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A Comparison of Three Sampling Gears for Capturing Aquatic Turtles in Missouri: The Environmental Variables Related to Species Richness and Diversity

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Abstract: *Donaldson Point Conservation Area (DPCA) is a lentic area within the Mississippi River floodplain that experiences seasonal flooding because of direct connectivity to the Mississippi River. Sampling for aquatic turtles was conducted during fall (October–November 2003) and spring (April–May 2004) using fyke nets, hoop nets and basking traps in both round and linear pools. Hoop nets were deployed with and without the use of leads, whereas paired fyke nets were positioned with their leads tied together or straight from the bank. The performance of each net and the turtle species captured were assessed. Catch-per-unit effort (CPUE) when using hoop nets and fyke nets was considerably greater in fall than in spring. Fyke nets set perpendicular to the bank produced a CPUE greater than did the other gears deployed in the spring and fall. We captured eight turtle species:* Trachemys scripta elegans, Graptemys pseudogeographica pseudogeographica, Alapone muticus muticus, Alapone spinifer spinifer, Sternotherus odoratus, Graptemys ouachitensis, Chrysemys picta dorsalis *and* Chelydra serpentina serpentina. *Species richness was greater in areas with deeper water with low transparency, and lower in water with high dissolved oxygen and with greater depth of hoop net deployment. Species abundance was the lowest when hoop nets were deployed in linear water bodies with high turbidity, lower pH and low dissolved oxygen. Because turtle species are important biotic components of large river communities, protecting floodplain aquatic habitats such as those found within DPCA may help sustain large river turtle assemblages.*

Key Words: *fyke net, hoop net, floodplain, Mississippi River, bootheel,* Trachemys, Graptemys, Apalone, Sternotherus, Graptemys, Chrysemys, Chelydra

Introduction

Lentic areas within the Mississippi River floodplain have been understudied because of sampling difficulties (Bodie et al. 2000). Floodplain habitats have high productivity (Megonigal et al. 1997) and provide habitat for freshwater turtle feeding, immigration, and reproduction (Wigley and Lancia 1998, Bodie et al. 2000). Unfortunately, much of the lentic floodplain habitat in the southeast and south-central U.S. has been lost or degraded (Dahl 2000). In southeast Missouri, for example, less than 10% of the historic bottomland hardwood forests remain today (MDC, unpubl. data). Further, in the middle Mississippi River (MMR – reach of river from Cario to St. Louis), the main river channel is disjunct from approximately 82% of its floodplain by an extensive levee system (Barko et al. 2006). Hence, little ecologically functional floodplain remains in this region.

Previous sampling projects in the MMR and southeast Missouri primarily emphesyed fishes (Barko et al. 2004a, 2004b; Open Rivers and Wetlands Field Station, unpubl. data). As a result, turtle data from large river floodplains along the MMR are lacking. Baseline data are needed to better understand how floodplains influence large river turtle assemblages and to provide baseline data to evaluate of the faunal impacts of such projects as the proposed St. Johns Basin-New Madrid Floodway Project (USACE 2002).

The sampling methods available for capturing aquatic turtles include a variety of hoop net configurations, basking traps, hand picking, and visual observations (Ream 1966, Dreslik and Kuhns 2000, Ream and Thomas 2002). However, no single sampling method is effective for all species in all habitats. Sampling methods need to be evaluated and standardized so that comprehensive and comparable assemblage surveys can be conducted throughout floodplains in Missouri and the southeast U.S. Furthermore, knowledge which methods are effective for sampling aquatic turtles in floodplains is needed to reliably document existing assemblages. Floodplain habitats in southeast Missouri provide habitat that could support rare species such as the Alligator Snapping Turtle (*Macroclemys temminickii*) and Western Chicken Turtle (*Deirochelys reticular miaria*) (Johnson 2000). Previous studies in this region yielded little information about the presence and quantity of these species, because these studies were species specific (Santhuff 1993, Shipman and Riedle 1994).

The objectives of this study were 1) to compare the number of aquatic turtles captured using three gear types and, 2) model the habitat variables that are correlated with species richness and species abundance.

