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EFFICACY OF TRAP MODIFICATIONS FOR INCREASING CAPTURE RATES OF AQUATIC SNAKES IN FLOATING AQUATIC FUNNEL TRAPS

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***Abstract.*—Increasing detection and capture probabilities of rare or elusive herpetofauna of conservation concern is important to inform the scientific basis for their management and recovery. The Giant Gartersnake (*Thamnophis gigas*) is an example of a secretive, wary, and generally difficult-to-sample species about which little is known regarding its patterns of occurrence and demography. We therefore evaluated modifications to existing traps to increase the detection and capture probabilities of the Giant Gartersnake to improve the precision with which occurrence, abundance, survival, and other demographic parameters are estimated. We found that adding a one-way valve constructed of cable ties to the small funnel opening of traps and adding hardware cloth extensions to the wide end of funnels increased capture rates of the Giant Gartersnake by 5.55 times (95% credible interval = 2.45–10.51) relative to unmodified traps. The effectiveness of these modifications was insensitive to the aquatic habitat type in which they were deployed. The snout-vent length of the smallest and largest captured snakes did not vary among trap modifications. These trap modifications are expected to increase detection and capture probabilities of the Giant Gartersnake, and show promise for increasing the precision with which demographic parameters can be estimated for this species. We anticipate that the trap modifications found effective in this study will be applicable to a variety of aquatic and semi-aquatic reptiles and amphibians and improve conservation efforts for these species.**

Key Words.—California; capture probability; detection probability; garter snake; Giant Gartersnake; imperfect detectability; sampling; *Thamnophis gigas*

INTRODUCTION

Robust estimation of demographic parameters requires accounting for the imperfect detectability of populations and individuals (MacKenzie et al. 2002, 2006; Williams et al. 2002; Amstrup et al. 2005). Low detection and capture probabilities can have several negative consequences including increased uncertainty in demographic parameter estimates, and sometimes the inability to estimate these parameters entirely (Link 2003). This increases model selection uncertainty and restricts the scope of models that can be fit to data, generally limiting the types of hypotheses that can be tested about a system. Increasing detection and capture probabilities is therefore an important goal for difficult-to-detect species.

Many reptiles and amphibians have characteristics that cause low detection and capture probabilities. Snakes, in particular, have secretive habits or are inactive for much of the year (Fitch 2001; Dorcas and Willson 2009). Although active searches can be effective for some species, they tend to have low repeatability and high levels of observer bias, leading to very misleading inference about relative abundance and potential difficulties when quantifying detection or capture probabilities (Dorcas and Willson 2009). Studies of occurrence, and especially demography, therefore often rely upon trapping as a method for sampling snakes. An extensive herpetological literature is dedicated to the evaluation of passive sampling techniques (e.g., Casazza et al. 2000; Johnson and Barichivich 2004; Winne 2005; Willson et al. 2005; Luhring and Jennison 2008). Despite this attention from herpetologists, detection and capture probabilities remain too low to reliably estimate demographic parameters for many species.

The Giant Gartersnake (*Thamnophis gigas*; Fig. 1) is an example of a rare, difficult-to-detect species for which the estimation of demographic parameters is difficult,

FIGURE 1. The Giant Gartersnake (*Thamnophis gigas*) at Gilsizer Slough, California, USA. (USGS Photograph by Matt Meshriy)

TABLE 1. Trap modifications evaluated for their effectiveness at capturing the Giant Gartersnake (*Thamnophis gigas*) in the Sacramento Valley of California, 2011 and 2012. NA indicates that a modification was not used that year. Traps with the same abbreviation between study years were identical.

