EFFECTS OF HABITAT MODIFICATION ON *ELSEYA STIRLINGI* TURTLE POPULATIONS IN THE NORTH JOHNSTONE RIVER

by

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Certificate of Approval

This is to certify that the accompanying thesis by Liliane E Dethier has been accepted in partial fulfillment of the requirements for graduation with Honors in Biology.

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May 12, 2010

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Abstract

Elseya stirlingi (Johnstone River snapping turtle) is a little-studied species restricted to the Johnstone River catchment of Queensland, Australia. Half the catchment's old-growth rainforest has been cleared and riparian zones have suffered from the impact. For these reasons, the Queensland Parks and Wildlife Service has listed *E. stirlingi* as a high priority species. My first goal was to address two hypotheses derived from previous studies: (1) riparian habitat modification results in less stable turtle populations and (2) turtles prefer logs over other microhabitats. Although I did not find relationships between habitat modification and population density or sex ratio, I found fewer young turtles at more disturbed sites than at less disturbed sites, supporting my first hypothesis. I also found more turtles on logs than expected if turtles were distributed randomly among microhabitats. My second goal was to describe new natural history data about *E. stirlingi* depth and substrate preferences. Follow-up studies should build on these results to more conclusively determine this species' conservation status.

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Introduction

Like much of Australia, the Atherton Tablelands of northern Queensland have been heavily modified since European colonization. The once expansive tropical rainforest region boasts high-nutrient soils, high annual rainfall, and underground minerals which make it ideal for mining, logging, and agriculture (Jameison et al. 2006). As a result, today crops, cow pastures, cities, and forests dominate the landscape. The Johnstone River is a major waterway on the Tablelands; both the North and South tributaries begin there and join in the coastal lowlands before emptying into the Pacific (Council 2005). Despite being a tropical rainforest, the Tablelands' high elevation results in lower temperatures and more distinct wet and dry seasons than its coastal counterpart (Cann 1998). The Johnstone River system supports two species of freshwater turtle, one of which, *Elseya stirlingi* (Chelidae), is only found in this catchment (O'Malley 2007). Because of its endemism and small geographic distribution, *E. stirlingi* is listed by the Queensland government as a high priority species which means scientists need to gather more information about it to evaluate its conservation status ("*Elseya sp.* (Johnstone River)" 2007).

Previous studies provide some insight into *E. stirlingi* natural history and ecology. These turtles tend to live near faster-flowing water (Wells 2007). Both juveniles and adults usually live within 250 meters of riffle zones (small rapids), but juveniles are more commonly found in these riffles (Turner 2006). Adults are active during both the night and day, while juveniles tend to be diurnal (Turner 2006). Though turtles spend most their lives submerged, they occasionally bask on sunny logs and rocks. Females also leave the river to nest on land (Turner 2006). *E. stirlingi* has few predators, the majority of which target nests and juvenile turtles. The only predators of adults are estuarine crocodiles (*Crocodylus porosus*) and bull sharks (*Carcharhinus leucas*) in coastal waters, but large ungulates such as horses and cattle can injure adult turtles by stepping on them (Turner 2006). Nest predators include white-tailed rats (*Uromys caudimaculatus*) and water rats (*Hydromys chrysogaster*) while predators of juveniles can include longfin eels (*Anguilla reinhardtii*), spotted arowana (*Scleropages leichardti*), egrets (*Egretta*), and the black-necked stork (*Ephippiorhynchus asiaticus*) (Turner 2006). *E. stirlingi* also house ectosymbionts of algae, flatworms, and oligochaetes, but scientists are unsure if this relationship is parasitic (Turner 2006).

E. stirlingi's diet is important for identifying possible conservation concerns because *E. stirlingi* lives in a modified habitat. It is omnivorous, but adults eat mostly fallen riparian vegetation. They also scrape algae off rocks leaving distinctive scratch marks (Turner 2006). O'Malley (2007) found that though both these foods are relatively low in calories, they comprise over 90% of the adult diet, probably because they are ubiquitous. When possible, *E. stirlingi* choose more nutrient-dense foods such as fruits and invertebrates. Juveniles, on the other hand, eat mostly protein-rich invertebrates, such as shrimp, insect larvae, mussels, and snails, probably to fuel their more rapid growth.

Freshwater turtles around the world are important members of their ecosystems, and *E. stirlingi* is no exception. Many turtles are keystone species because they participate in multiple trophic levels (Fitzsimmons and Tucker, Fund 2002, O'Malley 2007). *E. stirlingi* adults eat producers (riparian vegetation and algae) and consumers (invertebrates) while juveniles eat consumers (invertebrates) and at the same time are an important food source (as are eggs) (O'Malley 2007). Many freshwater turtles, *E.*

stirlingi included, clean water sources by eating algae and other dead plant matter (Fitzsimmons and Tucker). Finally, *E. stirlingi* connects aquatic and terrestrial ecosystems by living in the water, consuming terrestrial plants, and moving between the two during nesting. Because these turtles eat plants, they disperse plant seeds through their digestive tract, one of the only ways riparian seeds can travel upstream. Freshwater turtles often indicate ecosystem stability because in modified habitats their growth and reproductive rates can change, they store pollutants in their tissues, and they can suffer skin and eye lesions. Because *E. stirlingi* serves multiple ecological functions, its removal would likely negatively impact the ecosystem (O’Malley 2007). In addition, its diet makes it particularly susceptible to changes in both riparian condition and water quality.

Past and present land use practices in Northern Queensland have altered riparian vegetation and water ecology along the Johnstone River. The three prevailing land uses are forest, 54%, pastures and grazing, 28%, and canelands, 12% (Council 2005). Forest dominates the landscape because about half of the catchment is in the Wet Tropics World Heritage Area (WTWHA), a rigid international designation which protects the remnant rainforest from clearing (O'Malley 2007). Outside this protected area, lands have been modified heavily. In agricultural areas, 80% of the stream banks exhibit noticeable impacts including stream bank erosion and weed invasion (Council 2005). The lowland riparian condition is poor with high disturbance which means riparian zones have small buffers composed mostly of shrub and grasses, but very few trees (Council 2005). In places, exotic grasses and weeds dominate riparian zones, and cattle have unlimited access to the river (Council 2005). The Johnstone Shire Council has not performed similar studies upstream, but riparian zones are less impacted than in the lowland areas. In the upstream catchment, forest, urban residents, dairy farms, and cattle grazing are the most dominant land uses.

