

EVALUATING THE ROLE OF COMMON SNAPPING TURTLES (*CHELYDRA  
SERPENTINA*) IN FRESHWATER PONDS OF NORTH CAROLINA

A Thesis  
by  
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## **Abstract**

Evaluating the Role of Common Snapping Turtles (*Chelydra serpentina*) in Freshwater Ponds of North Carolina

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Trophic cascades have frequently been observed in aquatic ecosystems. Some larger organisms, such as freshwater turtles, are more likely to contribute to trophic cascades than others in freshwater pond ecosystems. For example, the common snapping turtle (*Chelydra serpentina*), can reduce prey populations and trigger long-lasting phytoplankton blooms after short visits. This study aimed to disentangle both direct and indirect effects of common snapping turtles in experimental ponds. Each experimental pond contained food webs differing in predator presence with large and small apex predators (short term visits by 3-9 kg common snapping turtles), mesopredator presence (adult eastern newts, *Notophthalmus viridescens*), and herbivorous prey (*Rana catesbeiana* tadpoles). I predicted a direct top-down effect of turtle predation on newts and tadpoles. I also predicted that snapping turtle predation on newts would lead to higher tadpole survival and growth, which indirectly would decrease algal biomass.

Tadpole survival, mass, and developmental stage differed among food webs.

Tadpoles had the largest masses in food webs with large turtles and newts. Tadpoles in food webs with newts and large turtles were further along developmentally than tadpoles in other food webs. Newt survival differed between food webs and appeared to be lowest in food webs with small turtles. There was no statistical difference in algal biomass among food webs at the conclusion of the experiment. Overall, these results highlight that a trophic cascade may occur in freshwater ponds following short term visits by common snapping turtles, but their role is complex and may be size dependent. My study also reinforces the need for more experimental research with freshwater turtles to elucidate their part in freshwater food webs.

## **Acknowledgments**

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## **Dedication**

I would like to dedicate this thesis to my dog, Maple. She was by my side for every hour spent on this document and I couldn't have done it without her.

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## **Foreword**

This thesis will be submitted to *Ichthyology and Herpetology*, a peer-reviewed journal. It has been formatted according to the style guide for that journal.

## INTRODUCTION

The evidence for trophic cascades has increased as more of the world's top predators disappear and trophic downgrading occurs across the planet (Shurin et al., 2002; Heithaus et al., 2008; Estes et al., 2011). Trophic cascades have been observed in both terrestrial (Schmitz et al., 2000; Shurin et al., 2002; Fortin et al., 2005) and aquatic ecosystems (Strong, 1992; Shurin et al., 2002; Heithaus et al., 2008). Despite the presence of trophic cascades in a variety of ecosystems, the top-down effects are most studied in aquatic ecosystems (Strong, 1992; Shurin et al., 2002; Shurin and Seabloom, 2005). Aquatic systems are heavily reliant on few, very important prey species and apex predators which keep intermediate prey populations in check and allow base trophic level organisms to thrive (Strong, 1992; Shurin et al., 2002). Freshwater systems specifically are characterized as having algae-based food webs with crucial apex predator species which make top-down effects more linear (Strong, 1992; Shurin et al., 2002). Prior studies have shown that because of their reliance on top predators, freshwater lentic systems are the most vulnerable to trophic cascades, and the removal of their apex predators can lead to food web collapse (Strong, 1992; Shurin and Seabloom, 2005).

One taxonomic group that can potentially contribute to top-down effects in aquatic ecosystems because of their size and longevity is turtles (Gomez-Mestre and Keller, 2003; Lindsay et al., 2013; Aresco et al., 2015; Garig et al., 2020). Unfortunately, turtles are among the most threatened vertebrate groups on the planet (Hoffmann et al., 2010, Lovich et al., 2018). The threatened status of many turtle species is especially concerning due to their long lives and large total biomass in aquatic habitats (Gibbons and Semlitsch, 1982; Iverson, 1982; Gibbons, 1987). For example, the loss of large, long-lived individuals in a population

would take years to recover since young turtles can take 10+ years to reach sexual maturity and egg mortality is often high (Gibbons, 1987; Miller, 2001; Lovich et al., 2018). This loss of top predators could hasten food web collapse in aquatic systems that are held in equilibrium by these organisms (Strong, 1992). For example, in marine environments, green sea turtles (*Chelonia mydas*) affect the environment via seagrass grazing (Fourqurean et al., 2010). When left without a shark predator, green sea turtles are capable of overgrazing sea groves and destroying crucial habitat for other sea life (Fourqurean et al., 2010). This decrease in seagrass cover also leads to a decline in the total amount of carbon able to be sequestered in these areas (Fourqurean et al., 2010). Despite the potential importance of turtles in aquatic ecosystems, and their rapid decline, particularly of freshwater turtles, surprisingly they remain an underrepresented group in food web literature (Lovich et al., 2018; Gibbons and Lovich, 2019).

Freshwater turtles can have effects on lower trophic levels in freshwater ecosystems (Lindsay et al., 2013). Freshwater turtles often are generalists with diverse diets and can affect their environment in various ways (Gomez-Mestre and Keller, 2003; Santori et al., 2020). Some generalist species, like the red-eared slider (*Trachemys scripta elegans*) have been documented to eat organisms higher in the food web, like fish and snails, as well as primary producers and macroalgae (Aresco et al., 2015). The ability of red-eared sliders to switch across trophic levels depending on food availability allows them to affect many different components of the food web simultaneously (Lindsay et al., 2013; Aresco et al., 2015). Therefore, omnivorous freshwater turtles have the potential for the strongest top-down effects in freshwater systems due to their ability to control both plant and animal prey populations (Lindsay et al., 2013; Aresco et al., 2015). Despite research confirming that

freshwater turtles have top-down effects on ecosystems, data is scarce for many common and rare species (Lovich et al., 2018).