	Trap Modification				
Study year	Material	Valve	Depth	Extensions	Abbreviation
2011	Vinyl	Open	Surface	NA	ViOS
	Vinyl	Open	Deep	NA	ViOD
	Vinyl	Valve	Surface	NA	ViVaS
	Vinyl	Valve	Deep	NA	ViVaD
	Galvanized	Open	Surface	NA	GOS
	Galvanized	Open	Deep	NA	GOD
	Galvanized	Valve	Surface	NA	GVaS
	Galvanized	Valve	Deep	NA	GVaD
2012	Vinyl	Open	NA	Standard	ViOS
	Vinyl	Open	NA	Extensions	ViOE
	Vinyl	Valve	NA	Standard	ViVaS
	Vinyl	Valve	NA	Extensions	ViVaE
	Galvanized	Open	NA	Standard	GOS
	Galvanized	Open	NA	Extensions	GOE
	Galvanized	Valve	NA	Standard	GVaS
	Galvanized	Valve	NA	Extensions	GVaE

but very important to inform management of their recovery. The Giant Gartersnake is endemic to marshes and sloughs in the Central Valley of California, and is federally and state-listed as a threatened species because of extensive habitat loss (California Department of Fish and Game Commission 1971; Hansen and Brode 1980; Frayer et al. 1989; U.S. Fish and Wildlife Service 1993, 1999). It is a notoriously wary and difficult-to-sample species (Wright and Wright 1957), but conserving the Giant Gartersnake requires information on its distribution, demography, and response to habitat management, all of which rely on the estimation of demographic parameters. The objective of our study was to compare capture rates of the Giant Gartersnake among different modifications to existing commercially available traps (Casazza et al. 2000). We modified traps to address two processes that affect detection and capture probabilities: the process of an individual entering a trap, and the process of an individual that has entered the trap escaping from it (Rodda et al. 1992; Willson et al. 2005).

MATERIALS AND METHODS

Study sites.—We conducted our study at two sites, Gilsizer Slough and Colusa National Wildlife Refuge (NWR) in the Sacramento Valley. Gilsizer Slough is located in rural Sutter County, California, USA, and consists of a remnant slough channel of the Yuba River, created freshwater marshes, and agriculture (predominantly rice). Colusa NWR is located in rural Colusa County, California, USA, and is managed for multiple species. Colusa NWR similarly consists of created freshwater marshes, seasonal wetlands, and alkali grasslands restored from agricultural uses in a matrix of rice agriculture. A network of canals occurs within and around both sites. We trapped within the canals and created marshes at each site.

Field methods.—We trapped from 2011–2012, with trap modifications varying from one year to the next. Year one of the study (2011) occurred at Gilsizer Slough, and year two (2012) occurred at both Gilsizer Slough and Colusa NWR. We made all trap modifications to floating aquatic funnel traps as described by Casazza et al. (2000).

In year one, we explored the effects of trap material (vinyl-coated expanded steel [Vi], galvanized hardware cloth [G]), sampling depth (surface [S], deep [D; the small opening of the funnel just barely below the surface]), and a one-way valve (valve [Va; Fig. 2], open [O]) on capture rates of the Giant Gartersnake. We expanded the small end of the factory funnel opening on all traps to 3.8 cm diameter to allow entry of larger

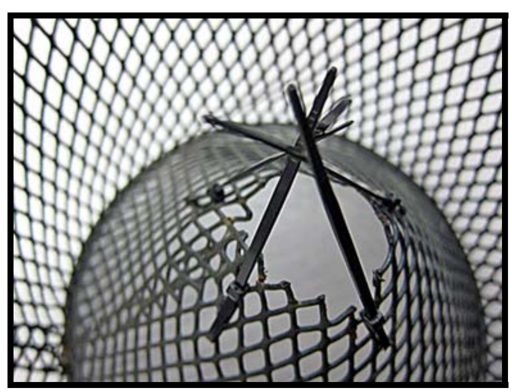

FIGURE 2. Cable tie one-way valves (Va) placed in the small opening of the funnel to prevent escape of captured snakes.