In addition to affecting riparian vegetation, land use practices affect water quality. The Johnstone River has been polluted by dairy waste, agricultural runoff, and fertilizers. In 2003 the Malanda Dairy Factory was fined 60,000 Australian dollars for discharging waste in the North Johnstone River, possibly multiple times before discovery (Anonymous 2003). Agricultural runoff pollutes the Johnstone River with sediment and potentially dangerous fertilizers and pesticides. Several known endocrine disrupters—chemicals that can disrupt hormone functioning—come from these agricultural pollutants (O'Malley 2007). The endocrine system in many animal species is very sensitive to environmental influence so these chemicals can, and have been shown to, alter sexual characteristics (Hollander 1997; Colborn and Theyer 2000). As I describe below, endocrine disrupters seem to affect amphibians and reptiles species especially.

Though *E. stirlingi* is poorly studied, researchers can infer potential risk factors from knowledge of other freshwater turtle species. Many freshwater turtles are in danger; two thirds are threatened, primarily due to habitat degradation, and many have not been evaluated (Fund 2002). In the Johnstone River one sign of habitat degradation is reduction of submerged and partially-submerged logs. (O'Malley 2007). Though log use by particular species has not been well studied, logs can serve many ecological functions for freshwater turtles. They provide protection from predators and storms, and create safe, accessible basking sites (Moll and Moll 2004). Logs also foster algal and invertebrate growth which are both important food sources for *E. stirlingi* (Moll and Moll

2004). In North America, log abundance appears to influence turtle density (Moll and Moll 2004). In Australia, local Aborigines remark on the apparent decrease in Johnstone River turtles (O'Malley 2007). Land modification surrounding the Johnstone River has degraded riparian zones, polluted the river, and reduced logs, all habitat impacts that require study because they might affect *E. stirlingi* populations.

The Queensland Environmental Protection Agency listed *E. stirlingi* as a high priority species in its “Back on Track” species prioritization framework ("*Elseya sp*. (Johnstone River)" 2007). This designation results from *E. stirlingi*’s limited range, and calls for more information to better evaluate its conservation status. In the most extensive study on *E. stirlingi* to date, O’Malley (2007) examined population health at four lowland sites with varying levels of habitat modification. She used population density, size distribution, and sex ratios to determine whether population health (referred to here as population stability) and habitat modification were inversely related. She concluded that population health was directly correlated to riparian modification, but acknowledged that we need more research to support these conclusions.

The overarching goal of my study was to establish preliminary data on *E. stirlingi* in the upstream North Johnstone River. The first part of this study tested the hypotheses that (1) level of riparian modification determines population stability and that (2) turtles prefer logs over other microhabitats. I predicted that populations in more modified riparian zones would have lower population densities, biased sex ratios, or size distributions skewed towards adults as compared to less modified sites (O'Malley 2007). I also predicted that turtles would be found on logs more frequently than expected based on log abundance. I used data from both my research team and O’Malley’s study to evaluate more of the river system. The second part of this study described natural history of this little-known species in the upstream North Johnstone River by examining turtle distribution on various substrates and depths.

Materials and Methods

Study Locations

My research team and I studied *E. stirlingi* at four sites along the Johnstone River from May to November 2008 (Fig 1). The sites were deep, flat-water pools in the upstream North Johnstone River, and we sampled each three times. We named them after their private landowners: Hickeys, Allwoods, Mahars, and Fannings (Fig 1). In analysis, I used additional data from O'Malley's thesis (2007) in the downstream Johnstone River to expand the sample size and scope of my study (Fig 2). My research team and I captured 96 individuals in the upstream sites and O'Malley (2007) captured 240 in her study.

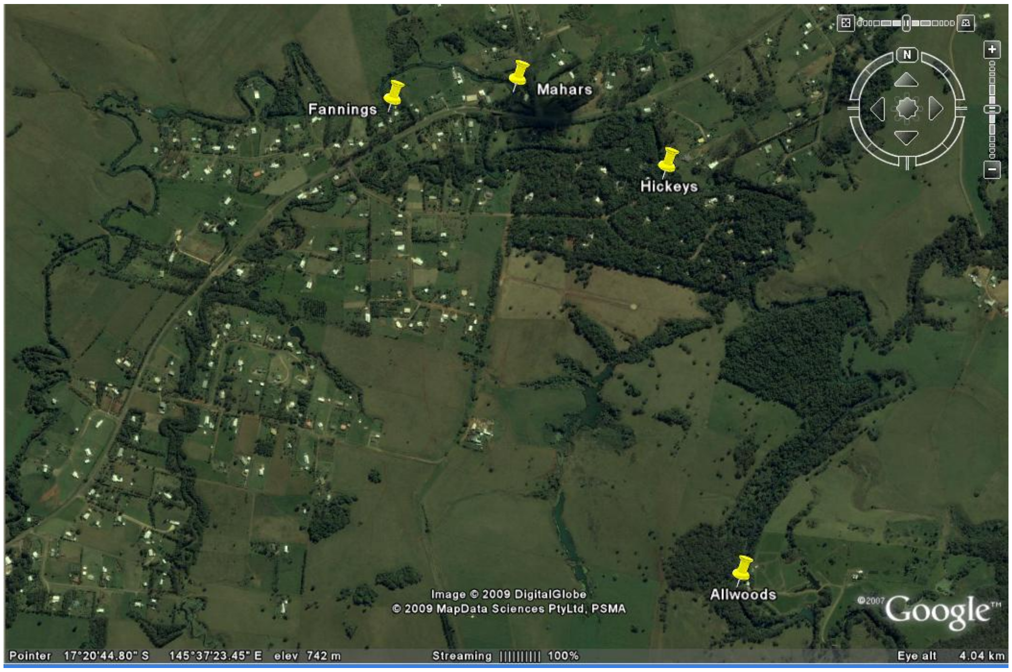

Figure 1. Map of the four sample sites in the upstream Johnstone River.

