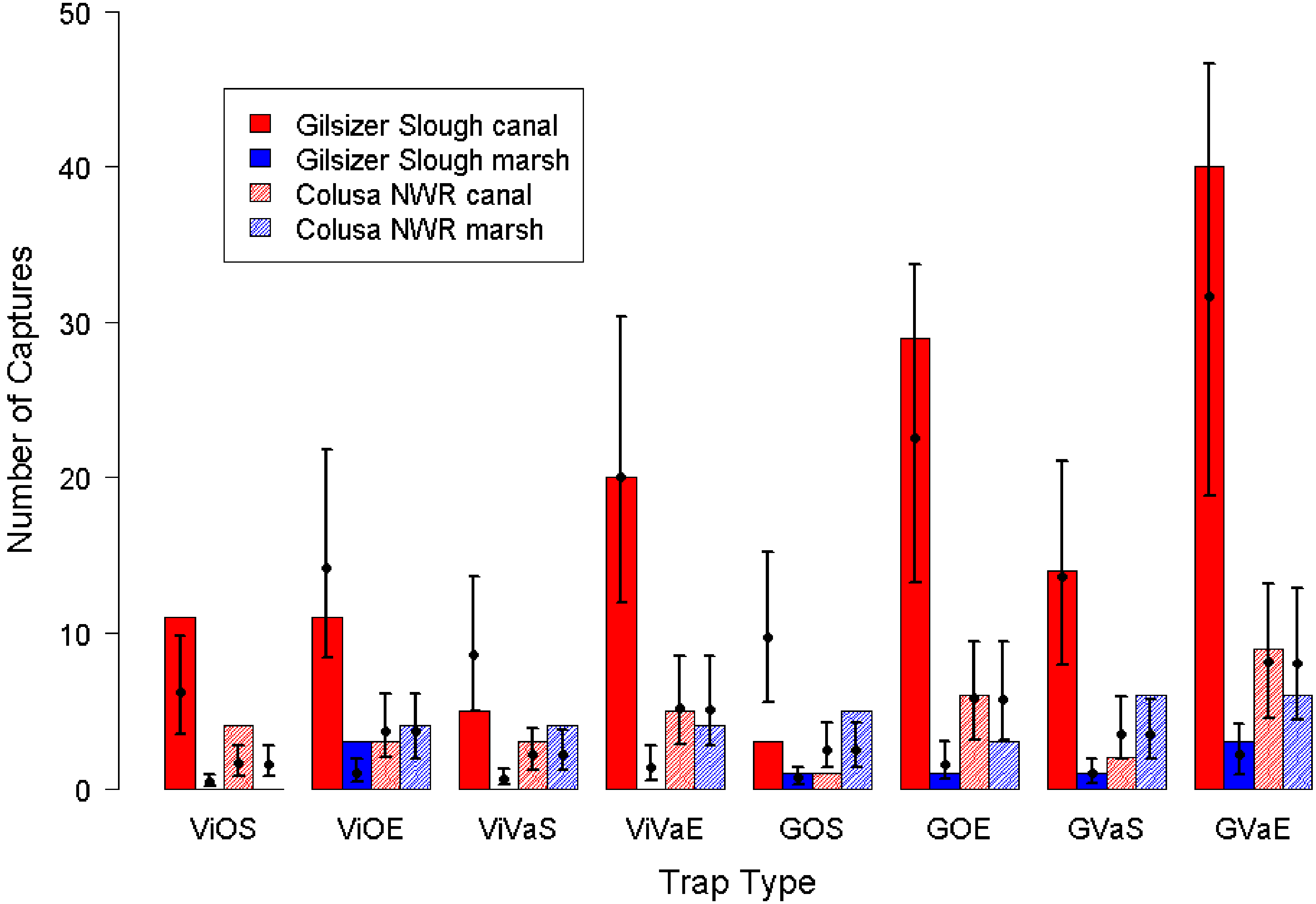


Fig. 3.



50
40
30
20
10
0
Number of Captures
Gilsizer Slough canal
Gilsizer Slough marsh
Colusa NWR canal
Colusa NWR marsh
ViOS
ViOE
ViVaS
ViVaE
GOS
GOE
GVaS
GVaE
Trap Type

Fig. 4.

Appendix A.

Halstead, Brian J., Glenn D. Wylie, and Michael L. Casazza. 2013. Efficacy of trap modifications for increasing capture rates of aquatic snakes in floating aquatic funnel traps. *Herpetological Conservation and Biology* 8:65-74.