2011 Final Report

Assessing Texas Freshwater Turtle Populations:

Project status and results from selected studies

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Texas parks and Wildlife Department

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Executive Summary

This represents the report for the fourth and final year of the project. The project lost funding in Year 3 and we were able to maintain a fourth year of funding using residuals and the gracious contributions from TPWD enabling the completion of an orderly shut down of the research. We have been able to publish a group of papers in peer reviewed journals from the research completed in the years of the project thus far. We also have such manuscripts now in review from work completed during year four.

We have demonstrated that the current regulations for commercial turtle harvest are not likely to be sustainable (Brown et al, 2011). We consider that contribution to the literature to represent the single best conclusion from the entirety of the research conducted for this project. It was published in the top wildlife management journal and provides the best summary of our work, outcomes, and management interpretation under the original questions we sought to address. The second benefit would have come from accurate overall population abundance comparisons across our study sites statewide. Unfortunately we were not able to achieve 20% recapture rates at any of the study sites in the shortened grant period. We did come close in a few years at a few locations but estimates of statewide abundance will now await either future funding or the continuing volunteer efforts of the collaborators over time.

This report contains the reporting for our work during the final year of the project and represents direct contributions to confirming that our methods 1) are robust to detection, 2) enable year after year trapping efforts without compromising the detection values, 3) our low overall captures for softshell turtles are unlikely to be simply consequent of trapping method, and finally 4) interpond dynamics for turtles (source sink dynamics) meet criteria that increases the probability of impacts consequent of non-sustainable harvest dynamics at a given geographic location.

We will continue to assemble the data from all years and will continue to update TPWD with the manuscripts as they are completed and published. One of the three projects from 2011 is now in review (See Mali et al. (in review) below). Others will require additional work prior to successful publication. As an example we will retrap in the spring of 2012 during class field trips in order to contribute the data necessary for publication of the softshell lentic escape/capture probability paper (this report pages 13-17). Two other contributions, interpond movement dynamics and average harvest as a percentage of total turtles in a given pond are underway but will require at least another year of data prior to submission. We intend to find the funds necessary to enable that work to continue to completion and submission. This continues our successful publishing of the work completed thus far. We consider each to represent a chapter in the final report for this project and include each as PDFs supplementing this report. The contributions to the peer-reviewed literature from this project from the Texas State University group thus far, are:

Brown, D. J., A.D. Schultz, J.R. Dixon, B.E. Dickerson, and M.R.J. Forstner. (**submitted April 25, 2011, accepted pending revisions Sept 30, 2011**). Freshwater turtle decline in the Lower Rio Grande Valley of Texas. Chelonian Conservation and Biology

Brown, D., I. Mali, and M.R.J. Forstner. 2011. No difference in short-term temporal distribution of trapping effort on hoop net capture efficiency for freshwater turtles. Southeastern Naturalist 10(2):245-250.

Brown, D.J., B. Devolld, and M.R.J. Forstner. 2011. Escapes from hoop nets by Red-eared sliders (*Trachemys scripta elegans*). Southwestern Naturalist 56(1):124-127.

Brown, D.J., V.R. Farallo, J.R. Dixon, J.T. Baccus, T.R. Simpson, M.R.J. Forstner. 2011. Freshwater turtle conservation in Texas: Lingering harvest effects and efficacy of the current management regime. JWM 75(3):486-494.

Brown, D._and M.R.J. Forstner. 2009. A safe and efficient technique for handling of *Siren spp.* and *Amphiuma spp.* in the field. Herpetological Review 40(2):169-170.

Dickerson, B. E., A.D. Schultz, D.J. Brown, B. DeVolld, M.R.J. Forstner, and J.R. Dixon. 2009. Geographic Distribution (Hidalgo County). *Chelydra serpentina serpentina*. Herpetological Review 40(4):448.

Brown, D., J.R. Dixon_and M.R.J. Forstner. 2008. Geographic distribution. *Graptemys pseudogeographica kohni*. Herpetological Review 39(4):481.

Manuscripts now in review:

Mali, Ivana, D.J. Brown, M.C. Jones, and M.R.J. Forstner. (**submitted Aug 4, 2011**). Is switching bait an effective way to improve capture and recapture success for freshwater turtles. Southeastern Naturalist.

Copies of these papers are provided in Appendix 1: Outcomes from the Texas turtle assessment.

2011 Research outcomes: PART I

IS SWITCHING BAIT AN EFFECTIVE WAY TO IMPROVE CAPTURE AND RECAPTURE SUCCESS FOR FRESHWATER TURTLES?

INTRODUCTION

Capture-recapture sampling is one of the most widely used techniques for monitoring demographic components of wildlife populations (Nichols, 1992). A major assumption of this method is that all individuals in a population at the time of sampling have the same probability of capture (Carothers 1979, Koper and Brooks 1998). Post-capture changes in animal behavior can bias demographic estimates (Carothers 1979, Feldhamer and Maycroft 1992, Nichols et al. 1984). These behavioral changes are commonly referred as "trap happy" responses (i.e., probability of recapture increases relative to probability of initial capture [Chao et al. 2004, Deforce et al. 2004]) and "trap shy" responses (i.e., probability of recapture decreases relative to probability of initial capture [Brocke 1972, Carothers 1979]).

In addition to potential biases introduced through post-capture behavioral changes, sampling tools can inherently select for certain segments or individuals in a population. For instance, the two most common sampling tools for freshwater turtles are hoop nets and basking traps (Koper and Brooks 1998, Ream and Ream 1966), and hoop nets have been shown to be inherently male-biased (Ream and Ream 1966). Despite this, hoop nets are probably the most commonly used sampling method for freshwater turtles (Davis 1982, Lagler 1943, Thomas et al. 2008). Hoop nets are typically baited, with baits seeking to cater to species-specific preferences (Ernst 1965, Jensen 1998, Thomas et al. 2008). Bait is usually placed in closed containers with numerous holes to allow scent dispersal while eliminating potential for bait consumption (Lagler 1943, Nall and Thomas 2009).

We are aware of four studies that examined the efficiency of different bait types used for hoop net sampling of freshwater turtles (Ernst 1965, Jensen 1998, Thomas et al. 2008, Voorhees et al. 1991). Ernst (1965) found that turtles were most attracted to sardines among six types of bait. Voorhees et al. (1991) used seventeen different types of bait and found that bait with jelly-like fluid (fresh mussel, canned creamed corn, and canned sardines) was the most successful in capturing nine species of freshwater turtles. Jensen (1998) found different bait preferences between *Macroclemys temminckii* (Alligator snapping turtle) and *Trachemys scripta elegans* (Red-eared slider), with Alligator snapping turtles preferring fresh fish and Red-eared sliders preferring fresh chicken entrails. Thomas et al. (2008) found that freshwater turtles prefer frozen fish and canned mackerel over creamed corn In addition, Deforce et al. (2004) noted a "trap happy" behavior of *Phrynops gibbus* (Gibba turtle) towards hoop nets baited with chicken meat.

As a part of freshwater turtle assemblage in Texas, we have surveyed freshwater turtles annually in the Lower Rio Grande Valley (LRGV) of Texas since 2008 and in the Lost Pines ecoregion of Texas since 2009. Based on annual captures and recaptures per unit effort (CPUE and RPUE, respectively) and by knowing that harvest in these sites did not occur for the past 5 years, it appears that freshwater turtles in these study areas develop a trap shy response to baited hoop nets. This hypothesis is supported by a diminishing number of new captures each year, coupled with consistently low recapture rates (Fig. 1). Unfortunately, allowing for long periods of time between re-sampling (ca. 1 year) has not mitigated this perceived trap aversion. Since turtles are attracted by the bait placed inside the hoop nets, it is a possible they develop negative olfactory response to the bait, and thus become trap shy. If this is the case, long-term studies that utilize hoop nets could underestimate population sizes and make false conclusions about population trends.

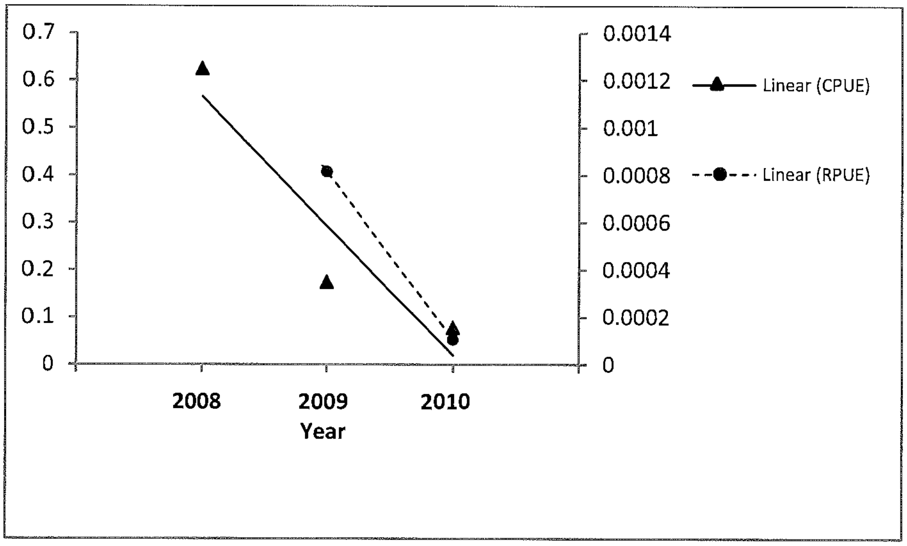

Figure 1. Mean capture per unit effort (CPUE; left axis) and recapture per unit effort (RPUE; right axis) of *Trachemys scripta elegans* at ponds in the Lower Rio Grande Valley (LRGV) of Texas that have been trapped annually since 2008 ($n = 4$). The substantial annual decrease in CPUE suggests that individuals captured in previous years become "trap shy". The decline in RPUE provides further evidence, as we would expect RPUE to increase as more individuals in the population become marked.

For the fourth year of assessing freshwater turtle populations in Texas, we tried to overcome decreasing capture and recapture rates by switching the bait from sardines to red meat. We switched the type of bait used to investigate the possibility that perceived trap shy behavior was due to a negative olfactory response to the bait used during the initial capture (i.e., previous years). We also investigated the possibility that bait preference may be individual-specific, rather than species-specific.

STUDY SITE

We conducted this study using 15 ponds that were surveyed for multiple consecutive years as part of a statewide assessment of freshwater turtle populations in Texas. Eleven ponds were located in the LRGV in south Texas and contained Red-eared sliders and *Apalone spinifera emoryi* (Texas spiny softshell). Four ponds were located in the Lost Pines ecoregion in central Texas and contained Red-eared sliders and *Chelydra serpentina* (Common snapping turtle).

Additional information on the study areas can be found in Brown et al. (2011a,b,c).

METHODS

Of the 15 ponds used in this investigation, we trapped six annually since 2008, excluding two that were not trapped in 2010, seven since 2009, and two since 2010. We trapped all ponds during the summer months when the turtles were likely to be most active (Thomas et al. 1999). We used 76.2 cm diameter single-opening, single-throated, widemouth hoop nets with a 2.54 cm mesh size and four hoops per net (Memphis Net & Twine Co., Memphis, Tennessee). We extended the nets using two wooden posts placed lateral to the trap mouth and connected to the first and last hoop. We attempted to keep the locations within ponds and total area trapped consistent among years.

Between 2008 and 2010 we used exclusively fish-based bait (primarily canned sardines), and in 2011 we used exclusively red meat from beef brisket. In all years we replaced the bait every two days. Annual trapping intensity varied among years and among sites, depending on study goals in a given year (see Brown et al. 2011a, b). In 2011 we completed 40 days at each site except one, where we completed only 20 trap days due to a lack of trap security. Although we acknowledge that annual differences in trap days could bias our CPUE comparisons, in a previous study we found that CPUE in these study areas was comparable if more than 10 trap days were completed (Brown et al. 2011b), which was also the case for all sites and years in this study.

We measured and marked all captured turtles. We measured carapace length and width, plastron length and width, and body depth to the nearest 1.0 mm using tree calipers (Haglof, Madison, Mississippi). We weighed captures to the nearest 10 g using spring scales (Pesola, Baar, Switzerland). We individually marked hardshell turtles using the numbering system of

Cagle (1939) and a portable rotary tool (Dremel, Racine, Wisconsin). We marked softshell turtles by engraving individual numbers on the posterior end of the carapace using the same rotary tool. We determined sex using secondary sexual characteristics (Gibbons and Lovich 1990, Conant and Collins 1998).

We used paired randomization tests with 10,000 iterations to test for effects of bait-switching. The p-values in these tests represent the proportion of trials resulting in capture differences as great or greater than those obtained (Sokal and Rholf 1995). Thus, a small p-value means that it is unlikely our results were obtained by random chance given the inherent distribution of the data. For each species we determined if CPUE differed between 2011 and the first year the pond was trapped, and analyzed only those sites that corresponded with their geographic distribution (clarify the ending clause of this sentence). Thus, all 15 sites were included in the analysis for Red-eared sliders, 11 sites were included for Texas spiny softshells, and four sites were included for Common snapping turtles. We used this analysis to draw inferences concerning species-specific bait preferences.

For Red-eared sliders, we also determined if CPUE differed between 2011 and the last year the site was trapped prior to 2011. For this analysis we excluded two sites that were initially trapped in 2010. We used this analysis to determine if switching bait was an effective way to increase CPUE in long-term studies. Finally, we determined if Red-eared slider RPUE differed between 2011 and the last year the site was trapped. We used this analysis to determine if switching bait was an effective way to increase RPUE (i.e., mitigate the hypothesized negative olfactory response causing trap shy behavior). For this analysis we excluded the two sites that were initially trapped in 2010, as well as one site that was first trapped in 2009 because no red-eared sliders were captured preventing a calculation of RPUE. We did not conduct the final two analyses for Texas spiny softshells or Common snapping turtles due to reduced site numbers and low recapture rates (Table 1). We inferred statistical significance at $\alpha = 0.05$. However, because of the relatively small sample sizes we considered $\alpha = 0.1$ to indicate a result that was trending on significance, and thus potentially biologically meaningful. We conducted statistical analyses using program R 2.7.2 (The R Foundation for Statistical Computing, Vienna, Austria). We calculated CPUE and RPUE using the following formulas; note that RPUE explicitly accounted for differences in number of marked individuals at the beginning of each year:

CPUE = (# OF CAPTURES) / (# OF TRAP DAYS)

RPUE = (((# OF RECAPTURES) / (# OF MARKED INDIVIDUALS FROM PREVIOUS YEARS))) / (# OF TRAP DAYS)

RESULTS

Red-eared sliders

Mean CPUE was 0.19 in 2011 and 0.28 the first year each site was trapped. Although mean CPUE decreased, the difference between the two years was not significant ($P = 0.12$); Table 1.). However, we found that CPUE increased relative to the previous year each site was trapped (mean = 0.09; $P < 0.001$). Mean RPUE was 0.0016 in 2011 and 0.0015 the previous year each site was trapped; this difference was not significant ($P = 0.44$).

Texas spiny softshell and Common snapping turtles

For Texas spiny softshells, mean CPUE was 0.04 in 2011 and 0.01 the first year each site was trapped; this increase was trending on significance ($P = 0.07$). For Common snapping turtles, mean CPUE was 0.03 in 2011 and 0.06 the first year each site was trapped; this decrease was trending on significance ($P = 0.09$).

Table 1. Capture per unit effort (CPUE) and recapture per unit effort (RPUE) for three species of freshwater turtles (*Trachemys scripta elegans, Apalone spinifera emoryi*, and *Chelydra serpentina*) trapped in the Lower Rio Grande Valley (LRGV) and Lost Pines ecoregion of Texas between 2008 and 2011.

Site no.	*Trachemys scripta elegans* CPUE RPUE				*Apalone spinifera emoryi* CPUE RPUE				*Chelydra serpentina* CPUE RPUE			
LRGV	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
1	0.218 NA[1]	0.0656 0.00005	0.0615 0	0.25 0	0.081 Na[2]	0.0328 0	0.025 0	0.05 0	X	X	X	X
2	NA	0.72 na	0.225 0.00035	0.175 0.00047	NA	0.02 na	0.1 0	0.2 0	X	X	X	X
3	1.44 na	0.46 0.00056	0.15 0.00022	0.25 0.00036	0 na	0 0	0 0	0 0	X	X	X	X
4	0.45 na	0.12 0.00222	0.025 0	0.375 0.00625	0 na	0.06 0	0.025 0	0 0	X	X	X	X
5	NA	0.16 na	0.0625 0.00156	0.1 0	NA	0 na	0 0	0 0	X	X	X	X
6	0.036 na	0.005 0	NA	0.2 0	0 na	0 0	NA	0 0	X	X	X	X
7	0.391 na	0.054 0	0.075 0.0002	0.2 0	0.0226 na	0.005 0	0 0	0.025 0	X	X	X	X
8	0.055 na	0.226 0	NA	0.475 0.00204	0 na	0 0	NA	0 0	X	X	X	X
9	NA	0.28 na	0.2 0	0.35 0	NA	0 na	0.0375 0	0.15 0	X	X	X	X
10	NA	0.154 na	0.0375 0	0.3 0.00192	NA	0 na	0.0125 0	0 0	X	X	X	X
11	NA	NA	0.125 na	0 0	NA	NA	0.0375 na	0 0	X	X	X	X
Lost Pines Ecoregion	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
12	NA	0 na	0.0375 na	0.025 0	X	X	X	X	NA	0.024 na	0 0	0.025 0
13	NA	NA	0.05 na	0.075	X	X	X	X	NA	NA	0.0375 na	0 0
14	NA	0.114 na	0.0375 0.00031	0 0	X	X	X	X	NA	0.029 na	0 0	0 0
15	NA	0.02 na	0.0375 0.0125	0.075 0.00833	X	X	X	X	NA	0.143 na	0.0125 0	0.075 0.1

[1]NA- the site was not trapped
[2]na- RPUE could not be calculated

DISUSSION

The results of this study indicate that switching bait can be an effective way to maintain high capture-rates in long-term freshwater turtle investigations using baited hoop nets. Interestingly, based on our analyses it appears that bait preferences within the species ("individual-specific" bait preferences) can influence captures. Thus, maintaining baiting consistency when using CPUE as a metric for comparing relative abundance differences among sites could be important. In terms of species-level responses, we did not find significant preferences for any of the species. However, we must take into consideration that it appears trap shy behavior is occurring, and if so the analyses comparing CPUE in 2011 to the first year the site was trapped would be biased in favor of fish-based bait. In this context, we believe there is weak evidence that Texas spiny softshells prefer red meat over fish, and this topic deserves further study.

