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The conservation implications of riparian land use on river turtles

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Abstract

Agriculture is the dominant land use in the Lower Flint River Basin (LFRB) of south-western Georgia, USA, and is often a significant disturbance factor affecting streams and riparian habitats. Streams in the LFRB harbor a great diversity of freshwater turtles, which are among the many groups of aquatic fauna impacted by agricultural disturbance to riparian habitats. The objective of this study was to assess turtle diversity and abundance in both agriculturally impacted and unimpacted or restored reaches of streams in the LFRB. In 2007 and 2008, we used hoop traps and effort-managed snorkel surveys to sample turtles on 14 reaches of two streams (Ichawaynochaway and Spring Creeks). We recorded 823 captures of 674 individuals representing nine turtle species. There was a measurable association between the percentage of riparian undisturbed land cover and the number of turtles captured for the four most frequently captured species (*Trachemys scripta*, *Graptemys barbouri*, *Pseudemys concinna* and *Sternotherus minor*). We found a negative relationship between the total number of turtles captured and percentage of undisturbed land cover within a 287 m buffer width due to a significant increase in the number of *T. scripta* in less-forested sections of the creeks; however, the number of *G. barbouri* captures declined with reduced undisturbed land cover. Species evenness was positively correlated with percentage of undisturbed land. These results suggest that loss of riparian forest is associated with a decline in freshwater diversity (evenness) and a decline in the abundance of the endemic, state protected *G. barbouri*; however, overall turtle abundance may remain stable or increase with loss of riparian forest cover due to an increase in common, cosmopolitan species. Our results suggest that maintenance or restoration of riparian forests is critical to freshwater turtle conservation.

Introduction

Many aquatic fauna associated with stream and river ecosystems are affected by anthropogenic activities in the adjacent riparian zone (Allan, 2004). Urbanization, industrial practices and agriculture have been linked to declines in some aquatic fauna. Agriculture, because of its extensive distribution, may be the greatest threat to some species (Richter *et al*., 1996). The effects of agricultural activities on freshwater habitats are diverse (e.g. Richards, Johnson & Host, 1996; Wang *et al*., 1997; Carpenter *et al*., 1998); however, lack of information on the basic ecology of some river biota makes it difficult to determine potential effects of agricultural land use on these species.

Freshwater turtles can be diverse constituents of river ecosystems and are potentially vulnerable to a range of direct and indirect human activities (Klemens, 2000; Bodie, 2001). The south-eastern US is a global hotspot for freshwater turtle diversity (Buhlmann & Gibbons, 1997). The Lower Flint River Basin (LFRB) of Georgia is part of the Apalachicola–Chattahoochee–Flint (ACF) River Basin, and it supports nine turtle species, 35% of freshwater species in the south-eastern US (Buhlmann & Gibbons, 1997), including two state protected species, the alligator snapping turtle *Macrochelys temminckii* and Barbour's map turtle *Graptemys barbouri* (Jensen *et al*., 2008). The south-eastern US has been identified as harboring the second highest diversity of turtles in the world and is a top turtle priority area that has been considered in a global conservation strategy (Buhlmann *et al*., 2009). Proximate human impacts on freshwater turtles include disturbance of reproductive activity (Moore & Seigel, 2006), mortality on roads associated with nesting migrations and dispersal (Steen *et al*., 2006) and harvesting for food (Klemens & Thorbjarnarsen, 1995). For example, *M. temminckii* populations were depleted by commercial exploitation (Sloan & Lovich, 1995), although populations in some streams appear to be recovering (Jensen & Birkhead, 2003). Non-point source pollution, stream channelization and sedimentation can also impact river turtle populations, though the impacts may be inconspicuous or more difficult to measure (Moll, 1995; Moll & Moll, 2004). For example, *G. barbouri* has a specialized diet, with females consuming predominantly mollusks (Sanderson, 1974); hence, the species is likely affected by disturbance to riparian and instream habitats that leads to declines in native mollusks (Moll, 1995; Lindeman, 1999). Not all freshwater turtle species respond negatively to human activities. For example, the yellow-bellied slider *Trachemys scripta*, is a cosmopolitan species common in streams and wetlands in the south-east (Gibbons, 1990), and is known to persist and even thrive in human-altered habitats (Gibbons, 1970; Moll, 1980).