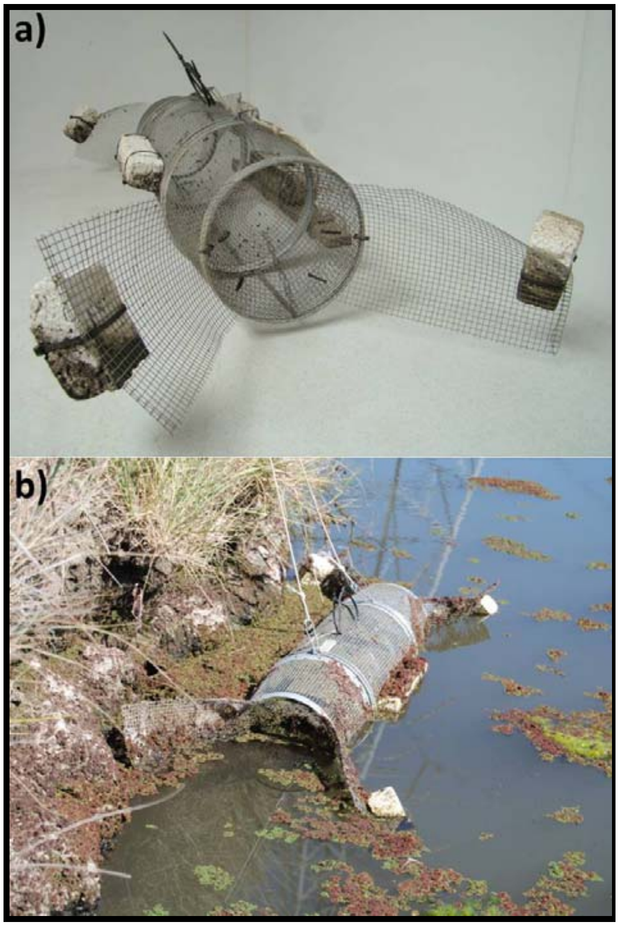

FIGURE 3. Hardware cloth funnel extensions to expand the wide funnel opening (E) on floating aquatic funnel traps. (a) View of the trap as constructed, and (b) example of trap deployed along a canal bank. Polystyrene floats on the ends of the extensions stabilize the trap to keep the hardware cloth extensions approximately centered at the water's surface.

snakes. We constructed traps in all eight combinations of trap material, sampling depth, and funnel opening (Table 1). We established four transects of 24 traps each, and placed three traps of each type in a randomly selected order along each transect. Two transects were placed along the banks of canals, and two were placed along the edge of emergent vegetation in marsh habitat. We deployed traps on 18 April 2011, and checked them daily through 8 September 2011.

In year two, we eliminated the depth modification so that all traps were floated at the surface, and replaced it with modifications to the funnel (extensions [E; Fig. 3], standard [S]; Table 1). Funnel extensions were rectangular pieces of hardware cloth cable-tied to the funnel to extend the width of the large funnel opening (Fig. 3). We checked traps daily at Gilsizer Slough from 20 April to 27 September 2012 and at Colusa NWR from 10 May to 16 August 2012. We counted and removed non-target species (e.g., anurans, fishes, and invertebrates) from every fifth trap on each transect to quantify relative prey availability as a part of related studies. We allowed potential prey to accumulate in other traps, with the exception that traps were emptied of large numbers of crayfish. We marked each 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. For analysis, we treated each capture as an independent event. We occasionally captured non-target snake species, but because our traps were intended to capture the Giant Gartersnake, we do not consider these other species here.

Analytical methods.—We examined non-independence of capture rate with trap type using Poisson regression with a log link function on the sums of captures in each trap type × habitat (× site, in year two) combination. Because we used different modifications each year, we conducted a separate analysis for each year of the study. In year one, we considered six different models. Our null model consisted of an effect of habitat type on capture rate, which corresponded to the hypothesis that capture rate varied by habitat, but that capture rates were identical among the trap modifications. To this model we added main effects for each trap modification, which allows capture rates to vary additively among trap modifications. We also considered a model that contained two-way interactions among the effects of trap modifications and another that considered a three-way interaction among the effects of trap modifications, so that one modification could render another modification more or less effective than if the modification occurred alone. 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 models allowed us to evaluate whether trap modifications varied in their effectiveness among different habitat types, and whether modification interactions varied by habitat type. We did not consider a four-way interactions model because our data were too sparse to fit a model of this complexity.

In year two, we had the added complexity of two sites. Therefore, we expanded our null model in year two to include an interaction of site with habitat (including main effects). This model represented the hypothesis that capture rates were equal among trap modifications, but differed among the four combinations of habitat and site. Because of poor model fit of even highly parameterized models, we added a log-normal random effect at the level of summation (trap type × habitat ×

TABLE 2. Measures of model fit for capture rates of the Giant Gartersnake (*Thamnophis gigas*) in year one at Gilsizer Slough, California, 2011. Models are listed in order of decreasing support. All models include an intercept; models with interactions also include main effects.