One omnivorous, freshwater turtle species with known top-down effects in freshwater ponds is the common snapping turtle (*Chelydra serpentina*) (Garig et al., 2020). Common snapping turtles are a large freshwater turtle species that is capable of long migrational movements (Obbard and Brooks, 1980; Obbard and Brooks 1981; Congdon et al., 1994). These migrations average around 5 km via water, and up to 0.5 km overland (Obbard and Brooks, 1980). The migrations of snapping turtles also give them the opportunity to interact with various prey communities across ponds over a short period of time (Obbard and Books, 1980; Obbard and Brooks, 1981). Snapping turtles can have top-down effects on prey species and phytoplankton that persist for up to a month following a short-term visit (Wilbur, 1997). Indeed, a four-day visit by a snapping turtle decreased the overall survival of Southern Leopard frogs (*Rana sphenocephala*) but increased their mass at metamorphosis (Garig et al., 2020). To date, no studies have been conducted to explore both the indirect and direct effects of common snapping turtles on freshwater communities.

While observational and experimental data are now available on the direct role of common snapping turtles in their ecosystems, the indirect role is not well understood. To test this, I simulated four different food webs in freshwater mesocosms: 1) a prey control food web with only herbivorous bullfrog tadpoles, 2) an intermediate food web with an intermediate predator *Notophthalmus viridescens* and tadpole prey, 3) a top food web with small common snapping turtles and intermediate predators with tadpole prey, and 4) a top food web with large common snapping turtles and intermediate predators with tadpole prey. Prey responses (survival of all prey and growth of tadpoles) and ecosystem responses (algal

biomass) were all measured. Due to their predator status and generalist feeding habits, I hypothesize that common snapping turtles will cause a decrease in the overall survival of both intermediate predators and prey species, and an increase in the size of remaining tadpole survivors (e.g., thinning effect). I also hypothesize that algal biomass will increase in mesocosms with higher trophic levels present due to a reduction in the number of herbivores.

## **MATERIALS AND METHODS**

### *Study System and Species*

The common snapping turtle, *Chelydra serpentina*, is a large, omnivorous freshwater turtle often considered to be a top predator in freshwater ecosystems (Steyermark et al., 2008). These turtles have a native range that spreads throughout most of North America and are considered transitory predators within that range due to their large home territories (Obbard and Brooks, 1981; Steyermark et al., 2008). Eastern newts served as the intermediate predator in this experiment. Eastern newts, *Notophthalmus viridescens*, are a known prey item of common snapping turtles but are also cited as a keystone predator in some freshwater ecosystems (Smith, 2006; Chapman et al., 2017). Eastern newts commonly prey on smaller amphibians, like tadpoles, for as long as their gape-limit allows. Tadpoles of the American bullfrog, *Rana catesbeiana*, were used as the base prey organism in the experiment. These tadpoles are herbivores and grow quickly to survive the winter as tadpoles. Common snapping turtles, Eastern newts, and American bullfrogs are all commonly found in Western North Carolina and as such are familiar with one another as prey and predator, so there were no novel interactions in this study.

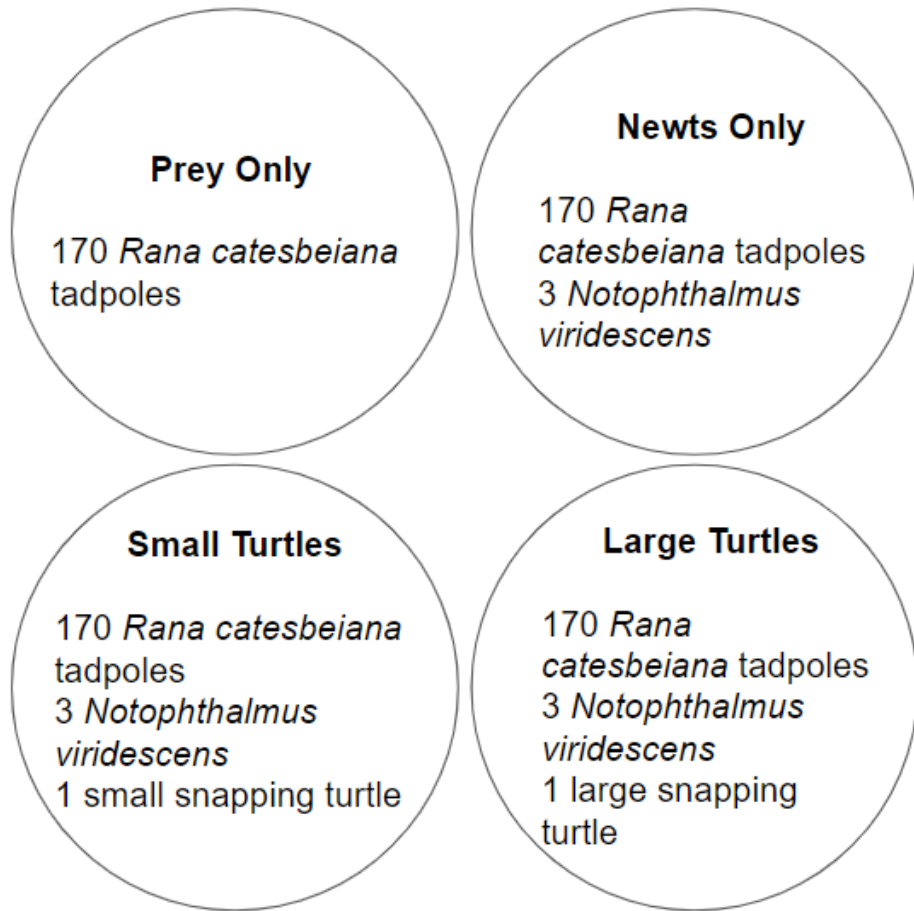
### *Experimental Methods*

Experimental organisms were collected from freshwater ponds in western North Carolina and eastern Tennessee for the mesocosm experiment. Bullfrog egg masses were hand collected, while *Notophthalmus viridescens* were caught in dip nets. Common snapping turtles were trapped using hoop nets. Mesocosms were run in 1100L polyurethane cattle tanks (1.52m diameter) housed on the campus of Appalachian State University. Each tank was filled with city water treated with a dechlorinating solution (Amquel©, Hayward, CA) and inoculated with 1L of local pond water one month prior to the addition of any experimental organisms. Each mesocosm also received four white ceramic tiles one month before adding experimental organisms. Ceramic tiles were deployed to determine algal biomass as an indicator of primary productivity (Lindsay et al., 2013).