Methods

Sampling Site

Our study was conducted at Donaldson Point Conservation Area (DPCA), New Madrid County, Missouri. This conservation area consists of a large river floodplain that is unobstructed by levees (Fig. 1). Hydrology is influenced by seasonal flooding by the Mississippi River (Fig. 2). Donaldson Point Conservation Area is dominated by a bottomland hardwood forest composed of eastern cottonwood *Populus deltoides*, hackberry *Celtis occidentalis*, box elder *Acer negundo*, green ash *Fraxinus pennsylvanica*, pecan *Carya illinoinensis,* silver maple *Acer saccharinum*, sweet gum *Liquidumbar styraciflua*, and sycamore *Platanus occidentalis* (MDC 2000). Natural depressions and floodplain pools within DPCA support bald cypress *Taxodium distichum* and tupelo *Nyssa aquatica* (MDC unpublished data 2000). Blew holes, borrow pits, and chutes comprise 25.5 ha of the aquatic habitat. Aquatic habitat sampled and designated round or linear. Land use in areas surrounding DPCA is primarily agricultural, with the crops including cotton (*Gossypium hirsutum*), rice (*Oryza sativa*), soybeans (*Glycine max*), and corn (*Zea mays*) (MDC unpblished data 2000).

Sampling Techniques

Data were collected during October–November 2003 and April–May 2004. We sampled these months because water temperatures generally exceeded 15°C, which presumably ensured turtle activity (Finkler 2004).

Aquatic habitats were selected and designated round (R) or linear (L). We divided all aquatic habitats into 50 × 50 m grids using a Geographic Information System (GIS) and aerial photography. We then assigned each grid a number, and selected sampling sites using a random number generator. Three types of gear were deployed: hoop nets, fyke nets, and basking traps.

Hoop nets were 1.2 m long and consisted of seven fiberglass hoops, with the first being 1.2 m in diameter. Successive hoops decreased in 2.5 cm increments towards the cod end. The

Figure 1. Location of Donaldson Point Conservation Area, New Madrid County, MO. in relation to the Mississippi River. Site types, Round (R) and Linear (L) are also indicated.