A major motivation for conducting this study was to determine if we could increase recapture success by switching bait (i.e., to test out negative olfactory response hypothesis). Our approach failed as we did not detect a significant increase in RPUE in 2011. Moreover, among 12 study sites we tested, we detected an increase in RPUE at only five ponds (Table 1.). Since the project started in 2008, we marked over 800 red-eared sliders and over 200 softshell turtles in the LRGV. Over the years we accumulated only 44 red-eared sliders recaptures (13 recaptures in 2011 alone) and no softshell recaptures. This leaves turtle dynamics in these sites in question. Switching the bait did not appear efficient way to increase number of recaptures, and thus it could be that most turtles in our study areas develop a negative visual association with the hoop nets. If so, switching the type of trap used could increase RPUE. We intend to continue trapping these sites using different types of traps (i.e. basking traps) and test this hypothesis in the future.

In conclusion, the integration of capture-recapture methodology to freshwater turtle sampling using baited hoop nets, an incentive-based sampling method, remains challenging in our study areas. Unfortunately, it is only possible to census ponds (i.e. obtain N) if they are pumped dry and turtles are noodled from the mud over a series of days, which in most situations is both unattractive and unrealistic. Previous investigators have suggested that the optimal way to maximize CPUE and RPUE is to use multiple sampling tools (Koper and Brooks 1998, Ream and Ream 1966). Unfortunately, different sampling tools have different inherent biases associated with them, and thus using a combination of sampling tools could introduce additional uncertainty in capture-recapture estimates.

2011 Research outcomes: PART II

HOOP NET ESCAPES AND INFLUENCE OF SEEDED TRAPS ON TEXAS SOFTSHELL TURTLE (*APALONE SPINIFERA EMORYI*) CAPTURES

INTRODUCTION

Because of difficulties to conduct census for most wildlife populations, choosing an appropriate sampling method is crucial when monitoring population structure and dynamics (Witmer, 2005). For passive sampling techniques, increasing trap efficiency and decreasing biases is important way to increase precision of population size estimates (Gamble, 2006; Witmer, 2005). In the case of freshwater turtle populations, numerous trapping methods have been developed, such as basking traps, fyke nets, trammels, hoop nets etc (Ream and Ream, 1966, Gamble, 2006). The best evidence of obtaining population size would be combining these methods (Koper and Brooks, 1998; Ream and Ream, 1966). However, because of time, money, and personal constraints, using combination of different methods is often difficult to achieve. Therefore, hoop nets remain one of the commonly used devices for trapping aquatic turtles since they are easy to manage and do not require intensive labor (Largler, 1943, Conant and Collins, 1998; Thomas et al., 2008).

However, several authors observed and reported escapes from hoop nets (Fraizer, 1990, Koper and Brooks, 1997; Gamble, 2006). For example, Frazer (1990) reported 80% of painted turtles and 25% of snapping turtles escaped from the nets within 24 hour periods which show that different species have different escape rates. In addition, studies show that males are more likely to be captured by hoop nets (Ream and Ream, 1996; Gamble, 2006; Fraizer, 1990). As an explanation, some authors hypothesized that turtles are not only attracted by the traditional bait placed in the trap, but also by the other turtles present in the trap (Cagle and Chaney, 1950; Fraizer, 1990; Ream and Ream, 1966). However, if the species present in the trap is hazardous to others, it will prevent them from entering the traps (Cagle and Chaney, 1950). Still, no specific statistical analysis has been conducted addressing this possibility of attraction. Escapes from the traps and skewed sex ratios toward males can be important source of bias when estimating population size and structure in freshwater turtles. Possible explanations can be summarized as followed: 1.Populations of turtles are male biased, 2. Turtles in the trap will attract the others, 3. Females in the trap will attract more males, 4. Females are more likely to escape from the traps (Fraizer, 1990; Cagle and Chaney, 1950).

The purpose of this experiment was first to determine if sex or body size influence Texas spiny softshell turtle (*Apalone spinifera emoryi*) escapes, and second, to test if "seeded" traps-traps with turtles purposefully placed in the traps attract more turtles of the same or different species as well as the same or opposite sex within the same species.

STUDY SITE AND METHODS

The study was done at Big Bend National Park (BBNP) in 2010 and Black Gap Wildlife Management Area (BGWMA) in 2011, both located in Brewster County, Texas. We trapped and seeded turtles along the Rio Grande River that is abundant in Texas spiny softshells and Big Bend sliders (*Trachemys gaigeae*) (Conant and Collins, 1998). We followed Brown et al. (2009) study for choosing the appropriate hoop nets. All the traps were single throated, widemouth, with 76.2 cm diameter single opening. We spread traps along the shore lines at one site in BBNP and two sites at BGWMA. The distance between the traps was between 5 and 10m apart, depending on available vegetation to which we tied the traps to, and all the traps were set with the entrance downstream (Lagler, 1943). 40 traps were placed in the Rio Grande River on June 4th 2010 and remained there until June 8th 2010 (160 trap days). Initial 40 traps days were not included in analysis because there were no seeded turtles. 40 traps were placed at each of the 2 locations in the Rio Grande River on June 14th 2011. 9 traps were added to one of the locations on June 18th and all 49 traps were pulled the following day. The rest of the traps (40) were pulled on June 20th (449 trap days). Initial 80 trap days were not included in the analysis because they contained no seeded turtles. Traps were baited with canned sardines and placed in non-consumable containers containing holes for scent dispersal (Brown et al, 2009; Gamble, 2006); bait was replaced every 2 days. In 2011, we added fresh fruit to the traps on the first day in hopes of catching Big Bend River Cooters (*Pseudemys gorzugi*). For all captured turtles we recorded carapace length and width, plastron length and width, and body depth to the nearest 1.0mm using tree calipers (Haglof, Madison, Mississippi), and determined the weight to the nearest 10g using spring scales (Pesola, Baar, Switzerland). Sex was determined by using secondary characteristics with pre-cloacal portion of the tail lying beyond the edge of the carapace in males and before or at the edge of the carapace in females (Berry and Shine, 1980). Softshells were marked by engraving individual numbers on the posterior end of the carapace while Big Bend sliders were marked by notching marginal scutes on the carapace using a rotator tool (Dremel, Racine, Wisconsin). Only softshells were used for seeding at random. There were no more than one turtle seeded per trap and each turtle was used only one time. There were 1-24 seeded traps per day; therefore, not all traps were seeded at all times. Every 24 hours we recorded escapes from seeded traps as well as new captures in seeded and unseeded traps.

We used logistic regression to test if escape was sex or size biased and randomization of two sample t-tests to test if seeded traps attracted more turtles than unseeded traps (Brown et al., 2009). Body depth was used as a measurement of body size (Brown et al., 2009).

RESULTS

In both years we caught Texas spiny sofshells and Big Bend sliders but no Big Bend river cooters. During both trapping season we caught lesser number of turtles in the river than expected (Table 2). We seeded 41 turtles in 2010 and 29 turtles in 2011 of various size and sex. Out of 70 seeded turtles (43 males, 26 females, and one juvenile), eight escaped (~11%). Logistic regression showed that neither body depth nor sex was related to escapes (p= 0.11 and 0.63 respectively). Even when we ran the logistic regression separately for each parameter, body depth or sex was not related to escapes (p= 0.14 and 0.89 respectively). However, out of 8 turtles that escaped, 6 were male (75% of all escapes), one was a female and one was a juvenile. Statistically insignificant results might be due to a small sample size, and we seek to trap the river next season in order to get sufficient sample size that will enable us to publish our results. Randomization test showed that seeded traps did not attract more turtles of Texas spiny softshell and Big Bend slider pooled together (p= 0.91). When testing only intraspecific attraction to seeded traps there were no differences in captures of softshells in seeded versus unseeded traps (p= 0.54).

Table 2. Trapping effort and number of captures in the Rio Grande River during 2010 trapping season at Big Bend National Park (BBNP) and during 2011 trapping season at Black Gap Wildlife Management Area (BGWMA)

Site	Trap days	*Apalone spinifera emoryi*	*Trachemys scripta gaigeae*	*Trachemys scripta elegans* (and hybrids)
BBNP	160	42	15	0
BGWMA	499	30	23	8

DISCUSSION

The escape rate of Texas spiny softshells was lesser than the escape rates in painted turtles and snapping turtles. Also, our study showed different trends than the similar study on red-eared sliders where sex was related to escapes while body size was not (Brown at el., 2009). In addition, majority of the escapes in Brown at al. (2009) study were females while in our study they were males.

Our study does not support hypothesis that turtles are attracted to hoop nets because of the presence of other turtles in the traps. There were no differences in captures in seeded vs. unseeded traps for softshells. However, overall captures of softshells were skewed toward males: out of 70 captures, 43 were males, 26 were females, and for one turtle we were unable to determine sex and classified it as a juvenile. This suggests that hoop nets might be male biased as previously reported. Furthermore, six out of eight escapes were males, opposing hypothesis that females are more likely to escape from the nets. However, we focused on Texas spiny softshell turtles and when compared with the study on red-eared sliders (Brown et al., 2009), we can conclude that escapes could be species specific. This study can be useful in any future studies of softshell population estimates that use hoop nets.

2011 Research outcomes: PART III

INTERPOND TURTLE DYNAMICS

Movement of freshwater turtles across the landscape has been well documented (i.e. Rowe, 2003; Browne et al., 2006; Joyal et al., 2001; Roe and Georges, 2007 etc.); therefore, we can consider them highly vagile taxa. It is hypothesized that turtles conduct such movements to different habitats for several reasons: search for mates, better resources, due to drought conditions, etc. (Doody et al, 2002; Parker, 1984; Tuberville et al., 1996; Browne et al., 2006 etc.). However, the exact patterns of turtle overland movements are still poorly understood as the results of previous studies are not consistent and often times are contradictory (Thomas et al., 1999; Carter et al., 2000; Litzgus and Mousseau, 2004). In the case of freshwater turtles in Texas, overland movements/migrations are crucial for populations' sustainability.

Under current regime in Texas, freshwater turtles are protected from commercial harvest in public but not private water bodies. This regime operates under a major assumption that such protection of public waters should buffer the remaining regions against overexploitation (McCullough 1996). That means that emigration from non-harvested private and public waters acts to replenish harvested ponds and keep the populations sustainable. Thus, all harvest is drawn from private water and the public waters act as source populations for impending commercial harvests. Therefore, understanding proximate cues for overland movement of freshwater turtles is essential in establishing managerial recommendations. In other words, to be able to criticize advantages or disadvantages of this regime we must understand turtle interpond dynamics. Unfortunately, monitoring overland movement on our long term study sites in the LRGV is impossible to achieve. Therefore, we intend to investigate spatial and temporal turtle movement in enclosed pond system across a small landscape. With this long term monitoring of interpond movement, we aim to understand:

1. How is sex and size correlated with movement patterns?
2. Under which environmental and seasonal circumstances turtles are most likely to move?

Another reason for establishing the enclosed pond system is to directly test the source-sink theory. The invasion of freshwater turtles has been documented in previous studies (Tuberville et al., 1996), but none of them addressed the issue in the light of harvest. Our goal is to assess how long it takes to repopulate harvested water body, if such an event even occurs. Monitoring our experimental system will help us understand if the current management regime in Texas is accurate, and does the current regime need to be improved.

PROJECT OUTLINE

Study Site

This set of studies is being conducted in a complex of ponds within a private property parcel in Guadalupe County, Texas. The site contains 3 ponds completely fenced off where turtle immigration/emigration is prevented- closed system (Figure 2). In addition, one of the ponds is fully exclosed and has "gate" built into the fencing which facilitates turtle movement between Exclosure Pond and the other two ponds. The second exclosure contains two ponds, called the Lake and House Pond which are not fenced separately. In no-drought conditions, the Exclosure and House Pond have perimeters 96 and 87 meters long respectively. The Lake is unique because in a sense represents 2 ponds that are connected by the 5m wide and 45m long canal. During the drought, the canal dries splitting the Lake into two separate ponds. Due to severe 2011 drought, not only the canal dried, but we also pumped the water from the right side of the Lake to its left side and to the House Pond. The Exclosure Pond was pumped dry in 2009 as a part of the harvest intensity study (see 2009 report). As the study was done, the pond water was replaced and a single turtle placed in it with the turtle gate remaining closed to confirm that the pond perimeter fencing was "turtle-proof".

Study Design

In the spring of 2011, we populated Exclosure Pond with PIT (Passive Integrated Transponders) tagged turtles we trapped in the Lake and House Pond as well as turtles trapped from the ponds on the private property in Blanco County, Texas. We finished populating the Exclosure Pond on June 4th, 2011; ending up with 63 PIT tagged turtles and 1 male untagged red-eared slider (*Trachemys scripta elegans*) (representing the original single male stocked to test the fencing in 2009. Out of 64 turtles in Pond 1, two are softshells (*Apalone spinifera guadalupiensis*), four are Texas river cooters (*Pseudemys texana*) and the rest (58) are red-eared sliders. Out of 58 red-eared sliders, 29 are females, 25 are males, and 4 are juvenile, and since they present the most abundant species in the pond, their movement will be our focus. We allowed ~a month long "cool down" period before opening the turtle gate in order to prevent any movement simply due to turtle displacement into the new environment. We opened the gate on July 14th, 2011.

The movement of turtles in and out of the Exclosure is monitored in 2 different ways: ISO-2001 (Biomark©) chip reader and RECONYX© game camera (Figure). The reader antenna is placed just below the surface at the turtle gate, and the reader is connected to the power supply at all times reading the chip numbers and the date and time turtles cross the gate. Stored data can be downloaded on a computer at any time. The game camera is placed just above the gate capturing the photographs of not only marked individuals but also any non-chipped individuals in the Lake and House Pond that we did not catch. This detection array provides an opportunity to know at all times what the number of adults in the Exclosure is from day to day, and to evaluate the parameters affecting movement into and out of the pond.

Our first goal is to monitor the interpond turtle movement for at least a year. This will give us the information about seasonal movement patterns as well as demographic (sex and size) movement patterns. Then, we want to simulate the harvest of adult individuals in the Exclosure by trapping the pond using traditional hoop nets (as harvest of freshwater turtles is usually done). The reason behind the harvest is first to calculate the percentage of adult turtles taken out of the population by such event- harvest, or demonstrate harvest intensity within a known system. Second, in a potentially more important reason, to continue monitoring the interpond movement after that harvest in order to observe how quickly the pond affected by the harvest can be recovered/repopulated to sustainable levels. If such an event even occurs, we seek to find out how long of a "cool down" period is needed before the pond can be harvested again. Although our study is done in a completely enclosed system and it cannot exactly mimic the dynamics of wildlife turtle populations or the landscape dynamics, this is the only way to precisely test the source-sink theory because the enclosed system enables us to know the number of adults in the Exclosure at all times. This project is unique in many ways. Although some previously published studies on interpond turtle movement were able to encounter seasonality patters, the studies were usually unable to establish the time of the day turtles moved. On the other hand, we are able to monitor the time of the day turtles move, every day, regardless of the time or conditions. Also, we are not aware of any published study that examined turtle dynamics in the light of harvest. The results of these studies can be used when writing policies and making managerial decisions in order to protect freshwater turtles from overharvest.

With this experimental design, there is much more that can be investigated. In our original project outline, we are focusing only on the adults since this age class is usually the target of harvest. However, it is also possible to account for the recruitment and growth rates as well as density dependence the populations might show. Very few studies explored density-dependence of freshwater turtles (Fordham et al., 2009), and the harvest of game animals is usually based on this key characteristic of wildlife populations. Although, the four year assessment of freshwater turtle populations in Texas under Texas Parks and Wildlife Department is now over we aim continue to study turtle population as we describe in this chapter.

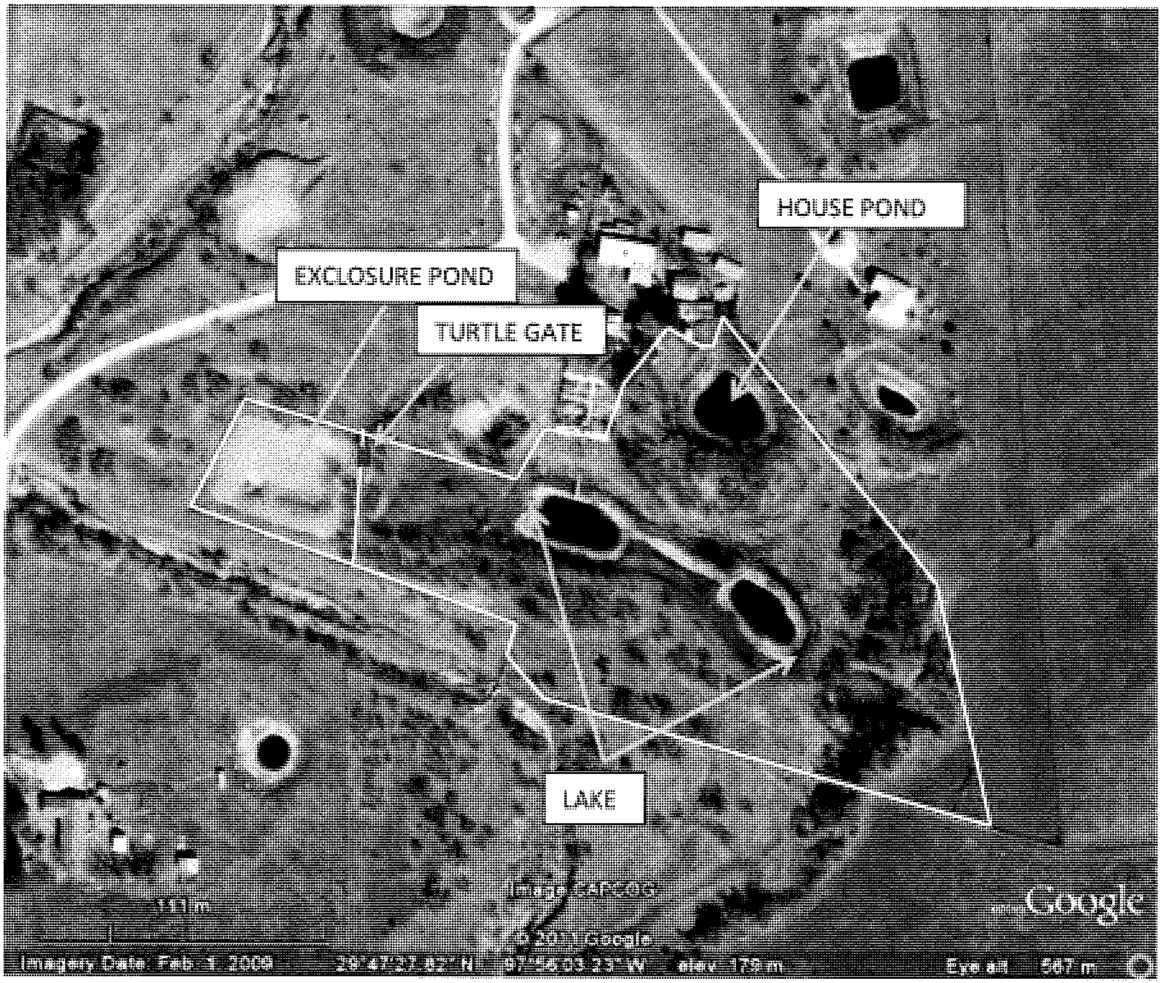

Figure 2. Aerial view of the exclosed pond system showing 3 fenced off ponds with one of them being fully exclosed (Exclosure Pond) with the "gate" built into the fencing which facilitates turtle movement

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APPENDIX 1:

Outcomes from the Texas turtle assessment

Freshwater Turtle Decline in the Lower Rio Grande Valley of Texas

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ABSTRACT. – In 2009 we repeated a freshwater turtle survey conducted in 1976 in the Lower Rio Grande Valley (LRGV) of Texas. We sought to evaluate the outcomes of increased urbanization and land-use changes in the LRGV over the past 30 years have on regional turtle populations. The 24 original trapping locations were relocated and when possible re-trapped with equal trapping effort using baited hoop nets. We captured significantly fewer red-eared sliders (*Trachemys scripta elegans*) and Texas spiny softshells (*Apalone spinifera emoryi*) in 2 recently urbanized counties (Cameron and Hidalgo), and more red-eared sliders and Texas spiny softshells in a non-urbanized county (Willacy). Increased urbanization, land-use changes, and commercial turtle harvest are likely responsible for the decline of freshwater turtles in the LRGV.

