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AN ASSESSMENT OF TWO METHODS FOR SAMPLING RIVER TURTLE ASSEMBLAGES

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***Abstract.*—We compared the effectiveness of baited hoop traps and effort-managed snorkel surveys for detecting freshwater turtle species within two streams in southwestern Georgia, USA. Snorkel surveys provided the highest detection probability for the four most frequently captured species. We captured the Barbour's Map Turtle (*Graptemys barbouri*), a threatened species in the southeastern U.S., 90% of the time by snorkeling; whereas, we captured the Yellow-bellied Slider (*Trachemys scripta*) 88% of the time by hoop traps. We captured adults and juveniles with both methods, with the exception of juvenile Loggerhead Musk Turtles (*Sternotherus minor*), which we caught only via snorkeling. The two methods captured turtles of similar sizes. Seasonal and physical constraints can affect visibility and access to capture locations, limiting snorkeling sessions. We recommend use of both techniques to capture a range of sexes, sizes, and species of turtles in Coastal Plain streams. However, species-specific surveys may benefit by lower effort with the use of only one method.**

Key Words.—Coastal Plain; detection probability; Georgia; *Graptemys barbouri*; hoop trapping; snorkel surveys; *Sternotherus minor*, *Trachemys scripta*

INTRODUCTION

Herpetofauna are notoriously cryptic in habit, yet until recently few studies have accounted for detection probability during research and monitoring efforts. Incorporating measures of detection is essential to making accurate inferences about abundance or a population's response to environmental impacts from comparative or long-term data (MacKenzie and Kendall 2002; Mazzerolle et al. 2007). When working with assemblages of species that differ in behavior, it is unlikely that a single technique will be effective at detecting all species, thus a suite of capture techniques may be required (Liner 2006). Further, various sampling methods can yield differing detection probabilities for any single species (Gunzburger 2007). Nevertheless, researchers are often limited in the numbers of techniques they can employ, so assessments of the effectiveness of individual methods are valuable (Plummer 1979).

Baited hoop traps are commonly used to sample omnivorous, active-foraging freshwater turtles (Legler 1960). However, these methods are generally ineffective for herbivorous and molluscivorous turtles species like *Pseudemys* spp. and *Graptemys* spp., as these species do not respond to bait (MacCulloch and Gordon 1978). Further, hoop traps or fyke nets may be ineffective at capturing small size classes of turtles (Ream and Ream 1966). Alternative methods such as basking traps (Ream and Ream 1966; MacCulloch and Gordon 1978) and fyke nets (Vogt 1980) are used to capture species that do not readily come to bait (Plummer 1979; Browne and Hecnar 2005). Not surprisingly, studies of whole turtle assemblages rely on multiple sampling methods, although the detection probabilities of the individual and combinations of techniques are seldom reported (Dreslik et al. 2005; Smith et al. 2006; Browne and Hecnar 2007).

Hand capture via snorkeling ("goggling") has been used to supplement other methods of aquatic turtle capture (Marchand 1945; Chaney and Smith 1950; Allen and Neil 1950). This method is particularly effective in clear, shallow lakes and rivers. For example, Carr (1952) recounts a goggling trip of Lewis Marchand and colleagues in which 60 Barbour's Map Turtles (*Graptemys barbouri*) were captured over three days on the Chipola River in northwest Florida, and Marchand (1945) captured 163 *Pseudemys* spp. via snorkeling in Rainbow Run, a spring-fed river in west-central Florida. Polisar (1995) found that snorkeling for *Dermatemys mawii* resulted in more captures than any other method used in tributaries of the Belize River. Further, snorkeling yielded captures of all size classes of *D. mawii*. Though snorkeling may provide greater detection of some turtle species and size classes, the technique can be limited by dynamic water conditions and the difficulty in standardizing captures across observers with different abilities. For example, Polisar (1995) described several challenges with free diving for turtles, such as seasonal fluctuations in visibility and stream depth and the variation in the observer's ability to reach all depths to search for turtles.

The objectives of the present study were to compare species detection rates and assess capture by species and sex for snorkeling and baited hoop trapping for an assemblage of freshwater turtle species in southwestern Georgia. Streams in the southeastern United States, particularly those that drain into the Gulf of Mexico, are among the richest in turtle diversity in the world (Buhlmann and Gibbons 1997). Streams in southwestern Georgia contain as many as nine turtle species (Jensen et al. 2008). Georgia's State Wildlife Action Plan has identified monitoring populations and determining the effects of human activities on the composition and abundance of freshwater turtles as a priority conservation action (Georgia Department of Natural Resources, http://www.gadnr.org/cwcs/Documents/strategy.html). These objectives can be met with more rigor when capture techniques have been thoroughly assessed.