Seventeen mesocosm tanks were randomly assigned to one of four food webs (Fig. 1). Each mesocosm received 170 *Rana catesbeiana* tadpoles on July 17<sup>th</sup>. All tanks but the control food web received 3 eastern newts on July 19<sup>th</sup>. Small turtles were considered individuals with mass less than 5kg ( $X = 3.764\text{kg}$ ,  $SE = 0.271\text{kg}$ ) and large turtles were those with mass greater than 5kg ( $X = 8.95\text{kg}$ ,  $SE = 0.104\text{kg}$ ). All of the small and large turtles were also different sexes, with all small turtles being female and all large turtles being male. To mimic the short-term visits of snapping turtles during their migration movements, common snapping turtles were only present in the mesocosms for 4 days, from July 21<sup>st</sup>-July 25<sup>th</sup> (Garig et al., 2020). After their four-day visit, turtles were removed from the mesocosms and returned to the ponds where they were initially captured. The introduction of organisms to a tank was staggered by 48 hours, starting with tadpoles, then newts, and ending with common snapping turtles. Due to complications while trapping for newts and common



snapping turtles, there were uneven numbers of replicates for each food web. There were 5 replicates of the control food web, 4 replicates of the newt-only food web, 5 replicates of the small snapping turtle food web, and 3 replicates of the large snapping turtle food web.



**Fig. 1.** Mesocosm food webs (in bold) that vary by presence of newts and turtles.

### *Experimental measurements*

The direct effects of turtle predation were determined by comparing prey survival across experimental food webs. Tadpole and newt survival was calculated for all tanks as the number of individuals remaining out of the initial total. Growth (mass in grams) and development (Gosner, 1960) of tadpole prey was compared among food webs to determine if predator presence influenced tadpole responses. To compare growth and development, I collected and weighed 20 tadpoles from each mesocosm at 3-week intervals throughout the experiment (August 15th, September 5th, October 3<sup>rd</sup>, and October 15th). Tadpole mass of all tadpoles, as well as Gosner stage of 20 individuals, was measured at the conclusion of the experiment. Pre-metamorphosis development rate and body size can be indicators of the size at metamorphosis, which has frequently been used as an indicator for future amphibian reproductive and survival success (Smith-Gill and Berven, 1979; Werner, 1986; Semlitsch et al., 1988).

The indirect effects of common snapping turtles on lower mesocosm trophic levels were measured as changes in algal biomass. Measurements of algal biomass were made by scraping off algae from tiles and measuring their dry mass (Lindsay et al., 2013). Tiles were cleaned and sanitized prior to deployment in the mesocosms one month prior to the addition of tadpoles. One tile was collected from each mesocosm at the time of tadpole introduction and then on July 17<sup>th</sup>, August 7<sup>th</sup>, August 28<sup>th</sup>, and October 17<sup>th</sup>.

### *Statistical Analysis*

All response variables were analyzed using generalized linear mixed-effect models (GLMM) in R with the lme4 package (Bates et al., 2015). Means from individual mesocosms

were calculated for each variable (tadpole survival, tadpole mass at four sampling periods, tadpole stage at experiment conclusion, algal mass, and newt survival). GLMMs were then conducted with these means using the food web treatments as a fixed effect to determine if food web variation led to trophic cascades. Survival data for tadpoles and newts was transformed using the logit function. The natural log of tadpole and algal masses were used. Tukey's post-hoc tests were run with the `glht` function to analyze all GLMMs (Hothorn et al., 2008).

## RESULTS

### *Predator Response*

All large and small snapping turtles survived the duration of the experiment. Newt survival differed between food webs (SS = 43.831, df = 2,  $P=0.0309$ ; Fig. 2). Although the food web with small turtles had the lowest newt survival, post-hoc analyses did not detect pairwise differences (Fig. 2).