Model	Bayesian p-value	pD[a]	Mean deviance	DIC
Material × valve × depth + habitat	0.207	8.8	69.2	78.0
Material × valve + material × depth + valve × depth + habitat	0.123	7.9	70.8	78.7
Material × valve × habitat + material × depth × habitat + valve × depth × habitat	0.149	13.4	66.6	80.0
Material × habitat + valve × habitat + depth × habitat	0.045	7.8	77.5	85.3
Material + valve + depth + habitat	0.032	4.9	81.1	86.1
Habitat	0.008	2.0	84.7	86.7

[a] pD is a measure of the effective number of parameters.

site) to account for overdispersion in the observed counts of captures to the null model. We then added the same effects to the year two null model as we did to the year one null model, resulting in a set of six models.

We analyzed the models for both years using Bayesian inference (McCarthy 2007; Kéry 2010). We established uninformative N(mean = 0, SD = 100) priors for all model coefficients, and an uninformative U(min= 0, max = 10) prior for the standard deviation of the log-normal random effect in the year two models. We assessed goodness-of-fit of each model with a Bayesian p-value (Link and Barker 2010; Kéry 2010), and examined relative fit of models within each study year with the deviance information criterion (DIC). We chose to use DIC for model selection because it is appropriate for selecting the model with the best short-term predictive performance (Spiegelhalter et al. 2002), which is relevant to the problem of predicting which traps will be most effective in similar sampling situations.

From the model with the lowest DIC for each year, we calculated several derived parameters. We compared the observed number of captures to that predicted from the null model (using the posterior predictive distribution for each habitat × site combination; without random effects in year two) 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 each year and examined the 95% credible interval of each ratio to see if it contained one. Posterior distributions that did not contain one were considered evidence for statistical differences in capture rates between trap types. Finally, we described the range of snout-vent lengths of individual snakes captured in each trap type in year two to examine evidence for bias in size distributions sampled by each trap type.

We used standard Markov-chain Monte Carlo (MCMC) techniques to obtain posterior inference from the models. We ran each model on five chains of 100,000 iterations each, after a burn-in period of 10,000 iterations. We thinned each chain by a factor of five, and based posterior inference on the remaining 100,000 iterations. We examined history plots and calculated the Gelman-Rubin statistic (Gelman and Rubin 1992) to examine convergence. No evidence for lack of convergence was observed for any model (all R-hat < 1.06). We conducted the analysis using OpenBUGS 3.2.2 (Lunn et al. 2009) called through R 2.15.1 (R Core Team 2012) using the package R2OpenBUGS (Sturtz et al. 2005). Unless otherwise indicated, all results are presented as posterior mean (95% credible interval).

RESULTS

In year one, we captured 50 individual Giant Gartersnakes 71 times (48 in canals, 23 in wetlands) at Gilsizer Slough. One individual was captured eight times in four different trap types; no other individuals were captured more than three times. There was little support for an interaction between trap modification and habitat type and the best model (by DIC) included a three-way interaction, which indicated that all modifications affected each other's effectiveness (Table

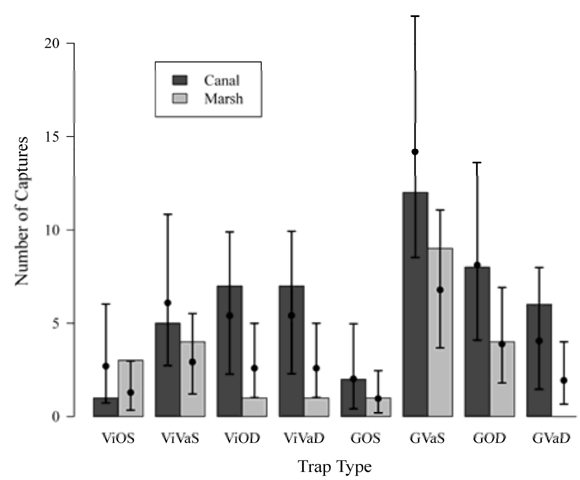

FIGURE 4. Observed number of Giant Gartersnake (*Thamnophis gigas*) captures (bars) in year one in each trap type in canals and marshes at Gilsizer Slough, California, 2011. Black dots and error bars represent the mean (95% credible interval) expected number of captures for each trap type based upon the best supported model.