MATERIALS AND METHODS

Study area.—This study took place on Ichawaynochaway (Baker County, Georgia) and Spring Creeks (Decatur and Miller counties, Georgia) in the Lower Flint River Basin (LFRB) of southwestern Georgia. The creeks are located in the Dougherty Plain physiographic district, which is characterized by karst topography (Ward et al. 2005). Southwestern Georgia has a high variability in annual rainfall with an average of 1270 mm per year and precipitation and stream flows are lowest during summer (Golden and Hess 1991; Golladay and Battle 2002). In drainages of the LFRB, rocky limestone shoals and deep, wide, sandy pools are common. Both creeks have ground water input from the Upper Floridan Aquifer (Hicks, D.W., and S.W. Golladay. 2006. Impacts of agricultural pumping on selected streams in southwestern Georgia. Submitted to Georgia Environmental Protection Division, Atlanta, Georgia). During late spring and summer, both creeks are clear enough to see the bottom in most areas unless there have been recent rain events, which reduce visibility.

Turtle surveys.—We randomly selected seven 1-km study segments on each creek (14 total sites) and a 0.5-km section in the center of each 1-km segment as the focus of survey effort. We surveyed from June to August 2007 on Ichawaynochaway Creek and June to September 2008 on Spring Creek. We trapped using baited hoop traps over five consecutive nights twice during the sampling period and used snorkel surveys twice over the sampling period at each study section (for more detail, see Sterrett et al. in press). In most cases, both sampling methods were independent although due to water clarity limitations, these methods did overlap on several occasions.

During each survey, we placed five large (4-hoops 1.2-m diameter, 3.8-cm mesh size) and five small (3-hoops 0.9-m diameter, 3.8-cm mesh) hoop traps (Memphis Net and Twine, Memphis, Tennessee, USA) baited with fish in the center 0.5-km section of each 1-km study segment. We set traps approximately 50 m apart on alternating banks in locations where traps were mostly inundated by water. Traps were run for five consecutive nights and we them checked daily and re-baited as necessary.

During snorkel surveys, we standardized search effort as follows: 3–4 surveyors for 2–3 h (actual time was recorded), time of day (1300 EST start time, when possible), and surveyor experience, with 1–2 experienced surveyors and 1–2 volunteer surveyors on each survey. At least one experienced surveyor with extensive experience snorkeling and capturing turtles was present for all surveys. Volunteers were all wildlife biologists that varied in experience with freshwater turtles and snorkeling and contributed only a few days each to sampling. We quantified capture success as the number of turtles captured per person-hour. During each survey, we searched the study section twice (once upstream and once downstream). Surveyors thoroughly searched all accessible areas within each stream section. Particularly high numbers of captures in one section limited sampling in that section to one upstream search.

We measured maximum straight-line carapace length (CL), maximum plastron length (to the nearest 1 mm), and body mass (to the nearest 10 g) for each captured turtle. We gave each turtle a unique identification code by marking the marginal scutes (Cagle 1939), except softshell turtles (*Apalone* spp.), which were marked with zip-ties or notches following Plummer (2008).

Data analyses.—We used program PRESENCE (MacKenzie and Kendall 2002; Hines 2006) to estimate the single season detection probability (p) for the four most frequently captured turtle species for each method, each year. To use PRESENCE, at least 60 captures per species were required, so we did not calculate detection probabilities for infrequently captured species. In the analysis, we pooled data from both creeks and calculated sampling occasions as trap-nights [N = (10 traps set for 5 nights)(2 trapping sessions)(7 replicates [0.5-km sections])(2 creeks) = 1400] and snorkeling visits [N = (2 snorkeling sessions)(7 replicates [0.5-km sections])(2 creeks) = 28]. To calculate detection probability for both methods combined, we used the equation,

$$p_{\text{both methods}} = 1 - (1 - p_{\text{method 1}})(1 - p_{\text{method 2}})$$

(described in Farmer et al. 2009), where $p_{\text{method 1}}$ and $p_{\text{method 2}}$ were obtained from program PRESENCE. Standard error for detection probability estimates for