### *Tadpole Response*

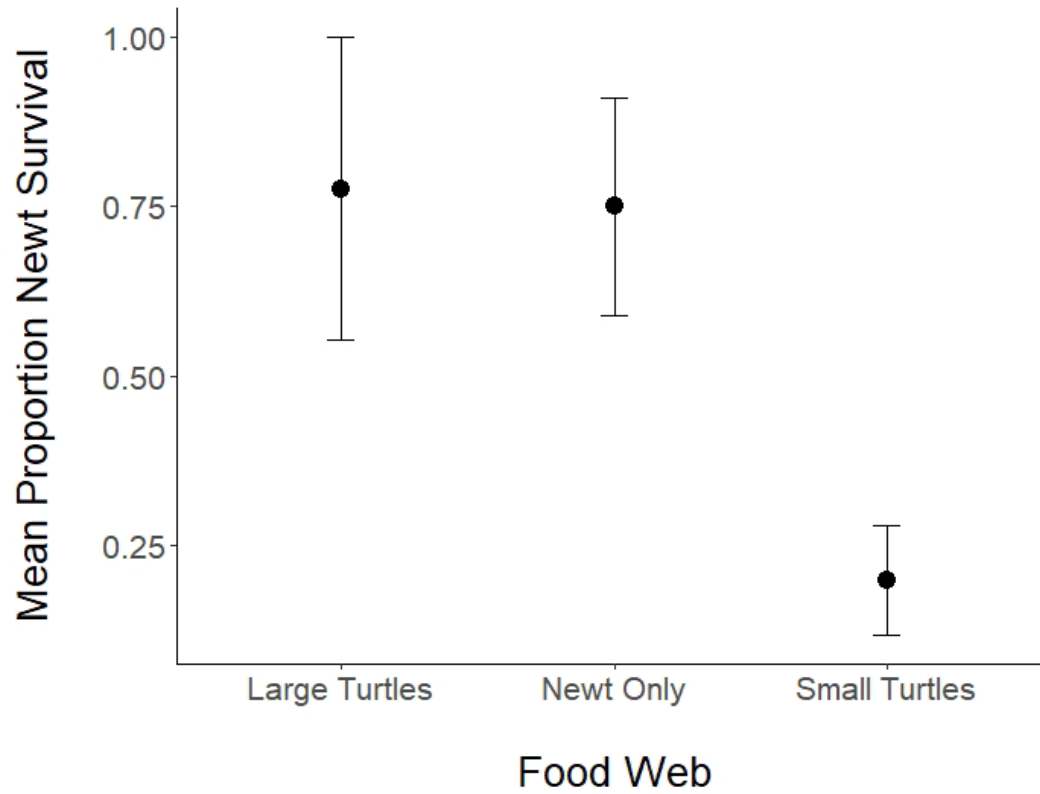
Mean tadpole mass differed between food webs during all sampling periods (SS = 2.0189, df = 3,  $P < 0.001$ ; Fig. 3). On August 15th, tadpoles in the large turtle food web were the largest ( $Z \leq -7.842$ ,  $P < 0.001$ ). On September 5<sup>th</sup> and October 3rd, tadpoles in the food webs with large turtles and newts had similar masses ( $Z=-1.261$ ,  $P=0.591$  and  $Z=0.282$ ,  $P=0.992$ ) and were larger than tadpoles in other food webs (Fig. 3). At the conclusion of the experiment on October 15th, tadpoles in the newt only food web were the largest ( $Z=5.728-16.064$ ,  $P \leq 0.001$ ). Tadpoles in food webs with large turtles had the second largest masses overall ( $Z=-9.861-5.728$ ,  $P \leq 0.001$ ). Tadpoles in the prey-only food web and those with

small turtles were statistically similar and smaller than the other food webs ( $Z=0.828$ ,  $P = 0.841$ ; Fig. 3).

Tadpole developmental stage also differed between food webs at the end of the experiment ( $SS = 126.47$ ,  $df = 3$ ,  $P < 0.001$ ; Fig. 4). Tadpoles in food webs with only prey and with small turtles were at similar stages of development ( $Z=1.226$ ,  $P=0.611$ ). Tadpoles in food webs with large turtles and newts were also in similar stages of development ( $Z=1.701$ ,  $P=0.336$ ) but were further in development (Gosner stage 25 vs. 28; Fig. 4) than tadpoles with small turtles and only prey ( $Z=-3.847-6.152$ ,  $P \leq 0.032$ ; Fig. 4). Tadpole survival did not differ between food webs ( $SS = 2.0189$ ,  $df = 3$ ,  $P = 0.1501$ ; Fig. 5).

#### *Algal Biomass Response*

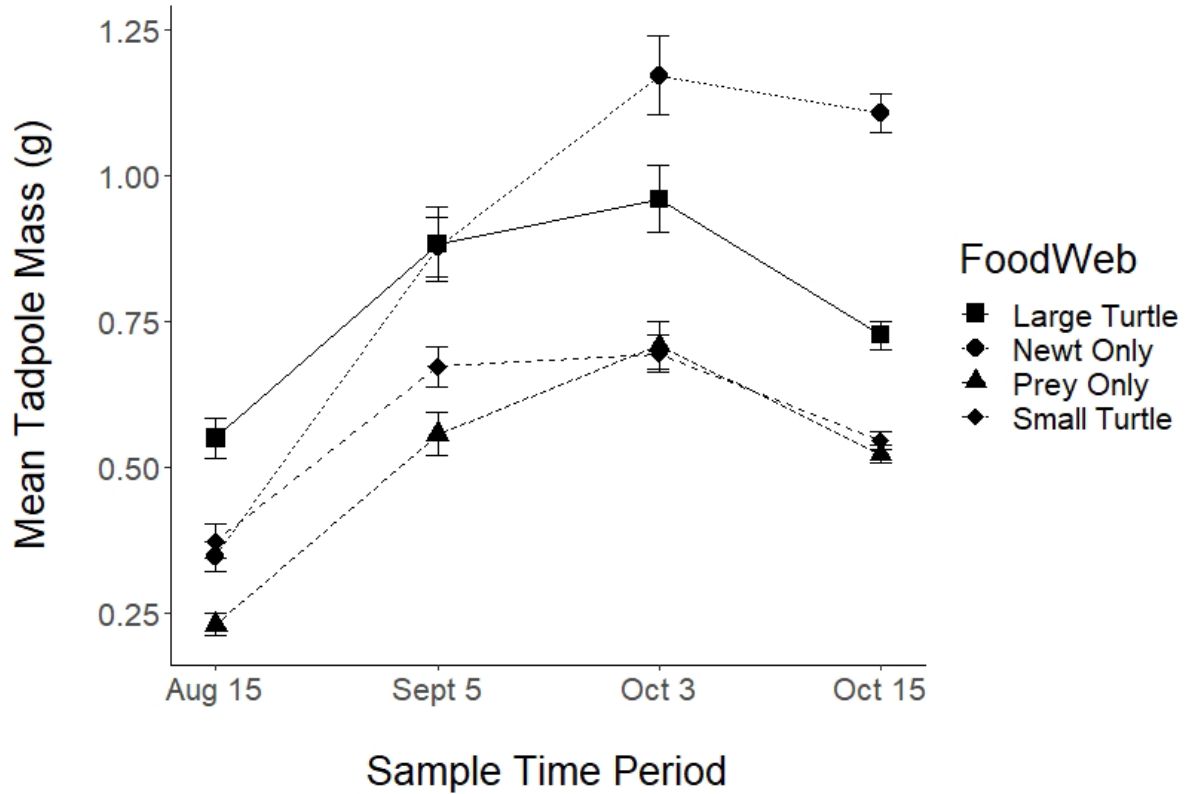
Algal biomass did not differ between food webs ( $\chi^2 = 0.552$ ,  $df = 3$ ,  $P=0.907$ ; Fig. 6). Algal biomass also did not differ significantly over time webs ( $\chi^2 = 7.269$ ,  $df = 3$ ,  $P=0.064$ ; Fig. 6). Algal biomass was similar in all food webs during the first three sample periods with an increase in variability during the sampling period on October 15<sup>th</sup> (Fig. 6).