Currently, agricultural lands encompass *c.* 25% of the ACF (50 688 km^2) River Basin (Ward, Harris & Ward, 2005) and *c.* 50% of the LFRB (Golladay & Battle, 2002). Although riparian forests have been cleared in many agricultural areas in the region, forests are being restored in some areas (Golladay & Battle, 2002). The effects of human activities on river turtles in the LFRB are not well understood. Therefore, our objectives were to (1) estimate turtle species diversity and abundance on two major tributaries of the LFRB (Ichawaynochaway and Spring Creeks); (2) determine whether turtle diversity and abundance were associated with percentage of undisturbed riparian land cover. Specifically, we tested the hypothesis that abundance of *G. barbouri*, and overall turtle species evenness and abundance were positively correlated with percentage of undisturbed riparian habitat adjacent to the creeks.

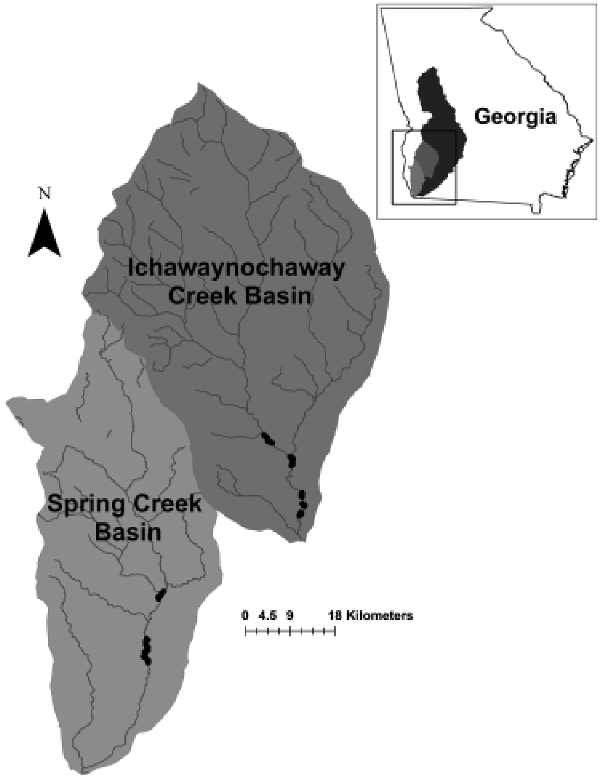

Figure 1 Location of 14 turtle study sites (black dots) on Ichawaynochaway Creek (Baker County, GA) and Spring Creek (Miller County, GA). The dark gray area represents the entire Flint River Basin. The light gray areas (foreground) are the Ichawaynochaway and Spring Creek Basins where this study took place.

Methods

Our study took place on Ichawaynochaway (Baker County) and Spring Creeks (Decatur and Miller Counties) in southwestern Georgia, USA (Fig. 1). Study sites are located in the Dougherty Plain, characterized by karst topography (Ward *et al.*, 2005). In drainages of the LFRB, rocky limestone shoals and deep, wide, sandy pools are common. Both creeks have ground water inputs fed primarily by the Upper Floridan Aquifer, the shallowest aquifer in the region (Golladay, Hicks & Muenz, 2007). Both creeks have areas with significant riparian forest buffer and areas dominated by riparian agriculture with limited riparian forest cover; however, the creeks differ in the relative proportions of these conditions. Ichawaynochaway Creek flows through extensive areas that receive minimal human impact including *c.* 24 km through Ichauway, the Joseph W. Jones Ecological Research Center property. Portions of Ichawaynochaway Creek north of Ichauway are located within areas used predominantly for agriculture. In contrast, Spring Creek has greater areas of adjacent agriculture and minimal riparian buffers. Both creeks are subjected to ground and surface water withdrawals for irrigation during the growing season (April–September), which can cause significant declines in flow (Golladay *et al.*, 2007). Both creeks also support a diverse aquatic fauna, including at least nine turtle species (Jensen *et al.*, 2008; S. C. Sterrett, pers. obs.).

Using 2007 National Agriculture Imagery Program (USDA Aerial Photography Field Office, 2007) aerial photography (1 m) and ArcGIS, each creek was delineated into consecutive 1 km sections starting at an arbitrarily chosen point upstream where the creek began to occupy a recognizable channel. Each section was then categorized as either undisturbed (>90% forest cover), marginally disturbed (50–70% forest cover) or severely disturbed (<40% forest cover, Fig. 2). We randomly selected three undisturbed, two marginally disturbed and two severely disturbed sections from each creek for turtle sampling. Two randomly selected sections were inaccessible and were replaced by the next available randomly selected sections (sites 2 and 30) on Spring Creek. The sampling (described below) was conducted within a 0.5 km reach located at the center of each 1-km study section. We attempted to maximize independence of sampling sections by choosing sections that were separated by at least 1.5 km and selecting sections randomly from among a larger number of potential sections.