TABLE 3. 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 for each year. Ratios above the diagonal are for 2011 (Deep modification); ratios below the diagonal are for 2012 (Extension modification). Ratios in *italics* are statistically different from one.

	Numerator Trap Type 2011							
Numerator Trap Type 2012	ViOS	ViOD/E	ViVaS	ViVaD/E	GOS	GOD/E	GVaS	GVaD/E
ViOS		2.66	2.99	2.67	0.99	*4.00*	*6.99*	2.00
ViOD/E	*2.38*		1.00	1.14	0.43	1.72	*3.00*	0.86
ViVaS	1.44	0.58		1.00	0.38	1.50	*2.62*	0.75
ViVaD/E	*3.43*	1.44	*2.38*		0.43	1.71	*2.99*	0.86
GOS	*1.62*	0.71	1.18	*0.52*		*6.03*	*10.51*	3.01
GOD/E	*3.86*	*1.62*	*2.80*	1.18	*2.38*		1.91	0.55
GVaS	*2.33*	1.02	*1.62*	0.71	1.44	0.58		*0.30*
GVaD/E	*5.55*	*2.33*	*3.86*	*1.62*	*3.43*	1.44	*2.38*	

2). Unmodified vinyl traps in canals had fewer captures than expected under the null model of no difference in capture rates among traps (Fig. 4). Galvanized traps with valves in wetlands had more captures than expected under the null model (Fig. 4). Based upon the best supported model, galvanized traps with valves performed statistically better than all other traps except galvanized deep traps (Table 3; Fig. 4). Similarly, galvanized deep traps performed statistically better than vinyl and galvanized traps on the surface (Table 3; Fig. 4). Galvanized traps with valves were 6.99 (2.08–20.03) times more effective than unmodified vinyl traps (Table 3).

In year two, 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. Five individuals were captured five or more times; in each of these cases, the individual was trapped in at least four different trap types. As in year one, interactions of trap modifications with habitat type were not strongly supported, and the model selected as best by DIC was the main effects model, indicating that the effects of trap modifications were independent of one another and therefore additive (Table 4). At Gilsizer Slough, vinyl traps with valves and unmodified galvanized traps in canals had fewer captures than expected under the null model of no difference in capture rates among traps (Fig. 5). Galvanized traps with extensions (both with and without valves) in canals had more captures than expected under the null model at Gilsizer Slough (Fig. 5). At Colusa NWR, unmodified vinyl traps in wetlands had fewer captures than expected under the null model of no difference in capture rates among traps (Fig. 5). Based upon the best supported model, galvanized traps with extensions and valves performed statistically better than all other traps except galvanized traps with extensions (Table 3; Fig. 5). Galvanized traps with extensions also performed statistically better than all other traps except galvanized traps with extensions and valves, vinyl traps with valves, and unmodified galvanized traps (Table 3; Fig. 5). Galvanized traps with extensions and valves were 5.55 (2.45–10.51) times more effective than unmodified vinyl traps (Table 3). Captured individuals in year two ranged in size from 228–924 mm snout-vent length (SVL), with small and large individuals captured in every combination of trap modifications except unmodified galvanized traps and galvanized traps with valves (Table 5).

DISCUSSION

In general, the three trap modifications we tested were effective at increasing capture rates of the Giant Gartersnake, though interactions among modifications make broad generalizations difficult in year one. In most

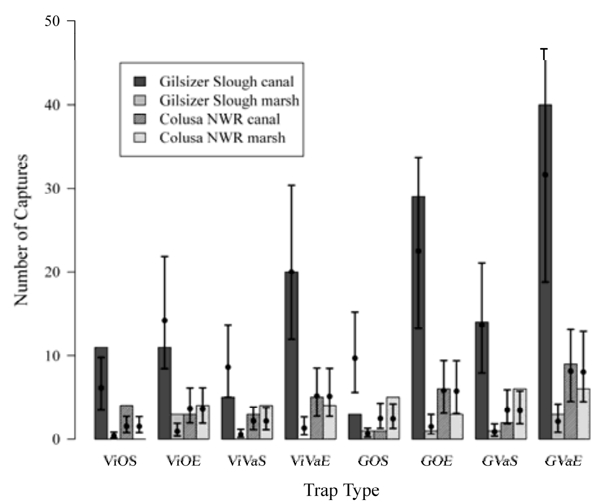

FIGURE 5. Observed number of Giant Gartersnake (*Thamnophis gigas*) captures (bars) in year two in each trap type in canals and marshes at Gilsizer Slough and Colusa National Wildlife Refuge, California, 2012. Black dots and error bars represent the mean (95% credible interval) expected number of captures for each trap type based upon the best supported model.