KEY WORDS. – freshwater turtles; Lower Rio Grande Valley, red-eared slider (*Trachemys scripta elegans*), Texas, Texas spiny softshell (*Apalone spinifera emoryi*), urbanization

Typical consequences of urbanization include an increase in density of humans and substantial land modification (Kline et al. 2001; Henderson 2003; Siren 2007). Consequently, urbanization often negatively impacts wildlife populations (Czech 2000; Dietz and Adger 2003; Morgan and Cushman 2005). The influence of humans on the health and persistence of wildlife populations depends on how human-induced habitat changes affect the natural history of the species, and whether the species is directly useful to humans (e.g., harvest for consumption). Habitat changes due to urbanization typically negatively affect biodiversity, but can benefit individual species (Hansen et al. 2005).

Many freshwater turtles are declining in human-dominated landscapes (Gibbons et al. 2000). They require water to survive, and water is often highly regulated and manipulated (Levine 2007), sometimes with lethal consequences to turtles (Hall and Cuthbert 2000). However, introduced water bodies (e.g., golf course and sewage treatment ponds) can provide valuable habitat for turtles in urbanized environments (Germano 2010; Rose 2011). Freshwater turtles are arguably the most vulnerable vertebrate taxa to road mortality (Gibbs and Shriver 2002; Aresco 2005), and are negatively impacted by the increase in mesopredators that accompanies urbanization (Boarman 1997; Prange et al. 2003). In addition, wild freshwater turtles are collected for human consumption and the pet trade, both of which have global markets (Warwick et al. 1990; Ceballos and Fitzgerald 2004).

Historically, economic health in the Lower Rio Grande Valley (LRGV) of Texas was driven by agricultural production (Lopez 2006). Over the past 3 decades, particularly since the enactment of the North American Free Trade Agreement (NAFTA) in the 1990s, intense human population growth and associated urbanization has occurred in Cameron and Hidalgo counties.

The human population in Cameron County increased from 189,400 (57 people/km^2) in 1976 to 387,717 (117 people/km^2) in 2006 (United States Census Bureau 1982, 2007). The human population in Hidalgo County increased from 249,000 (61 people/km^2) in 1976 to 700,634 (171 people/km^2) in 2006. Based on population density, land transformation, accessibility, and electrical power infrastructure as a combined measure of the human footprint, the city of Brownsville in Cameron County now has the largest human footprint on earth (Sanderson et al. 2002). In contrast, Willacy County, which borders both Cameron and Hidalgo counties, remains a low human density, agriculture-dominated, county.

Despite the substantial land use changes in Cameron and Hidalgo counties, these counties are also rich in public and private parks, preserves, and refuges. The LRGV is one of the premier spots for bird watching in the world, and houses the only verified endangered ocelot (*Leopardus pardalis*) population in the United States (Jackson et al. 2005). These wildlife "sanctuaries" could serve to maintain robust freshwater turtle populations within what has become a heavily human modified urban landscape.

In this study we sought to determine if land use changes over the past three decades have influenced the abundance of freshwater turtles in the LRGV. To our knowledge only one previous study exists as a reference for past freshwater turtle abundances in the LRGV, which was conducted in 1976 (Grosmaire 1977). Therefore, this study was by necessity a comparison between two "snapshots" in time, and our sampling design was inherently limited to sites surveyed in 1976. However, in addition to surveying the 2 recently urbanized counties (Cameron and Hidalgo), Grosmaire (1977) also surveyed Willacy County, providing a useful internal control for the study, and potentially enabling inferences of urbanization effects.

METHODS

Sampling Methods. — Grosmaire (1977) trapped 3, 3, and 18 sites in Cameron, Hidalgo, and Willacy counties, respectively. We trapped all of the Cameron County and Hidalgo County sites, and 10 of the Willacy County sites (Fig. 1). The remaining 8 sites in Willacy County were not available in 2009, being either dry or non-existent (i.e., ponds had been filled). The sites consisted of federal and state protected areas ($n = 3$), public and private ponds ($n = 5$), and public flowing waters (i.e., rivers and canals; $n = 8$). Grosmaire (1977) trapped turtles using 76.2 cm diameter double-throated steel hoop nets baited with canned fish, fresh fish, or beef scraps. We trapped turtles using 76.2 cm diameter single-throated fiberglass hoop nets baited with canned fish, fresh fish, or shrimp. Because one of the authors (JRD) supervised the 1976 trapping, we were able to repeat the original trap placement method. We placed traps along pond, canal, and river borders, securing traps to reeds or other vegetation. We placed traps equidistant to one another when possible, with distances between traps ranging from 2 m to 6 m. Traps were checked daily in both studies.

The total trapping effort in 1976 for the 18 re-trapped sites was 1065 trap days, with trapping conducted between 21 May and 15 November (primarily in June and July). The total trapping effort for this study in 2009 was also 1065 trap days, with trapping effort among the sites matching the 1976 trapping. In 2009 we trapped between 18 May and 28 September (primarily in May and June). Data collected in both studies included species, sex, carapace length and width, plastron length and width, body depth, and weight. In both studies sex was determined using secondary sexual characteristics (Gibbons and Lovich 1990, Conant and Collins 1998). Hard-shelled turtles were individually marked in both studies using carapace notches (Cagle 1939). Soft-shelled turtles were individually marked in 1976 using metal fish tags, and in 2009 using a portable rotary tool.

Statistical Analyses. — We used paired randomization tests with 10,000 iterations to determine if number of red-eared slider (*Trachemys scripta elegans*) and Texas spiny softshell (*Apalone spinifera emoryi*) captures differed between 1976 and 2009 in Cameron and Hidalgo counties (i.e., the urbanized counties), and Willacy County (i.e., the non-urbanized control county). We used total number of unique captures at each site as the sampling unit. The p-values obtained were the proportion of trials resulting in a difference between years as great or greater than the one obtained in this study (Sokal and Rohlf 1995). We inferred significance at $\alpha = 0.05$. We performed statistical analyses using R version 2.10.1 (The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Grosmaire (1977) captured 292 red-eared sliders and 26 Texas spiny softshells in Cameron and Hidalgo counties in 1976 (Table 1). We captured 5 red-eared sliders and 5 Texas spiny softshells in Cameron and Hidalgo counties in 2009. Grosmaire (1977) captured 19 red-eared sliders and 11 Texas spiny softshells in Willacy County in 1976, whereas we captured 62 red-eared sliders and 27 Texas spiny softshells at these sites in 2009. We captured significantly fewer red-eared sliders ($p = 0.009$) and Texas spiny softshells ($p = 0.034$) in Cameron and Hidalgo counties, and significantly more red-eared sliders ($p = 0.008$) in Willacy County. We did not detect a difference in number of Texas spiny softshells captured in Willacy County ($p = 0.094$).

DISCUSSION

We captured fewer red-eared sliders and Texas spiny softshells in Cameron and Hidalgo counties compared to 1976, supporting our contention of the negative effects of urbanization on these species. In contrast, we captured more red-eared sliders and Texas spiny softshells in Willacy County, reinforcing that our results are likely related to urbanization effects. However, 3 of the sites in Cameron and Hidalgo counties were federal and state protected areas, and turtle captures were substantially lower in all of them (see Table 1). It is likely that the decline in freshwater turtles at these protected sites is due to land-use changes, with current habitat management actions focused on enhancing waterfowl and shorebird foraging habitat (United States Fish and Wildlife Service 1997). This draw-down management approach includes periodic draining of wetlands and extended periods with low water levels, which results in low annual habitat suitability for these freshwater turtle species (Ernst and Lovich 2009).

The United States Fish and Wildlife Service, Texas Parks and Wildlife Department, and communities in the LRGV recently partnered to create the World Birding Center, which includes 9 official sites and dozens of unofficial sites in the LRGV promoted as being exceptional for bird watching. Despite the physical protection of these sites from development, and the presence of open water at the majority of the sites, these sanctuaries are not managed for freshwater turtles and most do not appear to house robust populations. As part of a larger study investigating freshwater turtle harvest effects in the LRGV, we sampled many of these sanctuaries (Brown et al. 2011). Only 3 of 13 sampled sanctuaries appeared to house robust freshwater turtle populations (i.e., Southmost Preserve, Edinburg Scenic Wetlands, and a fish hatchery operated by Texas Parks and Wildlife Department). The water at these 3 sites was deeper than most of the other sanctuaries (1 to 1.5 m), and thus was likely more suitable for freshwater turtles.

Urbanization will continue to increase in the LRGV, with the human populations in Cameron and Hidalgo counties projected to grow by 36.9% and 44.2%, respectively, over the next 30 years (Rio Grande Regional Water Planning Group 2001). The 59.7% increase in urban land-use in Hidalgo County between 1993 and 2003 resulted in a 19.3% reduction in surface water (Huang and Fipps 2006), and this trend will certainly continue as water is redirected for urban use. Thus, to prevent further declines of freshwater turtles from much of Cameron and Hidalgo counties in the near future it is imperative that the public and private parks, preserves, and refuges seek a habitat management strategy that balances the needs of freshwater turtles with those of waterfowl and shorebirds. Draw-down management is problematic because it forces entire populations of turtles to temporarily disperse from water bodies. This undoubtedly increases the probability that a population will be negatively impacted by prominent urbanization effects such as road mortality (Aresco 2005), mesopredator predation (Boarman 1997), and human collecting (Ceballos and Fitzgerald 2004). Thus, the optimum solution would probably be persistent spatial segregation of aquatic habitats for birds and turtles.

In recent years significant commercial freshwater turtle harvest has occurred in the LRGV (Ceballos and Fitzgerald 2004), and we detected probable harvest impacts in this region (Brown et al. 2011). Therefore, we cannot discount the potential impact of commercial turtle harvest on the non-protected sites (i.e., direct take) or protected sites (i.e., potential source-sink interactions with harvested sites) in this study. In addition, 2007 and 2008 were intense drought years in the LRGV, which also may have influenced turtle movement patterns, and thus our survey results in 2009. However, we maintain that the contrast between the results from Cameron and Hidalgo counties drawn from protected sites and those from Willacy County drawn from non-protected (in terms of legal harvest regulations; Texas Parks and Wildlife Department

2007) sites are likely better explained by effects of urbanization and habitat management changes since 1976.

We are currently facing worldwide declines of reptiles and amphibians (Wake, 1991; Gibbons et al., 2000). Although long-term monitoring programs are optimal for detecting and responding to species declines (Sherman and Morton, 1993; Daszak et al., 2005), in the absence of these data periodic "snapshot" surveys can be a valuable species conservation tool (e.g., Foster et al., 2009). However, historic surveys often lack crucial information necessary for repetition, particularly agency reports and theses. For instance, Grosmaire (1977) reported turtle captures but did not report trapping effort. We were able to replicate the study only because one of the authors (JRD) retained the original data files. Thus, we emphasize the importance of reporting effort in survey-based studies, regardless of whether or not the results are intended for publication.

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Table 1. Number of freshwater turtles captured at 16 sites in the Lower Rio Grande Valley (LRGV) of Texas in the summer and fall of 1976 and 2009.

Sampling Location	County	Trap days	Red-eared sliders		Texas spiny softshells	
			1976	2009	1976	2009
McCloud Hood Reservoir	Cameron	5	0	1	0	0
Laguna Atascosa NWR[a]	Cameron	280	16	0	5	0
Arroyo Colorado river	Cameron	5	0	1	0	5
Irrigation canal	Hidalgo	5	0	0	0	0
Bentsen-Rio Grande SP[b]	Hidalgo	120	19	0	6	0
Santa Ana NWR	Hidalgo	480	257	3	15	0
Irrigation canal	Willacy	20	9	1	0	0
Cattle pond	Willacy	10	0	11	1	0
Cattle pond	Willacy	20	8	17	0	0
Irrigation canal	Willacy	5	0	10	0	0
Retention pond	Willacy	10	1	16	0	2
Irrigation canal	Willacy	5	0	0	0	0
Irrigation canal	Willacy	70	0	7	10	12
Irrigation canal	Willacy	5	0	0	0	11
Cattle pond	Willacy	20	1	0	0	0
Arroyo Colorado river	Willacy	5	0	0	0	2

[a] NWR = National Wildlife Refuge

[b] SP = State Park

Figure 1. Locations of freshwater turtle sampling sites in 3 counties in the Lower Rio Grande Valley (LRGV) or Texas. Sites were trapped using baited hoop nets in the summer and fall of 1976 and 2009 to determine if freshwater turtles have been impacted by urbanization and land-use changes in Cameron and Hidalgo counties.

No Difference in Short-term Temporal Distribution of Trapping Effort on Hoop-net Capture Efficiency for Freshwater Turtles

Donald J. Brown[1,*], Ivana Mali[1], and Michael R.J. Forstner[1]

Abstract We investigated the influence of trapping duration on freshwater turtle captures using baited hoop-nets. We trapped 9 ponds in the Lower Rio Grande Valley and 6 ponds in the Lost Pines ecoregion areas of Texas in the summer of 2010 using high-intensity, short-duration trapping (40 traps/1 day) and low-intensity, longer-duration trapping (10 traps/4 days). We found that the number of captures was not different between sampling schemes. However, the mean capture rate was twice as high after the first day of low-intensity trapping. This study showed that researchers seeking to maximize captures per-unit-effort (CPUE) should focus on the least time-intensive, labor-intensive, and expensive way to complete the trapping effort, rather than short-term temporal distribution of trapping effort.

Introduction

Estimation of demographic components (e.g., population size and survivorship) is fundamental to many population-monitoring programs (Buckland et al. 2000, Campbell et al. 2002). Capture-recapture methods are widely used and are often the most accurate means for estimating demographic components (Amstrup et al. 2005). These methods rely on capturing and marking individuals, and then recapturing the individuals during later sampling periods. Because of time, money, and personnel constraints, researchers often seek to maximize capture efficiency (Gamble 2006) through determining when, where, and how to best sample a population to optimize captures per-unit-effort (CPUE), while minimizing biases that skew estimates (Thompson 2004).

Many techniques have been developed for sampling aquatic turtle populations (Lagler 1943, Vogt 1980). Hoop-nets remain one of the most common turtle-trapping devices used today (Davis 1982, Thomas et al. 2008). They are logistically superior to most other passive trapping devices (i.e., basking traps, fyke nets, and trammels) because they are lightweight, easily portable in large numbers, require only one worker, and provide easily quantifiable results. Several factors can influence hoop-net capture rates and affect sex- and size-specific capture probabilities, including trap size, trap placement, and type of bait (Cagle and Chaney 1950, Thomas et al. 2008). In addition, capture rates may change with trapping effort and duration.

The purpose of this study was to investigate the influence of trapping duration on turtle capture rates using baited hoop-nets. It is usually less expensive

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and time-consuming to conduct high-intensity trapping for short periods of time, as opposed to low-intensity trapping for longer time periods. However, this may result in fewer captures from a given population if highly variable abiotic conditions (e.g., temperature or precipitation) affect activity patterns and thus captures (Cagle 1950, Crawford et al. 1983), if the water body is large and turtles utilize different areas on different days (Bodie and Semlitsch 2000, Brown and Brooks 1993), or if captures increase as turtles become accustomed to presence of the traps (Vogt 1980). Alternately, high-intensity trapping may increase captures by increasing the concentration of bait scent in the water, or both trapping schemes may produce comparable CPUE results.

Field-Site Description

We conducted this study in two ecoregions of Texas, the Lower Rio Grande Valley (LRGV), and the Lost Pines. We trapped freshwater ponds in Cameron, Hidalgo, and Willacy counties in the LRGV, and Bastrop County in the Lost Pines. Ponds in the LRGV were typically bordered by reeds, primarily *Typha* spp. (cattails) and *Arundo donax* L. (Giant Cane). Ponds in the Lost Pines were typically surrounded by *Pinus taeda* L. (Loblolly Pine), *Juniperus virginiana* L. (Eastern Red Cedar), and *Quercus stellata* Wangenh (Post Oak) trees. Pond area ranged from 0.08 ha to 8.2 ha (mean = 2.01 ha) across all sites.

Two freshwater turtle species are found in the LRGV that were not captured in this study, *Kinosternon flavescens* (Agassiz) (Yellow Mud Turtle) and *Chelydra serpentina* (L.) (Eastern Snapping Turtle). Based on our extensive freshwater turtle work in the LRGV since 2008, densities seem to be low for both species (Dickerson et al. 2009). In addition to turtles, we routinely captured *Nerodia rhombifer* (Hallowell) (Diamond-backed Watersnake) and *Siren intermedia texana* Goin (Rio Grande Lesser Siren) in LRGV ponds. Two of the LRGV ponds also contained *Alligator mississippiensis* (Daudin) (American Alligator) during this study.

Two freshwater turtle species are found in the Lost Pines that were not captured in this study, the Yellow Mud Turtle and *Pseudemys texana* Baur (Texas Cooter). We did not capture other aquatic reptile fauna in the Lost Pines during this study, but have observed large numbers of *Nerodia erythrogaster transversa* (Hallowell) (Blotched Watersnake) and several *Agkistrodon piscivorus leucostoma* (Troost) (Western Cottonmouth) at the same ponds during other investigations.

