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Changes in a Turtle Community from a Northern Indiana Lake: A Long-Term Study[1]

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Abstract.—**Knowledge of the long-term dynamics of freshwater turtle communities is important if we are to understand fully the impacts of human-induced changes in their aquatic and terrestrial habitats. We present data on a turtle community that has been monitored intermittently for more than 20 years and regularly for more than 10 years (1992–2003). The composition of the community has shifted with a decrease in the dominance of Painted Turtles (*Chrysemys picta*). This shift reflects a decline in the number of *C. picta* over the past decade, whereas numbers of other species have remained relatively constant. Adult survivorship of *C. picta* has declined in the past decade. The proportion of *C. picta* with watercraft propeller damage has increased, whereas propeller damage has remained constant for the two other species for which we have data, the Northern Map Turtle (*Graptemys geographica*) and the Red-Eared Slider (*Trachemys scripta*). Our study suggests that the turtle community in Dewart Lake has shifted from 1992–2003. It seems likely that this shift has occurred because of a decline in *C. picta*, possibly as a result of increased use of the lake by humans.**

Understanding the long-term dynamics of freshwater turtle communities is important if we are to understand fully the impacts of human-induced changes in aquatic and terrestrial habitats inhabited by freshwater turtles. Because most freshwater turtles are relatively long-lived (Gibbons, 1987), short-term studies or "snapshots" of freshwater turtle community responses to human-induced changes may not give a true picture of the ultimate consequences of such changes for turtle community composition and structure. However, it is becoming increasingly clear that freshwater turtle populations and communities are under growing pressures from human activities and associated alterations of the environment (e.g., Garber and Burger 1995; Klemens, 2000; Marchand and Litvaitis, 2004; Steen and Gibbs, 2004).

We present data on a freshwater turtle community that has been monitored intermit-

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tently for more than 20 yr, with reference data dating back nearly 40 yr. With these data, we consider short-term and long-term fluctuations in the composition of this turtle community, as well as changes in the abundances of individual species. Few studies have considered temporal changes in turtle communities (e.g., Stone et al., 1993; Congdon and Gibbons, 1996). In addition, there has been a rapid increase in the recreational use of the study lake (Dewart Lake) in the past decade; thus, we are particularly interested in assessing whether such changes have impacted this community of turtles.

Methods and Materials

Study Area.—We studied the community of freshwater turtles in the marsh at the southeast end of Station Bay (area = 4.5 ha) in the southeast corner of Dewart Lake near Syracuse, Indiana (Kosciosko County). Turtle populations have been studied in Dewart Lake for over 40 years (see Wade and Gifford, 1965), with relatively regular study since 1979 (see Iverson, 1988; Smith and Iverson, 2002, 2004).

Significant residential development of the shoreline of Dewart Lake was begun by 1965 and had nearly reached saturation, with respect to construction, in the late 1970s to early 1980s (JFNew, Dewart Lake diagnostic study, Unpubl. report for the Dewart Lake Protective Association [Available from GRS], 2005). The vast majority of the shoreline of Dewart Lake is now lined with concrete seawalls (JFNew, Dewart Lake diagnostic study, Unpubl. report for the Dewart Lake Protective Association [Available from GRS], 2005). Boat access to the lake by nonresidents likely increased in the late 1980s with the creation of a public access point by the Indiana Department of Natural Resources in 1985, and a further increase likely occurred with the paving of the boat launch in the early 2000s (JFNew, Dewart Lake diagnostic study. Unpubl. report for the Dewart Lake Protective Association [Available from GRS], 2005).

Methods.—We have sampled the turtle community in Station Bay nearly annually (in late July through early August) since 1979 using a variety of trapping and capture methods. Station Bay surveys prior to 1992 used aquatic wire funnel traps (N = 5–15; see Iverson, 1979). These traps inadequately sampled the entire turtle community (see Appendix 1), and hence, we did not analyze the community data for these years. However, we did use the data from marked individuals from these years for survivorship and propeller damage estimates (see below).