We used ArcMap (ESRI, v 9.2) to categorize and quantify surrounding land cover (undisturbed vs. disturbed) three buffer widths for each of the 1 km creek sections containing study reaches. The first buffer width (15.24 m) was the standard for Georgia streams (Wenger, 1999). The other buffer widths (123 and 287 m) represented the mean minimum and mean maximum terrestrial migration distances for

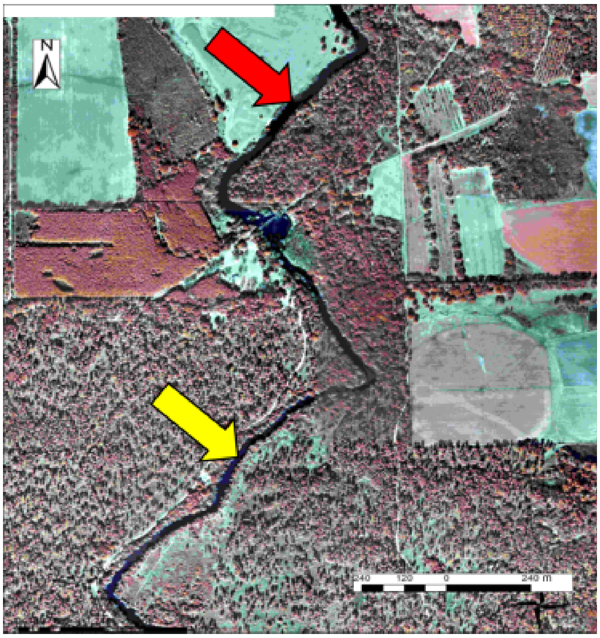

Figure 2 Aerial photograph depicting impacted (red arrow) and unimpacted (yellow arrow) areas of Ichawaynochaway Creek, in south-west Georgia.

freshwater turtles, including river turtles (Semlitsch & Bodie, 2003). We used 2001 National Land Cover Data (NLCD; Homer *et al*., 2004; 30 m pixel size) to quantify undisturbed versus disturbed land cover. Disturbed land cover included areas designated by NLCD as developed, pasture, row and cultivated crops. This category was dominated by agricultural land uses. All other land-cover types were included in the undisturbed category, which was dominated by deciduous, evergreen and mixed forest but also included several other, less common land-cover classes, that is grassland, scrub/shrub, palustrine emergent wetland and palustrine forested wetland. We layered these land-cover maps with 2007 National Agriculture Imagery Program (USDA Aerial Photography Field Office, 2007) aerial photography (1 m). We edited all land-cover changes between 2001 and 2007 to create a final 2007 land-use map. Fluvial aquatic habitat, based on the average width of the stream in each section, was removed from the total land cover; hence, total land cover within each buffered 1 km section varied based on the width of the stream.

We sampled for turtles from May–August 2007 at Ichawaynochaway Creek and June–September 2008 at Spring Creek. At both creeks, we sampled each 1 km section twice over the sampling period using both baited hoop traps and effort-managed snorkel surveys. We chose these two sampling methods as the most complementary and practical methods to capture a variety of species on these two creeks (see Sterrett, 2009).

During each sampling period, we placed five large (1.2 m dia, four hoops, 3.8 cm mesh size) and five small (0.9 m dia, three hoops, 3.8 cm mesh) fish-baited hoop traps (Memphis Net and Twine, Memphis, TN, USA) in each 0.5 km reach, *c*. 50 m apart on alternating banks when water levels were suitable. We set traps for five nights within each reach, checked traps daily and re-baited as necessary. Measurements taken on all captured turtles included straight-line carapace length, plastron length and body mass. Each turtle was given a unique identification code by marking the marginal scutes (Cagle, 1939), except for softshell turtles (*Apalone* spp.), which were marked with zip-ties in 2007 and notches in 2008 (following Plummer, 2008).

We used snorkeling to survey each 0.5 km reach twice (upstream and downstream), although a high number of captures during a snorkel survey at one site did not allow us to search the section twice during one visit. We controlled for search effort (three to four surveyors for 2–3 h), time of day (13:00 h start time, when possible) and surveyor experience. We searched all accessible habitats within the stream. We were unable to free dive into pools >4 m deep that may have contained turtles. We measured and marked all turtles captured during snorkel surveys as described above.