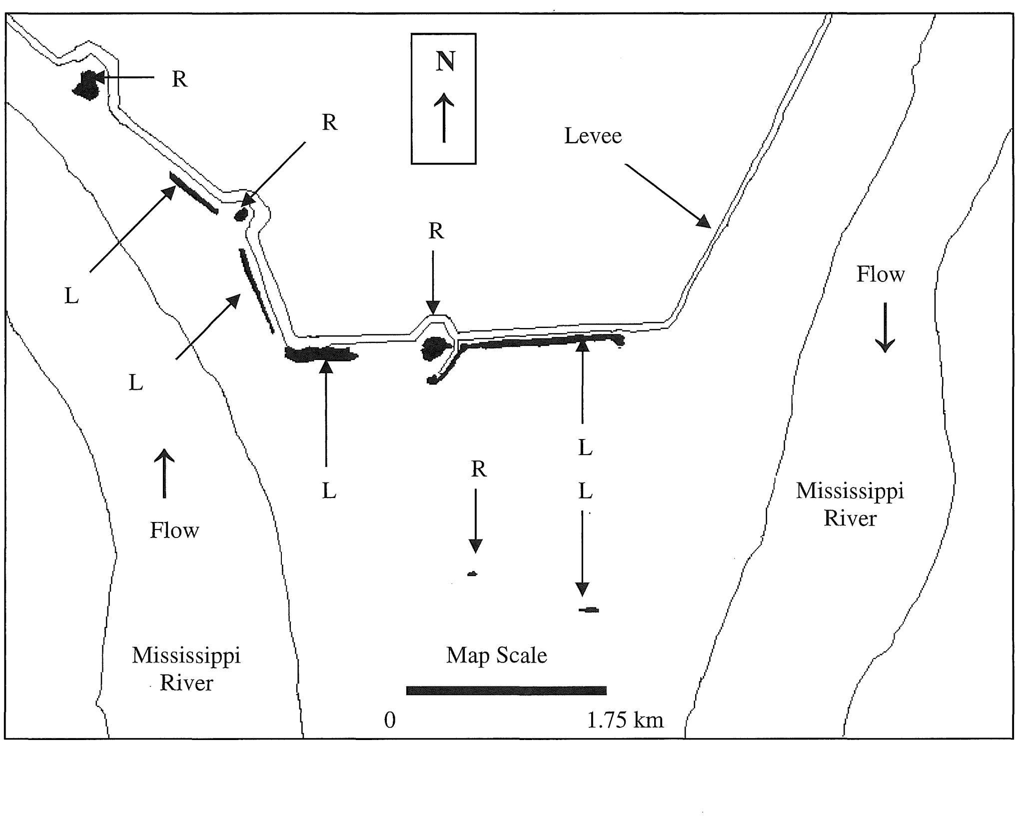
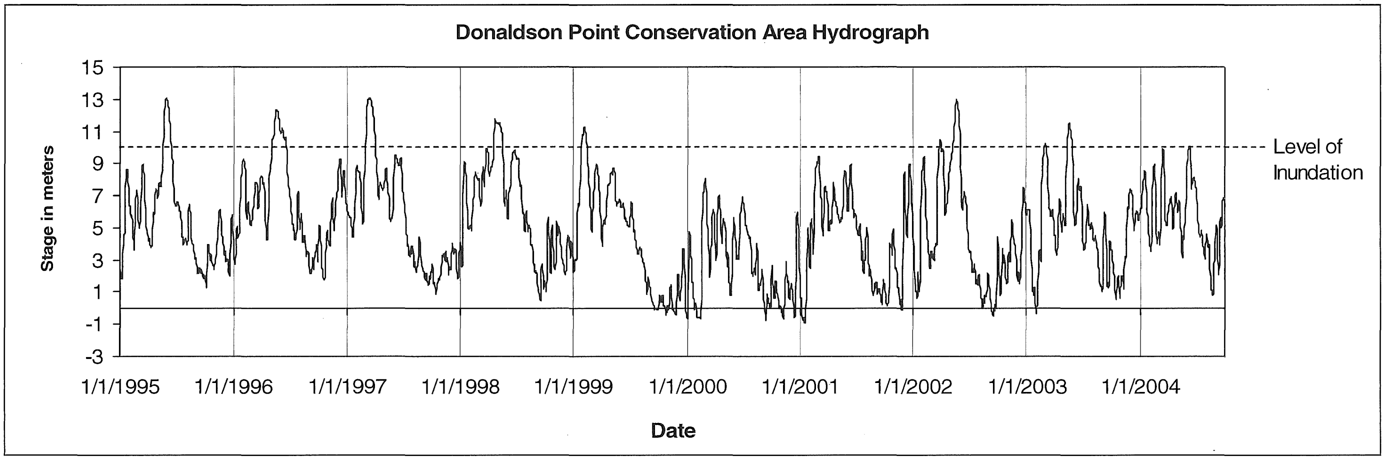


Figure 2. Seasonal flooding cycles where Donaldson Point Conservation Area is inundated at a river stage of 10 m. Location of river gauge (latitude. 36-34-59, longitude 89-31-56 at Lower Mississippi River KM 1430.7).



mesh was 1.8 cm bar (consistent with that of our fyke nets). Finger-style throats were attached at the second and fourth hoops of each net. The throat apertures (size of the throat opening) were 50.4 cm and 39.6 cm diameter, respectively. Hoop nets were set in two configurations to determine the effectiveness of a lead extending from the opening. Hoop net pairs with a lead were set with their open ends facing each other. Leads were 1.2 m × 10 m with a mesh size of 0.32 cm bar. Hoop nets with no leads were run in the same configuration but bridles of 10 m × 0.3 cm rope were used to hold the nets in place. Rock bags were attached to the cod ends of all net sets to prevent the nets them from collapsing.