All ponds sampled contained fish populations. We captured *Lepomis megalotis* (Rafinesque) (Longear Sunfish) and *Ictalurus punctatus* (Rafinesque) (Channel Catfish) in hoop-nets in the Lost Pines. We did not specifically identify fish species in the LRGV captured during this project. We know that one pond had been previously stocked with *Micropterus salmoides* (Lacepède) (Largemouth Bass), and these were occasionally seen in traps. At several of the sites in the LRGV, we observed *Cichlasoma cyanoguttatum* (Baird and Girard) (Rio Grande Cichlid) alongside abundant introduced *Oreochromis aureus* (Steindachner) (Blue Tilapia), *Hypostomus* spp. (suckermouth catfish), and *Cyprinus carpio* L. (Common Carp) in past years. Among notable native fishes, we captured several *Awaous banana* (Valenciennes) (River Goby) at one of the LRGV sites in 2008 and 2009.

The majority of ponds were located on preserves or state parks. One pond in the LRGV was located on a private ranch stocked with cattle.

Methods

We trapped 9 and 6 ponds in the LRGV and Lost Pines, respectively. Trapping sites were chosen based on access and security from trap-theft. We conducted short-term, high-intensity trapping by placing 40 hoop-nets in each pond for 1 day (23–25 hours). We conducted longer-term, low-intensity trapping by placing 10 hoop-nets in each pond for 4 days (94–97 hours). Ponds were randomized for initial trap intensity, and were re-trapped with opposite intensity after a 33- to 55-day cool-down period. The goal of performing both sampling schemes at each pond was to mitigate the influence of inherent population-size differences on study results.

We spaced traps evenly along the edges of ponds, tying them to reeds or other vegetation at 5- to 15-m (40 traps/1day) or 20- to 60-m (10 traps/4 days) intervals. We marked individual trap locations with a portable GPS unit (Map60, Garmin Ltd., Olathe, KS) to ensure that the same area was trapped during the second trapping event at each site. We performed this study between 10 May and 13 July 2010.

We used 76.2-cm-diameter single-opening, single-throated, widemouth hoop-nets with a 2.54-cm mesh size and four hoops per net (Memphis Net and Twine County, Memphis, TN). Traps were kept taut using wooden posts connected to the first and last hoop. Two stretcher posts were used for each trap, located lateral to the mouth opening. We baited all traps with sardines in non-consumable containers containing holes for scent escape. Fresh bait was used for high-intensity trapping, and bait was refreshed every 2 days for low-intensity trapping. We placed flotation devices between the two middle hoops to prevent drowning and to keep traps parallel with the water's surface. We inspected traps for holes and damage daily.

We measured carapace length and width, plastron length and width, and body depth of captured individuals to the nearest 1.0 mm using tree calipers (Haglof, Madison, MS). Turtles were weighed to the nearest 10 g using spring scales (Pesola, Baar, Switzerland), and individually marked by notching the carapace using a rotary tool (Dremel, Racine, WI). We determined sex using secondary sexual characteristics (Conant and Collins 1998, Gibbons and Lovich 1990).

We used a paired randomization test with 10,000 iterations to determine if total number of captures differed by sampling-duration scheme (i.e., 40 traps/1 day or 10 traps/4 days), using pond as the sampling unit. The P-value obtained was the proportion of trials resulting in a capture difference between duration schemes as great or greater than the one obtained (Sokal and Rohlf 1995). We then re-performed the test using only *Trachemys scripta elegans* (Wied-Neuwied) (Red-eared Slider) captures, which represented 79.5% of total captures. We removed captures for individuals captured more than once within a sampling period ($n = 1$). We treated recaptures between sampling periods as new individuals ($n = 2$). We conducted the statistical analyses using R 2.7.2 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

We captured 65 turtles while conducting high-intensity trapping and 62 turtles conducting low-intensity trapping (Table 1). In the LRGV, we captured 78 Red-eared Sliders and 19 *Apalone spinifera emoryi* (Agassiz) (Texas Spiny Softshell). In the Lost Pines, we captured 23 Red-eared Sliders and 7 Eastern Snapping Turtles. Number of captures between the two trapping schemes was not different for the complete data set ($P = 0.437$), or when only Red-eared Sliders were included ($P = 0.429$). For low-intensity trapping, we obtained 50% of total captures on the first day of trapping, 14.5% on day 2, 22.6% on day 3, and 12.9% on the fourth day of trapping.

Discussion

We found that short-term high-intensity trapping yielded similar total captures to longer-term low-intensity trapping (Table 1). Therefore, at least for Red-eared Sliders, when the goal is to maximize CPUE, the least time-intensive, labor-intensive, and expensive way to complete the trapping effort should be primary considerations, rather than temporal distribution of trapping effort. This study also showed that total effort matters. We captured 52.3% more turtles in the 40 traps/1 day sampling scheme than in the first day of the 10 traps/4 days sampling scheme. However, from the perspective of capture-rates, 10 traps/1 day was more effective than 40 traps/1 day, with mean capture-rates of 0.21 and 0.11 turtles per trap day, respectively.

Table 1. Number and captures per-unit-effort (CPUE) of freshwater turtles captured in baited hoop nets using short-term, high-intensity trapping and longer-term, low-intensity trapping at 9 ponds in the Lower Rio Grande Valley (LRGV) and 6 ponds in the Lost Pines areas of Texas. Ponds were trapped with both sampling schemes to mitigate the influence of inherent population size differences on results.

Study area	40 traps/1day total	10 traps/4 days total	Day 1	Day 2	Day 3	Day 4
LRGV	0	6	0	1	4	1
LRGV	1	3	2	0	0	1
LRGV	6	6	0	1	3	2
LRGV	8	18	16	1	0	1
LRGV	2	3	1	1	1	0
LRGV	2	5	0	3	1	1
LRGV	1	3	2	0	1	0
LRGV	13	7	4	0	3	0
LRGV	13	0	0	0	0	0
Lost Pines	2	4	3	0	0	1
Lost Pines	6	1	1	0	0	0
Lost Pines	1	1	1	0	0	0
Lost Pines	3	4	1	2	0	1
Lost Pines	3	1	0	0	1	0
Lost Pines	4	0	0	0	0	0
Sum	65	62	31	9	14	8
CPUE	0.108	0.103	0.207	0.06	0.093	0.053

Besides maximizing CPUE, these results have important implications for study repetitions and long-term monitoring of freshwater turtle populations. First, it is probably more important to focus on repeating observations within the same general time-frame (e.g., season, month, or week) than to focus on equal temporal distribution of sampling effort. Activity patterns and captures have been shown to vary substantially by season (Brown and Brooks 1993, Ream and Ream 1966, Thomas et al. 1999). Secondly, capture rate might not be an appropriate metric for assessing change if total effort is not repeated. This topic warrants further study, as it is not always tenable to exactly repeat trapping effort every year in long-term monitoring programs. Based on this study, the mean capture rate was similar between sampling schemes when 50% of the effort was completed in the low-intensity trapping (mean capture rate = 0.13 turtles per trap day). Therefore, when using capture rate as a proxy for abundance differences, we recommend that trapping effort does not vary by more than 50% due to the risk of concluding artificial abundance differences among sites or years.

Finally, we found that capturing no turtles in one sampling period did not mean that the habitat wasn't suitable. For 3 of the ponds, we captured turtles in only 1 sampling period. In one of these ponds, a 5.3-ha oxbow lake in the LRGV, we captured no turtles during the 4-day low-intensity trapping event, but captured 13 during the high-intensity event. Given that this water body is located in a highly urbanized area, we speculate that most of the turtles were present in the pond during the low-intensity trapping, but were simply not near enough to the traps to be attracted by the scent. This result is contrary to our expectation that longer-term trapping would be a more efficient trapping scheme in larger water bodies, and may indicate a bait-scent-concentration effect. However, because we captured 42 turtles during both sampling schemes in the 6 largest ponds (1.5–8.2 ha), it is not apparent that increasing bait scent in larger water bodies attracts more turtles.

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Escapes from Hoop Nets by Red-Eared Sliders (*Trachemys scripta*)

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ESCAPES FROM HOOP NETS BY RED-EARED SLIDERS (*TRACHEMYS SCRIPTA*)

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Abstract—We investigated the influence of sex and depth of body on escapes from hoop nets by red-eared sliders (*Trachemys scripta*) to assess if escapes from traps potentially biased estimates of structure of populations. Turtles remained in traps ≥34 h and traps were checked at ca. 12-h intervals. Depth of body was not a significant variable in escapes from hoop nets, but sex was a significant variable, with only females escaping. This study provides evidence that previous reports on the inefficiency of hoop nets and on rates of captures that are male-biased could result from escapes rather than differential attraction to traps.

Resumen—Investigamos la influencia del sexo y profundidad del cuerpo en los escapes por las tortugas de orejas rojas (*Trachemys scripta*) de trampas de aros para evaluar si los escapes de trampas podrían sesgar las estimaciones de la estructura de poblaciones. Las tortugas permanecieron en trampas ≥34 horas, y fueron revisadas en intervalos de cerca a 12 horas. La profundidad del cuerpo no fue una variable significativa en escapes de las trampas, pero el sexo sí fue una variable significativa con sólo las hembras escapando. Este estudio proporciona evidencia de que los informes anteriores sobre la ineficiencia de trampas de aro y de las tasas de captura a favor de los machos podrían resultar de escapes en lugar de atracción desproporcional a las trampas.

Determining and monitoring structures of populations often are key components of research and management of wildlife (Campbell et al., 2002; Bolen and Robinson, 2003; Dinsmore and Johnson, 2005). Fully censusing populations typically is not feasible (Witmer, 2005); thus, sampling techniques are used to provide estimates of structure within or among populations (Buckland et al., 2000; Cooper et al., 2003; Lancia et al., 2005).

Many techniques have been developed for sampling populations of aquatic turtles (Lagler, 1943; Vogt, 1980). Hoop nets are among the most common turtle-trapping devices used today (Davis, 1982; Conant and Collins, 1998; Thomas et al., 2008), and they are superior to most other passive-trapping devices (i.e., basking traps, fyke nets, and trammels) because they are lightweight, easily portable in large numbers, require only one worker, and provide easily quantifiable results. Despite these advantages, previous research has demonstrated that hoop nets might lead to biased estimates (Ream and Ream, 1966; Frazer et al., 1990; Gamble, 2006). Hoop nets are baited to attract turtles, and thus, are an incentive-based method of capture. If the incentive favors one sex or age-class over another, estimates of demographic parameters could be inaccurate (Voorhees et al., 1991; Thomas et al., 2008). Further, captured individuals attract additional turtles (Ream and Ream, 1966; Frazer et al., 1990). This might lead to male-biased captures during mating seasons as males are attracted to females in traps (Cagle and Chaney, 1950).

The ability of turtles to escape traps is another potential source of bias. Hoop nets are designed to provide turtles with easy entrance and difficult exit, but do not prevent escape from the trap. Frazer et al. (1990) reported that 80% of painted turtles (*Chrysemys picta*) and 25% of snapping turtles (*Chelydra serpentina*) escaped hoop nets over a 24-h period, indicating that interspecific differences likely exist in rates of escape. Size, strength, and behavioral differences between sexes and among age-classes might influence intraspecific rates of escape. The purpose of our study was to determine if sex or depth of body influenced escapes of red-eared sliders (*Trachemys scripta*) from hoop nets.

We performed our experiment 16 May–1 July 2009 in an 8.2-ha oxbow lake at the Nature Conservancy of Texas Southmost Preserve (25°51′N, 97°23′W; near Brownsville, Texas). We used 76.2-cm diameter, single-opening, single-throated, widemouth hoop nets with 2.54-cm mesh and 4 hoops/net (Memphis Net and Twine Company, Memphis, Tennessee). Traps were kept taut using wooden posts connected to the first and last hoop. Two stretcher posts that were lateral to the opening were used for each trap. Because the type of hoop nets we used had wide ellipsoid openings (ca. 50 cm unstretched), depth of body (i.e., plastron to uppermost point on the carapace) was chosen as the relevant size parameter for testing the influence of size.

Height of openings of traps is a proxy for the area available for turtles to find the escape route. Because individual traps differed in height of opening, they also differed in potential for escape. To mitigate the influence of individual traps, we measured height of underwater, flaccid openings of 25 new hoop nets to the nearest 0.25 cm and chose traps between the 30th (1.27 cm) and 70th (2.03 cm) percentile of the height of openings to be used for this experiment. For the duration of the study, 14 hoop nets were individually numbered with metal tags and they were not moved. Distances between traps were 2–4 m. To simulate a realistic trapping environment, traps were baited with sardines in non-consumable containers with holes to allow escape of scent; bait was refreshed every 2 days. Flotation devices were placed between the two middle hoops to prevent drowning and to keep traps parallel with the surface of the water. By lifting each trap out of the water each day, we inspected traps for holes and damage. To mediate undetected bias due to inherent differences in traps, we replaced individual traps if more than one turtle escaped, which occurred one time during this study. Although turtles were not assigned randomly to traps, we typically assigned turtles by their individual number, resulting in essentially random placement.

We conducted this experiment using 139 red-eared sliders. Of the turtles, 54 were captured by dip nets or hoop nets in the oxbow lake at Southmost Preserve. The remaining turtles were either taken from nearby ponds and reservoirs ($n = 77$) or captured on roads ($n = 8$) in Cameron County, Texas. No turtle used in the study had been marked previously, and thus, we assumed that none had been captured previously. Length and width of carapace, length and width of plastron, and depth of body were measured to the nearest 1.0 mm using calipers (Haglof, Madison, Mississippi), weighed to the nearest 10 g using spring scales (Pesola, Baar, Switzerland), and individually marked by notching the carapace with a rotary tool (Dremel, Racine, Wisconsin). We determined sex using secondary sexual characteristics. Male red-eared sliders have elongated foreclaws and the pre-cloacal portion of the tail lies beyond the edge of the carapace

TABLE 1—Ratios of red-eared sliders (*Trachemys scripta*) that escaped and did not escape from hoop nets by depth of body and sex.

Depth of body (mm)	Males	Females	Juveniles[a]
<40	0:3	1:3	1:20
40–59	0:32	1:11	—
60–79	0:21	0:13	—
80–99	0:6	1:22	—
≥100	—	1:8	—

[a] Juveniles lacked secondary sexual characteristics.

(Gibbons and Lovich, 1990) and females have short foreclaws and the pre-cloacal portion of the tail terminates before or at the edge of the carapace. Turtles with a depth of body <40 mm, which corresponds to a length of carapace of ca. 100 mm, were considered to be juveniles. We were able to confidently determine sex of six juveniles with depths of body >31 mm by their longer foreclaws and lengthened and thickened tails.

To ensure representation among sizes of males and females, we classed turtles into nine categories by sex and depth of body. We released turtles in cohorts of 6–14 individuals, with 1 turtle placed in each trap. Thus, not all traps contained turtles during each release of cohorts. Traps were then checked ≥3 times/release of cohorts at ca. 12-h intervals. We chose this time frame to simulate the longest period a turtle could remain in a trap in a study using daily trap-checking. Checking traps every 12 h allowed us to determine if time spent in the trap influenced number of escapes. Turtles that did not escape were kept in traps ≥34 h. When we had not captured new turtles for the experiment, we left turtles that had not escaped in hoop nets for an additional ca. 12-h interval.

We used logistic-regression models to test for differences in number of escapes from hoop nets (Lindsey, 1995). The first model included depth of body as the predictor and escape from hoop nets as the binary response variable. The second model included both depth of body and sex as predictors, with juveniles of undetermined sex removed from the dataset. We used likelihood-ratio tests to determine if the predictors significantly changed the intercept-only model (i.e., deviance greater than chance alone). We did not formally test time spent in trap due to the low number of escapes. All statistical analyses were performed using R 2.8.1 (R Foundation for Statistical Computing, Vienna, Austria).

Five of 139 turtles (3.6%) escaped from hoop nets; four were female (7.0% of seeded females), one was a juvenile of undetermined sex, and none was male. Depth of body was not a significant variable in either the model with only depth of body (Deviance $\chi^2_{1,137} = 0.045$, $P = 0.832$) or the model with depth of body and sex (Deviance $\chi^2_{1,117} = 0.001$, $P = 0.976$). Sex was a significant variable (Deviance $\chi^2_{1,116} = 7.062$, $P = 0.008$; Table 1). Three individuals escaped within 13 h, and two within 12.5–27 h of being placed into a trap. No individual escaped after 27 h, despite 43 turtles remaining in traps for 45.5–50 h.

The overall rate of escape for red-eared sliders was lower than rates for either the painted turtle or snapping turtle as reported by Frazer et al. (1990). We used similar traps and bait, indicating that substantial interspecific differences exist. However, this could be due to differences in heights of flaccid openings of hoop nets between the two studies. It is likely that larger openings greatly increase the probability of escape. As Frazer et al. (1990) conducted their study in August, we cannot discount seasonality as a potential factor influencing rates of escape, but we are unaware of behaviors that would shift this rate dramatically from early to late summer. Interspecific differences in rates of escape and inherent differences in traps could explain why some researchers have concluded that hoop nets are inferior traps for capturing some species of turtles (Vogt, 1980; Gamble, 2006).

We detected no effect of depth of body on number of escapes. Therefore, at least for red-eared sliders, if biases related to size exist, they are likely a result of attraction to traps and not a consequence of turtles escaping. However, sex did influence escapes from hoop nets. It is unclear why females escaped and males did not, but the lack of a size-related effect indicates that neither size nor strength influences abilities to escape. It is possible that females simply move more in traps, and thus, have a higher probability of finding the opening. When we checked traps, juveniles and males usually were hanging onto the netting at the front of the trap below the throat, whereas locations of females were unpredictable. Differences in rates of escape between sexes could help explain why hoop nets are regarded as a male-biased method of capture (Ream and Ream, 1966). Vogt (1979) noted that for *C. picta,* traps containing males or females captured more turtles than traps without turtles, with no difference detected between sexes when additional captures of females were removed from the dataset.

This study provides evidence that previous reports on the inefficiency of hoop nets and on rates of captures that are male-biased could be, at least partially, a result of escapes rather than attraction. Further investigations should focus on taxa more prone to escapes, such as *C. picta.* It is possible that hoop nets are equally efficient or more efficient than basking traps if the investigator employs a rigorous trap-checking routine.