Starting in 1992, we surveyed Station Bay with 2.5-cm mesh fyke nets (N = 2–10) deployed with 15-m leads between a pair of 90-cm hoop diameter funnel traps. Fyke nets quickly trapped fish, which served as bait; no supplementary bait was necessary. Traps were checked every 2–3 h from sunrise to 1–2 hours postsunset. No species of turtle entered the trap during the night (Smith and Iverson, 2004). All captured turtles were retained and released at the end of the sampling period (2–5 days). We individually marked all *Chrysemys picta* more than 100 mm in carapace length with various combinations of notches in the marginal scutes of the carapace and on the plastron. We also individually marked all *Graptemys geographica* and *Trachemys scripta*; however, samples sizes and recapture rates of these species were too low to allow survivorship estimates. We did not mark the other species because marks were easily lost or confused with natural erosion of the carapace (e.g., *Sternotherus odoratus*), or logistical difficulties with marking or the very low numbers captured each year made marking untenable (e.g., *Apalone spinifera*, *Chelydra serpentina*). For each trap check, we recorded the number of each species captured. We also noted any individuals bearing signs of propeller wounds from encounters with motorized watercraft.

Statistical Methods and Analyses.—We analyzed population trends by using capture rates per trap day and total number of captures for each species and regressing these on year. We report total capture data as well as per trap day data because the number of fyke nets varied among years, but the area trapped did not.

To analyze trends in community structure, we used a two-dimensional, nonmetric multidimensional scaling (MDS) procedure to ordinate the proportional representation of the seven turtle species in the fyke net years (Kenkel and Orloci, 1986). Multidimensional scaling was used because it makes few assumptions about the distribution of species included in the ordination, and the MDS axis coordinates (i.e., Dimensions 1 and 2 below) are linear and orthogonal, allowing use of ANOVA and related tests (e.g., Kenkel and Orloci, 1986). MDS analysis was performed on the standardized Euclidean distance matrix of the proportions to standardize the variance. Correlations of the two MDS dimensions with the turtle species were used to assist in interpreting the two MDS dimensions produced in the analysis (e.g., Tessier and Welser, 1991; Rettig, 2003). We regressed the MDS dimensions on year to look for trends in the community structure.

Based on mark-recapture records, we estimated survival for *C. picta* more than 100 mm carapace length using the mark-recapture model (basically the Cormack-Jolly-Seber model) of the program MARK (White and Burnham 1999). The fully parameterized model provided the best goodness of fit ($P \leq 0.05$ in all three cases). In addition, we compared the proportion of total

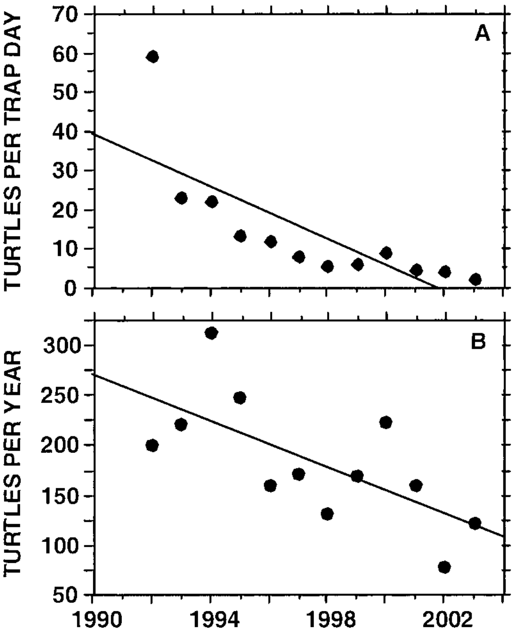

FIG. 1. (A) Number of *Chrysemys picta* caught per trap day from 1992–2003; (B) total number of captures of *Chrysemys picta* caught in a given year from 1992–2003.

captures of *C. picta* made in each year that were first-year turtles.

We tallied the proportion of *C. picta*, *G. geographica*, and *T. scripta* with a carapace length over 100 mm captured each year that showed signs of propeller damage. Given the fact that turtles are long-lived, they will accumulate propeller scars as they grow; therefore, the proportion of turtles bearing such scars might be expected to increase over time. However, young turtles will be constantly added to the population and older turtles will be disappearing; therefore, we do not believe the accumulation of propeller scars as turtles grow older should bias our results or interpretations. This applies in particular to our species comparisons because we might expect all three species to accumulate scars over time. Thus, any difference in accumulation rates among species should be a result of differential susceptibility to propeller wounds.