We used an ANOVA to detect differences among the mean abundance (all species, both methods combined), mean abundance of each species and species evenness (J'; Zar, 1998) relative to percentage of undisturbed land cover on Ichawaynochaway Creek and Spring Creek. We used linear regression to determine if turtle abundance and evenness responded to differing percentages of undisturbed land cover. We used a multivariate general linear model with creek as a categorical predictor variable and percentage of undisturbed land cover within a 287 m buffer width as a continuous variable to determine whether the number of individual turtles captured per species per creek section differed between creeks or as a function of undisturbed land cover. For this analysis, we only included data for the four most frequently captured species (*T. scripta, G. barbouri,* eastern river cooter *Pseudemys concinna* and loggerhead musk turtle *Sternotherus minor*). All data were normally distributed. All statistical analyses were conducted using Statistica 8.0 ©1984–2008 (StatSoft Inc., Tulsa, OK, USA).

For analyses of turtle abundance, we used numbers of individuals of each species as our dependent variable. We recognize that, ideally, we would estimate abundance of each species using a mark–recapture procedure that accounts for capture probability (Mazzerolle *et al*., 2007). However, because we used two capture techniques that varied in effectiveness among species and between sexes, and detection rate of species during snorkeling varied with habitat and daily fluctuations in water clarity (Sterrett, 2009), we would have needed capture probabilities that were species, sex, technique and habitat specific. We were unable to catch sufficient numbers of each species by sex to estimate these capture probabilities, so we used numbers of individuals ignoring sex as a superior dependent variable to count data; however, our abundance estimates are low because they did not account for imperfect detection of individuals.

Results

Between May and September 2007 and 2008, we recorded 1400 trap nights and 242.75 person-hours of snorkeling within the fourteen 0.5 km reaches on Ichawaynochaway and Spring Creeks. We detected nine turtle species between the two creeks. *Pseudemys concinna* and *S. minor* were captured in similar numbers with both methods. *Graptemys barbouri* was captured most frequently by snorkeling (88% of individuals) and *T. scripta* by trapping (87% of individuals). Three species (Florida softshell *Apalone ferox,* Gulf coast spiny softshell *Apalone spinifera* and snapping turtle *Chelydra serpentina*) were captured only in traps. The Florida cooter *(Pseudemys floridana*) was only captured by snorkeling. *Macrochelys temminckii* were captured most frequently by trapping (72%). For a more detailed description of capture efficacy for the different sampling methods, see Sterrett (2009).

We recorded 823 captures of 674 individuals representing nine turtle species (Table 1: 349 on Ichawaynochaway Creek and 474 on Spring Creek). The mean number of individual turtles captured among all study reaches was 59 ± 10.7 (mean $\pm$ standard error, range 21–172). Ninety-five per cent of captures were comprised of four species; *P. concinna* (16%, 134), *S. minor* (9%, 60), *G. barbouri* (15%, 121) and *T. scripta* (55%, 451; Table 1, Fig. 3). *Macrochelys temminckii* were captured in all but one of the study reaches on Ichawaynochaway Creek ($n = 8$); however, the species was captured in only three reaches on Spring Creek ($n = 10$). A single *A. ferox*, *A. spinifera* and *C. serpentina* were captured on Ichawaynochaway Creek in 2007, and 13 *A. spinifera* were captured on Spring Creek in 2008. *Pseudemys floridana* was only captured within Spring Creek, although this species occurs in Ichawaynochaway Creek (S. C. Sterrett, pers. obs.). We recaptured 149 turtles (one to five times) on all study reaches. Most recaptures were *T. scripta* (73%, 109), followed by *G. barbouri* (13%, 19) and *P. concinna* (8%, 12). Eleven individuals [*P. concinna* (five)*, G. barbouri* (two)*, T. scripta* (three) and *P. floridana* (one)] were recaptured in a reach different from their initial capture.

The percentage of undisturbed land cover varied among reaches, but generally decreased with increasing buffer width. Sites within Ichauway were largely undisturbed at all buffer widths, however, sites north of Ichauway represented some of the most disturbed sites on Ichawaynochaway Creek. The percentage of undisturbed land cover within all buffer widths ranged from 42 to 100%. Mean percentage of undisturbed land cover changed from 90.8 to 80.9% on Ichawaynochaway Creek and from 97.2 to 76.8% on Spring Creek between the 15.24 and 287 m buffers, respectively. There was no measurable difference in undisturbed land cover at any of the buffer widths between creeks (15.24 m buffer: MS = 144.3, $F_{1,12} = 1.77$, $P = 0.2083$, 123 m buffer: MS = 13.1, $F_{1,12} = 0.06$, $P = 0.8035$, 287 m buffer: MS = 58.62, $F_{1,12} = 0.22$, $P = 0.6504$).