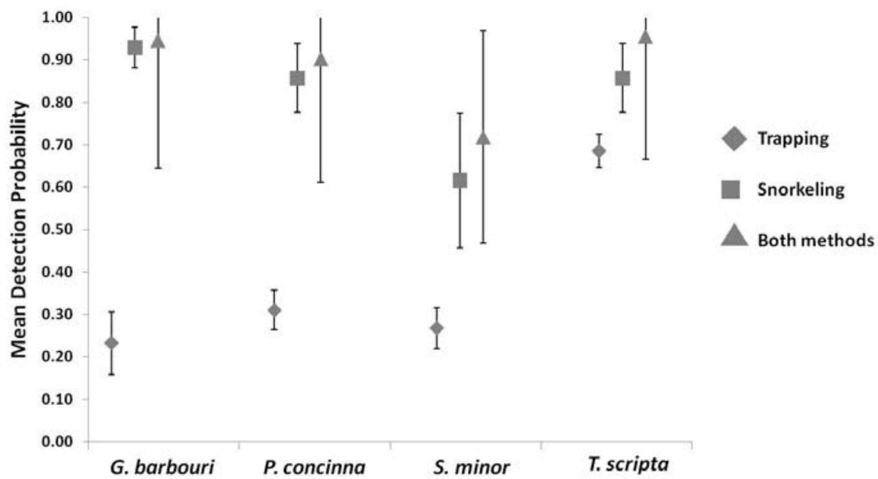

FIGURE 1. Mean detection probabilities (±SE) of the four most frequently captured turtle species by sampling method and for both methods combined. An uncapped standard error bar indicates a standard error of >1. Sampling was conducted on Ichawaynochaway (Baker County) and Spring Creeks (Decatur and Miller counties) in the lower Flint River Basin of southwestern Georgia,USA, in 2007–2008.

each species and each method were calculated using the delta method of
approximating standard error (Williams et al. 2002). We used Chi-square analysis to determine if the sex ratio of captured turtles differed among species. Means were considered significantly different at α = 0.10. We used a general linear model to investigate if capture method, sex, or species (independent variables) had any influence on carapace length of adults (dependent variable). We did not differentiate turtle capture by trap type until late in the study, so we could not examine the differences in detection probability between large and small hoop traps.

RESULTS

We trapped for 10 nights per study section (1400 trap nights total), which required approximately 10–20 person hours to set and check traps at each site. Effort-managed snorkeling required two 3-hour visits (9–12 person hours) per site (242.75 total person hours). We captured 674 individual turtles (823 total captures) representing nine species on the two creeks over the course of the study. Four species (Yellow-Bellied Slider, *Trachemys scripta*; Barbour's Map Turtle, *Graptemys barbouri*; River Cooter, *Pseudemys concinna*; Loggerhead Musk Turtle, *Sternotherus minor*) comprised 95% of all individual captures. We captured at least one individual of all nine species by both methods. We captured most (90%, n = 102) *G. barbouri* by snorkeling, whereas we captured most (88%, n = 301) *T. scripta* in traps. We captured 20 *T. scripta* and two *G. barbouri* with one method and later recaptured them with another method during the study. Captures by traps and snorkel surveys were similar for *P. concinna* (40% and 60%, respectively, n = 120) and *S. minor* (53% and 47%, n = 70). Ten of 14 recaptured *P. concinna* were captured with both methods. We only caught one *S. minor* with both methods. We caught most Alligator Snapping Turtles (*Macrochelys temminckii*; 72%, n = 18) by trapping. We caught Spiny Softshell Turtles (*Apalone spinifera;* n = 14), Florida Softshell Turtles (*A. ferox*; n = 1), and Common Snapping Turtles (*Chelydra serpentina*; n = 3) only in traps. All Florida Cooters (*P. floridana*; n = 7) were captured by snorkeling.

Detection probabilities for the four most frequently captured species were all greater for effort-managed snorkeling than for baited hoop trapping (Fig. 1). *Graptemys barbouri, P. concinna*, and *S. minor* all had similarly low detection probabilities with baited hoop trapping (Fig. 1). Baited hoop trapping produced a similar detection probability for *T. scripta* compared to snorkeling. The combination of snorkeling and baited hoop trapping did not significantly improve detection compared to snorkeling alone for any of the four most frequently captured species (Fig. 1).