TABLE 1. Results of regression analyses of the changes in captures per trap day and total captures for five species of turtle from Station Bay, Dewart Lake from 1992 to 2003. $N = 12$ in all cases. N.S. = not significant.

	Captures per trap day	Total captures
Sternotherus odoratus	$r^2 = 0.46$, $P = 0.014$, slope $= -0.32$	N.S.
Chelydra serpentina	$r^2 = 0.45$, $P = 0.017$, slope $= -0.10$	N.S.
Graptemys geographica	$r^2 = 0.36$, $P = 0.038$, slope $= -0.08$	N.S.
Trachemys scripta	$r^2 = 0.43$, $P = 0.021$, slope $= -0.05$	N.S.
Apalone spinifera	N.S.	N.S. (if outlier year [1992] excluded)

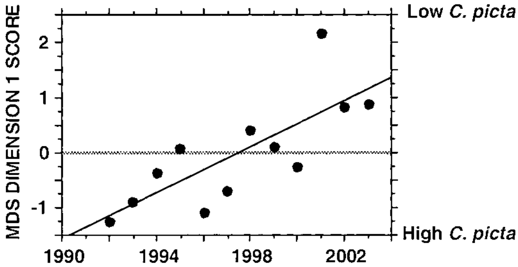

FIG. 2. Changes in Dimension 1 scores from the Multidimensional Scaling analysis of the turtle community of Station Bay, Dewart Lake during the fyke net years (1992–2003) using proportional representation of each turtle species.

RESULTS

Population Trends.—Number of painted turtles, *C. picta*, caught per trap day declined from 1992 to 2003, with a relatively steep decline from 1992 through 1996 (Fig. 1A; $N = 12$, $r^2 = 0.79$, $P = 0.0001$; Turtles per trap = 6701–3.35[year]). There was also a consistent decline in the total number of *C. picta* captures per year (Fig. 1B; $N = 12$, $r^2 = 0.45$, $P = 0.017$; Total captures = 23385–11.62 [year]).

For the other species of turtles in Station Bay, there were significant declines in the number of turtles caught per trap day (except *A. spinifera*), but there were no significant changes in the total number of captures per year from 1992 to 2003 (Table 1).

In addition to the six relatively common species of turtles, we rarely encountered Blanding's Turtles (*Emydoidea blandingii*) during our study from 1979–2003 (i.e., no more than one in any given year). We captured a single Spotted Turtle (*Clemmys guttata*) by hand in May 1984.

Community Trends.—The MDS analysis produced two dimensions explaining 99.98% of the variance. The first dimension of the MDS analysis on the proportional representation of each species increased over the years (Fig. 2; $N = 12$, $r^2 = 0.59$, $P = 0.0035$). Dimension 1 was negatively related to the proportion of *C. picta*, positively related to *S. odoratus*, and not related to *C. serpentina*, *E. blandingii*, *G. geographica*, *T.*

TABLE 2. The relationships between Dimensions 1 and 2 of a Multidimensional Scaling Analysis on the proportional representation of each turtle species from 1992–2003 in Station Bay of Dewart Lake. See text for explanation.

	Dimension 1		Dimension 2	
	r	*P*	*r*	*P*
C. picta	−0.89	0.0001	0.30	0.35
S. odoratus	0.99	< 0.0001	−0.06	0.86
C. serpentina	0.26	0.42	0.54	0.07
E. blandingii	0.21	0.52	−0.24	0.45
G. geographica	−0.30	0.34	−0.94	< 0.0001
T. scripta	0.39	0.21	0.25	0.43
A. spinifera	0.16	0.61	0.34	0.28

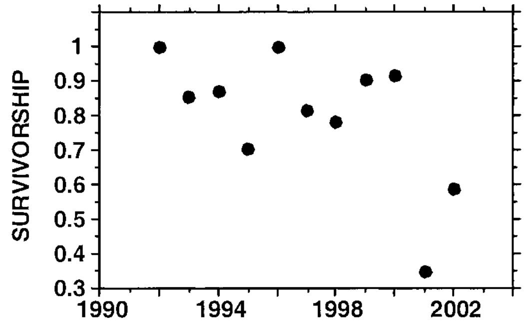

FIG. 3. Estimates of annual survivorship of *Chrysemys picta* in Station Bay, Dewart Lake from 1992–2003.

scripta, or *A. spinifera* (Table 2). The second dimension was not related to the year ($N = 12$, $r^2 = 0.02$, $P = 0.71$) or the proportions of *C. picta*, *S. odoratus*, *C. serpentina*, *E. blandingii*, *T. scripta*, and *A. spinifera* but was negatively related to the proportion of *G. geographica* (Table 2). This MDS analysis suggests that there was a shift in the structure of the Station Bay turtle community, with a decline in *C. picta*, an increase in *S. odoratus*, and a peak in the abundance of *G. geographica* during the middle of the study.