Pseudemys concinna were captured more frequently on Spring Creek (14 ± 3) than on Ichawaynochaway Creek (5 ± 2; MS = 224, $F_{1,12} = 4.88$, $P = 0.0474$). Eight (± 3) *Sternotherus minor* were captured on Ichawaynochaway Creek and two (± 1) were captured within Spring Creek (MS = 138.3, $F_{1,12} = 4.21$, $P = 0.0625$). There was no difference in the number of captures of *G. barbouri* (9 ± 2, 8 ± 3, MS = 14, $F_{1,12} = 0.39$, $P = 0.5422$) and *T. scripta* (25 ± 7, 39 ± 18, MS = 240.3, $F_{1,12} = 0.39$, $P = 0.5449$) between

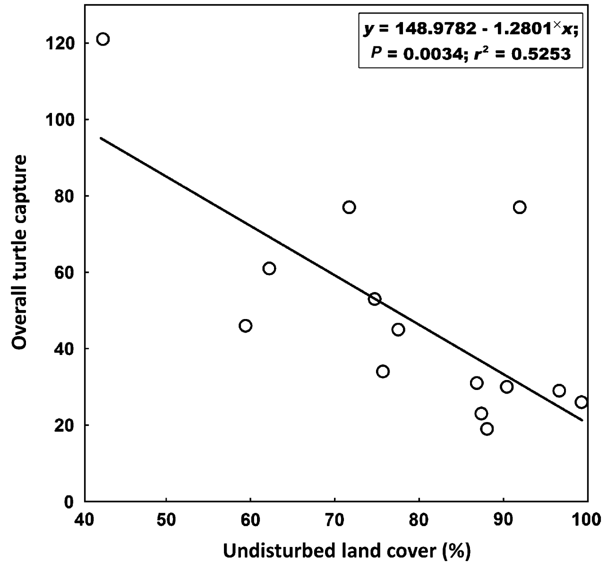

Figure 3 Relationship between total numbers of turtle captures versus percentage of undisturbed land cover at 14 study reaches on Ichawaynochaway and Spring Creeks in the Lower Flint River Basin in south-west Georgia.

Table 1 Turtles captured on Ichawaynochaway and Spring Creeks in south-west Georgia in summer 2007 and 2008

Turtle species	Ichawaynochaway Creek	Spring Creek	Total
Florida softshell turtle *Apalone ferox*	1	0	1
Gulf coast spiny softshell turtle *Apalone spinifera*	1	13	14
Snapping turtle *Chelydra serpentina*	1	2	3
Barbour's map turtle *Graptemys barbouri*	66	55	121
Alligator snapping turtle *Macrochelys temminckii*	8	10	18
River cooter *Pseudemys concinna*	35	99	134
Florida cooter *Pseudemys floridana*	0	7	7
Loggerhead musk turtle *Sternotherus minor*	60	14	74
Yellow-bellied slider *Trachemys scripta*	177	274	451
Total	349	474	823

Turtles were captured using fish-baited hoop traps and effort-constrained snorkeling.