With one exception, the distributions of male, female and juvenile turtles caught by snorkeling and baited hoop trapping were similar for the four most common turtle species (snorkeling χ^2 = 43.3, df = 6, *P* = 0.00; trapping χ^2 = 16.9, df = 6, *P* = 0.01; Fig. 2). The exception was that juveniles of *S. minor* were detected using snorkeling but were never captured in a baited hoop trap. More individuals of each sex of *T. scripta* were captured by trapping, while more individuals of each sex of *G. barbouri* were captured by snorkeling

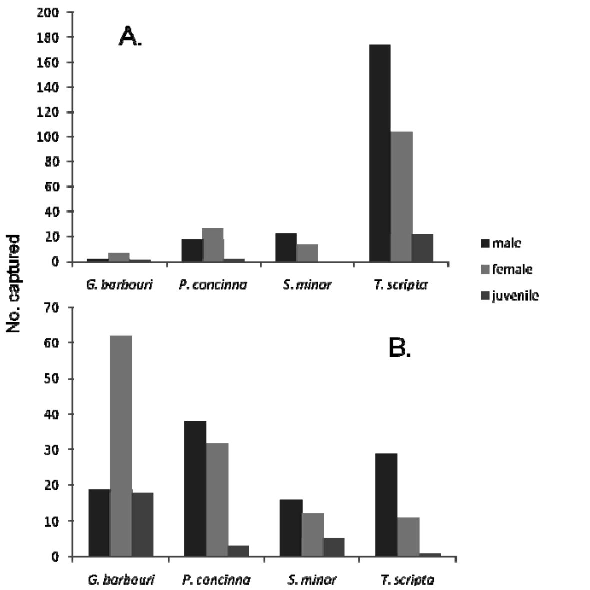

FIGURE 2. Number of turtles captured by sex for the four most frequently captured species on Ichawaynochaway and Spring Creeks, Georgia, USA, in 2007–2008. Sampling methods included A.) Large and small hoop traps (χ^2 = 16.9, df = 6, *P* = 0.01) and B.) Effort-managed snorkeling (χ^2 = 43.3, df = 6, *P* = 0.00).

(Fig. 2). The overall model showed that species and sex had significant effects on CL (*F* = 243.9, df = 3, *P* = 0.00 for species; df = 1, *F* = 152.86, *P* = 0.00 for sex; Fig. 3). However, method did not have a significant effect on CL of the four most frequently captured species (*F* = 0.021, df = 1, *P* = 0.88; Fig. 3).

DISCUSSION

The baited hoop net is a standard trap for freshwater turtles and is considered a reliable method for detecting many species (Plummer 1979). In our study, across all sampled habitat (7 km of creek), baited hoop trapping or snorkeling were both sufficient to detect all nine species of turtles expected to be present in the study streams; however, snorkel surveys yielded higher detection rates for the four most common species at the finer scale (within a 0.5 km section) and yielded captures of all obligate riverine species with the exception of *A. spinifera*. Baited hoop trapping yielded a detection probability similar to that of snorkel surveys only for *T. scripta* and the combination of the two methods had no measurable increase in detection over snorkeling alone. Therefore, our results suggest that baited hoop trapping is inferior to snorkeling for detecting river turtles in this system, particularly for rare species or species with habits that do not draw them to bait. When considering the effectiveness of a method, it is important to take into account the time, effort, and expertise required relative to the detection probability achieved. Further, the choice of method used in a particular system should be species specific.

With one exception, the two methods did not differ in the distributions of sexes or size classes of turtles. The one exception was the failure to capture juvenile *S. minor* in traps. This was likely due to their small size (hatchlings are 22–30 mm in CL; Ernst and Lovich 2009) and ability to slip through the mesh size of the standard hoop traps we used. Despite perceptions that small turtles are more cryptic than large turtles (Carr

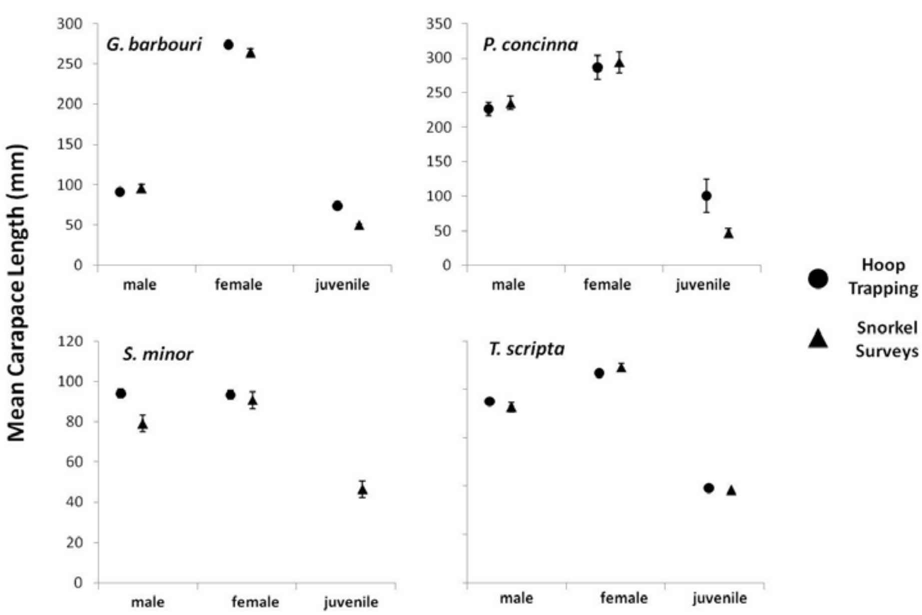

FIGURE 3. Mean carapace length of the four most frequently captured turtles by hoop trapping and effort-managed snorkeling on Ichawaynochaway and Spring Creeks, Georgia, USA, in 2007–2008. Error bars represent standard error.