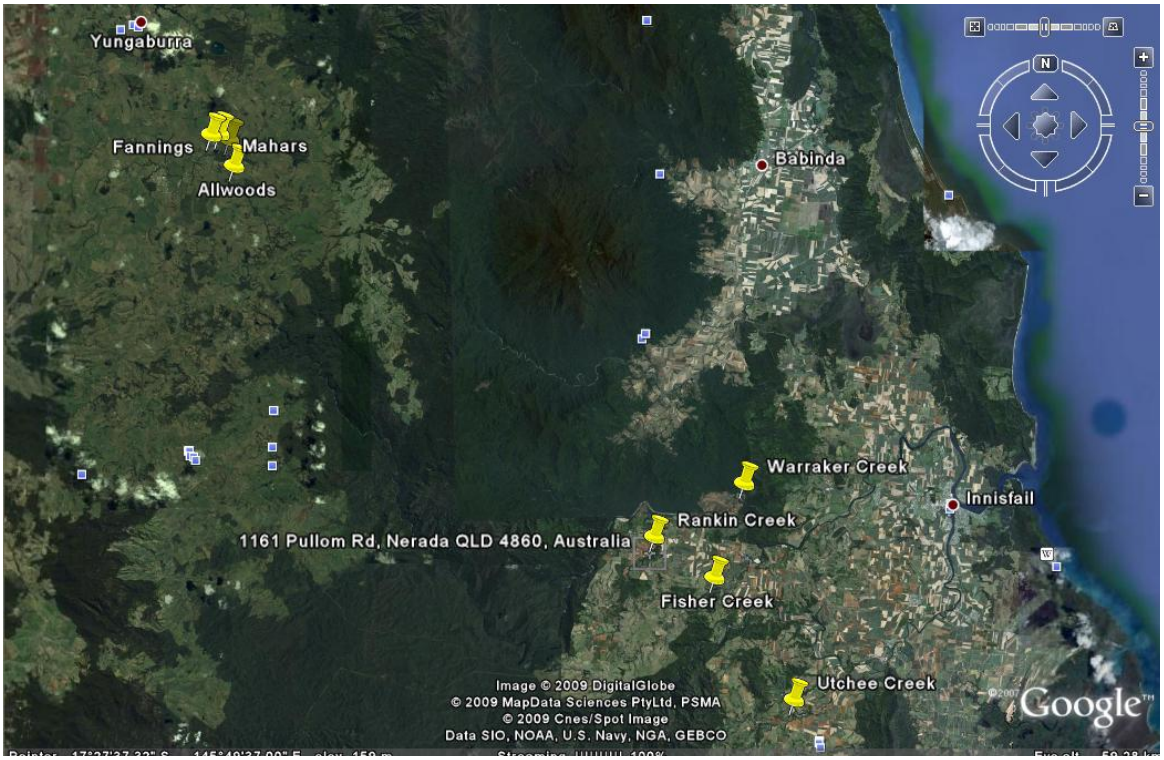

Figure 2. Map of all eight sample sites in the Johnstone River.

Table 1. Sample dates and locations of all sites

Site	Up or Downstream	Dates (2008 unless 2007)	Longitude (S)	Latitude (E)	Elevation (m)
Allwoods	Upstream	8 Dec, 3 Nov, 20 Nov	17°21’16.00”	145°37’52.99”	713
Hickeys	Upstream	2 Sep, 4 Oct, 6 Nov	17°20’25.74”	145°37’43.06”	736
Fannings	Upstream	30 May, 23 Oct, 7 Nov	17°20’17.19”	145°37’07.03”	725
Mahars	Upstream	21 Oct, 5 Nov, 21 Nov	17°20’15.04”	145°37’24.40”	71
Warraker Creek	Downstream	O’Malley 2007	17°31’16.5”	145°54’43.6	44
Fisher Creek	Downstream	O’Malley 2007	17°34’15.8”	145°53’44.2	96
Utchee Creek	Downstream	O’Malley 2007	17°38’9.0”	145°56’23.5”	66
Rankin Creek	Downstream	O’Malley 2007	17°32’58.1”	145°51’44.4	65

Species Description

E. stirlingi shares the Johnstone River with *Wollumbinia latisternum,* the saw-shelled turtle. They are distinguishable by several key features. *E. stirlingi* has a gold inner ring around the iris and a plate extending laterally down the top of its head sometimes referred to as “earmuffs” (Figure 3, Wells 2007). *E. stirlingi* are also larger at maturity.

Figure 3. Photograph comparing *W. latisternum* (left) and *E. stirlingi* (right). Note the distinguishing gold iris and "earmuffs," circled in red, of *E. stirlingi*.

Turtle Capture and Processing

At each site two experienced turtle-catchers snorkeled at the same time for an average of 90 minutes looking for turtles. Previous studies determined that this snorkel and capture method is most effective (O'Malley 2007). When the snorkelers captured a turtle, they recorded the depth and substrate of the river where it was first sighted, with on-shore researchers. To help minimize errors they used four depth categories: 0-30 cm, 30-100 cm, 100-300 cm, and over 300cm; and six substrate categories: rock, gravel, leaf litter, log, silt, and clay. When substrate was a mixture, they chose the most dominant to record. The on-shore researchers marked each turtle with a number on its plastron corresponding to the recorded data and placed the turtles in a container in the shade.

Processing involved identifying sex, recording age, measuring straight carapace length (SCL), and notching marginal scutes of each turtle. We determined sex (male or female) by turtle size and tail length: males are smaller as adults and have longer tails while females are larger as adults with shorter tails (Fig 4). We categorized turtle age by whether it exhibited obvious sex traits (adult) or not (juvenile). We measured SCL with calipers from the medial superior carapace to the medial inferior carapace (Fig 5). Finally, we marked the marginal scutes of each turtle with a unique alphabetical code, and tagged the back feet of large turtles so that we could identify recaptures in the future.