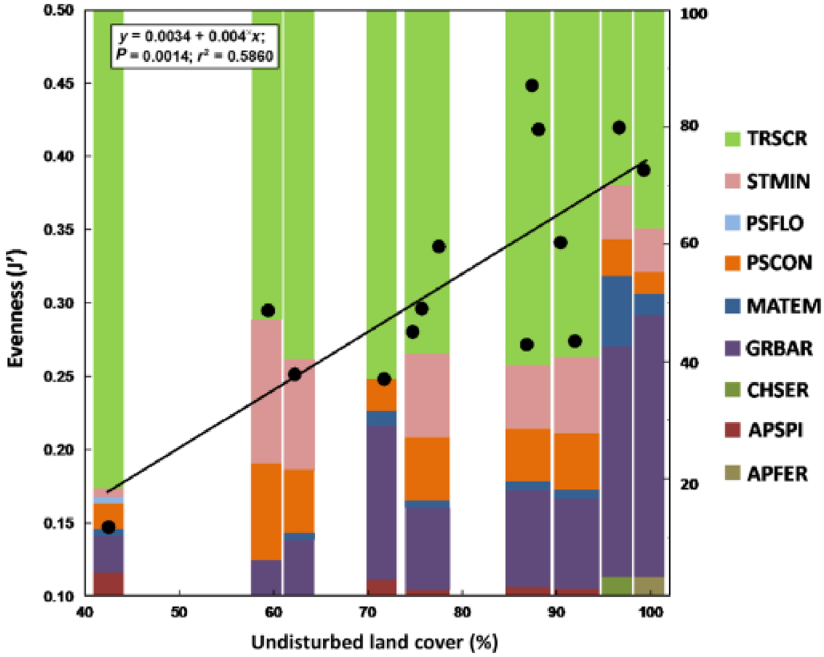

Figure 4 Relationship between evenness (J') of turtle species and percentage of undisturbed land cover at 14 study reaches on Ichawaynochaway and Spring Creeks in the Lower Flint River Basin in south-west Georgia. Points represent actual evenness values whereas bars represent individual sites along a gradient from most to least disturbed. The second *y*-axis represents percentage of each species captured at each site. In three instances, percentage of each species captured were averaged across sites with similar undisturbed land cover only to illustrate the trend. Statistics represent the correlation between evenness (J') and undisturbed land cover. TRSCR, *Trachemys scripta*; STMIN, *Sternotherus minor*; PSFLO, *Pseudemys floridana*; PSCON, *Pseudemys concinna*; MATEM, *Macrochelys temminckii*; GRBAR, *Graptemys barbouri*; CHSER, *Chelydra serpentina*; APSPI, *Apalone spinifera*; APFER, *Apalone ferox*.

Ichawaynochaway and Spring Creeks, respectively. There was no difference in species richness (5 ± 0.3, 6 ± 0.4, MS = 0.6429, $F_{1,12} = 0.90$, $P = 0.3615$) or total number of captures (50 ± 9.5, 68 ± 19.6, MS = 370.3, $F_{1,12} = 0.45$, $P = 0.517$) between Ichawaynochaway and Spring Creeks, respectively.

There was a negative relationship between the total number of turtles captured and percentage of undisturbed land cover at the 287 m buffer width ($n = 14$, $r^2 = 0.54$; $P = 0.0026$, Fig. 3); however, evenness (J') was positively related to percentage of undisturbed land cover ($r^2 = 0.59$; $P = 0.0014$, Fig. 4). General linear model results showed that within each creek, there was a measurable effect of percentage of undisturbed land cover at all three buffers on the numbers of individual turtles captured for the four most frequently captured species (*P. concinna, S. minor, G. barbouri* and *T. scripta*, 15.24 m buffer: Wilk's $\Lambda = 0.0314$, $F_{4,7} = 53.92$, $P = 0.0000$, 123 m buffer: Wilk's $\Lambda = 0.0479$, $F_{4,7} = 34.77$, $P = 0.0001$, Table 2). The relationships between percentage of undisturbed land cover and number of individual turtles captured was not consistent between Ichawaynochaway and Spring Creeks, for *P. concinna* and *S. minor*, but the relationship was consistent for *G. barbouri* and *T. scripta* (Table 1; Fig. 5). The number of individual *G. barbouri* captured decreased and the number of individual *T. scripta* captured increased with decreasing percentage of undisturbed land cover (Fig. 4).

Discussion

Agricultural activities affect aquatic biodiversity, although these effects have not been described for most vertebrates other than fishes (Allan, 2004). Saumure, Herman & Titman

Table 2 Effects of creek and percentage of undisturbed land cover (within a 287 m buffer) on number of turtles captured within 14 study reaches on Ichawaynochaway and Spring Creeks, in south-west Georgia

Source of variation	Wilk's Λ	*F*-value	Degrees of freedom	*P*-value
Creek	0.2070	6.7030	4,7	0.0152
% Undisturbed land cover	0.1155	13.4011	4,7	0.0021
Creek × undisturbed land cover	0.2257	6.0041	4,7	0.0203

(2007) described the effects of agricultural machinery on the survival of wood turtles *Glyptemys insculpta* and stressed the importance of riparian buffer zones for semi-aquatic turtles. Deforestation associated with some forms of agriculture, such as center pivot agricultural fields, may encroach on riparian areas and increases potential for runoff and siltation of streams, which may affect prey availability and instream habitat for river turtles (Dodd, 1990; Moll & Moll, 2000). In our study, turtle abundance and species composition (evenness) varied with percentage of undisturbed land cover around the stream, and thus, agricultural land use. Somewhat surprisingly, we found a strong negative relationship between total number of turtle captures (abundance) and percentage of undisturbed land cover (Fig. 3). This relationship was driven by larger numbers of *T. scripta* within sections of the creek with little riparian forest cover (Fig. 4). Despite increased numbers of turtles in stream sections with little forest cover, evenness declined as percentage of undisturbed land cover declined (Fig. 5). The decline in evenness was a result of both a decline in the number of