1952), we found that small turtles were easily seen at the base of logs and twigs when snorkeling.

While our results suggest that snorkeling yields higher detection probabilities than baited hoop trapping with less effort (two days versus five), snorkeling may not be as effective in other contexts. Ichawaynochaway Creek and Spring Creek are relatively clear water bodies with excellent visibility on most summer days, when precipitation and flow are low. More degraded water bodies, which are arguably more common, are likely to have poor visibility, limiting the effectiveness of snorkeling. In these situations, baited hoop trapping may still be the most effective method for sampling turtles. Because detection can be low and vary among species, use of baited hoop traps should account for detection probability in predicting habitat occupancy by turtle species (*sensu* Rizkalla and Swihart 2006). In situations where baited hoop traps are the best option, methods such as basking traps or basking surveys should supplement trapping to detect species not attracted by bait.

Further, while the focus of this analysis was on detection of species within a section of creek, we acknowledge that the most efficient methods may differ if the objective is to capture large numbers of individuals for population estimation. Koper and Brooks (1998) report that neither baited hoop traps, basking surveys, nor hand captures were adequate for estimating turtle population size, but that a combination of methods improved the accuracy of estimates. Multiple methods tend to yield greater numbers of captures than any single method. In our study, neither of the two methods alone maximized captures for all species. Baited hoop traps captured many more *T. scripta* of both sexes, indicating that this method would be most useful in estimation of *T. scripta* population size. By contrast, snorkeling captured more *G. barbouri* of both sexes, indicating that this technique would be better suited to accurately estimating the species' abundance. Few *M. temminckii* (n = 18) were captured during the course of the study, suggesting that either the combined effort of both methods was not robust enough to capture large numbers of *M. temminckii* or densities are relatively low in this area (Jensen and Birkhead 2003). Greater sampling effort (more traps and/or more snorkeling surveys) might be required to capture sufficient numbers of this species to estimate population size. The surprisingly few captures of *A. spinifera* during the study remain a mystery. While conducting snorkel surveys, we observed two adult *A. spinifera*, but were unable to capture either individual. *Apalone spinifera* are known for their rapid swimming, which made it challenging for surveyors to make a capture once they had observed an individual. However, this species is often captured readily in baited hoop traps (Plummer 1979). It is possible that this species also occurs in low densities in the creeks sampled and that more trapping effort would be required to yield captures.

We did not attempt to use three other common methods for surveying turtles in this study: basking traps, direct observation of basking turtles, and fyke nets. Koper and Brooks (1998) suggested that basking observations are an efficient and unbiased way to estimate population size for *Chrysemys picta*. Basking traps and fyke nets are also effective for turtles not attracted to bait (Plummer 1979). We feel that at the scale of our study, the effort needed to use basking traps would not have improved detection and may not have increased greatly the numbers of turtles observed. Setting up basking traps and monitoring them would require a similar or greater effort than baited hoop trapping, and a greater effort than snorkeling. Further, basking trap effort would be difficult to standardize because of the need for available basking substrates to attach traps, and would be biased against species that bask under the surface of the water. We also did not attempt to install fyke nets in the stream sections because of the inability to reliably set these in limestone substrate and because of occasional high flows which may have damaged or dislodged nets during times of sampling. Vogt (1980) found fyke nets highly effective in pond and backwater areas, but noted their inconvenience in faster current.

Our results show that the most common method used in studies of aquatic turtles, baited hoop trapping, can have lower power to detect some species at finer spatial scales. We found that snorkel surveys provided a better level of detection than hoop trapping for all turtle species; however, hoop trapping did yield higher numbers of *T. scripta*. Collectively, the results suggest that the most effective method for sampling freshwater turtles will depend on the focal species and study objectives. Multiple capture methods may be required if the objectives are to accurately measure both habitat occupancy and abundance. Further, the most effective method is likely to vary depending on whether local conditions limit opportunities to use methods such as snorkel surveys.

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