Fyke nets consisted of a lead, frame, and cab. The lead was 15 m long and 1.3 m high. The frame and cab together were 6.0 m long when fully extended. Two rectangular spring-steel rods that were 0.9 m high and 1.8 m wide formed the frame. Two mesh wings extended from the sides of the first frame to the middle of the second frame forming a 5.1 cm vertical gap, and the cab was constructed of six 0.9 m diameter steel hoops. There were two throats, one on the first hoop (40 mesh aperture) and on the third hoop (32 mesh aperture). Fyke nets were set in two different configurations to determine the efficacy of having one large lead between two fyke nets compared to two separate leads. One configuration consisted of two fyke nets tied lead to lead so that the combined lead length was 30 m. The second configuration was a single fyke net set with the lead tied to the bank with the remainder of the net running perpendicular into the water. For every fyke net pair set with leads tied together, two LTRMP fyke nets were run off the bank.

Basking traps consisted of 15.24 cm PVC cut into 0.9 m sections fitted together using 90° elbows to form a square float. From this float, 1.8 cm bar mesh netting was hung to form a basket underneath. From the top of the float, a 90 cm × 5 cm × 20 cm board was placed bisecting the float. At each end of the board, 50 cm × 5 cm × 20 cm boards were attached using hinges. These end boards angled down and into the water forming ramps that enabled turtles to climb onto the board to bask.

Each gear was set a minimum of 10 times each season. The sample site was recorded using Global Positioning System (GPS) coordinates, and all gear were baited with cut fish and set for 24 h. Bait consisted of a mixture of shortnose gar *Lepisosteus platostomus*, common carp *Cyprinus carpio*, bluegill *Lepomis macrochirus*, and gizzard shad *Dorosoma cepedianum* (Santhuff 1993). For each net set, the date, time, UTM, gear, site type, effort in time (h/min.), water temp (°C), dissolved oxygen (mg/1), Secchi disk visibility (cm), specific conductance (µS/cm), and water depth at gear deployment (m) were recorded. All captured turtles were identified to species, abundance, and measured for carapace length (mm).

Statistical Analyses

Before analysis, we separated turtles into adult and juvenile categories following reported carapace lengths (Johnson 2000). We used a Principal Components Analysis (PCA) on each data set to reduce the dimensionality of the environmental variables (SAS v.6, 1989). We then used stepwise multiple regression with indicator variables in an effort to describe the relationship between the predictor and response variables (Neter and Wasserman 1974; Kullberg and Scheibe 1989; Barko et al. 2004a). For example, if sampling occurred in the spring, $X_1 = 1$ and 0 otherwise (i.e., fall sample). The default conditions were used for entrance into the model ($P \leq 0.15$), and only sampling episodes that captured turtles were used in these analyses.

The regression model for species richness had the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where X_1 represents Secchi transparency, X_2 represents dissolved oxygen, X_3 represents hoop netting, and X_4 represents depth of gear deployment.

The regression model for species abundance had the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where X_1 represents Secchi transparancy, X_2 represents dissolved oxygen, pH, and turbidity, X_3 represents hoop nets, and X_4 represents hole shape and season.

To evaluate the efficacy of each gear type, we compared overall CPUE for each gear type and CPUE for each species captured.

Results

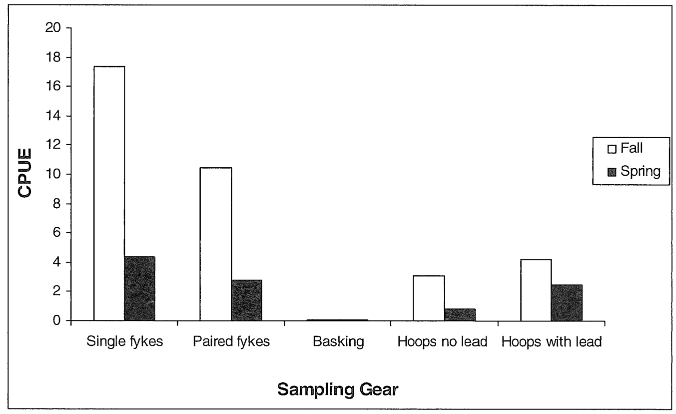
We captured a total of 724 turtles representing eight species (Table 1); 92% were adults and 8% were juveniles. Eighty-three percent of all turtles captured were trapped in fall. The most abundant turtle was red-eared slider *Trachemys scripta elegans* (64%), followed by false map turtle *Graptemys pseudogeographica pseudogeographica* (28%).