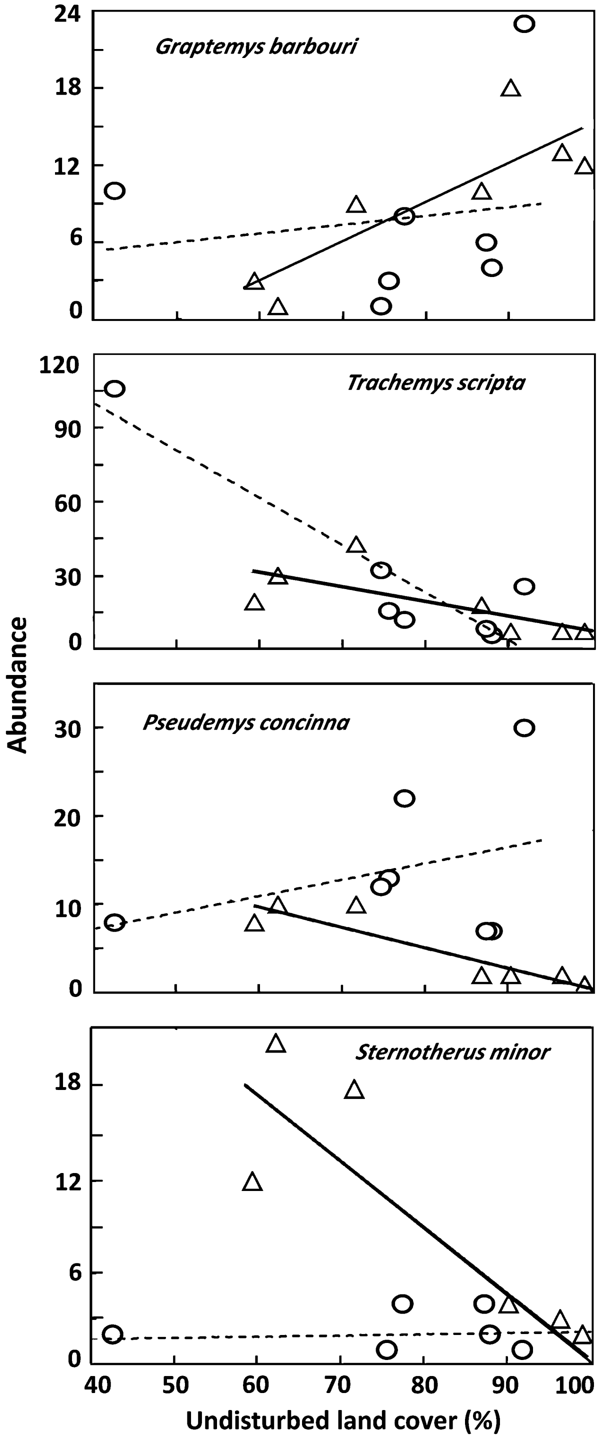

Figure 5 Linear regression of the four most frequently captured turtle species versus percentage of undisturbed land cover on each creek (Ichawaynochaway Creek-triangles, solid line; Spring Creek-circles, dotted line).

G. barbouri and the numerical dominance by *T. scripta*. *Graptemys barbouri* has a specialized diet consisting predominantly of mollusks, which are vulnerable to the effects of riparian forest loss, including changes to instream habitat conditions (Moll, 1995; Lindeman, 1999). *Trachemys scripta* are dietary generalists, and their relatively broad, omnivorous diet contributes to the ability of this species to thrive in disturbed conditions (Knight & Gibbons, 1968; Gibbons, 1970). Other studies of turtle communities and other taxa such as fishes have consistently shown declines in dietary specialists and dominance by generalist species with increasing human disturbance to riverine environments (Moll, 1980; Jones *et al.*, 1999; Burcher *et al.*, 2008).

We found a strong positive relationship between *G. barbouri* captures and percentage of undisturbed land cover on both creeks. Given an apparent relationship between riparian condition and freshwater mollusk abundance (Poole & Downing, 2004; Newton, Woolnough & Strayer, 2008), we expected to see the same relationship in *S. minor*, another molluscivorous species (Zappalorti & Iverson, 2006). However, patterns of *S. minor* captures and undisturbed land cover were inconsistent between creeks. We captured too few *S. minor* on Spring Creek to evaluate whether there was a relationship between undisturbed cover and *S. minor* abundance on that creek; however, we did see what appeared to be a relatively strong negative relationship between numbers of *S. minor* and undisturbed land cover on Ichawaynochaway Creek. This relationship was paradoxical compared to the pattern for *G. barbouri* seen on the same creek. The assumption that *S. minor* is as dependent on mollusks for food as *G. barbouri* may explain this paradoxical result. *Sternotherus minor* were routinely captured in fish-baited hoop traps, whereas, *G. barbouri* were rarely captured by baited hoop traps. Data on the foraging behaviors and diets of these species within stream habitats of varying condition may help resolve the differential associations of these species to riparian land use.