TABLE 4. Measures of model fit for capture rates of the Giant Gartersnake (*Thamnophis gigas*) in year two at Gilsizer Slough and Colusa National Wildlife Refuge, California, 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.

Model	Bayesian p-value	pD[a]	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

[a] pD is a measure of the effective number of parameters.

cases, one-way valves, floating traps deeper in the water column, and funnel extensions increased capture rates, regardless of habitat type. In addition to these modifications, galvanized hardware cloth traps outperformed vinyl-coated steel traps. The best-performing traps in each year resulted in a five-and-a-half to seven-fold increase in capture rates relative to unmodified vinyl traps. These results should translate directly into increased detection and capture probabilities for the Giant Gartersnake.

Although we targeted two processes, entry rates and escape rates, in our consideration of trap modifications, the mechanisms leading to some of our results were not entirely clear. We suspect that galvanized traps were more effective than vinyl traps because they present less visual obstruction to the Giant Gartersnake. This should positively affect capture rates by decreasing trap avoidance and reducing the visual cue presented by the trap opening, which is likely a visually bright spot from inside the trap, especially when it is at the surface. The galvanized traps therefore likely increased capture rates by both increasing the likelihood of trap entry and decreasing the likelihood of trap escape.

We hypothesize that floating traps deeper in the water column likely reduced escape rates of captured individuals. The reduction in escape rates could have been caused by two mechanisms. One is a reduction in the visual cue to the funnel opening discussed above. The other mechanism by which deep traps likely decreased escape rates was because of Giant Gartersnake behavior. Although Giant Gartersnakes readily dive to escape predators, they also frequently swim along the water's surface. By floating traps so that the small opening of the funnel is below the surface of the water, the likelihood of chance encounter with the trap opening is probably reduced. Alternatively, the Giant Gartersnake might be better sampled deeper in the water column, as observed for some aquatic salamanders (Schalk et al. 2010).

TABLE 5. Minimum and maximum snout-vent lengths (SVL) of Giant Gartersnakes (*Thamnophis gigas*) captured in each combination of trap modifications at Gilsizer Slough and Colusa National Wildlife Refuge, California, 2012.

Trap modification	Minimum SVL (mm)	Maximum SVL (mm)
ViOS	332	918
ViOE	332	920
ViVaS	332	920
ViVaE	228	923
GOS	505	875
GOE	314	924
GVaS	310	835
GVaE	323	924

Similar to floating traps deeper in the water column, the cable tie one-way valves were intended to reduce escape rates. Indeed, we were inspired to try the valves by the description and diagram of "inward projecting prongs" in Fitch (2001). The valves, when applied to traps at the surface in year one, resulted in the greatest increase in capture rates by a single modification. These results were similar to those observed for the Brown Treesnake (*Boiga irregularis*), for which striking a balance between snakes entering a visually obstructed entrance and preventing escape of snakes that have entered the trap proved crucial (Rodda et al. 1992, 1999). The reduction in escape rates was apparently greater than any potential reduction in entry probability when traps were floated at the surface. The reduced capture rates observed for deep traps with valves was unexpected. We suspect that the likelihood of entry into these traps was reduced because of behavioral avoidance by snakes. It is possible that the survival cost of becoming entrapped underwater has selected for greater avoidance of pushing through objects offering resistance underwater than at the surface in the Giant Gartersnake, but no data exist to substantiate this hypothesis. The reduced effectiveness of the valves on deep traps, which was exaggerated for galvanized traps relative to vinyl traps, was likely a major factor supporting the three-way interaction model in year one.