**Fig. 2.** Mean proportion of newts surviving the experiment in each food web with error bars showing standard error. Survival of newts differed significantly between food webs but post-hoc analyses did not detect statistical differences ( $SS = 43.831$ ,  $df = 2$ ,  $P=0.0309$ ).

**Table 1.** ANOVA results for newt survival GLMM.

<b>Source of Variance</b>	<b>SS</b>	<b>df</b>	<b>F</b>	<b>P</b>
Food Web	43.831	2	5.2467	0.03087
Residuals	37.593	9		

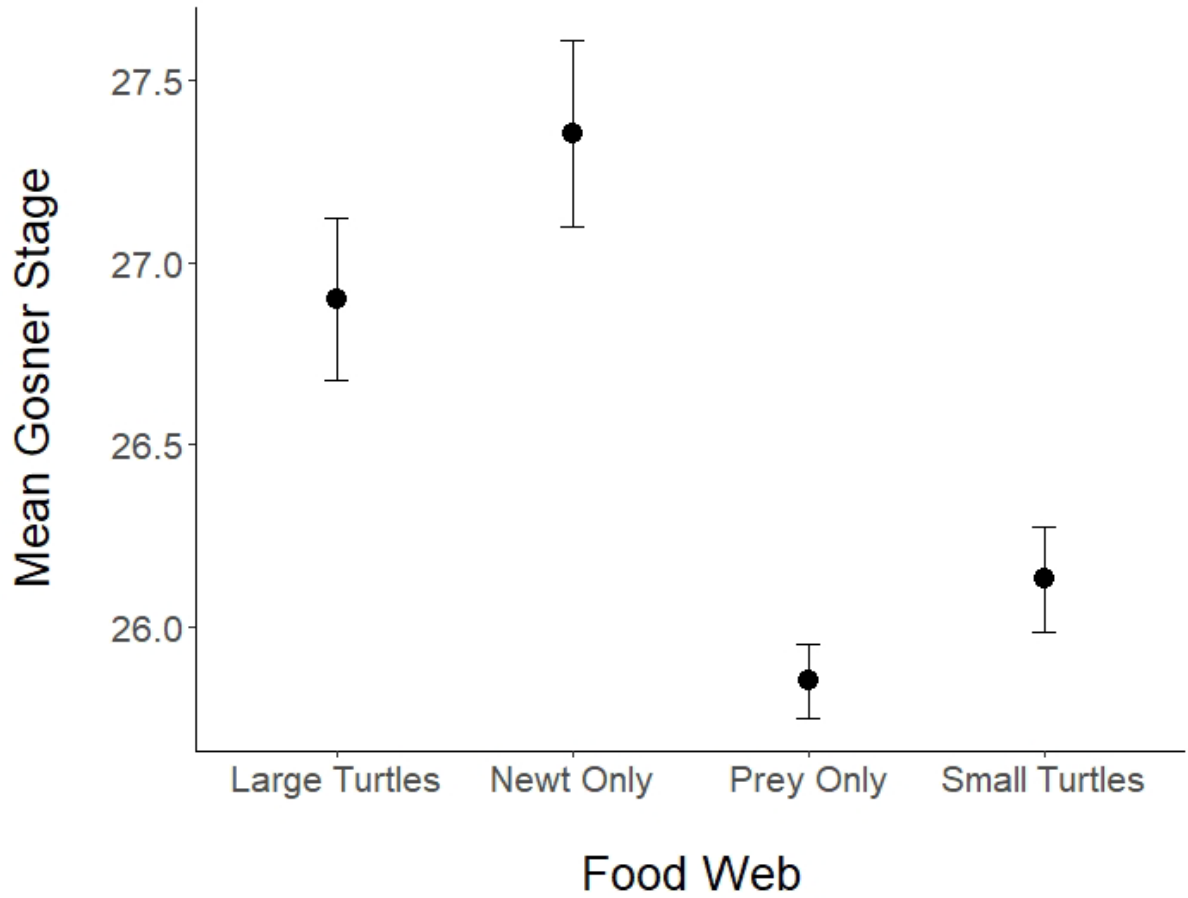


**Fig. 3.** Average tadpole mass (g) over four sampling periods with error bars showing standard error around the mean. Twenty tadpoles were measured during the August 15th, September 5th, and October 3rd sampling periods. All surviving tadpoles were measured on October 15th at the conclusion of the experiment.