The proximate effects of the loss of undisturbed land cover associated with agricultural practices on instream habitat or biota have not been evaluated for the creeks in our study. Runoff from agricultural land increases nitrogen loading, which can increase abundance of macrophytes and algae (Allan, 1995), while reducing the abundances of fishes (Jones *et al.*, 1999; Burcher *et al.*, 2008), mollusks (Poole & Downing, 2004; Sharpe & Nichols, 2007) and other macroinvertebrates (Wang *et al.*, 1997; Lammert & Allan, 1999). With these types of shifts in resources available within agriculturally dominated streams, we would expect to see increases in omnivores, like *T. scripta* and generalized herbivores such as *P. concinna*, and decreases in dietary specialists like *G. barbouri* and *S. minor*. Further, map turtles feed extensively on Asiatic clams (*Corbicula fluminea*; Shively & Vidrine, 1984; Lindeman, 2006; S. C. Sterrett, pers. obs.). The potential for *C. fluminea* and other invertebrate prey of aquatic turtles to accumulate toxins from agricultural practices warrants attention (Pereira *et al.*, 1996).

The loss of riparian forest cover, as a result of agricultural practices, may also lead to physical alterations of instream habitat, such as depth heterogeneity and increased sediments (Walser & Bart, 1999) that may affect the distribution and abundance of turtles (Bodie, 2001). Some river turtles are strongly associated with particular substrates; for example, spiny softshell inhabit rivers with sandy substrate where they can burrow (McGaugh, 2008; Plummer *et al*., 2008; Plummer, Lee & Mills, 2008); whereas some map turtles rely on shoals to feed (Sanderson, 1974; Buhlmann, Tuberville & Gibbons, 2008). *Graptemys barbouri* are often associated with limestone substrate (Sanderson, 1974; Enge & Wallace, 2008), which is abundant in streams of the LFRB. We found many *G. barbouri* sheltering under instream large woody debris (LWD; Sterrett, 2009). Both instream and emergent LWD is likely important to map turtles as substrate for prey (mollusks, algae, macroinvertebrates), basking substrate for thermoregulation and resting substrate (Lindeman, 1999). It is also possible that map turtles seek shelter under LWD from predators including American alligator *Alligator mississippiensis* or river otter *Lutra canadensis*) during inactive periods. Woody debris is also important to other emydid turtles in this system; however, Auth (1975) found that sliders readily bask at the water surface unlike map turtles, which commonly bask aerially on emergent LWD (Sanderson, 1974). Clearing forest for agriculture could reduce the accumulation of LWD in streams. Angradi *et al*. (2004) related LWD density to unstabilized banks and forested riparian land use. Furthermore, a recent study found positive correlative relationships between riparian forest width and LWD in agricultural land classes (McIlroy *et al*., 2008).

Finally, the removal of riparian forest could affect nesting patterns for some turtles. Unlike *T. scripta*, which move readily across the terrestrial landscape and nest up to 500 m from water (Gibbons, 1990), the river turtles in this study (*P. concinna, S. minor, G. barbouri, A. spinifera* and *M. temminckii*) rarely leave the water except for the purpose of laying eggs; these species generally nest no farther than 250 m from the water (Meylan, 2006). Deforestation would alter the thermal environment and potential vulnerability of nests and nesting females to predators (Janzen & Morjan, 2001; Spencer & Thompson, 2003). While reducing or altering nesting habitat may be an intuitive mechanism, we must recognize that river turtles will make long distance aquatic movements to nesting sites (Moll & Moll, 2004). For example, Daigle, Galois & Chagnon (2002) observed a spiny softshell turtle that moved 7 km in a creek to find a suitable nesting site. While it is possible that alterations to adjacent land may reduce turtle nesting habitat, it less likely that there is a proximate relationship between turtle abundance and adjacent forest cover, especially in these streams where riparian disturbances are patchy.

Land cover affected the local composition and abundance of freshwater turtles on two creeks in south-western Georgia. The major finding of our study was that the common species, *T. scripta*, was most abundant in disturbed stream reaches, whereas overall turtle diversity was greatest in less disturbed stream reaches. In particular, restoration and maintenance of riparian forests appears important to the endemic *G. barbouri*. Future work is needed to establish the mechanistic relationship between undisturbed forested land cover, agricultural land use, in-stream conditions and turtles.

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