Survival and Age Structure of Chrysemys picta.—The Cormack-Jolly-Seber estimates for adult *C. picta* show relatively high survival throughout most of the study period; however, survival seems to have declined during the study (Fig. 3). The proportion of *C. picta* captured in a year that were first year turtles did not show any significant trends over time ($N = 8$, $r^2 = 0.006$, $P = 0.86$).

Propeller Damage Trends.—For *C. picta*, the proportion of captured turtles that showed signs of propeller damage increased throughout the study period (Fig. 4; $N = 11$, $r^2 = 0.51$, $P = 0.013$; Proportion = –19.3 + 0.01[Year]). The proportions of captured *G. geographica* ($N = 11$, $r^2 = 0.25$, $P = 0.12$) and *T. scripta* ($N = 11$, $r^2 = 0.122$, $P = 0.29$) showing signs of propeller damage showed no pattern during the study period (Fig. 4)

DISCUSSION

Our results strongly suggest that there has been a change in the turtle community in Station Bay of Dewart Lake from 1992–2003. It appears that much of the shift in the community has been the result of a recent decline in the abundance of *C. picta*. For *C. picta*, both catch per trap-day rates and the total number of captures declined even though the number of traps that we used increased. In contrast, total numbers of captures of the other species showed no changes. A drastic decline in the population of *C. picta* was also observed on the E. S. George Reserve in Michigan between the late 1950s and the late 1960s, but its cause was not determined (Wilbur, 1975; Congdon and Gibbons, 1996).

Why does *C. picta* show such a decline in numbers, whereas other turtles show no decline? Survival of adult *C. picta* was fairly high throughout much of the study but dropped significantly in recent years (Fig. 3). The proportion of captures that were first-year *C. picta* did not change significantly over time, suggesting that the population structure remained constant and that recruitment was in proportion to the size of the population. Thus, it appears that differential survival among the turtle species in this community may be at the root of the change in the community. Unfortunately, we cannot estimate survival for the other species of turtles, because of low capture and recapture rates and inability to mark individuals reliably (e.g., *S. odoratus*).

An alternative explanation is that *C. picta* simply moved to other parts of Dewart Lake in recent years. We do not believe such an explanation is likely. First, we rarely caught a Station Bay *C. picta* in a nearby channel despite the distance to the opening of the channel being only 100 m from Station Bay. In addition, mark-recapture studies done in 1964 and 1965 (Wade and

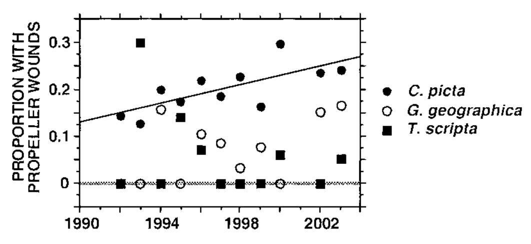

FIG. 4. Changes in the proportion of turtles showing propeller damage from 1992–2003 for *Chrysemys picta*, *Graptemys geographica*, and *Trachemys scripta* in Station Bay, Dewart Lake.

Gifford, 1965; G. Powell, unpubl.) found no movement of nearly 1000 marked turtles into or out of Station Bay. These observations suggest that *C. picta* has high site fidelity and has not exhibited any major emigration from Station Bay. Next, it is not clear why the turtles should leave Station Bay for other areas of the lake since Station Bay is one of the least disturbed and least developed areas of the lake (e.g., there are no houses directly on the Bay, nor are there any concrete retaining walls). Finally, it seems unlikely that only *C. picta*, and not the other species of turtles, would leave Station Bay.