Single fyke nets captured the most turtles in both seasons, followed by fyke net pairs with attached leads, hoop nets with leads, hoop nets without leads, and basking traps (Fig. 2). The same trend held when CPUE was examined for species representing $\geq 1\%$ of the relative abundance (Fig. 3). Environmental variables measured at the sampling sites varied among seasons (Table 2). In summary, Secchi transparency, conductivity, temperature, net depth, pH and DO were generally higher in the fall, whereas turbidity was generally higher in the spring.

Table 1. Turtle species and abundance collected at sampling sites within Donaldson Point Conservation Area, Missouri, during fall 2003 and spring 2004.

Turtle Species	Fall 2003	Spring 2004	Total
Red-eared slider (*Trachemys scripta elegans*)	402	62	464
False map turtle (*Graptemys pseudogeographica p.*)	161	40	201
Common snapping turtle (*Chelydra serpentina s.*)	11	12	23
Stinkpot (*Sternotherus odoratus*)	16	1	17
Southern painted turtle (*Chrysemys picta dorsalis*)	8	2	10
Eastern spiny softshell (*Alapone spinifera s.*)	0	7	7
Midland smooth softshell (*Alapone muticus m.*)	0	1	1
Ouachita map turtle (*Graptemys ouachitensis o.*)	0	1	1
Total	598	126	724

Figure 3. Seasonal comparison of catch-per-unit effort (CPUE) by gear types deployed at Donaldson Point Conservation Area in fall 2003 and spring 2004.



For species richness, the first 7 PCA axes produced eigenvalues greater than 1.0 (3.1, 2.1, 1.7, 1.5, 1.3, 1.1, and 1.0, respectively), yet only axes 1, 2, 3, and 7 explained a significant amount of variation (41%) and remained in the stepwise regression model ($F = 18.84$, d.f. = 4, 107, $\underline{P} < 0.0001$; Table 3). The eigenvectors that defined these axes were: PCA1 = Secchi transparency (–0.51), PCA2 = dissolved oxygen (–0.50), PCA3 = hoop nets (–0.75), and PCA7 = depth of gear deployment (0.70). Species richness was greatest when gears were deployed in deeper waters, whereas richness declined as transparency (Secchi depth) increased, dissolved oxygen increased, and hoop nets were deployed (Table 3). This model did not reveal any

Table 2. Mean ($\pm$SD) and range (in parentheses) of values for environmental variables collected at turtle sampling sites within Donaldson Point Conservation Area, Missouri, during fall 2003 and spring 2004.

Environmental Variables	Fall 2003	Spring 2004
Secchi transparency (cm)	57.2 ± 17.9 (100–33)	36.8 ± 12.4 (54–18)
Conductivity (µS/cm)	404.7 ± 65.7 (607–331)	384.8 ± 15.4 (402–353)
Temperature (C°)	20.2 ± 3.3 (25.7–14.0)	18.3 ± 2.3 (22.5–14.5)
Depth at net deployment (m)	2.1 ± 1.0 (4.5–0.5)	1.9 ± 1.9 (9.8–0.6)
pH	8.0 ± 0.7 (9.3–6.9)	7.9 ± 0.4 (8.4–7.2)
Turbidity (NTU)	$13.7 + 6.0$ (27.0–6.4)	30.0 ± 18.5 (74.0–11.5)
Dissolved oxygen (mg/L)	$9.3 + 4.5$ (17.3–3.6)	7.2 ± 2.4 (11.3–3.2)
Mean fish length (mm)	$160.8 + 28.5$ (240.0–101.33)	174.1 ± 61.2 (435.5–92.5)

Table 3. Results of the stepwise multiple regression analysis comparing species richness of turtles sampled at Donaldson Point Conservation Area, Missouri, to environmental variables measured at each sampling site and three gear types.