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Research Article

Freshwater Turtle Conservation in Texas: Harvest Effects and Efficacy of the Current Management Regime

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ABSTRACT The collapse of Asian turtle populations led to the creation of a worldwide freshwater turtle market in the 1990s. Texas is one of several states in the United States that has capitalized on this market. The Texas Parks and Wildlife Department (TPWD) recently instituted regulations designed to protect turtles from commercial harvest in public waters. Two counties in the Lower Rio Grande Valley (LRGV) accounted for 66.1% of known wild turtle harvest in 1999, with no reported harvest in subsequent years. We sampled 60 sites in the LRGV to determine if we could detect harvest effects. We also investigated the potential for sustainable harvest under the new harvest guidelines using source-sink dynamics implemented in a Geographic Information System (GIS) approach. We detected differences congruent with harvest effects for red-eared sliders (*Trachemys scripta*) and Texas spiny softshells (*Apalone spinifera*). Based on a GIS analysis of water bodies throughout the entire state, we estimated that only 2.2% of water bodies are protected under the current commercial harvest regulations. We determined source water bodies could supply 30.5% of sink water bodies in the LRGV, and we concluded that long-term sustainable turtle harvest is unlikely under the current management regime due to the intensity of commercial harvests, the low number of protected water bodies, and non-robust or non-interactive protected populations. One solution to this would be modification of the regulations to include season and bag limits, a management strategy currently implemented in various forms by 14 states in the eastern half of the United States.

KEY WORDS *Apalone* spp., commercial harvest, freshwater turtles, Geographic Information System (GIS), red-eared sliders, softshells, Texas, *Trachemys scripta*.

Despite being considered non-game animals by most wildlife management agencies, freshwater turtles have been harvested worldwide for centuries (Moll and Moll 2004). Freshwater turtles are currently harvested or procured for many purposes, including food, traditional Chinese medicine, turtle farms, pet trades, reptile expositions, zoos, and aquariums (Warwick et al. 1990, Fisher 2000, Gibbons et al. 2000, Ceballos and Fitzgerald 2004, Prestridge 2009). Turtle meat is considered a delicacy in many Asian countries, and excessive harvest for this market caused the collapse of Asian turtle populations and created a worldwide turtle market in the 1990s (Klemens 2000, Rhodin 2000, Guynup 2005). Texas is one of several states in the United States where entrepreneurs capitalized on this market (Ceballos and Fitzgerald 2004, Lowe 2009, Prestridge 2009).

At least 377,534 freshwater turtles were exported from Texas between 1995 and 2000, with the number of exports increasing annually (Ceballos and Fitzgerald 2004). During this period only 35,743 imports were reported, indicating Texas is a major supplier in the worldwide turtle market. Spiny softshells (*Apalone spinifera*) and red-eared sliders (*Trachemys scripta*) accounted for 87.9% of the take of the 16,110 wild-caught turtles reported in 1999 (Ceballos 2001). Furthermore, 69.9% of the take came from 3 counties in the Lower Rio Grande Valley (LRGV): Hidalgo (38.5%), Cameron (27.6%), and Willacy (3.8%). After 1999, regulation changes required only commercial dealers to file annual reports and allowed non-game collectors to sell their captures to dealers with commercial permits. This aggregative mechanism prevents determination of the geographically fine-scale harvest locations available for the 1999 season (Prestridge 2009). In fact, prior to 2007, the Texas Parks and Wildlife Department (TPWD) did not require commercial turtle harvesters to submit annual reports prior to permit renewal and consequently much of the take went unreported (J. Brennan, TPWD, personal communication). Commercial harvesters reported taking 46,879 red-eared sliders and softshells (*Apalone* spp.) from the wild between 2002 and 2007, with none taken from Hidalgo, Cameron, or

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Willacy counties. Based on TPWD harvest reports, commercial turtle harvesters apparently move from county to county annually, probably to maintain high capture-rates. Between 2003 and 2008, 40.2% of all amphibians and reptiles taken from the wild were red-eared sliders (Prestridge 2009).

Little information exists about the impacts of harvest and procurement on freshwater turtle populations. A higher catch-per-unit-effort was reported for painted turtles (*Chrysemys picta*) in non-harvested versus harvested lakes in Minnesota (Gamble and Simons 2004). Conversely, northern snake-necked turtles (*Chelodina rugosa*) in Australia responded to experimental population reduction with increased hatchling recruitment and survival (Fordham et al. 2009). Close and Seigel (1997) found harvested wetlands in Louisiana had significantly smaller male and female red-eared sliders. Because turtles are sold by weight for food markets, there is an incentive to harvest larger turtles.

Fisheries researchers have long been engaged in harvest impact studies, and this information can give insight into expected outcomes of intense turtle harvest, provided the taxa respond similarly to harvest. Selective harvesting has been responsible for population declines and alteration of population structures for several fish species. The use of selective gill nets caused a reduction in the mean length of European whitefish (*Coregonus lavaretus*) in the Gulf of Finland (Heikinheimo and Mikkola 2004). Long-term selective harvesting resulted in a decrease in size at maturity for North Sea plaice (*Pleuronecetes platessa*; Rijnsdorp 1993) and caused accelerated growth rates, a reduction in age at maturity, and a shorter life-span in Atlantic (Arctic-Norwegian) cod (*Gadus morhua*; Borisov 1978). Fordham et al. (2007) found a similar result with northern snake-necked turtles in Australia, confirming that reduced densities of large turtles resulted in accelerated growth rates and reduction in size at maturity.

In 2007, TPWD instituted regulations designed to protect non-game animals from over-harvesting (TPWD 2007). Under the new regulations, all freshwater turtles were protected from harvest on public lands and in public waters. However, the commercial take of the most commonly harvested turtle species remained unregulated on private property. These species included red-eared sliders, softshell turtles, and common snapping turtles (*Chelydra serpentina*). In 2008, TPWD began a 5-year investigation of freshwater turtle populations, involving several universities and agencies. The investigation was designed to provide useful information on population distributions, sizes, structures, and movements as a basis for future commercial harvest regulations.

The current regulations are based on a spatial harvest management model, where over-harvesting and subsequent population collapse in private waters is prevented by replenishment of turtles from public waters (i.e., source-sink). Public water includes all flowing waters and lakes, and all water bodies on state land (Texas Administrative Code §11.021). This harvest management regime has been used for decades by federal and state agencies for managing game species (e.g., National Wildlife Refuges [NWR] and Wildlife Management Areas) with variable but overall positive results (Burroughs 1946, Bellrose 1954, Halpern 2003).

Our objectives were 3-fold. 1) We sought to determine if intensive harvest in the LRGV of Texas produced detectable harvest effects, 2) we performed spatial analyses for the entire state using a Geographic Information System (GIS) to determine the level of protection gained under the current harvest restrictions, and 3) we investigated the potential for protected waters to serve as long-term source populations for harvestable (i.e., private) waters in the LRGV.

STUDY AREA

We conducted our study in Cameron (2,346 km^2), Hidalgo (4,066 km^2), and Willacy (1,545 km^2) counties in the LRGV (Fig. 1). Cameron and Hidalgo counties accounted for 66.1% of the reported wild turtle harvest in 1999, whereas Willacy County accounted for only 3.8% (Ceballos 2001). Agriculture dominated land use in the subtropical LRGV over the last century (Levine 2007). However, human population growth increased substantially over the last 3 decades, resulting in heavy urbanization in Cameron and Hidalgo counties (U.S. Census Bureau 1982, 2007). Between 1976 and 2006 the human populations in Cameron, Hidalgo, and Willacy counties increased by 205%, 281%, and 12%, respectively.

METHODS

Historical record information for harvested sites was minimal due to a lack of perceived harvest threat to turtle populations prior to 2007. Consequently, we were unable to obtain exact localities for turtle harvest in our study area. Therefore, we trapped turtles throughout 2 heavily harvested counties (Cameron and Hidalgo) and an adjacent low harvest county (Willacy) to investigate harvest impacts. In addition to heavy harvest, these counties offered us the opportunity to compare our data to a study conducted prior to commercial turtle harvest in the LRGV (Grosmaire 1977). We trapped turtles at sites within Cameron and Hidalgo counties likely harvested prior to the new regulations on turtle harvest, as well as sites unharvested in recent years (i.e., NWRs, state parks, and nature preserves). We did not randomly select water bodies because our ability to trap a given water body was contingent upon landowner, agency, city, or water district consent. Despite this constraint, we trapped qualitatively suitable water bodies throughout the 3 counties. Trapped sites were $\geq$1 km apart to avoid re-sampling the same populations. We avoided trapping in eastern and northern Willacy County, eastern Cameron County, and northern Hidalgo County, due to predominantly saline and hypersaline water bodies (U.S. Fish and Wildlife Service 2009). In addition, we avoided locations where trap theft or worker safety was clearly an issue. We trapped 21, 17, and 22 sites across Cameron, Hidalgo, and Willacy counties, respectively, completing 5,245 trap days between 10 May 2008 and 14 June 2008 and between 16 May 2009 and 7 July 2009. We conducted this research under TPWD permit

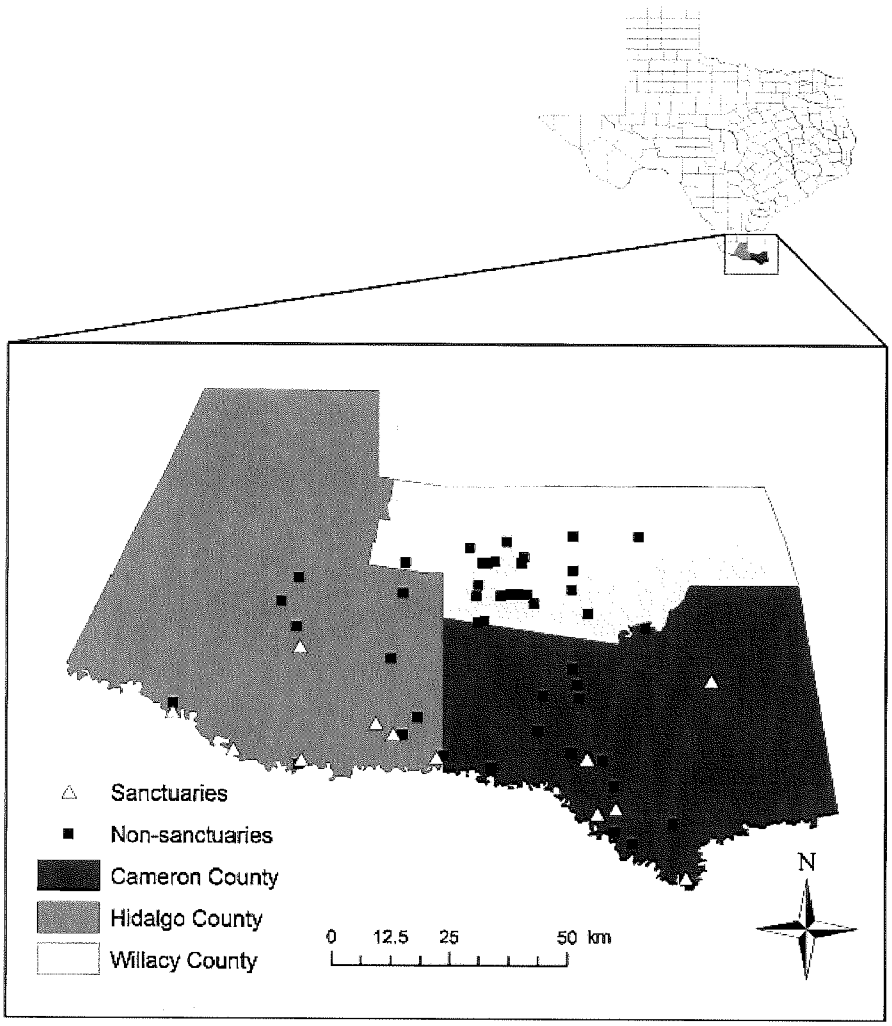

Figure 1. Lower Rio Grande Valley (LRGV) counties in which we studied freshwater turtle harvest in Texas, USA. We trapped 60 sites across these 3 counties, completing 5,245 trap days between 10 May 2008 and 14 June 2008, and 16 May 2009 and 7 July 2009. We avoided eastern and northern Willacy County, eastern Cameron County, and northern Hidalgo County, due to predominantly saline and hypersaline water bodies. Trapped sites were $\geq$1 km apart to avoid re-sampling the same populations.

SPR-0102-191. Trapping and handling methods were approved by the Texas State University-San Marcos Institutional Animal Care and Use Committee (Protocol No. 0715_0428_07).

Trapping Methods

We used 76.2-cm-diameter fiberglass single-throated hoop nets (Memphis Net & Twine Co., Memphis, TN) baited with canned fish, fresh fish, shrimp, or squid in non-consumable containers containing holes for scent dispersal. We re-baited traps every 2 days and when traps were moved. We systematically placed traps along canal, river, pond, and lake borders, securing them to reeds or other vegetation, equidistant to one another when possible. Distances between traps ranged from 2 m to 8 m, depending on the number we used and water body size. We typically moved a portion of the traps to new locations within the site every 2 days to avoid capture bias in locations subjected to multi-day trapping. This sampling design allowed us to maximize habitat coverage given geographic and effort constraints.

We recorded species, sex, carapace length and width, plastron length and width, body depth, and weight for all captures. We measured turtles using Haglof® tree calipers (Haglof, Madison, MS) accurate to 1.0 mm. We weighed individuals using Pesola® precision scales (Pesola, Baar, Switzerland) accurate to 20 g (mass <2,500 g) and 100 g (mass $\geq$2,500 g).

We determined sex using secondary sexual characteristics. Adult male red-eared sliders have elongated foreclaws, and the pre-cloacal portion of the tail extends beyond the edge of the carapace (Gibbons and Lovich 1990). The pre-cloacal portion of the tail in male Texas spiny softshells (*Apalone spinifera*) is also substantially longer (Conant and Collins 1998). We classified red-eared sliders as juveniles if plastron length was <100 mm and <160 mm for males and females, respectively (Gibbons and Greene 1990). We classified

Texas spiny softshells as juveniles if plastron length was <88 mm and <160 mm for males and females, respectively (Webb 1962). We did not assign a sex to juveniles unless obvious male characteristics were expressed. We individually numbered red-eared sliders using carapace notches (Cagle 1939) and imprinted unique numbers into the posterior edge of the carapace of Texas spiny softshells using a Dremel® (Dremel, Racine, WI).

Statistical Analyses

We used 1-way analysis of variance (ANOVA) to test for size and capture-rate differences among sanctuaries (i.e., NWRs, state parks, and nature preserves), non-sanctuaries (i.e., sites in Cameron and Hidalgo counties likely harvested prior to the new harvest regulations), and Willacy County (Kleinbaum et al. 1998). We initially included a habitat-type predictor in 2-way ANOVA models to determine if type of water body (i.e., still vs. flowing) explained turtle size differences. Because habitat-type was not significant in any analyses, we did not include it as a predictor in the final models.

We compared red-eared slider and Texas spiny softshell capture-rate using site as the sampling unit. We calculated capture-rate as the number of turtles captured per trap day, excluding recaptures. We excluded sites without captures to control for trapping potentially unsuitable habitat. We excluded sites with <50 trap days to maximize the probability that our capture data represented realistic abundance differences among populations. We used a square-root transformation to normalize Texas spiny softshell capture-rates (Fowler et al. 1998).

We compared adult male and female red-eared slider and Texas spiny softshell carapace lengths using individual turtles as the sampling unit. We used carapace length to compare mean length differences by sex. For all analyses we considered results to be significant if the probability of occurrence by random chance alone was ≤5% (i.e., $P \leq 0.05$). When results were significant, we used Tukey's Honestly Significant Difference (HSD) test to determine which means were different (Kleinbaum et al. 1998). We performed all statistical analyses using R (R Version 2.7.2, www.r-project.org, accessed 25 Aug 2008).

Spatial Analyses

We estimated the area and number of protected and unprotected water bodies under current harvest regulations throughout the state. In addition, we performed a more detailed examination of the counties included in this harvest investigation. We investigated the potential for protected water bodies in Cameron, Hidalgo, and Willacy counties to serve as source populations for unprotected (i.e., harvestable) water bodies. We performed all spatial calculations and generated all maps using ArcMap 9.3.

We obtained a base shape file of Texas counties from the Texas Natural Resource Information System (TNRIS 2009), and shapefiles of water bodies within the counties from the United States Geological Survey's National Hydrography Dataset (2009). We acquired locations of national, state, and city parks, as well as other public land from TNRIS (2009). We supplemented the protected layer by manually adding large public water bodies not delineated in the original shapefile. We used these layers to estimate the total area and number of protected water bodies in Texas.

We obtained base shapefiles of Cameron, Hidalgo, and Willacy counties from TNRIS (2009), and shapefiles of water bodies within the counties from the United States Geological Survey (2009). We used county grid maps from Texas Department of Transportation (TXDOT 2009) and Ortho-imagery files from the United States Department of Agriculture (2009) to include canals and other major water bodies missing from the National Hydrography Dataset. We considered water bodies protected if they occurred within public land (including all flowing waters), parks, or nature preserves. We attained locations of NWRs, TPWD property, National Park Service property, preserves, and city parks from the Texas General Land Office (2009). We left public areas readily accessible to poaching as protected, despite known poaching at some of these locations (M. Sternberg, U. S. Fish and Wildlife Service, personal communication), resulting in a conservative estimate of truly protected areas. We considered all remaining water bodies to be located on private land and therefore accessible for turtle harvesting.

We placed 1-km buffers around water bodies to determine the proportion of unprotected (sink) populations that theoretically could be continually recolonized by robust protected (source) populations. Sliders can disperse great distances, but typical home-range sizes are <1 km (Schubauer et al. 1990, Ernst et al. 1994). We clipped the protected layer from the total water bodies layer to determine the number of protected water bodies. The total number of water bodies within this clip was the number of protected water bodies, and the difference from the total was the number of unprotected water bodies. We then calculated total area of protected and unprotected water bodies. We determined the number of currently unprotected water bodies that could theoretically be supplied by robust source populations by calculating the difference between the protected and total number of water bodies present within the 1-km buffer.

We also investigated the potential for highways to interfere with turtle movements between protected and unprotected water bodies. We obtained a Texas roads shapefile from TNRIS (2009) and selected highways in the LRGV. We calculated total highway mileage that intersects with the 1-km buffers around protected sites. We also eliminated unprotected water bodies within the 1-km buffers that would require turtles to cross highways to reach them.

RESULTS

We captured 676 unique red-eared sliders and 185 unique Texas spiny softshells at 48 of the 60 trapped sites. Of these captures, 338 red-eared sliders and 57 Texas spiny softshells came from 10 of the 13 trapped sanctuary sites. We recaptured 26 red-eared sliders and 4 Texas spiny softshells, including 2 red-eared sliders and 1 Texas spiny softshell that we recaptured twice.

Table 1. Capture-rate (CR) by species (no. of turtles per trap day) of freshwater turtles captured between 10 May 2008 and 14 June 2008 and between 16 May 2009 and 7 July 2009 for predictors used we used to determine if intensive freshwater turtle harvest in the lower Rio Grande Valley (LRGV) of Texas resulted in lower captures per unit effort in harvested areas.