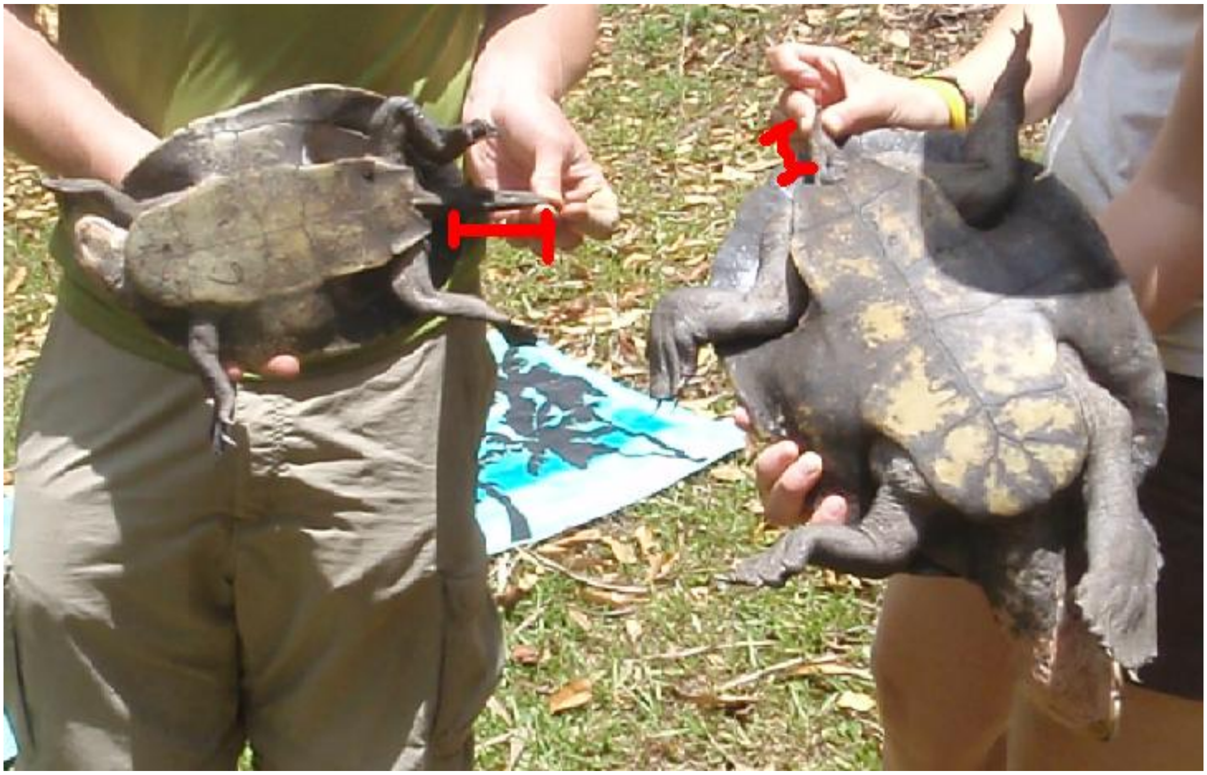

Figure 4. Males (left) have smaller bodies and longer tails while females (right) have larger bodies and shorter tails.

Figure 5. Straight carapace length (SCL) from medial superior carapace to medial inferior carapace.

Mapping the Sites

We started by sketching each site from shore with a range finder, protractor, and compass. Then we stretched a measuring tape across the river and recorded the width (Fig 6). Every five meters along that measuring tape we recorded depth (using a weighted measuring tape) and substrate (a snorkeler dove down to observe it). We used the same depth and substrate categories as when recording turtle location. We then moved the measuring tape five meters downstream and repeated the process. The result was a grid of five meter squares with depth and substrate data at each intersection (Fig 6). From these data we drew aerial maps of the sites with substrate and depth proportions and used the

ImageJ computer program to calculate surface area. Because we only measured depth and substrate every five meters, we may have recorded fewer logs than present (at Allwoods and Mahars we did not find any). In addition, when we pivoted the measuring tape around corners we took a higher density of substrate and depth recordings which could have skewed substrate abundance in analyses (Fig 6).

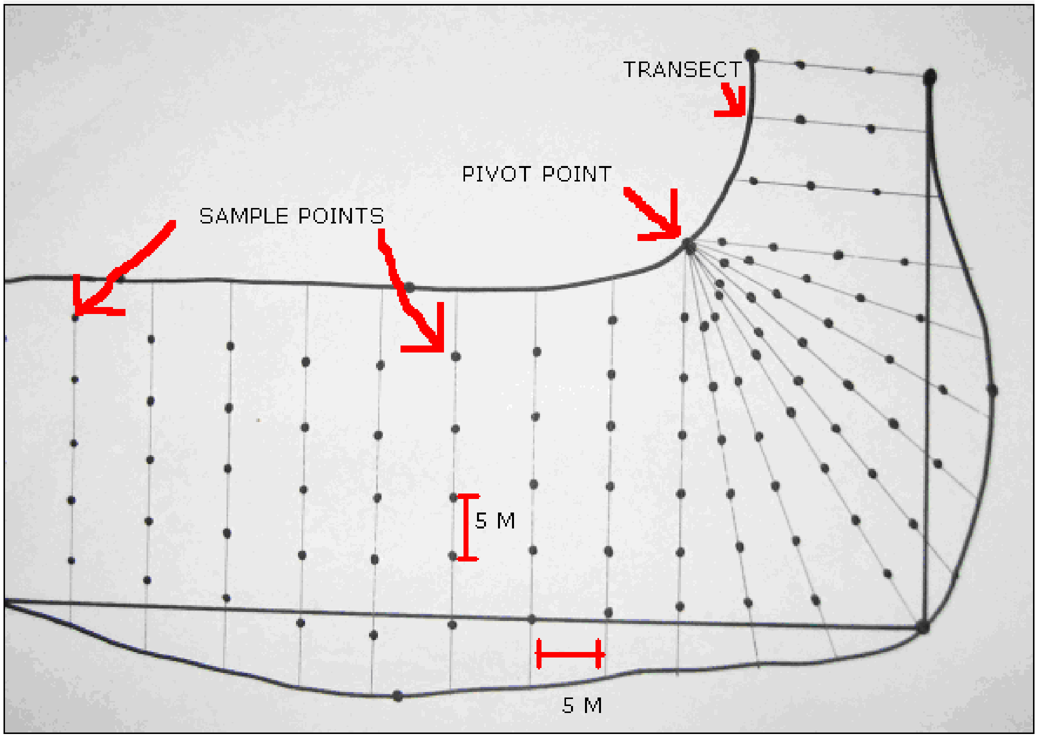

Figure 6. Diagram of one site (Fannings) with examples of transect sampling.

Habitat Modification

After field research I determined the level of riparian modification in upstream sites using an aerial image of each site from Google Earth (Google Earth 2008). Within a 0.25 x 0.25 km square centered on the snorkeling entry-point, I used ImageJ software to trace forest boundaries and calculate percentage area forested. Two sites had more than 50% forest cover: Hickeys (76%) and Allwoods (66%), while two had less than 50%

forest cover: Mahars (45%) and Fannings (24%). I evaluated upstream habitat modification based on riparian forest cover while O'Malley (2007) used the Tropical Rapid Appraisal of Riparian Condition (TRARC), based on visual assessment of the riparian zone. The less modified sites were Allwoods (upstream), Hickeys (upstream), and Warraker Creek (downstream); the moderately disturbed site was Fisher Creek (downstream), and the highly disturbed sites were Fannings (upstream), Mahars (upstream), Utchee Creek (downstream), and Rankin Creek (downstream) (Fig. 2).

Statistical Analysis

I used several techniques to compare population variables among sites with different levels of habitat modification. O'Malley (2007) and I measured population density differently, and this prevented statistical analysis of the combined dataset. O'Malley calculated the number of turtles captured per snorkeler hour per hectare, while I calculated the number of turtles captured per hour per hectare. I compared the eight sites qualitatively based on the density estimate, plus or minus the standard error. I compared sex ratios among low, medium, and high modification sites using a generalized linear mixed model with binomial error (equivalent to logistic regression). This allowed me to control for non-independence of sites within regions (upland sites vs. O'Malley's lowland sites) using a random effect, and for the non-independence of turtles within a site by assigning site as a random effect nested within habitat modification level. Thus my degrees of freedom were adjusted to reflect eight independent cases of habitat modification potentially influencing sex ratio. I compared average turtle size between sites with high and low riparian modification with a general linear mixed model in which turtle size was a rank variable. I controlled for non-independence of sites within regions (upland sites vs. O'Malley's lowland sites) using a random effect, and for the non-independence of turtles within sites by assigning site as a random effect nested within habitat modification level. Thus my degrees of freedom were adjusted to reflect eight independent cases of habitat modification potentially influencing turtle size.