**Table 2.** ANOVA results for tadpole mass GLMM.

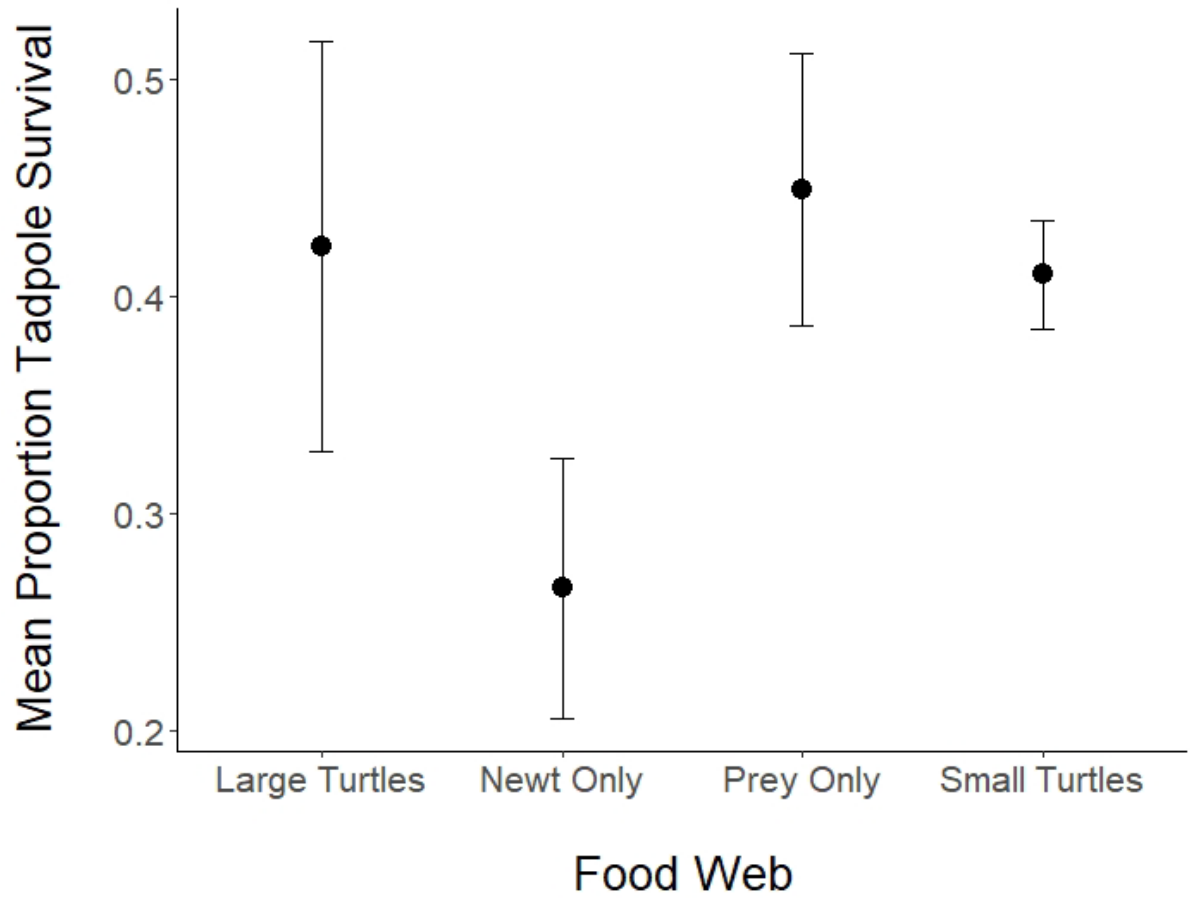
<b>Source of Variance</b>	<b>SS</b>	<b>df</b>	<b>F</b>	<b>P</b>
Food Web	115.08	3	91.44	$<2.2 \times 10^{-16}$
Residuals	912.85	2176		



**Fig. 4.** Mean developmental stage (Gosner) was observed for 20 tadpoles from each tank at the conclusion of the experiment. Tadpoles in food webs with large turtles and only newts were more developed than tadpoles with small turtles and no predators. Means are graphed with standard error indicated with error bars.

**Table 3.** ANOVA results for tadpole Gosner stage GLMM.

<b>Source of Variance</b>	<b>SS</b>	<b>df</b>	<b>F</b>	<b>P</b>
Food Web	126.47	3	16.011	$9.47 \times 10^{-10}$
Residuals	882.07	335		