Predictor	Species	Mean CR	SD	*n*
Cameron County	Red-eared slider	0.142	0.13	11
Hidalgo County	Red-eared slider	0.086	0.059	6
Willacy County	Red-eared slider	0.289	0.255	11
Sanctuary	Red-eared slider	0.153	0.208	10
Non-sanctuary	Red-eared slider	0.123	0.112	17
Cameron County	Texas spiny softshell	0.059	0.084	11
Hidalgo County	Texas spiny softshell	0.04	0.05	6
Willacy County	Texas spiny softshell	0.088	0.114	11
Sanctuary	Texas spiny softshell	0.012	0.021	10
Non-sanctuary	Texas spiny softshell	0.052	0.073	17

Red-eared slider capture-rates were not different among sanctuaries, non-sanctuaries, and Willacy County ($F_{2,35} = 2.73$, $P = 0.079$). Texas spiny softshell capture-rates were also not different among sanctuaries, non-sanctuaries, and Willacy County ($F_{2,35} = 1.68$, $P = 0.201$). Among non-sanctuary sites, mean capture-rate was lowest in Hidalgo County for both species (Table 1). Mean capture-rate was higher in sanctuaries than non-sanctuaries for red-eared sliders, and lower in sanctuaries than non-sanctuaries for Texas spiny softshells.

Male red-eared slider carapace lengths did not differ among sanctuaries, non-sanctuaries, and Willacy County ($F_{2,252} = 0.18$, $P = 0.833$). Conversely, Tukey's HSD test determined female red-eared sliders were larger in sanctuaries than non-sanctuaries and larger in Willacy County than non-sanctuaries ($F_{2,247} = 5.02$, $P = 0.007$; Table 2). Male Texas spiny softshells were larger in sanctuaries than non-sanctuaries and larger in sanctuaries than Willacy County (Tukey's HSD test: $F_{2,88} = 13.16$, $P < 0.001$). Tukey's HSD test also determined that female Texas spiny softshells were larger in sanctuaries than non-sanctuaries and larger in sanctuaries than Willacy County ($F_{2,38} = 13.34$, $P < 0.001$).

Spatial Analyses

Our analyses indicated 1,432,800 ha of fresh water occurred in the state, with 45.2% protected from harvest under current regulations (Fig. 2). We estimated 1,007,464 water bodies in the state, with 22,637 protected (i.e., 2.2%). There were 23,703 ha of inland water in the study area, with 14,090 ha protected from harvest (i.e., 59.4%). Of the 14,090 ha of protected water, 53.9% was unsuitable habitat due to hypersaline or saline conditions. Based on our 1-km home-range buffer, 22.9% of harvestable water could be replenished by protected source populations.

The total number of water bodies in Cameron, Hidalgo, and Willacy counties was 1,069 with 269 protected (i.e., 25.2%). The percentage of harvestable water bodies potentially replenished by protected source populations was 30.5%. We estimated 184.8 km of highway intersected 1-km buffers around protected water bodies in the LRGV. When we considered highways as barriers to movement between water

Table 2. Mean carapace length (CL) by sex and species (mm) of freshwater turtles captured between 10 May 2008 and 14 June 2008 and between 16 May 2009 and 7 July 2009 for predictors we used to determine if intensive freshwater turtle harvest in the lower Rio Grande Valley (LRGV) of Texas resulted in smaller-sized turtles in harvested areas.

Predictor	Species	Sex	Mean CL	SD	*n*
Cameron County	Red-eared slider	M	161.4	30.6	49
		F	211.4	23.9	32
Hidalgo County	Red-eared slider	M	177.0	31.4	10
		F	205.5	27.2	11
Willacy County	Red-eared slider	M	160.4	31.8	80
		F	221.3	21.3	84
Sanctuary	Red-eared slider	M	160.6	31.0	115
		F	222.4	23.5	123
Non-sanctuary	Red-eared slider	M	162.5	31.7	61
		F	209.9	24.6	43
Cameron County	Texas spiny softshell	M	147.2	13.7	21
		F	289.9	42.1	7
Hidalgo County	Texas spiny softshell	M	165.0	32.1	6
		F	256.2	39.7	5
Willacy County	Texas spiny softshell	M	150.7	13.4	38
		F	259.7	43.4	12
Sanctuary	Texas spiny softshell	M	171.3	18.6	26
		F	351.7	61.8	17
Non-sanctuary	Texas spiny softshell	M	151.2	20.0	27
		F	275.8	42.9	12

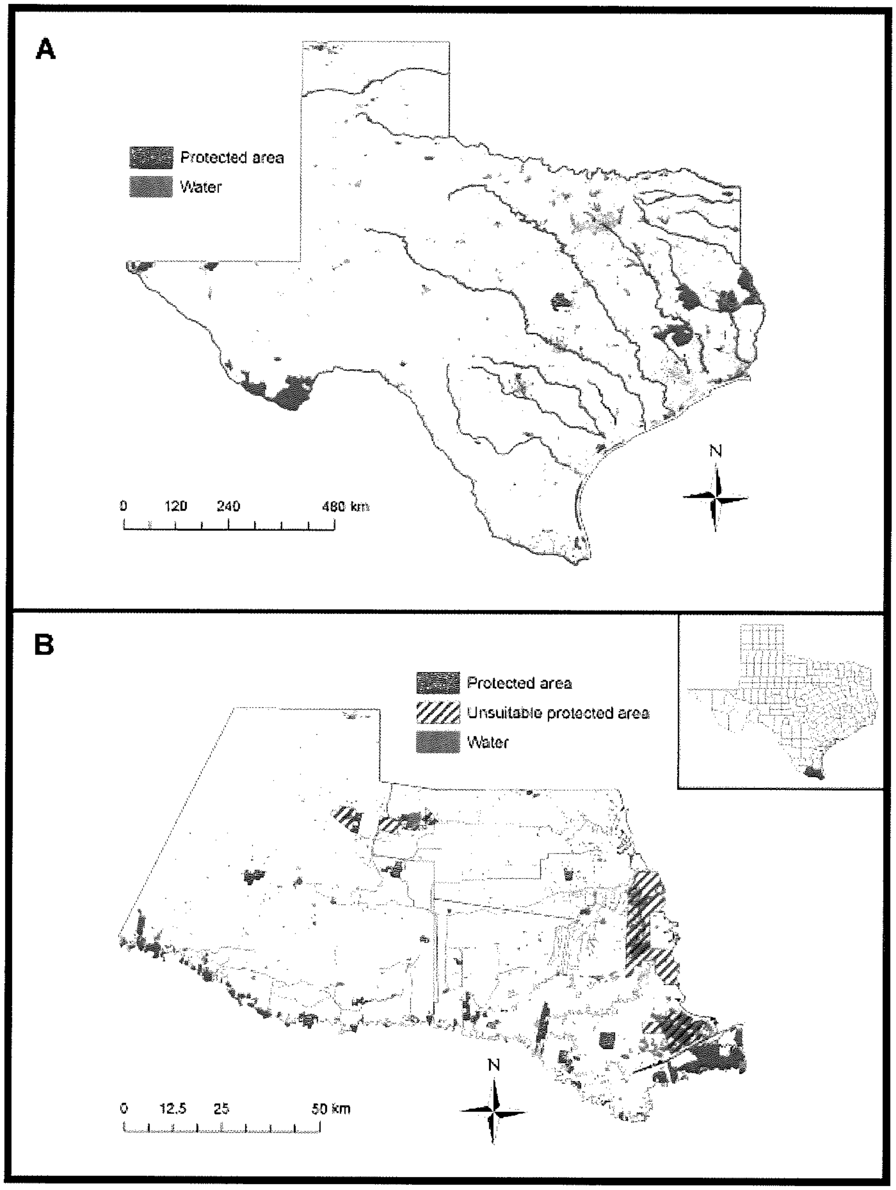

Figure 2. (A) Areas protected and unprotected from freshwater turtle harvest by the Texas Parks and Wildlife Department (TPWD) as of 2007 in the state of Texas, USA. No commercial harvest is permitted in public water bodies, whereas unregulated harvest of common turtle species is allowed in private water bodies. Approximately 94% of Texas is privately owned, resulting in 2.2% of the estimated 1,007,464 water bodies in the state being protected. (B) Water bodies protected and unprotected from freshwater turtle harvest in Cameron, Hidalgo, and Willacy counties, Texas, USA. Unsuitable protected areas contain protected water that is predominantly hypersaline. This unsuitable freshwater turtle habitat represents 53.9% of the protected water body area in this study. Although these unsuitable zones extend onto private properties, we did not have the data to map their extent. Based on our analyses there were 1,069 water bodies in our study area, 269 of which were protected (i.e., 25.2%).

bodies, the percentage of harvestable water bodies potentially replenished by protected source populations was reduced to 28.0%.

DISCUSSION

We found female red-eared sliders were larger in sanctuaries and Willacy County, compared to non-sanctuaries, congruent with our expected results based on previous research. However, we did not find differences between counties or sanctuaries and non-sanctuaries for male red-eared sliders, which may be explained by females being targeted more often for food markets due to their larger size, as well as replacements for turtle farm breeding stock. Male and female Texas spiny softshells were larger in sanctuaries compared to non-sanctuaries and Willacy County. We were told by numerous local fishermen that unlike red-eared sliders, softshell turtles were a valued food source in the LRGV. We were not surprised that Texas spiny softshells were smaller in

Willacy County than sanctuaries, given 64.3% of Texas spiny softshell captures in Willacy County came from heavily fished canals.

No capture-rate results were significant due to large among-site variability, although among non-sanctuary sites, capture-rates were lowest in Hidalgo County and highest in Willacy County for both species. Only 3 of the 13 sanctuary sites had robust red-eared slider populations (i.e., Edinburg Scenic Wetlands, Southmost Preserve, and TPWD fish hatchery), which is a consequence of most federal and state wildlife management areas in the LRGV primarily managing for shorebirds and waterfowl. Draw-down management results in periodic draining of wetlands or maintaining consistently low water levels to support foraging activity, which can create low-suitability turtle habitat (U.S. Fish and Wildlife Service 1997, Byron et al. 1999, Hall and Cuthbert 2000). These management decisions have resulted in the loss of previously robust freshwater turtle populations in favor of other management objectives. Grosmaire (1977) captured 257 unique red-eared sliders in 480 trap days at Santa Ana NWR using hoop nets, whereas we captured only 5 in 280 trap days. In addition to sanctuary management changes, turtle harvest near sanctuaries may be creating attractive sinks for turtles as densities are reduced in harvested waters. Increased dispersal into sinks would be an unintended consequence of the current TPWD management efforts that would manifest itself in higher movements of turtles from sanctuaries.

Turtle harvesting results in average body size reductions (Close and Seigel 1997, Gamble and Simons 2004), which is consistent with long-term fisheries research (Rijnsdorp 1993, Heikinheimo and Mikkola 2004, Harvey et al. 2006). Fisheries experiments revealed a reduction in size was caused not only by the harvesting of larger individuals, but also by a consequent shift in genetic dominance towards inherently smaller or slower growth-rate individuals (Heikinheimo and Mikkola 2004, Allendorf and Hard 2009). The influence of harvest on the genetics of freshwater turtle populations is needed to determine if investigators are detecting a temporary artifact of harvest, or a true shift towards smaller individuals. Previous research has shown home-range size and successful recruitment are positively correlated with body size in freshwater turtles (Schubauer et al. 1990, Tucker et al. 1998, Litzgus et al. 2008). Therefore, body size reductions could have negative consequences for recruitment, population, and meta-population dynamics.

Our spatial analyses showed protection under the current regulations favors a much greater area than number of water bodies in the LRGV, which is not surprising, as Laguna Atascosa NWR, United States Fish and Wildlife refuge tracts, reservoirs, and irrigation canals account for most of the total protected area. Unfortunately half of this area contains unsuitable freshwater turtle habitat, and many of the remaining sites do not house large freshwater turtle populations. Capture-rates per trap day in 5 of 7 trapped reservoirs (0.104, SD $= 0.1$, $n = 5$) were far lower than the mean capture-rate for all other sites (0.261, SD $= 0.4$, $n = 55$). Freshwater turtles are a primary food source for adult American alligators (*Alligator mississippiensis*; Delany and Abercrombie 1986). An abundance of American alligators, coupled with periodic saltwater intrusion into freshwater zones due to extreme weather, seems to maintain low habitat suitability for freshwater turtles at Laguna Atascosa NWR. We captured no turtles at the refuge in 100 trap days, and Grosmaire (1977) captured only 16 in 280 trap days. We were informed of known poaching at NWR tracts in recent years (M. Sternberg, U. S. Fish and Wildlife Service, personal communication), indicating that new regulations may not deter harvesting from public waters, despite their legal status.

Only 2.2% of the water bodies in state are protected under current harvest regulations, which is not surprising, as 94% of Texas is privately owned (Texas Center for Policy Studies 2000). The LRGV is particularly rich in NWRs, state parks, and preserves with 25.2% of water bodies protected. However, protected sites are largely clustered around the Rio Grande and coastal areas. Consequently, only 30.5% of harvestable water bodies could potentially exist in a source-sink system; 28.0% if highways are considered turtle movement barriers. Granted, this assumes all unprotected water bodies are harvested, which is not true. Non-harvested unprotected water bodies would also serve as source populations. However, known harvest coupled with non-robust populations in many protected water bodies leads us to conclude a sustainable source-sink system is not possible without additional restrictive regulations.

We focused on only one of a suite of factors influencing freshwater turtle populations in the LRGV. Substantial human population growth has occurred in this region over the last 3 decades, particularly since the enactment of the North American Free Trade Agreement (NAFTA) in the 1990s, resulting in extensive urbanization in Cameron and Hidalgo counties (U.S. Census Bureau 1982, 2007). Water is redirected from agricultural to urban use as the human population grows and expands (Levine 2007). Hidalgo County alone experienced a 59.7% increase in urban land-use between 1993 and 2003, with a corresponding 10.3% decrease in irrigated land and a 19.3% decrease in surface water (Huang and Fipps 2006). Increased urbanization leads not only to loss of suitable habitat, but also increased road mortality (Gibbs and Shriver 2002, Steen and Gibbs 2004, Aresco 2005*a*). We estimated 184.8 km of highway within 1 km of harvest-protected water bodies in the LRGV. The high density of major roads exemplifies the reality that protection from harvest does not mean turtles are protected from mortality.

Conserving adult freshwater turtles is crucial to long-term population viability due to low fecundity, low hatching success, and delayed maturity (Congdon et al. 1993, 1994; Heppell 1998). There is evidence additive mortality as low as 1–5% to adult age classes may be the threshold most turtles can tolerate before incurring negative population growth (Doroff and Keith 1990; Congdon et al. 1993, 1994). Furthermore, other factors like road mortality and changes in water levels can be important impact factors on population dynamics (Bodie and Semlitsch 2000, Aresco 2005*b*). South

Texas is historically drought-prone (Stahle and Cleaveland 1988), and turtle migrations are often a response to unsuitable habitat conditions driven by changes in water levels (Cagle 1950). Many public water bodies in the LRGV are as vulnerable to desiccation as private water bodies, which can severely affect source-sink dynamics.

Our spatial analyses indicate long-term sustainable harvest is unlikely to be maintained under the current regulations consequent of both inadequate distribution and assured viability of protected source populations. McCullough (1996) proposed an active form of spatial harvest management, where the number, size, and placement of protected areas changes in response to harvest trends, theoretically resulting in protected areas that serve as robust source populations. This zonal management would be one attractive alternative to the current regime because the only required population data are estimated numbers of individuals harvested per location per unit time, a current requirement for commercial turtle harvesters.

However, because successful spatial harvest management depends on dispersal from protected areas, it assumes protected areas continually house robust populations. There is no evidence for the ability of protected areas in the LRGV to maintain robust, long-term source populations for turtles. Furthermore, harvest response may be slow due to the definitive life-history characteristics of turtles (Gibbons and Lovich 1990, Ernst et al. 1994). If dispersal-rates are high, there may be a substantial time-lag before overexploitation is detected, possibly resulting in depletion of turtles populations. Therefore, although it would likely be more effective than the current management regime, slow response times and the inability to ensure protected habitats remain suitable make even active spatial control a risky harvest management tool for turtles. This management regime would also require private waters be included in the harvest control, which is in direct conflict with the current paradigm. Furthermore, enforcing these regulations on private property is probably not feasible, as the origin of a given turtle is reported by the harvester post-take.

MANAGEMENT IMPLICATIONS

The commercial take of turtles in Texas is now managed analogously to stocked fish when in actuality turtle population ecology is more analogous to that of waterfowl as a wildlife resource. Consequently, we recommend that a more conservative approach be taken for commercial harvest management. In addition to the spatial control already enforced, harvest regulations should be modified to prevent turtle harvest during breeding and nesting seasons. Furthermore, bag and size limits should be enforced for female turtles due to their substantially greater influence on population viability. This typical game management approach is currently being utilized in various forms by 14 states in the eastern half of the United States (Lowe 2009). Eight other states have banned commercial turtle harvest. Only Oklahoma has a turtle management regime similar to that of Texas. It may be possible to harvest Texas' freshwater turtles sustainably, but it will require greater regulatory effort from TPWD, and probably a much lower harvest-rate.

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A Safe and Efficient Technique for Handling *Siren* spp. and *Amphiuma* spp. in the Field

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Siren spp. and *Amphiuma* spp. are large eel-like salamanders distributed throughout the coastal plain of the southeastern United States (Conant and Collins 1998). Much has been reported on capture methods for these species. Common methods include minnow and crayfish traps (Sorensen 2004), hoop nets (Snodgrass et al. 1999), dip nets (Fauth and Resetarits 1991), and baited hooks (Hanlin 1978). Recently, a trap capable of sampling these species at depths up to 70 cm was developed (Luhring and Jennison 2008). Because of their slippery skin and irritable nature, *Siren* spp. and *Amphiuma* spp. are difficult to handle. Little has been published on methods to aid in field-handling of these species. Sorensen (2004) used a modified squeeze box to restrain individuals (Cross 2000). Luhring (2005) restrained individuals by wrapping them in a damp cloth. Frese et al. (2003) anesthetized individuals prior to marking and measuring.

We found snake restraining tubes (King and Duvall 1984) to be a safe and effective device for restraining *Siren texana* (Dixon 2000) in the field (Fig. 1). The set we used included nine clear plastic tubes obtained from Forestry Suppliers Inc. (Jackson, Mississippi), measuring 609.6 mm in length and ranging in diameter from 9.5 to 50.8 mm. This allowed all *S. texana* encountered (N = 31), ranging from 84 to 443 mm snout–vent length, to be restrained effectively. An opening at each end of the tube allowed constant airflow to be maintained, and water was trapped in the tube with the *S. texana* which prevented desiccation.