The addition of hardware cloth funnel extensions in year two was intended to increase the rate of entry of individuals into traps by increasing the effective area sampled by each trap and allowing the wide funnel opening greater proximity to shorelines and edges of emergent vegetation along which Giant Gartersnakes frequently travel. When modifications were considered individually in year two, traps with funnel extensions exhibited the greatest increase in capture rates for both trap materials, a result consistent with increasing the rate of entry of snakes into the traps. Because the effects on capture rates of trap modifications in year two were all positive and independent of each other, traps with all modifications performed better than any single modification. Thus, galvanized traps with extensions and valves (floated at the surface) performed best and are therefore recommended for demographic studies of the Giant Gartersnake.

Conclusions about the demography of populations are sensitive to biases inherent in the sampling method used (Winne 2005; Willson et al. 2009). All of the combinations of trap modifications we evaluated captured snakes of similar sizes, and therefore are likely unbiased relative to one another with regard to snake size. Only one individual less than 300 mm SVL was captured, and we suspect that none of the traps evaluated is efficient for capturing neonate Giant Gartersnakes, which are born at approximately 210 mm SVL (Hansen and Hansen 1990; Halstead et al. 2011a). The largest individual captured measured 924 mm SVL, though several individuals only a few mm shorter were also captured. Individuals of these lengths likely represent all but the very largest snakes in these populations; the largest individual captured at all study sites during the two study years was a 945 mm SVL female captured by hand, but the next five largest individuals (SVL = 918 – 924 mm) were all captured in traps. Despite the lack of overall size bias in our study, samples of shorter duration could be temporally biased by environmental conditions and differences in behavior (particularly foraging) among different segments of the population (Winne 2005). These biases are irrelevant to the conclusions in this study, because all trap modifications were deployed in equal numbers at the same time. Further, modern mark-recapture models (Chao and Huggins 2005; Royle 2009) provide methods to both test and account for heterogeneity caused by these temporal and individual covariates.

Although we tested our modifications using the Giant Gartersnake, we suspect that these modifications will be equally successful for other aquatic snake species. The Giant Gartersnake was our target species, and is the only aquatic snake found at our study sites. Nonetheless, we captured five Valley Gartersnakes (*Thamnophis sirtalis fitchi*; one each in unmodified galvanized traps and galvanized traps with valves (both deep and shallow), and two in shallow vinyl traps with valves) in year one, and 101 in year two. Valley Gartersnake captures in year two were distributed approximately in the same proportions as Giant Gartersnake captures, with galvanized traps with extensions and valves yielding the most captures (28) and galvanized traps with extensions only yielding the second-most captures (21). We therefore expect that the trap modifications found successful for the Giant Gartersnake will be successful for other aquatic species, particularly those that swim on the water's surface.

The trap modifications we used were relatively simple to employ. Attaching the cable ties to the small end of the funnel openings is somewhat labor-intensive, but the resulting valves lasted > 1 y and required only occasional minor adjustments in the field. Attaching the hardware cloth funnel extensions was likewise somewhat labor-intensive, but this modification was highly effective when deployed. We typically transport the traps by inverting the funnel part of the trap into the cylindrical trap body; this was not possible with the funnel extensions in place. We therefore suggest that this modification is best used when sampling a single location for an extended period of time rather than for studies that involve a short sampling duration or frequent trap movement. Nonetheless, the gain in sampling efficiency might still make this a cost-effective option for these sampling situations as well.

Increasing detection and capture probabilities is an important step in examining the distribution and demography of many species of reptiles and amphibians. Greater detection probabilities will increase the efficiency of occupancy surveys (Kéry 2002; MacKenzie et al. 2002; MacKenzie and Royle 2005; Halstead et al. 2011b), which will increase the precision of estimates of the probability of occurrence and allow for more complex models and improved ability to detect the effects of variables that influence species distributions. Alternatively, increases in the efficiency of sampling could be used to decrease the number of repeat samples (days of sampling in the case of the Giant Gartersnake) while maintaining the current level of precision. Similarly, increased capture probabilities will allow increased precision of estimates of abundance, survival, and recruitment, and might be required to estimate these parameters for secretive species like snakes (Thompson et al. 2004; Dorcas and Willson 2009). Improved information about the distribution, abundance, and survival of herpetofauna will ultimately result in more effective conservation and management for these species.

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