I used a G-test to compare the number of turtles observed to the number expected on logs if turtles used logs according to log abundance. The expected number of turtles on logs was less than five which violates G-test assumptions. I could not calculate the alternative, Fisher's exact test, because of computational limitations. However, a simulation indicated that the exact test would have produced a similar result (results not shown).

I used G-tests to describe the other substrate choices of this species. I compared the number of turtles observed on each substrate and at each depth to the expected values assuming random distribution. As with the log substrate analyses, I violated G-test assumptions and was unable to calculate Fisher's exact test, but have evidence that the exact test would have produced a similar result (results not shown).

Results

A visual evaluation revealed no relationship between habitat modification and population density—the two upstream sites with highest densities were less modified and more modified—so I did not statistically analyze the data (Fig 7, Fig 8). Sex ratios were either equal or biased towards females at all sites except one (Warraker Creek) but exhibited no significant relationship related to habitat modification ($F_{2,4} = 2.80$, $p = 0.17$, Fig 9). Turtles at sites of low modification were significantly smaller than those at sites of high modification ($F_{2,5}$ = 17.03, p = 0.006, Fig 12). Although I observed the same range of sizes at low and high modification sites and a similar number of large adults at both types of sites, I found far more small turtles at the low disturbance sites (Figs 10, 11).

The number of turtles observed on logs was significantly higher than the number of turtles expected on logs based on log availability in the sites (G = 10.62, *d.f.* = 2, p = *0.005*, Fig. 13). Turtles were found more often on logs, rocks, and silt than expected and less often on gravel than expected by chance (G = 52.24, *d.f.* = 4, $p < 0.0001$, Fig. 14). Finally, turtles were found more often 100-300 centimeters deep than at any other depth based on depth abundance (G = 33.94, *d.f.* = 4, $p < 0.0001$, Fig. 15).

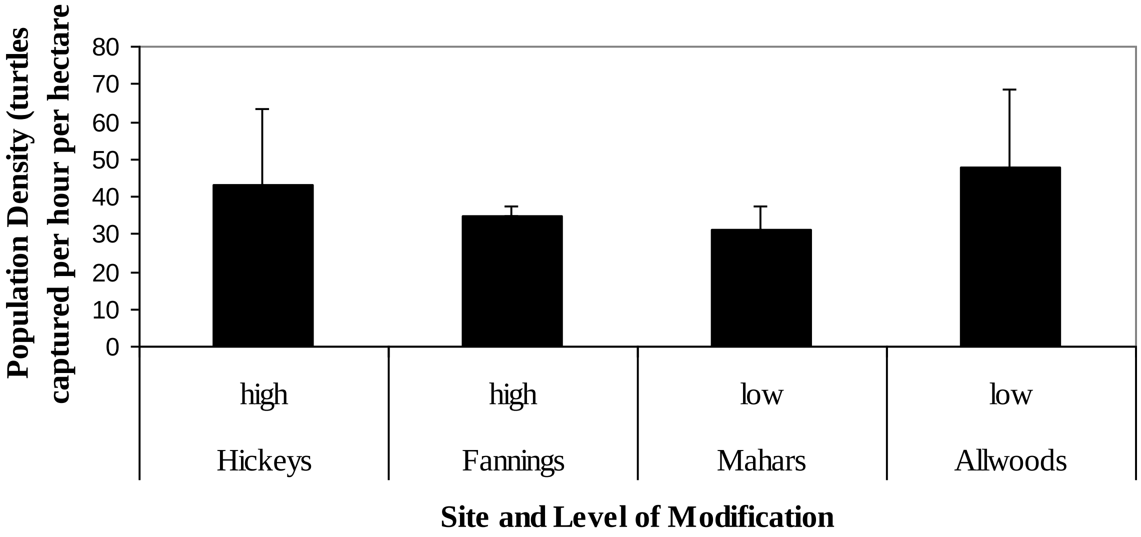

Figure 7. Population density (turtles captured per hour per hectare) ±SE for upstream sites.

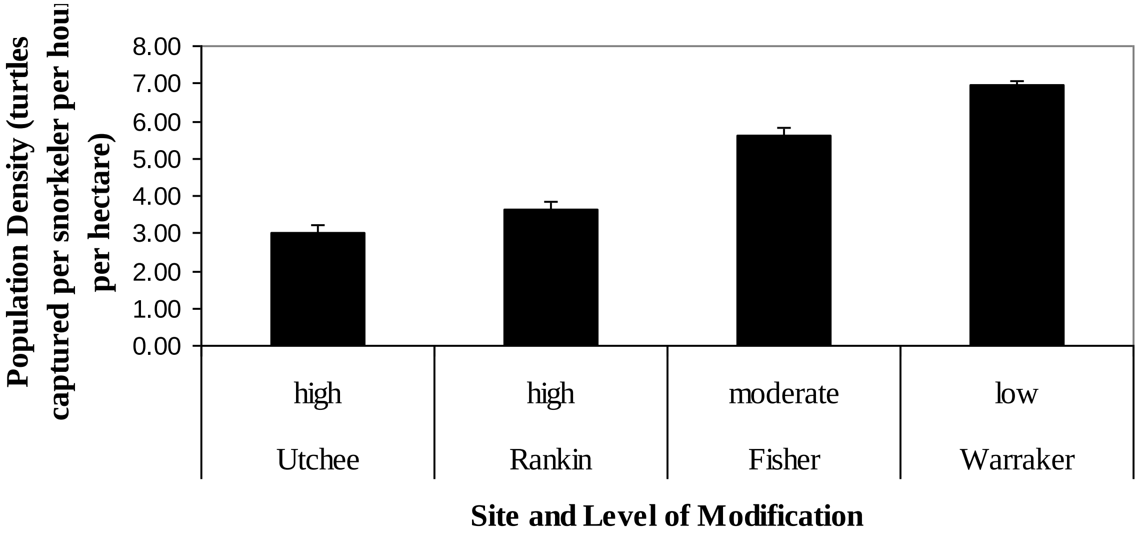

Figure 8. Population density (turtles captured per snorkeler hour per hectare) ±SE for downstream sites.