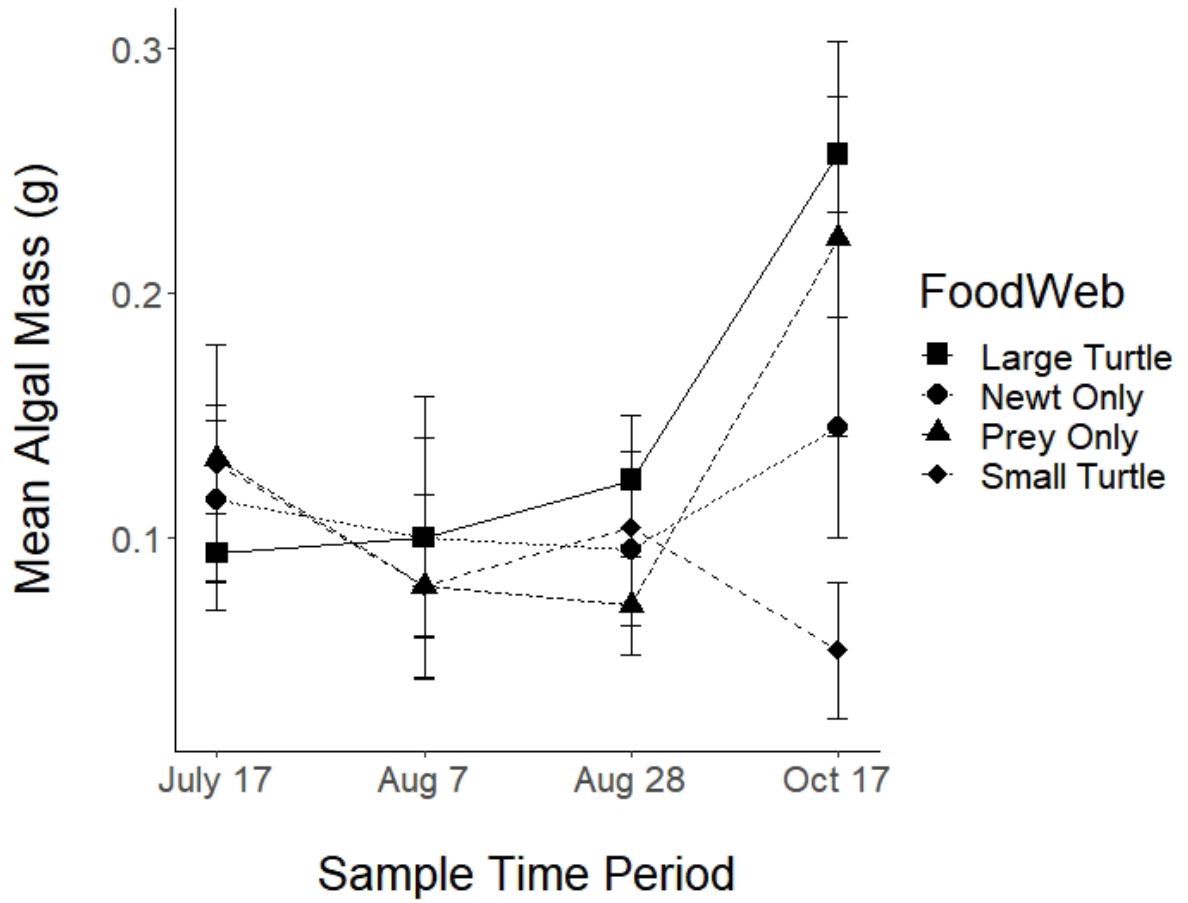


**Fig. 5.** The mean proportion of surviving tadpoles at the conclusion of the experiment.

Food web did not have a statistically significant effect on tadpole survival. Error bars show standard error around the mean.

**Table 4.** ANOVA results for tadpole survival GLMM.

<b>Source of Variance</b>	<b>SS</b>	<b>df</b>	<b>F</b>	<b>P</b>
Food Web	2.0189	3	2.0971	0.15
Residuals	4.1719	13		



**Fig. 6.** Mean algal biomasses were collected throughout the experiment and standard error around the mean is shown with error bars. Time period, food web, and the interaction effect had no statistical effect on algal biomass.

**Table 5.** ANOVA results for algal biomass GLMM.

<b>Source of Variance</b>	<b>SS</b>	<b>df</b>	<b>F</b>	<b>P</b>
Food Web	6.245	3	0.9251	0.4338
Residuals	144.007	64		

## DISCUSSION

This study, which mimicked a short visit by common snapping turtles, provides further evidence that turtles can trigger top-down changes in freshwater ponds. After a four-day visit, common snapping turtles decreased intermediate predator survival. Tadpole size and developmental stage were significantly affected by turtle presence, but that effect was dependent on turtle size. Indeed, tadpoles exposed to large turtles were larger and more developed than tadpoles without predators or those exposed to small turtles (Figs. 3 and 4). This study indicates that the transitory effects of common snapping turtles may change intermediate predator and prey populations. My study does not, however, indicate that common snapping turtles cause a trophic cascade because my measure of productivity, algal biomass, was unaffected. The results of my research also suggest that different sizes and sexes of common snapping turtles may have varying effects on freshwater communities, including nonconsumptive effects. This is important because size-dependent interactions have been documented as changing a predator's community affect and sex-specific effects of predators are also getting more recognition as a trophic factor (Shine, 1989; Bolnick et al., 2011; Ingram et al., 2011).

Although generalized linear mixed-effects models detected differences between food webs for newt survival ( $SS = 43.831$ ,  $df = 2$ ,  $P=0.0309$ ; Fig. 2), post-hoc pairwise comparisons did not find statistical significance. Even in the absence of pairwise differences, these results could be interpreted as biologically significant. For example, newt survival in food webs with small turtles was half that of those in food webs with only newts, meaning 1-2 more newts died in food webs with small turtles than in newt-only food webs. Throughout the study, the newt survival and tadpole growth in food webs containing small turtles



provided similar results to prey-only food webs. Both tadpole mass and Gosner stage were statistically similar in the prey-only and small turtle food webs (Figs. 3 and 4). This could be attributed to the decrease in newt survival caused by small turtle predation, or a decrease in newt activity level to avoid small turtle predators. Previous studies have shown significant decreases in newt activity levels in response to common snapping turtle visual and chemical cues but did not include measurements of foraging activity (Chapman et al., 2017).

However, newt activity and behavior were not observed in this study. It is also important to note that the proportion of newt survival was not 1 in two of the four newt-only food webs. This suggests that some newts may have escaped or died without predation. To investigate the potential predator effects of newts in those tanks, I calculated the survival rates of newts in tanks where some were lost. The tadpole survival from the two newt-only mesocosms with some newt mortality was compared to the tadpole survival in mesocosms with full newt survival. In one replicate, the tadpole survival was within one standard deviation (0.097) of that in the full newt survival mesocosms. In the other replicate, tadpole survival was almost two standard deviations lower than in the full newt survival tanks and only one newt made it to the end of the experiment. These results suggest that the lost newts in the newt only food webs most likely died or escaped after consuming tadpole prey.

Prey response differences in this study show that predator size can influence the role of a snapping turtle in pond food webs. Previous mesocosm studies have shown that newts will move within their environment to avoid common snapping turtles (Chapman et al., 2017). The high rates of newt predation by small turtles suggest that turtles of this size were potentially more active or more efficient predators of newts in mesocosms. One confounding factor for my experiment was that all small turtles were female, and all large turtles were

male. Thus, differences in prey survival and growth cannot be fully explained by size or sex alone. However, research with other species of freshwater turtles have indicated that female turtles, regardless of carapace size, tend to consume larger volumes of food and forage in different microhabitats than their male counterparts (Plummer and Farrar, 1981; Ford and Moll, 2004). My results align with this concept of female turtles consuming more prey, since all the smaller, female turtles had the highest rates of predation on intermediate predators (Fig. 2). It is also possible that these female turtles preferred a larger, more nutrient-rich prey like the newts, relative to the tadpoles, because they were exiting the nesting season (Iverson et al., 1997). Since female common snapping turtles make large migrations in search of nesting grounds, they likely have an energy deficit to fill after laying their eggs (Obbard and Brooks, 1980; Obbard and Brooks, 1981). Further research is needed to disentangle the independent and interactive effects of turtle size and turtle sex in determining top-down turtle effects in freshwater ecosystems.