What might explain the greater apparent mortality of *C. picta* relative to the other species of turtles? Based on conversations with people who visited the lake regularly in the late 1950s and early 1960s, and our own observations from 1979 on, it is clear that there has been (1) a drastic increase in shoreline residential development over the past two decades, and (2) a precipitous increase in the use of personal watercraft (boats and waverunners) in the past decade (see also JFNew, Dewart Lake diagnostic study. Unpubl. report for the Dewart Lake Protective Association [Available from GRS], 2005). It may be that *C. picta* is more susceptible to these factors than the other species, as evidenced by the differences in propeller wound rates. Further research on the mechanisms by which turtles can be affected by increased interactions with humans in a variety of contexts, and how these factors can differentially affect species, is needed (e.g., Garber and Burger, 1995; Marchand and Litvaitis, 2004; Nemoz et al., 2004; Steen and Gibbs, 2004).

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APPENDIX 1. Total captures of turtles during the course of the study, as well as historic data from 1964 (Wade and Gifford, 1965) and 1965 (G. Powell, unpubl.). Number of traps used and trap days (fyke nets only) for a given year are given when known.

	Non-fyke net years										Fyke net years										
	'64	'65	'79	'80	'82	'83	'84	'87	'88	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03
Traps	??	??	8	11	5	13	15	9	9	2	3	5	5	6	7	7	8	8	9	6	12
Trap days										3.4	9.5	13.9	18.3	18.4	21.0	22.0	26.3	24.0	33.0	18.5	46.5
C. picta	341	224	28	26	3	21	103	37	59	200	221	313	249	160	173	132	171	224	161	79	123
S. odoratus	197	195	7	20	0	5	22	23	55	19	48	104	104	36	59	83	87	77	168	50	77
C. serpentina	15	16	0	0	0	4	0	1	2	7	10	6	23	13	7	2	12	19	17	8	10
G. geographica	6	17	0	0	0	0	10	8	1	4	6	19	7	10	29	29	11	5	3	10	4
A. spinifera	3	0	0	0	0	1	0	1	0	0	8	10	6	1	1	0	3	2	6	3	4
T. scripta	4	2	0	0	0	0	0	0	0	3	8	16	14	12	6	3	14	16	19	7	18
E. blandingii	9	13	0	0	0	0	1	1	0	0	1	1	1	1	0	1	0	0	1	1	0

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Thermoregulation in Nocturnal Ecthotherms: Seasonal and Intraspecific Variation in the Mediterranean Gecko (*Hemidactylus turcicus*)

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ABSTRACT.—**Comprehensive investigations of thermoregulation have been primarily performed on diurnal lizards. The nocturnal gecko, *Hemidactylus turcicus*, was used to test a protocol proposed by P. E. Hertz, R. B. Huey, and R. D. Stevenson in 1993. Measures of body temperatures of field active geckos (T_b) and operative temperatures (T_e), the equilibrium body temperatures that animals would attain in given microclimates, were compared to measures of preferred temperatures (T_p) determined in a thermal gradient. Measurements were made on adult males, adult nongravid females, adult gravid females, and juvenile geckos in four seasons (June, August, October, March). Both T_b and T_e varied between seasons; however, T_b closely tracked T_e. No seasonal patterns existed in T_p; however, juveniles had the lowest T_p, whereas gravid females had the highest. Regardless, in all seasons geckos were ineffective thermoregulators. The low variability in T_e is the likely cause for this pattern. For such "thermoconforming" species, we suggest that the magnitude of the variation in T_b, T_e, and T_p be included in assessments of how well organisms regulate to their set-point (preferred), temperatures. We conclude that geckos, and possibly many nocturnal ectotherms, thermoregulate during the day when a more variable thermal environment exists.**

Small lizards are ectotherms that rely on behavioral thermoregulation for the maintenance of internal body temperatures for optimal functioning of cellular and organismal processes (Bartholomew, 1982). Behavioral thermoregulation includes site selection, basking, and posturing (Huey, 1982) and has many associated costs (Huey and Slatkin, 1976). For example, time spent thermoregulating may conflict with time spent foraging or finding mates and may make the lizard more vulnerable to predation (Huey and Slatkin, 1976). However, body temperature is correlated with digestion, development, locomotion, reproduction, learning, predation, and metabolism (Huey and Slatkin, 1976; Huey, 1982). Maintenance of body temperature near a preferred optimum should enhance performance, survival, and ultimately fitness (Huey and Slatkin, 1976).

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