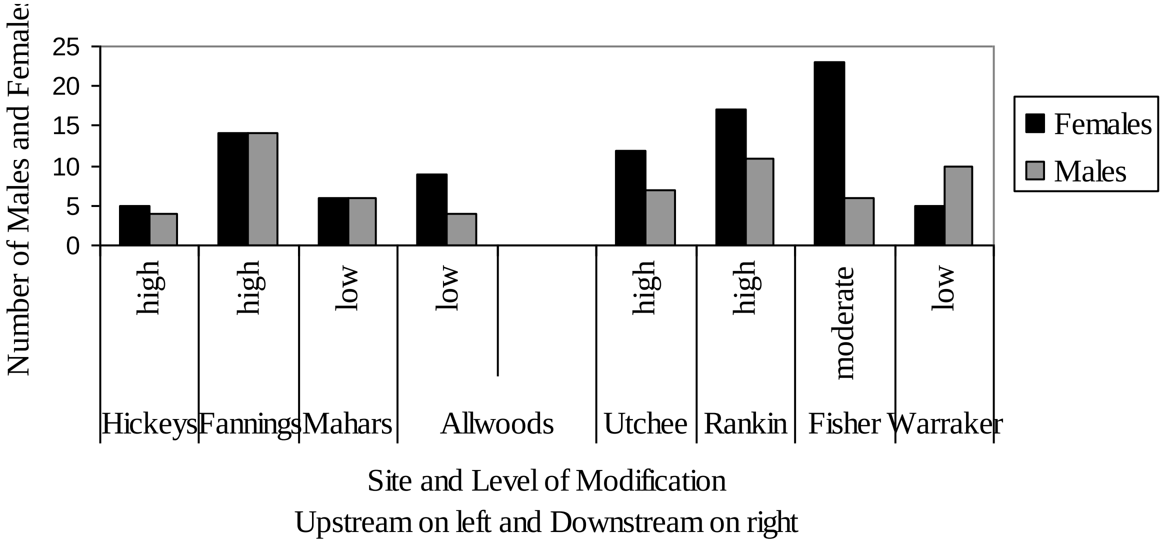

Figure 9. Number of Males and Females at each site.

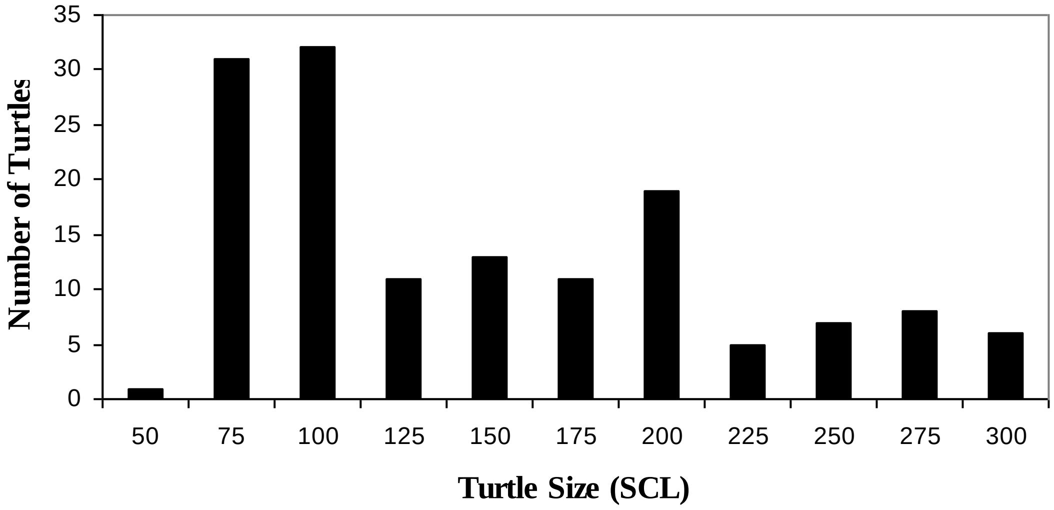

Figure 10. Number of turtles of each size category (SCL) found at sites experiencing low riparian modification.

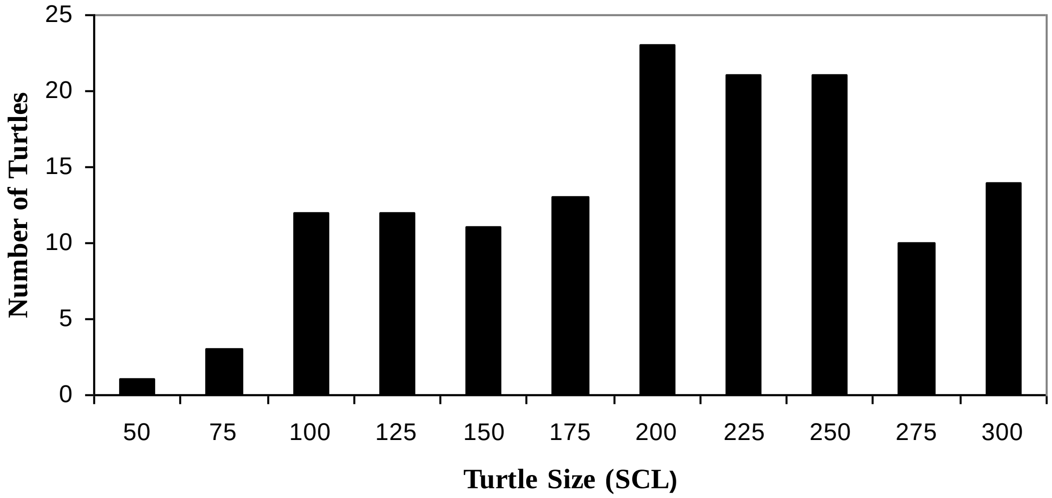

Figure 11. Number of turtles of each size category (SCL) found at sites experiencing high riparian modification.

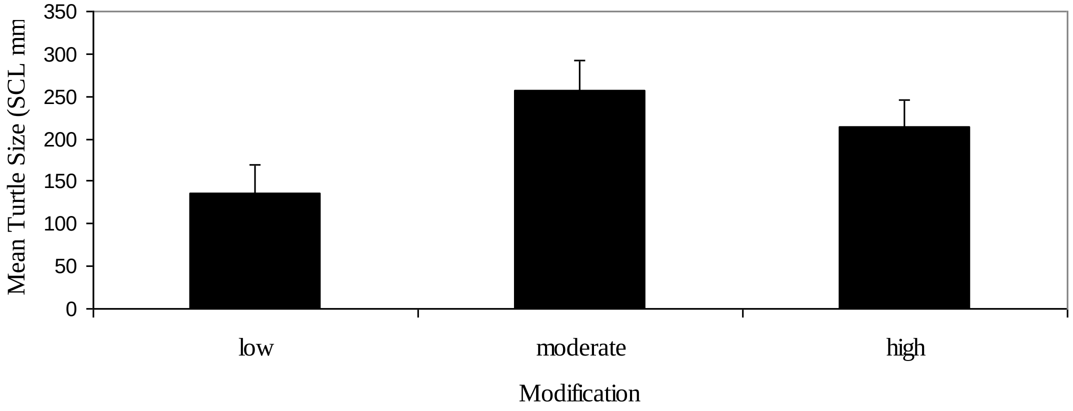

Figure 12. Mean size (±SE) of turtles at each level of modification.