Captured individuals were initially placed in holding bags so that they could be manipulated into entering the tubes. However, we found it more efficient to house the *S. texana* in a large cooler containing enough pond water to cover their bodies prior to handling. Individual *S. texana* were easily disturbed by touch and swam directly into tubes placed in the water in front of them when disturbed. This allowed us to minimize contact with *S. texana*, decreasing the potential for handling injuries to both salamander and worker. Typically, a large individual would attempt to back out of the tube when it was between one third and half way in. In such cases, we held the tube vertical to the ground, with the posterior end of the *S. texana* facing up, and pushed the body into the tube until only the tail was free. The individual was then less able to move within the tube, facilitating accurate measurements, tail-clips, and photographs. *S. texana* were ejected from the tubes directly into damp perforated laundry sacks to be weighed by holding the tubes vertically, with the anterior portion of the individuals facing up, and pulling lightly on the tail.

We found that a single person could restrain and obtain all necessary data on a given individual in under ten minutes. A potential drawback of this method is that the salamanders will never be perfectly linear due to the necessity of having enough space to facilitate movement into the tube. However, once an individual is placed in a given tube, a smaller tube can be inserted at the anterior end and the salamander can be coerced into it by touching its tail, resulting in a tighter fit and more accurate measurements. The handling method we used was effective for collecting standard data and facilitating tail-clips. This method may not be useful when extremely accurate measurements are required or when investigating some morphological characters, such as bite-marks (Fontenot and Seigel 2008; Godley 1983). However, the tubes may be useful for restraining individuals prior to administering anesthetic vapor.

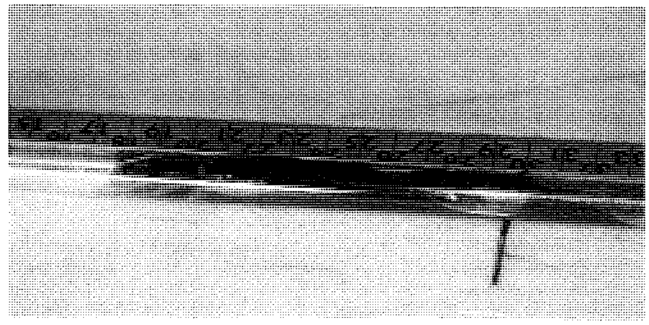

FIG. 1. *Siren texana* being restrained for measurements using a snake tube.

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Using PIT Tags to Evaluate Non-Individual-Specific Marks Under Field Conditions: A Case Study with Greater Siren (*Siren lacertina*)

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Mark-recapture models used in estimating population size require the capture, marking, and recapturing of marked animals (Donnelly and Guyer 1994). Although several methods are available for marking amphibians (see Ferner 1979), sirenids and Greater Siren (*Siren lacertina*), in particular, present several problems for marking schemes. Sirenids have fewer total toes (6 or 8) than most salamanders and this limits the applicability of toe clipping schemes. Additionally, the dark skin of Greater Sirens prevents marks made by tattooing and injectable dyes from being easily read (Sorensen 2003). The only known test of multiple marking techniques on *S. lacertina* was conducted on two captive animals (Sorensen 2003). The marking techniques used on the two captive animals included cyano-acrylic, tail-notching, heat-branding and Passive Integrated Transponders (PIT tags). Of these, only PIT tags were successful in creating a lasting mark and were later used in field studies. While it was not deemed applicable for Greater Siren, previous studies on Lesser Siren (*Siren intermedia*) used heat branding to create marks that lasted for up to 96 months (Frese 2000; Gehlbach and Kennedy 1978; Raymond 1991).

The required level of identity (e.g., individual, cohort) and persistence (e.g., permanent, month, day) for a mark is dependent on the specific goals of a mark-recapture study. I tested two types of non-individual-specific marks on *S. lacertina* in an isolated herbaceous bay wetland to determine their permanence and readability. Passive integrated transponder (PIT) tags are effective at providing a permanent individual mark in *S. lacertina* (Crabill 2007; Sorensen 2003). Their proven persistence as a mark for *S. lacertina* allowed me to use them as a redundant mark to test other marking techniques used in this study.

There are several individual marking schemes for toe clipping amphibians (see Donnelly et al. 1994). However the utility of toe clipping for individually marking *Siren* is fairly limited as they only have eight total toes (most toe-clipping schemes are designed for amphibians with 18 total toes). For this reason, toe-clipping in this study was considered to be a cohort mark (i.e., different toe-clip combinations can be used in order to separate animals into smaller groups by a pre-defined criterion such as period of capture). Tail notching has been successfully used as a marking technique for larval anurans (Turner 1960). Sirens often have minor damage to their tailfins that can resemble a tail notch (pers. obs.). To avoid confusion with naturally occurring tailfin damage, I used an elongate arc or "tail scoop" (see Luhring 2008) as a tailfin mark on each marked animal. Because there is not an effective way to vary the appearance of a tail scoop, this method was considered to be a non-specific capture mark.

Methods and Materials.—All animals were captured from September 2006 to September 2007 as part of an on-going study on greater siren and two-toed amphiuma at Dry Bay, a 5-ha fishless Carolina bay located on the Department of Energy's Savannah River Site in Aiken County, South Carolina, USA (Luhring 2008). A sampling period occurred each month for ten consecutive days (for a total of 130 nights of trapping over 13 months) with a fyke net, and multiple arrays of hoop nets, trashcan traps (Luhring and Jennison 2008; Luhring, *in press*), and plastic and steel minnow traps (see Luhring 2008 for details of trapping design). Upon return to the laboratory, animals were weighed to the nearest 0.1 g on a Mettler PC 440 electronic scale (Mettler Instrument Corporation, Hightstown, New Jersey), measured on a meter stick for snout–vent length (SVL) and total length to the nearest 1.0 mm, and were then marked. Animals were photographed with a Nikon D70 (model# 25218) or Nikon D200 (model# 25235) camera with a Nikon 18–70 mm f/3.5-4.5G ED IF AF-S DX Nikkor Zoom Lens (model#2149) mounted on a Bogen TC-2 copy stand (Bogen Imaging Incorporated, Ramsey, New Jersey) to document mark regeneration and for later use in morphometric measurements. Animals were restrained for marking by placing them on a wet cloth. The cloth was folded over the animal's head and then the side of the cloth was folded over the animal. The animal and cloth were then rolled together to the opposite end of the cloth (see Luhring 2008). This technique of restraining the siren permitted access to the area immediately posterior to the vent for injecting a PIT tag (AVID Marketing, Incorporated, Norco, California) and administering a tail scoop while restraining the siren. Sirens did not need to be restrained for toe-clipping as they typically did not react to this type of mark. Larger sirens (>300 mm SVL) also typically did not react to receiving a PIT tag, however, all animals were restrained in the cloth for PIT tagging and tail scooping.

All PIT tags were injected towards the distal end into the ventral side of the tail 1–3 cm posterior to the vent. This is the same area used by Sorensen (2003); however, I injected the PIT tag ventrally as the ventral aspect at this point was wider and doing so negated having to avoid the spinal column. Tail scoops were made with dissection scissors on the dorsal side of the tail fin. The scoop usually started at the widest part of the tail fin and was cut ~5–7mm deep in larger animals (>400mm SVL) and 2–5mm deep in smaller animals (<400mm SVL). The general rule of thumb in deciding tail scoop depth was that no cut should be deeper than a quarter of the tail depth (i.e., halfway to the middle of the tail). Tail tissue was easier

(20.185194°N, 97.195721°W; WGS84), 68 m elev. 25 March 2008. Tania Ramírez Valverde. Verified by Luis Canseco Márquez. Museo de Zoología, Universidad Nacional Autónoma de México (MZFC 22266). First record for Puebla, although many localities exist for adjacent Veracruz (Duellman 2001. Hylid Frogs of Middle America. SSAR Contrib. Herpetol. 18:xvi + 696 pp., x +1159 pp.). The frog was found in a seasonal evergreen forest (bosque tropical subperennifolia).

Submitted by **TANIA RAMÍREZ VALVERDE, AMAURI SARMIENTO ROJAS, YOCOYANI MEZA PARRAL,** and **ALDO MARTÍNEZ CAMPOS,** Laboratorio de Herpetología, Escuela de Biología, Benemérita Universidad Autónoma de Puebla, Ciudad Universitaria, Edif. 112-A, Boulevard Valsequillo y Av. San Claudio, Col. San Manuel, CP 72570, Puebla, Puebla, México (e-mail: crazygiro_20@hotmail.com).

TESTUDINES –TURTLES

APALONE MUTICA MUTICA (Midland Smooth Softshell). USA: KENTUCKY: Bracken Co.: Ohio River, 1.9 km W of Capt. Anthony Meldahl Locks and Dam (38.7974°N, 84.1923°W; WGS 84). 17 August 2009. Paul J. Krusling. Verified by Jeffrey G. Davis and John W. Ferner. Cincinnati Museum Center Herpetology Collection (CMC 11776). New county record (Kentucky's Comprehensive Wildlife Conservation Strategy. 2005. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky; http://fw.ky.gov/kfwis/stwg/).

Submitted by **PAUL J. KRUSLING**, Geier Collections and Research Center, Cincinnati Museum Center, 1301 Western Avenue, Cincinnati, Ohio 45203, USA (e-mail: pkrusling@gmail.com); and **JUDY GAMMON**, Scott High School 5400 Old Taylor Mill Road, Covington, Kentucky 41015, USA.

APALONE SPINIFERA (Spiny Softshell Turtle). MÉXICO: GUERRERO: Municipality of Copalillo: 5 km NE of Papalutla at the edge of Río Atoyac (18. 56766°N, 98.9511°W; WGS84), ca. 682 m elev. 11 December 2006. Juan Esteban Flores. Verified by Fausto R. Méndez de la Cruz. Colección del Laboratorio de Herpetología Vivario, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México (CLHV 4462-E). New municipality record and second record for the state, extending range 74.5 km NW of the Mezcala Bridge, Guerrero (Lemos-Espinal 1999. Bull. Maryland Herpetol. Soc. 35:40–42).

Submitted by **VÍCTOR HUGO JIMÉNEZ-ARCOS**, Laboratorio de Herpetología, Instituto de Biología, Universidad Nacional Autónoma de México, 3er Circuito exterior s/n, Ciudad Universitaria, Coyoacán, México, D.F. C.P. 04510 (e-mail: vhjimenezarcos@yahoo.com.mx); **SAMUEL SANTA CRUZ-PADILLA,** and **ARABEL ESCALONA-LÓPEZ,** Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Av. de los Barrios s/n, Los Reyes Ixtacala, Tlanepantla, México, C.P. 54090; **GUSTAVO CASAS-ANDREU**, Colección Nacional de Anfibios y Reptiles del Instituto de Biología, Universidad Nacional Autónoma de México. 3er Circuito exterior s/n, Ciudad Universitaria, Coyoacán, México, D.F. C.P. 04510; and **ERIC CENTENERO-ALCALÁ**, Laboratorio de Ecología, Unidad de Biotecnología y Prototipos, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Av. de los Barrios s/n, Los Reyes Ixtacala, Tlalnepantla, México, C.P. 54090.

CHELUS FIMBRIATUS (Matamata Turtle). BRAZIL: AMAZONAS: Santa Isabel do Rio Negro (0.3335° S; 65.3116° W; WGS84). Collected in Jaradi River with trammel nets. 18 Jan 2006. L. Schneider, R. C. Vogt, L. B. Santos-Junior, C.R. Ferrara. Verified by L. Bonora. Coleção de Repteis e Anfibios, Instituto Nacional de Pesquisas da Amazonia, Manaus, Amazonas, Brazil (INPAH 18506 and 18507). *Chelus* ranges throughout the Orinoco and Amazon River basins of Venezuela, Colombia, Ecuador, Peru, northern Bolivia, Surinam, French Guiana, and Brazil (Vogt 2008. Amazon Turtles. Grafica Biblos, Lima, Peru. 104 pp.). The nearest locality record is at the mouth of Rio Branco (1.468°S; 61.548°W; WGS84), on the border of Amazonas State and Roraima State, 400 km to the southeast (Hartline 1967; cited in Pritchard and Trebbau 1984. The Turtles of Venezuela. Society for the Study of Amphibians and Reptiles, Oxford, Ohio. 403 pp.). The present record for the Jaradi River, in the upper Rio Negro Basin, begins to fill in the 331,662 km^2 gap in the distribution between San Gabriel de Cachoeira, Brazil and the hydrographic basin of Venezuela and Guyana.

Submitted by **LARISSA SCHNEIDER** (e-mail: laribio@terra.com.br), **RICHARD C. VOGT**, **LADISLAU B. SANTOS-JUNIOR,** and **CAMILA R. FERRARA**, Instituto Nacional de Pesquisas da Amazônia (INPA), Caixa Postal 478, CEP 69011-970, Manaus, Amazonas, Brazil.

CHELYDRA SERPENTINA SERPENTINA (Eastern Snapping Turtle). USA: TEXAS: Hidalgo Co.: Male turtle (7.6 kg) captured in a pond at Frontera Audubon (26.14691°N, 97.98856°W; NAD 83). 30 May 2009. Brian E. Dickerson, Amanda D. Schultz, and Donald J. Brown. Verified by Toby Hibbits. Texas Cooperative Wildlife Collection (TCWC 93912), Texas A&M University. MRJF observed a *Chelydra s. serpentina* in Harlingen, Texas in 1983 but was unable to capture the turtle. During preparation for this record we were informed that additional *Chelydra* have been observed in the last ten years from both Hidalgo and Cameron counties (P. Burchfield, pers. comm.). Although the potential for anthropogenic dispersal cannot be ignored, in context, this individual and the other reports of this species in the area are evidence of an established wild population in extreme south Texas. Historically, the lack of surface water south of the Nueces River would likely have provided a barrier to dispersal for the species. However, modern drainage and livestock pond systems in this area are now very extensive. Trapping was conducted for the Texas Parks and Wildlife Department freshwater turtle assessment (permit SPR-0102-191). New county record (Dixon 2000. Amphibians and Reptiles of Texas. 2nd Edition. Texas A&M Univ. Press, College Station, 421 pp.).

Submitted by **BRIAN E. DICKERSON, AMANDA D. SCHULTZ, DONALD J. BROWN, BEI DeVOLLD,** and **MICHAEL R. J. FORSTNER** (e-mail: mf@txstate.edu), Department of Biology, Texas State University-San Marcos, San Marcos, Texas 78666, USA; and **JAMES R. DIXON**, Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843, USA.

CHRYSEMYS PICTA (Painted Turtle). USA: GEORGIA: Wilkes Co.: Washington, Newtown Road, 1.6 km N Jane Hill Road

(Arruda 1997. Conservação, Ecologia Humana e Sustentabilidade na Caatinga: Estudo da Região do Parque Nacional da Serra da Capivara - PI. IBAMA, Brasília. 96 pp.), and ca. 440 km airline from Lagoa do Muqueri (8.406687°S, 42.369043°W; WGS84), and Fazenda Veneza (8.751346°S, 42.265451°W; WGS84) (Olmos and Souza, *op. cit.*).

Submitted by **DIVA MARIA BORGES-NOJOSA**, Universidade Federal do Ceará, NUROF-UFC, Campus do Pici, Bloco 905, 60455-760, Fortaleza, Ceará, Brazil (e-mail: dmbnojosa@yahoo.com.br); and **DANIEL CASSIANO LIMA**, Universidade Estadual do Ceará, Av Mons. Tabosa s/n, 62500-000, Itapipoca, Ceará, Brazil (e-mail: dancassiano@yahoo.com.br).

TESTUDINES – TURTLES

CARETTA CARETTA (Loggerhead Sea Turtle). TRISTAN DA CUNHA: near Edinburgh (37.04°S, 12.18°W), 6 May 2008. Verified by Bruce L. Wing, Curator, Reference Collections, NMFS Auke Bay Marine Station, Juneau, Alaska. Photographs and correspondence archived (AB 2008-0025) in herpetological collections of NMFS Auke Bay Marine Station. Edinburgh is on the north shore of Tristan da Cunha, ca. 4000 km E of South America, 2700 km W of South Africa, and 1100 ± km N of Antarctic Convergence. Juvenile female washed ashore on rocky coastline during a storm, tangled in discarded fishing net. Turtle had minor injuries as a result of struggle with netting and rocks, but was alert, vigorous, and apparently healthy. Released in waters off a sandy beach. First record from Tristan da Cunha.

Submitted by **ROBERT PARKER HODGE**, ME2, POB 1521, Gig Harbor, Washington 98335, USA; and **ERIK MACKENZIE**, Edinburgh, Tristan da Cunha.

DERMOCHELYS CORIACEA (Leatherback Sea Turtle). TRISTAN DA CUNHA: Nightingale Island (37.24°S, 12.29°W), March 1979. Verified by Denise Hamerton, Natural History Collection Manager, Iziko Museum: SA Museum. Nightingale Island is 38 km SSW of Tristan da Cunha, which is ca. 4000 km E of South America, 2700 km W of South Africa, and 1100 ± km N of Antarctic Convergence. Adult male, accessioned as SAM ZR 44953 on 24 February 1982 at Iziko Museum: South Africa Museum, Cape Town. First record from Tristan da Cunha.

Submitted by **ROBERT PARKER HODGE**, ME2, POB 1521, Gig Harbor, Washington 98335, USA; and **ERIK MACKENZIE**, Edinburgh, Tristan da Cunha.

GOPHERUS BERLANDIERI (Texas Tortoise). USA: TEXAS: ARANSAS Co.: Aransas National Wildlife Refuge (28.309478°N, 96.803242°W). 20 November 2007. Russell Jackson. Voucher images were taken by Darrin Welchert. Verified by Jonathan Campbell. Amphibian and Reptile Diversity Research Center UTADC 1974–1980. New county record (Dixon 2000. Amphibians and Reptiles of Texas, 2nd Edition. Texas A&M Univ. Press, College Station, Texas. 421 pp.). The captured adult male presented a heavy keratinous fungal infection on the marginal and costal scutes of the carapace, and the entire plastron. The specimen was marked and released in the Aransas National Wildlife Refuge.

Submitted by **AKIKO FUJII**, Department of Biology, Texas State University, San Marcos, Texas 78666, USA (e-mail: af@txstate.edu); **DARRIN WELCHERT**, Aransas National Wildlife Refuge, Victoria, Texas 77904, USA (e-mail: darrin_welchert@fws.gov); and **MICHAEL R. J. FORSTNER**, Department of Biology, Texas State University, San Marcos, Texas 78666, USA (e-mail: mf@txstate.edu).

GRAPTEMYS PSEUDOGEOGRAPHICA KOHNII (Mississippi Map Turtle). USA: TEXAS: MILAM Co.: Hatchling captured in the Little River (30.84188°N, 96.71916°W; NAD 83). 11 July 2008. James R. Dixon. Verified by Toby Hibbitts. Trapping conducted for the Texas Parks and Wildlife Department freshwater turtle assessment (Permit No. SPR-0102-191). Specimen deposited in the Texas Cooperative Wildlife Collection (TCWC 93025) at Texas A&M University College Station. New county record (Dixon 2000. Amphibians and Reptiles of Texas. 2nd Edition. Texas A&M Univ. Press, College Station. 421 pp.).