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	P	Model R^2
Intercept	1.2590	0.0850	177.5089	219.49	<0.0001	
PCA Axis 2	0.3686	0.0669	31.8992	39.44	<0.0001	0.2163
PCA Axis 3	0.3488	0.0662	22.4111	27.71	<0.0001	0.3682
PCA Axis 1	0.1099	0.0484	4.4628	5.15	0.0253	0.3965
PCA Axis 7	–0.1470	0.0839	2.4825	3.07	0.0826	0.4133

Table 4. Results of the stepwise multiple regression analysis comparing turtle species abundance environmental variables measured at each sampling site and three gear types deployed at Donaldson point Conservation Area, Missouri.

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	P	Model R^2
Intercept	5.0625	0.8024	2870.4375	39.81	<0.0001	
PCA Axis 2	2.0464	0.5542	983.1294	13.63	0.0004	0.0948
PCA Axis 3	2.1145	0.6256	823.7565	11.42	0.0010	0.1742
CA Axis 1	1.3731	0.4572	650.3244	9.02	0.0033	0.2368
PCA Axis 4	–1.0970	0.6552	202.0310	2.80	0.0971	0.2563

significant effects of conductivity, fyke nets, basking traps, turbidity, pH, hole shape, mean fish length, or season.

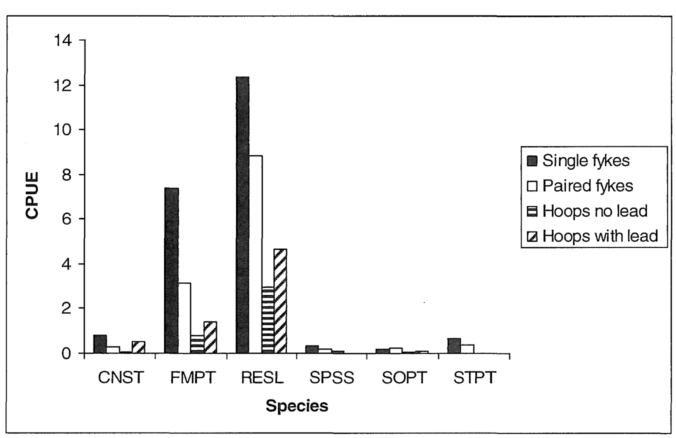
For species abundance, the first 7 PCA axes produced eigenvalues greater than 1.0 (3.1, 2.1, 1.7, 1.5, 1.3, 1.1, and 1.0, respectively), yet only axes 1, 2, 3, and 4 explained a significant amount of variation (26%) and remained in the stepwise regression model ($F=9.22$, d.f. $=4$, 107, $P<0.0001$; Table 4). The eigenvectors that defined the axes were: PCA1 = Secchi transparency (–0.50), PCA2 = turbidity (0.42), pH (–0.40), and dissolved oxygen (–0.50), PCA3 = hoop nets (–0.75), and PCA4 = hole type (0.52) and season (–0.48). Species abundance declined when Secchi transparency increased, hoop nets were deployed, gears were deployed in linear holes in the spring, and sample sites had higher turbidity combined with lower pH and dissolved oxygen. This model did not reveal any significant effects of conductivity, fyke nets, basking traps, depth at gear deployment, or temperature.

Discussion

Given the location of DPCA in relation to the Mississippi River, river water flows over and through the area at approximately 2–3 m/s at flood stage, which likely affected the spring assemblage. Studies have suggested that spring and fall mating peaks increases turtle activity (Cagle 1950). However, we captured more turtles in the fall, suggesting that activity was greater during this season. We speculate that the difference in relative abundance of turtles captured among our sampling seasons may be due to spring flooding of DPCA, contributing to higher turbidity levels. This may hinder the ability of turtles to carry out courtship rituals, which in turn may lead to lower turtle activity during spring mating peak. For example, courtship in red-eared sliders as explained by Cagle (1950), consists of a delicate "dance" by the male who, positioned in front of the female, swims backwards while the female swims forward. While the dance takes place the male titilates the females head. This dance is highly unlikley to occur where water velocity is of 2 m/s (Cagle 1950, Ernst and Barbour 1972). Because of spring flooding at DPCA, turtles may concentrate their courtship and mating habits during the fall; hence, the reason catch was greatest during this season.