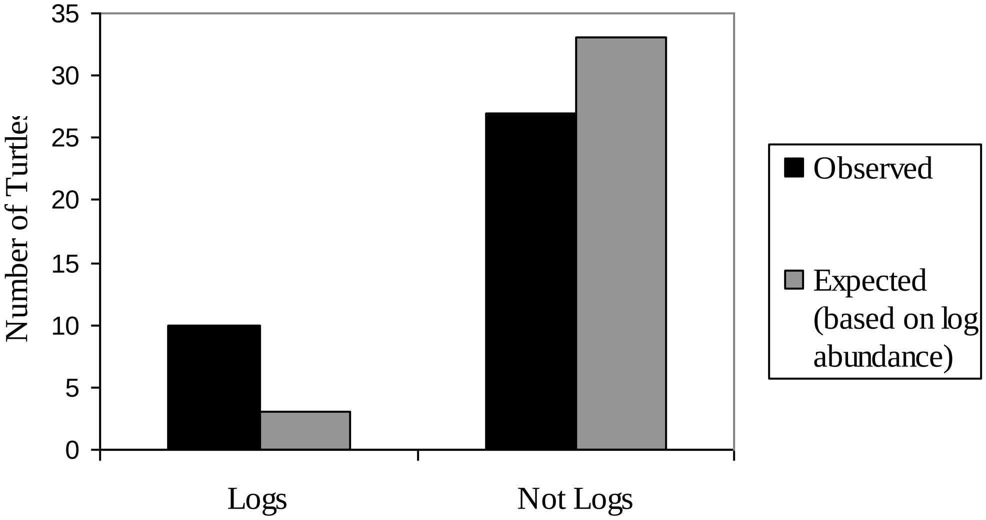

Figure 13. Number of turtles observed on logs or not on logs compared to the number of turtles expected on logs or not on logs based on log abundance in sites.

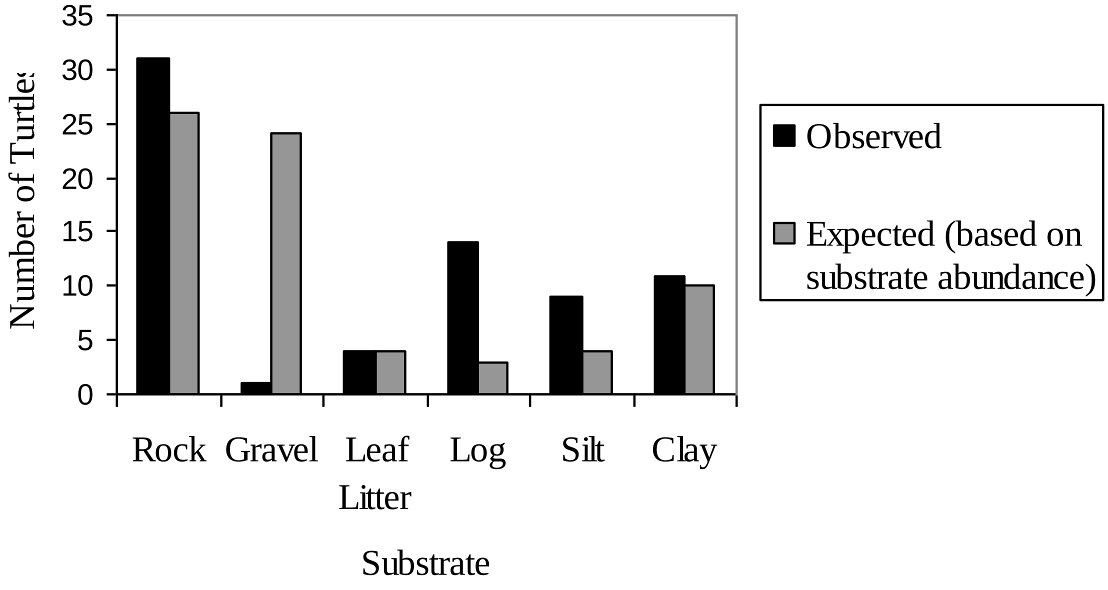

Figure 14. Number of turtles observed on each substrate compared to the number of turtles expected on each substrate based on substrate prevalence in sites

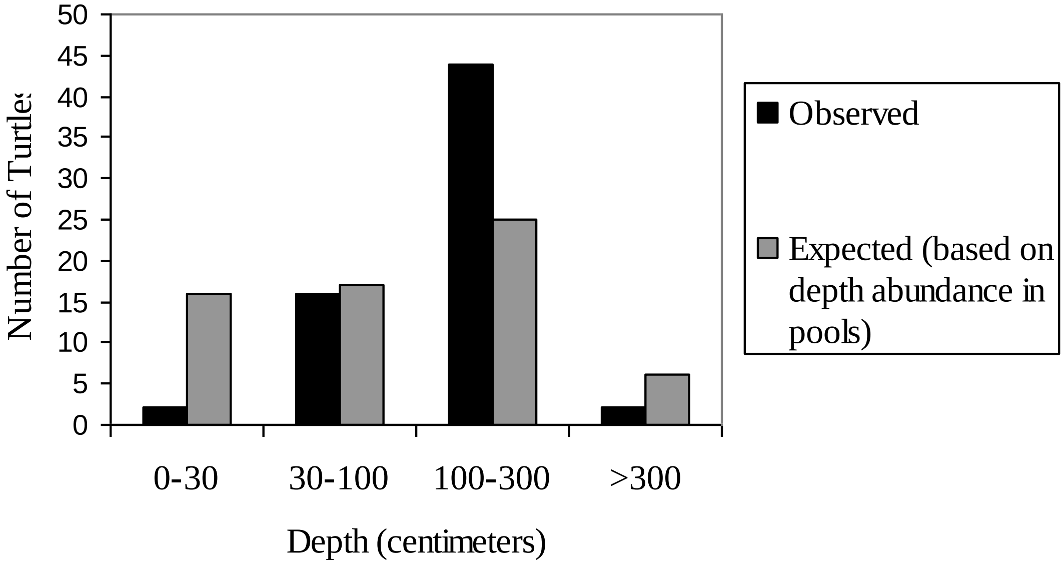

Figure 15. Number of turtles observed at each depth compared to the number of turtles expected at each depth based on depth prevalence in sites.

Discussion

Hypotheses

Turtle populations in more modified habitats appear less stable, and turtles appear to prefer logs over other substrates. The higher proportion of juveniles at less modified sites and smaller proportion of juveniles at more modified sites supported my hypothesis that riparian modification would affect population stability. Though population density and sex ratios did not support this hypothesis, the observed size distributions provide good evidence that habitat modification impacts population stability. Future studies are required to make firm conclusions about the entire species' stability. The presence of more turtles on logs than expected based on log abundance supported my second hypothesis that turtles would prefer logs as substrate.