Submitted by **DONALD J. BROWN** and **MICHAEL R.J. FORSTNER**, Department of Biology, Texas State University – San Marcos, San Marcos, Texas 78666, USA; and **JAMES R. DIXON**, Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843, USA.

MACROCHELYS TEMMINCKII (Alligator Snapping Turtle). USA: TENNESSEE: HAMILTON Co.: Collegedale, Spalding Road, Wolftever Creek (35.0316°N, 85.0313°W). 03 June 2003. David B. Ekkens. Verified by A. Floyd Scott. Austin Peay State University photo archive, APSU 17486. New county record. Female turtle, exhibiting 8 annuli. Turtle trapped in a downstream-facing 0.94-m hoop trap baited with sardines. Paul Moler, Florida Fish & Wildlife Conservation Commission, performed analysis of the mitochondrial DNA from a tail-clipped tissue sample. The results showed that the turtle belonged to Haplotype A, commonly found in the Tennessee River system. Therefore, it is not clear if this animal is a natural occurrence or one that has been translocated, given that the nearest record on the Tennessee River is 550 river km from the present location.

Submitted by **DAVID B. EKKENS**, Biology Department, Southern Adventist University, Collegedale, Tennessee 37315, USA (e-mail: dekkens@southern.edu); and **DAVID COLLINS**, Curator of Forests, Tennessee Aquarium, Chattanooga, Tennessee 37401, USA (e-mail: dec@tennis.org).

PSEUDEMYS NELSONI (Florida Red-bellied Cooter). USA: FLORIDA: BRADFORD Co.: Starke, SR 16, 1.6 km W Clay County line (29.95483°N, 82.06454°W). 13 March 2008. J. M. Butler. Verified by M. A. Nickerson. UF 152531. Sub-adult male found DOR. A second specimen UF 153667 was found DOR on 30 August 2008. New county record (Jackson 2006. *In* P. A. Meylan [ed.], Biology and Conservation of Florida Turtles, pp. 313–324. Chelonian Research Monographs No. 3.

Submitted by **BENJAMIN K. ATKINSON** (e-mail: bka@ufl.edu) and **J. MICHAEL BUTLER**, Department of Herpetology, Florida Museum of Natural History, University of Florida, Gainesville, Florida 32611, USA.

TERRAPENE ORNATA (Ornate Box Turtle). USA: ILLINOIS: SCOTT Co.: 7.4 km WSW of Winchester, and 8.9 km WNW of Alsey, crossing 700E (Hillview Road), 0.08 km S of jct with 500N (Lashmett Road) (39.59365°N, 90.52889°W). 01 June 2008. Veri-

Is Switching Bait an Effective Way to Improve Capture and Recapture Success for Freshwater Turtles?

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Abstract - We have conducted a capture-recapture study for freshwater turtles at sites in the Lower Rio Grande Valley and Lost Pines ecoregion of Texas each summer on an annual basis since 2008 and 2009 respectively. In 2011, we tested if annual decreases in captures per unit effort (CPUE) and recaptures per unit effort (RPUE) for freshwater turtles were related to species or individual-level bait preferences, or an olfactory-induced trap shy response, respectively. We found switching from fish-based bait to red meat improved CPUE for *Trachemys scripta elegans* Wied-Neuwied (Red-eared slider). However, we did not detect an RPUE increase, indicating the turtles did not develop an olfactory-induced trap shy response. We found weak evidence that *Apalone spinifera emoryi* Agassiz (Texas spiny softshell) preferred red meat over fish-based bait.

Introduction

Capture-recapture sampling is one of the most widely used techniques for monitoring demographic components of wildlife populations (Nichols, 1992). A major assumption of this method is that all individuals in a population at the time of sampling have the same probability of capture (Carothers 1979, Koper and Brooks 1998). Post-capture changes in animal behavior can bias demographic estimates (Carothers 1979, Feldhamer and Maycroft 1992, Nichols et al. 1984). These behavioral changes are commonly referred as "trap happy" responses (i.e., probability of recapture increases relative to probability of initial capture [Chao et al. 2004, Deforce et al. 2004]) and "trap shy" responses (i.e., probability of recapture decreases relative to probability of initial capture [Brocke 1972, Carothers 1979]).

In addition to potential biases introduced through post-capture behavioral changes, sampling tools can inherently select for certain segments or individuals in a population. For instance, the two most common sampling tools for freshwater turtles are hoop nets and basking traps (Koper and Brooks 1998, Ream and Ream 1966), and hoop nets have been shown to be inherently male-biased (Ream and Ream 1966). Despite this, hoop nets are probably the most commonly used sampling method for freshwater turtles (Davis 1982, Lagler 1943, Thomas et al. 2008). Hoop nets are typically baited, with baits seeking to cater to species-specific preferences (Ernst 1965, Jensen 1998, Thomas et al. 2008). Bait is usually placed in closed containers with numerous holes to allow scent dispersal while eliminating potential for bait consumption (Lagler 1943, Nall and Thomas 2009).

We are aware of four studies that examined the efficiency of different bait types used for hoop net sampling of freshwater turtles (Ernst 1965, Jensen 1998, Thomas et al. 2008, Voorhees et al. 1991). Ernst (1965) found that turtles were most attracted to sardines among six types of bait. Voorhees et al. (1991) used seventeen different types of bait and found that bait with jelly-like fluid (fresh mussel, canned creamed corn, and canned sardines) was the most successful in capturing nine species of freshwater turtles. Jensen (1998) found different bait preferences between *Macroclemys temminckii* Troost (Alligator snapping turtle) and *Trachemys scripta elegans* Wied-Neuwied (Red-eared slider), with Alligator snapping turtles preferring fresh fish and Red-eared sliders preferring fresh chicken entrails. Thomas et al. (2008) found that freshwater turtles prefer frozen fish and canned mackerel over creamed corn In addition, Deforce et al. (2004) noted a "trap happy" behavior of *Phrynops gibbus* Schweigger (Gibba turtle) towards hoop nets baited with chicken meat.

We have surveyed freshwater turtles annually in the Lower Rio Grande Valley (LRGV) of Texas since 2008 and in the Lost Pines ecoregion of Texas since 2009. Based on annual captures and recaptures per unit effort (CPUE and RPUE, respectively), it appears that freshwater turtles in these study areas develop a trap shy response to baited hoop nets. This hypothesis is supported by a diminishing number of new captures each year, coupled with consistently low recapture rates (Fig. 1). Unfortunately, allowing for long periods of time between re-sampling (ca. 1 year) has not mitigated this perceived trap aversion. Since turtles are attracted by the bait placed inside the hoop nets, it is a possible they develop negative olfactory response to the bait, and thus become trap shy. If this is the case, long-term studies that utilize hoop nets could underestimate population sizes and make false conclusions about population trends.

For this study, we switched the type of bait used to investigate the possibility that perceived trap shy behavior was due to a negative olfactory response to the bait used during the initial capture (i.e., previous years). We also investigated the possibility that bait preference may be individual-specific, rather than species-specific.

Field-Site Description

We conducted this study using 15 ponds that were surveyed for multiple consecutive years as part of a statewide assessment of freshwater turtle populations in Texas. Eleven ponds were located in the LRGV in south Texas and contained Red-eared sliders and *Apalone spinifera emoryi* Agassiz (Texas spiny softshell). Four ponds were located in the Lost Pines ecoregion in central Texas and contained Red-eared sliders and *Chelydra serpentina* Linnaeus (Common snapping turtle). Additional information on the study areas can be found in Brown et al. (2011a,b,c).

Methods

Of the 15 ponds used in this investigation, we trapped six annually since 2008, excluding two that were not trapped in 2010, seven since 2009, and two since 2010. We trapped all ponds during the summer months when the turtles were likely to be most active (Thomas et al. 1999). We used 76.2 cm diameter single-opening, single-throated, widemouth hoop nets with a 2.54 cm mesh size and four hoops per net (Memphis Net & Twine Co., Memphis, Tennessee). We extended the nets using two wooden posts placed lateral to the trap mouth and connected to the first and last hoop. We attempted to keep the locations within ponds and total area trapped consistent among years.

Between 2008 and 2010 we used exclusively fish-based bait (primarily canned sardines), and in 2011 we used exclusively red meat from beef brisket. In all years we replaced the bait every two days. Annual trapping intensity varied among years and among sites, depending on study goals in a given year (see Brown et al. 2011a, b). In 2011 we completed 40 days at each site except one, where we completed only 20 trap days due to a lack of trap security. Although we acknowledge that annual differences in trap days could bias our CPUE comparisons, in a previous study we found that CPUE in these study areas was comparable if more than 10 trap days were completed (Brown et al. 2011b), which was also the case for all sites and years in this study.

We measured and marked all captured turtles. We measured carapace length and width, plastron length and width, and body depth to the nearest 1.0 mm using tree calipers (Haglof, Madison, Mississippi). We weighed captures to the nearest 10 g using spring scales (Pesola, Baar, Switzerland). We individually marked hardshell turtles using the numbering system of Cagle (1939) and a portable rotary tool (Dremel, Racine, Wisconsin). We marked softshell turtles by engraving individual numbers on the posterior end of the carapace using the same rotary tool. We determined sex using secondary sexual characteristics (Gibbons and Lovich 1990, Conant and Collins 1998).

We used paired randomization tests with 10,000 iterations to test for effects of bait-switching. The p-values in these tests represent the proportion of trials resulting in capture differences as great or greater than those obtained (Sokal and Rholf 1995). Thus, a small p-value means that it is unlikely our results were obtained by random chance given the inherent distribution of the data. For each species we determined if CPUE differed between 2011 and the first year the pond was trapped, and analyzed only those sites that corresponded with their geographic distribution (clarify the ending clause of this sentence). Thus, all 15 sites were included in the analysis for Red-eared sliders, 11 sites were included for Texas spiny softshells, and four sites were included for Common snapping turtles. We used this analysis to draw inferences concerning species-specific bait preferences.

For Red-eared sliders, we also determined if CPUE differed between 2011 and the last year the site was trapped prior to 2011. For this analysis we excluded two sites that were initially trapped in 2010. We used this analysis to determine if switching bait was an effective way to increase CPUE in long-term studies. Finally, we determined if Red-eared slider RPUE differed between 2011 and the last year the site was trapped. We used this analysis to determine if switching bait was an effective way to increase RPUE (i.e., mitigate the hypothesized negative olfactory response causing trap shy behavior). For this analysis we excluded the two sites that were initially trapped in 2010, as well as one site that was first trapped in 2009 because no red-eared sliders were captured preventing a calculation of RPUE. We did not conduct the final two analyses for Texas spiny softshells or Common snapping turtles due to reduced site numbers and low recapture rates (Table 1). We inferred statistical significance at $\alpha = 0.05$. However, because of the relatively small sample sizes we considered $\alpha = 0.1$ to indicate a result that was trending on significance, and thus potentially biologically meaningful. We conducted statistical analyses using program R 2.7.2 (The R Foundation for Statistical Computing, Vienna, Austria). We calculated CPUE and RPUE using the following formulas; note that RPUE explicitly accounted for differences in number of marked individuals at the beginning of each year:

CPUE = (# OF CAPTURES) / (# OF TRAP DAYS)

RPUE = (((# OF RECAPTURES) / (# OF MARKED INDIVIDUALS FROM PREVIOUS YEARS))) / (# OF TRAP DAYS)

Results

Red-eared sliders

Mean CPUE was 0.19 in 2011 and 0.28 the first year each site was trapped. Although mean CPUE decreased, the difference between the two years was not significant ($P = 0.12$); Table 1.). However, we found that CPUE increased relative to the previous year each site was trapped (mean = 0.09; $P < 0.001$). Mean RPUE was 0.0016 in 2011 and 0.0015 the previous year each site was trapped; this difference was not significant ($P = 0.44$).

Texas spiny softshell and Common snapping turtles

For Texas spiny softshells, mean CPUE was 0.04 in 2011 and 0.01 the first year each site was trapped; this increase was trending on significance ($P = 0.07$). For Common snapping turtles, mean CPUE was 0.03 in 2011 and 0.06 the first year each site was trapped; this decrease was trending on significance ($P = 0.09$).

Discussion

The results of this study indicate that switching bait can be an effective way to maintain high capture-rates in long-term freshwater turtle investigations using baited hoop nets. Interestingly, based on our analyses it appears that bait preferences within the species ("individual-specific" bait preferences) can influence captures. Thus, maintaining baiting consistency when using CPUE as a metric for comparing relative abundance differences among sites could be important. In terms of species-level responses, we did not find significant preferences for any of the species. However, we must take into consideration that it appears trap shy behavior is occurring, and if so the analyses comparing CPUE in 2011 to the first year the site was trapped would be biased in favor of fish-based bait. In this context, we believe there is weak evidence that Texas spiny softshells prefer red meat over fish, and this topic deserves further study.

A major motivation for conducting this study was to determine if we could increase recapture success by switching bait (i.e., to test out negative olfactory response hypothesis).

Unfortunately this approach failed as we did not detect a significant increase in RPUE in 2011. Moreover, among 12 study sites we tested, we detected an increase in RPUE at only five ponds (Table 1.). Therefore, switching the bait did not appear effective, and thus it could be that most turtles in our study areas develop a negative visual association with the hoop nets. If so, switching the type of trap used could increase RPUE, and we intend to test this hypothesis in the future.

In conclusion, the integration of capture-recapture methodology to freshwater turtle sampling using baited hoop nets, an incentive-based sampling method, remains challenging in our study areas. Unfortunately, it is only possible to census ponds (i.e. obtain N) if they are pumped dry and turtles are noodled from the mud over a series of days, which in most situations is both unattractive and unrealistic. Previous investigators have suggested that the optimal way to maximize CPUE and RPUE is to use multiple sampling tools (Koper and Brooks 1998, Ream and Ream 1966). Unfortunately, different sampling tools have different inherent biases associated with them, and thus using a combination of sampling tools could introduce additional uncertainty in capture-recapture estimates.

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State University-San Marcos Institutional Animal Care and Use Committee (Protocol No.1010_0501_09).

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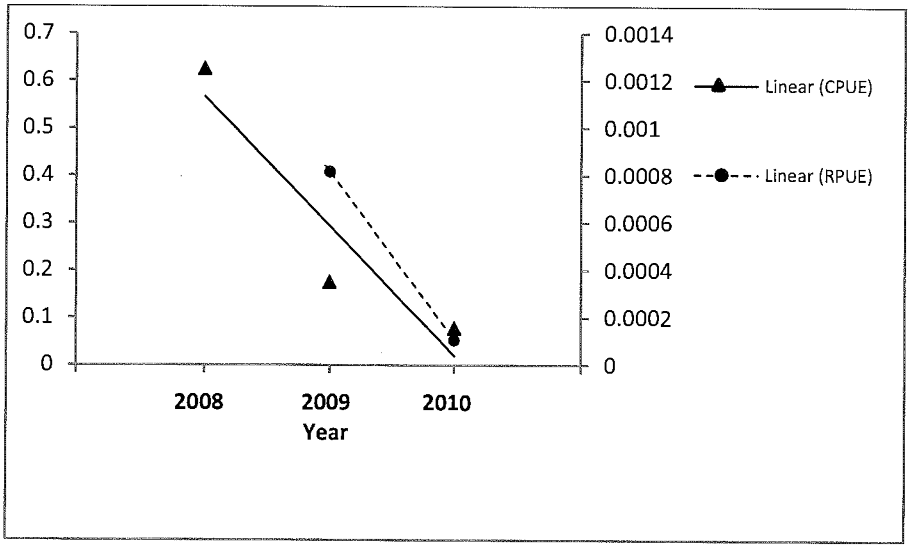

Figure 1. Mean capture per unit effort (CPUE; left axis) and recapture per unit effort (RPUE; right axis) of *Trachemys scripta elegans* at ponds in the Lower Rio Grande Valley (LRGV) of Texas that have been trapped annually since 2008 ($n = 4$). The substantial annual decrease in CPUE suggests that individuals captured in previous years become "trap shy". The decline in RPUE provides further evidence, as we would expect RPUE to increase as more individuals in the population become marked.

Table 1. Capture per unit effort (CPUE) and recapture per unit effort (RPUE) for three species of freshwater turtles (*Trachemys scripta elegans, Apalone spinifera emoryi*, and *Chelydra serpentina*) trapped in the Lower Rio Grande Valley (LRGV) and Lost Pines ecoregion of Texas between 2008 and 2011.

Site no.	*Trachemys scripta elegans* CPUE RPUE				*Apalone spinifera emoryi* CPUE RPUE				*Chelydra serpentina* CPUE RPUE			
LRGV	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
1	0.218 NA[1]	0.0656 0.00005	0.0615 0	0.25 0	0.081 Na[2]	0.0328 0	0.025 0	0.05 0	X	X	X	X
2	NA	0.72 na	0.225 0.00035	0.175 0.00047	NA	0.02 na	0.1 0	0.2 0	X	X	X	X
3	1.44 na	0.46 0.00056	0.15 0.00022	0.25 0.00036	0 na	0 0	0 0	0 0	X	X	X	X
4	0.45 na	0.12 0.00222	0.025 0	0.375 0.00625	0 na	0.06 0	0.025 0	0 0	X	X	X	X
5	NA	0.16 na	0.0625 0.00156	0.1 0	NA	0 na	0 0	0 0	X	X	X	X
6	0.036 na	0.005 0	NA	0.2 0	0 na	0 0	NA	0 0	X	X	X	X
7	0.391 na	0.054 0	0.075 0.0002	0.2 0	0.0226 na	0.005 0	0 0	0.025 0	X	X	X	X
8	0.055 na	0.226 0	NA	0.475 0.00204	0 na	0 0	NA	0 0	X	X	X	X
9	NA	0.28 na	0.2 0	0.35 0	NA	0 na	0.0375 0	0.15 0	X	X	X	X
10	NA	0.154 na	0.0375 0	0.3 0.00192	NA	0 na	0.0125 0	0 0	X	X	X	X
11	NA	NA	0.125 na	0 0	NA	NA	0.0375 na	0 0	X	X	X	X
Lost Pines Ecoregion	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
12	NA	0 na	0.0375 na	0.025 0	X	X	X	X	NA	0.024 na	0 0	0.025 0
13	NA	NA	0.05 na	0.075	X	X	X	X	NA	NA	0.0375 na	0 0
14	NA	0.114 na	0.0375 0.00031	0 0	X	X	X	X	NA	0.029 na	0 0	0 0
15	NA	0.02 na	0.0375 0.0125	0.075 0.00833	X	X	X	X	NA	0.143 na	0.0125 0	0.075 0.1

[1]NA- the site was not trapped
[2]na- RPUE could not be calculated