Seasonal flooding may have other implications regarding habitat use by turtles. Bodie et al. (2000) showed that *T. scripta*

Figure 4. Comparison of catch-per-unit effort (CPUE) by gear types for each species (CNST = common snapping turtle, FMPT = false map turtle, RESL = red-eared slider, SPSS = eastern spiny softshell, SOPT = southern painted turtle, STPT = stinkpot) captured at Donaldson point Conservation Area in fall 2003 and spring 2004. Basking gear and the midland smooth softshell was omitted due to low catch rate.



used scoured wetland habitats in the fall for overwintering, which may also help explain the greater number captured in the fall. Bodie and Semlitsch (2004) found that turtle species moved to seasonal wetlands from March–August because of the increased productivity in these habitats during this time. Lower water levels often occur in the fall, concentrating turtle populations (Cagle, 1950), which could also contribute to greater trapping success.

Red-eared sliders were caught in the greatest abundance in the fall and spring, which may be due to their preference for calm shallow water with the soft substrate, and presence of aquatic vegetation during much of the year (Cagle 1950, Ernst and Barbour 1972) which occurs at DPCA during much of the year. This species has not been shown to exhibit intraspecific competition through aggression for food or available habitat, which may contribute to the abundance commonly seen in red-eared sliders (Cagel 1950). Map turtles were less abundant at DPCA, likely because their preferred habitat includes large rivers and their adjacent backwaters (Ernst 1994), not floodplain pools. We speculate that these species were washed into the area because of seasonal flooding from the MMR, along with other big river turtle species such as spiny and smooth soft shells (Ernst 1999).

Observed species richness was greatest when fyke nets were deployed in deeper water. This may reflect the fact that our fyke net leads were set perpendicular to the bank, with depth being recorded at the cod end of the net. When deployed in deeper water, the lead extended across a greater range of depths, which could have captured different species that inhabit these different depths. Species differences in feeding may explain the differences in depth preference. For example, southern painted turtles forage along the bottom (Ernst 1994), whereas common snapping turtles may actively peruse or ambush their prey (Ernst 1994). Red-eared sliders forage along shallow edges (Ernst 1994), whereas false map turtles specialize in mollusks using a search and grab method (Ernst 1994). The lesser species richness in our hoop net captures is likely has a similar explanation. Hoop nets deployed, with or without leads, covered an area with a relatively consistent depth, and thus would probably not capture turtles foraging along the bank, reducing the likelihood of capturing species with this feeding strategy.

The fact that high transparency and low turbidity were associated with lower richness and abundance is likely a reflection of leads being used on most of our gears. In relatively clear water, leads and nets become more visible and may be more easily avoided by turtles. The lower catch of turtles during the spring in linear holes may be a consequence of linear holes having been more subject to flowing and deeper flood water, which would decrease turtle population density and, the lower catch (Cagle, 1950).

In general, our findings support those of Barko et al. (2004c) who also captured more turtles in fyke nets. Barko et al. (2004c) speculated that this was because of the 15-m lead attached to these nets, which likely created a greater opportunity for turtles to come into contact with the gear. In our study, we used the same length lead, which was longer than the 10-m lead used on our hoop nets. Although hoop nets have been used in many turtle studies (e.g., Frazer et al. 1991, Busby and Parmelee 1996, Harrel et al. 1996) and have been reported to capture approximately 3 to 5 turtles/net night in southeast Missouri as bycatch (Barko et al. 2004c), our findings indicate that fyke nets have the greatest efficacy for capturing turtles in large river floodplain systems, especially in the fall.

Our study suggests that large river floodplain turtle assemblages may respond to seasonal cues differently than lentic assemblages that are not subjected to unpredictable flood spates. The presence of large river species in our floodplain habitats suggests that lentic floodplain pools, with seasonal connections to large rivers, may be important for these species. Because information on the effect of flood pulse on the behavior of turtles is unknown, studies in large river floodplains are warranted.

Acknowledgments

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