Prey growth varied significantly across food webs (Fig. 3). My results suggest that tadpoles in food webs with large turtles and newts may have experienced a thinning effect where more food was available for fewer survivors. This is supported by the relatively low tadpole survival in newt-only food webs. Similarly, in food webs with large turtles where newt predation was low, newts were able to prey upon tadpoles until they became too large. This is well-documented in experimental food webs because newts are a gape-limited, keystone predator (Morin, 1986; Fauth, 1999; Smith, 2006; Urban, 2007). Growing large and reaching metamorphosis quickly is advantageous for larval amphibians to escape predation by leaving their aquatic environment and outgrow gape limited predators (Morin, 1986; Semlitsch and Wilbur, 1988; Semlitsch et al., 1988, Smith, 2006). The size of tadpoles at

metamorphosis is also positively correlated with their likelihood of survival (Berven and Gill, 1983; Altwegg and Reyer, 2003). Although I was unable to measure mass at metamorphosis, final mass of tadpoles in food webs with large turtles and only newts was larger and individuals were further along developmentally. The size and rate of growth of these tadpoles is likely beneficial for adult fitness and reproductive success (Semlitsch et al., 1988; Altwegg and Reyer, 2003). However, it is possible that tadpoles in food webs with small turtles and no predators may experience compensatory growth later on, resulting in little size differences between tadpole groups at metamorphosis (Capellán and Nicieza, 2007; Hector et al., 2012).

Another potential explanation for the trends in my data is pressure put on prey populations by nonconsumptive effects. Nonconsumptive effects of predators, especially generalists like the common snapping turtle, on prey have been well documented as a driving force behind cascading effects (Orrock et al., 2008; Peckarsky et al., 2008). Since the common snapping turtles were only present in the tanks for the first four days, differences after that period could be attributed to lingering behavioral changes. For example, there were changes in mean growth rate of tadpoles in all food webs over time, but the most drastic change was seen in the tanks with newts only. Looking at figure 3, in tanks with large turtles, tadpoles were the largest during the first sampling period, despite high newt presence. It is possible that in tanks where turtles were present, newts responded to chemical cues in the water and decreased their activity levels (Chapman et al., 2017). This supports the idea that newts may have reduced activity levels while turtles were present, which allowed the tadpoles to forage freely. Meanwhile, tadpoles in tanks with only newts seemed to grow quicker after the first sample was taken than tadpoles with other predators. Since the tadpoles

would have outgrown the newt gape limit by the first tadpole mass sample, it is unlikely that this growth is driven by direct consumptive effects. In the newt only tanks, newts were able to predate heavily on tadpoles which then experienced a thinning effect and an increase in growth rate once they were large enough to avoid predation. These results point to the conclusion that common snapping turtles, just by passing through a pond, can drastically change the way intermediate predators behave, which has a cascading effect on prey populations.

One hypothesis that was not supported was that common snapping turtle presence would cause a trophic cascade down to the lowest trophic level, algal biomass. Throughout the experiment, algal biomass remained similar in all food webs across time except during the last sampling period on October 17<sup>th</sup> (Fig. 6). The differences in algal biomass detected on October 17<sup>th</sup> could be due to a longer gap in algal sampling, 50 days versus 21 for all other sample intervals, which may have allowed for longer growth without disturbance. Another potential feedback could be from colonization via large algal mats on the carapace of common snapping turtles (Edgren et al., 1953). Many of the turtles used in this study did have algal mats present on their carapace, with coverage ranging from 5-50% of the total carapace area. However, the algae commonly present on common snapping turtle carapaces are epizoophytic, and therefore unable to persist off carapaces (Edgren et al., 1953). Thus, I do not believe the algae from turtle carapaces confounded the potential for further algal growth. The lack of an algal response, regardless of food web, indicates that the sampling method could have been biased. Ceramic tiles were placed on the bottom of the mesocosm tanks where snapping turtles frequently moved around while walking along the mesocosm bottom, however, mesocosms with only newts were still similar to prey-only mesocosms.

Furthermore, my study did allow for active tadpole grazing on algal standing stock on the algae tiles, which could have impacted my results. Future studies should consider multiple methods of monitoring algal biomass or exclusions of herbivorous prey.

Overall, my study reinforces prior evidence that a widespread turtle species, common snapping turtles, has the potential to change freshwater communities after short-term visits (Garig et al., 2020). By increasing tadpole mass at metamorphosis and rate of development, as well as reducing newt survival, common snapping turtles can alter the composition of freshwater food webs. Furthermore, my study suggests that snapping turtle size influences their effects, and future research is needed to determine whether those differences are driven by sex or size. Freshwater turtle trophic studies have focused primarily on the family Emydidae, but there are large gaps in our knowledge of the diet composition and trophic position of most other freshwater turtles (unpublished data). An estimated 61% of the 356 freshwater turtle species around the globe are at risk of extinction, and we have insufficient data to determine what the loss of these individuals would do to the ecosystem (Lovich et al., 2018). As freshwater turtle populations decline around the globe (Lovich et al., 2018), it has never been more imperative that we understand the roles that turtles play in freshwater communities.

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## Vita

Hailey Nicole Shoptaugh was born in Morehead City, North Carolina. Hailey grew up in Newport where she spent her time in the longleaf pine forests and on the beaches of North Carolina. Growing up in such a unique and fragile area, Hailey quickly learned to love and protect the environment. This led her to attend North Carolina State University where she graduated with a Bachelor of Science in Environmental Science in May of 2020.

Immediately following her graduation, Hailey knew she wanted to pursue a graduate degree with a dream of eventually entering academia as a research professor. She applied to be a part of the Davenport lab at Appalachian State University to work with common snapping turtles (*Chelydra serpentina*) and was accepted in early 2020. At Appalachian State University Hailey has been working towards a Master of Science in Biology and will receive this degree in Fall 2022.