I expected to see more juveniles at less modified sites because turtles usually have low juvenile survivorship, and thus stable populations have a high proportion of young (Bennett and Buhlmann 2005). My findings of fewer juveniles at more modified sites could predict future population decline resulting from decreased reproductive rates, decreased nest survivorship, or increased juvenile mortality; I will explore causes for higher rates of juvenile mortality in other freshwater turtle species. In New Hampshire, higher relative densities of adult *Chrysemys picta* correlated with higher road densities, implying that cars killed juveniles more frequently than adults (Marchand and Litvaitis 2004). *E. stirlingi* juveniles might experience similar mortality if more modified sites are nearer to roads than less modified sites. In Illinois, predators eat smaller *Trachemys scripta* turtles more often than larger ones (Tucker et al. 1999). Multiple studies link habitat modification and fragmentation with changes in predator presence and abundance (edge effects), which is another possible explanation for reduced juveniles at more modified sites (Winter et al. 2000; De Santo and Willson 2001).

At Allwoods, a less modified upstream site, and Mahars, a more modified upstream site, both landowners feed their turtles, and I do not know the type or quantity of food. Because juveniles and adults have different diets, this supplementary food could skew population demographics, which makes it difficult to evaluate the validity of my results. Supplementary food could also affect population density because in general additional food increases ecosystem carrying capacity, but these two sites had the highest and lowest population densities.

More modified sites did not exhibit lower population densities. Because my research team and I sampled during the transition between dry and wet seasons, rains increased sediment runoff in later samplings. The poor visibility made catching turtles more difficult. In addition, both snorkelers noted that the turtles seemed to learn as the study progressed, recognizing the snorkeler threat and swimming away sooner. For both these reasons sample sizes later in the study were dramatically smaller, and density estimates have large standard errors.

More modified sites did not exhibit skewed sex ratios. Animal populations usually exhibit 1:1 adult sex ratios, though there are many documented exceptions (Smith and Iverson 2002; Conner et al. 2005; Georges et al. 2006). Though *E. stirlingi d*eviate from expected 1:1 sex ratios, the pattern is unrelated to habitat modification. In this study size distribution data were more reliable indicators of population stability than either density or sex ratios, but all results are questionable because of the additional food.

E. stirlingi appeared to prefer logs as microhabitat in upstream sites. This knowledge is important for *E. stirlingi* conservation because logging and agricultural deforestation have reduced log density, and probably will continue to do so outside the World Heritage area (O'Malley 2007). Because logs serve important ecological functions for freshwater turtles, reduction of snags and log jams is one of the ten major causes of freshwater turtle decline worldwide (Bodie 2001). In addition to increasing habitat and food sources for freshwater turtles, they increase river-wide habitat diversity which increases the number of species the river can hold (Lester and Boulton 2008). Multiple American restoration projects have put wood back into rivers to improve habitat (Lester and Boulton 2008). Some of the beneficial results from these studies included increased fish and macroinvertebrate diversity, increased storage of organic material and sediment, and improved bed and bank stability (Lester and Boulton 2008). This is also a relatively simple, low-cost restoration solution. Log reduction might contribute to the decreased number of juvenile turtles in more modified sites—a question for a future study.

Natural History

Habitat and substrate preferences of *E. stirlingi* in the North Johnstone River contribute more information to its natural history. The results imply that turtles prefer logs, rock, and silt, and 100-300cm deep while avoiding gravel and the shallows. Qualitatively we observed larger turtles in deeper parts of the river and smaller turtles in shallower regions. Turtles might avoid shallow water because they are more visible and less mobile, and therefore more susceptible to predators. My research team and I sampled in the summer, when shallow water is warmer than deeper water, which might cause turtles to seek deeper water. Though *E. stirlingi* is not threatened or endangered, if restoration efforts along the Johnstone River become necessary, these data can help direct habitat improvements most beneficial to *E. stirlingi* populations.

Conservation Concerns

The Johnstone River has several risk factors which contribute to freshwater turtle population decline worldwide (Bodie 2001). I have addressed reduction of snags/log jams and human riparian use, and will now briefly address: pollution. During the study my research team and I encountered a turtle with milky eyes which did not appear to see snorkelers before capture (most turtles attempted to escape). Turner (2006) discovered eight individuals with milky eyes. Based on their responses to visual stimuli, he believed four to be completely blind and the other half partially blind. Though he did not study the cause of these irregularities, he suggested pollution. The prevalence of blindness in *E. stirlingi*, its causes, and reproductive impacts should be examined.

In addition to causing blindness, agricultural pollution could alter sex characteristics. *E. stirlingi* encounters known endocrine disrupting chemicals, the worldwide effects of which we are only just beginning to study more extensively (O'Malley 2007). There are few studies documenting the effects of endocrine disrupters on freshwater turtle species, and none on *E. stirlingi.* However, Kitana (2007) found that endocrine disrupting chemicals altered sex characteristics in male *Chrysemys picta*, another freshwater turtle species (Kitana et al. 2007). When exposed to endocrine-disrupting chemicals they exhibited reduced testicular weight, reduced epididymal sperm count, higher germ cell apoptosis, and longer precloacal lengths (Kitana et al. 2007). If they alter sex traits in *E. stirlingi,* endocrine disruptors might lower reproductive rates, causing the observed trends, of fewer small turtles in more modified habitats. However, unless they were introduced recently at only more modified sites, endocrine disruptors would more likely affect all turtles in the Johnstone River, rather than specific populations. These chemicals are still a concern given their impacts on many amphibians and reptilians, and should be further studied.

Although habitat destruction usually causes freshwater turtle population decline, there are notable exceptions. A study of *Apalone spinifera*, spanning 11 years with 290 individuals, demonstrated that this species survives in a heavily modified stream (Plummer et al. 2008). Human activities have extensively modified the stream; bulldozing in 1990 removed beaver dams, snags, debris, and woody vegetation on the bank. The stream previously had alternating riffles and deep pools, but construction replaced them with a relatively uniform streambed. *A. spinifera*'s survival rates, controlling for mortality differences across age classes, did not decrease as a result of the habitat modification (Plummer et al. 2008). My study implies that *E. stirlingi* is probably not because *E. stirlingi* is a specialist while *A. spinifera* is a generalist, *E. stirlingi* populations are more likely to decline in response to changing food availability. (Plummer et al. 2008). In addition, Size distribution patterns imply that habitat modification has affected population stability (Bennett and Buhlmann 2005; O'Malley 2007;). My study adds to overall understanding of *E. stirlingi* and provides a firm starting point for future studies to more conclusively evaluate its conservation status.

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