Herpetological Conservation and Biology 16(3):482–490.
Submitted: 9 September 2020; Accepted: 7 August 2021; Published: 16 December 2021.

Implications of Anthropogenic Habitat Modification on the Diet of Northern Map Turtles (*Graptemys geographica*)

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Abstract.—**Human alteration and regulation of natural river system flows are associated with dramatic abiotic and biotic changes to rivers. Likewise, these associated alterations may change the prey base and diets of riverine turtles. We examined the impacts of a major hydroelectric dam on the dietary ecology of a population of a state-listed endangered turtle, the Northern Map Turtle (*Graptemys geographica*), residing in a dam impoundment in the Susquehanna River in Maryland, USA. Zebra Mussels (*Dreissena polymorpha*) were most important for adult and juvenile females, mystery snails (*Cipangopaludina* sp.) were most important for adult males, and bryozoans were most important for juveniles of unknown sex. This is the first known report of bryozoan consumption by the Northern Map Turtle, although their consumption is known in congeners. The diets of map turtles we examined differed radically from those examined directly downriver of the dam in a previous study that preceded Zebra Mussel establishment. Zebra Mussel consumption by the impoundment population is consistent with other map turtle populations and is logical given that impoundments increase species invasion likelihood. Map turtle consumption of Zebra Mussels may benefit freshwater ecosystems given the impacts to native mussel fauna imposed by this invasive mussel species. The impact of this consumption on Zebra Mussel populations warrants further investigation, as do the impacts on long-term life-history characteristics of *G. geographica* because the effects of dietary shifts may take a long time to manifest in long-lived animals such as turtles.**

Key Words.—aquatic turtles; dietary shift; habitat alteration; Index of Relative Importance; invasive species; life history; rivers

Introduction

Alterations to natural river systems caused by human activity, such as river damming, can influence local riverine habitats. The conversion of flowing rivers to still waters reduces aquatic complexity and river biodiversity (Poff and Allan 1995; Abramowitz 1996; Ward 1998). Altered and regulated river flow is associated with increased turbidity, sedimentation, salinization, oxygen/thermal stratification, a reduced plant community, slowed flows, and altered thermal conditions (Calow and Petts 1994). Modified river systems tend to create uniform, simplified environments that are detrimental to species that are sensitive to such alterations (Vandewalle and Christiansen 1996). Larger dams cause hypoxic water conditions independent of seasonality (Tucker et al. 2012), and river impoundments may reduce upstream riffle habitats that are necessary for aquatic invertebrates (Choy 1998). Given the known abiotic and biotic changes associated with dams, it is logical for river damming to have ecological ramifications on riverine turtles through the creation of artificial lotic and lentic conditions (Carrière et al. 2009; Tucker et al. 2012; Richards-Dimitrie et al. 2013).

One method of analyzing the ecology of a species is through a dietary analysis (Hyslop 1980). Characterizations of aquatic turtle diet are used for varied purposes. For example, such studies can be used to understand turtle species presence and interactions with seasonal habitat variation, as well as analyzing anthropogenic influences, such as the effects of poaching pressure on diet (Georges 1982; Kennett and Tory 1996; Sung et al. 2016). Analyses of aquatic turtle diet may have implications beyond dietary ecology, such as relating diet to other life-history aspects (e.g., clutch size, growth rate, fecundity, age at maturity; Gibbons 1967; Gibbons and Tinkle 1969; Lindeman 1996).

Anthropogenic influence on river systems, especially alteration to the historical flow of a river, impacts riverine turtle ecology (Vandewalle and Christiansen 1996; Tucker et al. 2012). Likewise, we expect concomitant changes in prey availability as a river is modified (Dodd 1990). Evidence of such change is seen in the decreased dietary breadth and diversity of turtles in river dam impoundments in comparison with the same species in natural river conditions (Tucker et al. 2012). Altered sex ratios potentially related to reduced growth rates of juvenile and male Northern Map Turtles (*Graptemys geographica*) in river segments fragmented by dams and locks as opposed to intact river segments were hypothesized to correlate with impoundments reducing shallow water foraging habitat for juveniles and males (Bennett et al. 2009).

River impoundment also reduces turtle biodiversity as compared to natural rivers, an effect that increases with larger impoundment size (Tucker et al. 2012). Vandewalle and Christiansen (1996) found a reservoir on the Des Moines River, USA, to contain the lowest riverine turtle diversity compared to other river systems that lacked major reservoirs within the Mississippi and Missouri River drainages within Iowa, USA. In this paper, we examine impacts of a major hydroelectric dam on the dietary ecology of a population of a state-listed endangered turtle, the Northern Map Turtle, residing in a dam impoundment. Given the biotic and abiotic effects associated with river damming, we aim to provide greater understanding of how the diet of map turtles upriver of the dam differ from those directly downriver of the dam.

Materials and Methods

***Study site*.**—We collected diet samples from Northern Map Turtles in the Susquehanna River, Maryland, USA, a major component of the Chesapeake Bay watershed that supplies half the freshwater of the bay (Risser and Siwiec 1996). The portion of the Susquehanna River in Maryland upriver of the Conowingo Hydroelectric Dam stretches approximately 8 km to the Maryland-Pennsylvania border and straddles the border between Harford and Cecil counties, Maryland. This section of river comprises the dam reservoir and reaches a maximum depth of approximately 22 m, although exact depths are subject to change (Peco Energy Company 1995). The Conowingo Hydroelectric Dam (1,416.7 × 31.7 m), which bisects the Susquehanna River in Maryland, was built in 1928 and is among the most powerful hydroelectric dams in the U.S. (Power Plant Research Program 2008; Exelon Generation Company 2009).

We captured turtles from two tributaries of the Susquehanna River in central Maryland, Broad Creek and Conowingo Creek, both of which occur upriver of the hydroelectric dam. Broad Creek is a partially channelized stream situated 3–4 km northwest across the Susquehanna River from Conowingo Creek and is 5–6 km northwest of the Conowingo Hydroelectric Dam. We captured turtles in Broad Creek up to approximately 600 m upriver from the Susquehanna River confluence, where water depths range from approximately 3–5 m. Benthic substrate largely consists of thick mud and detritus with rock near the bank.

Conowingo Creek is situated 3 km northwest of the Conowingo Hydroelectric Dam. We captured turtles in Conowingo Creek within 250 m upstream of the Susquehanna River confluence. The creek bottom has a gentler slope from the bank than Broad Creek, and water depths typically only reach 1–2 m in this section. Both Broad and Conowingo creeks experience water depth fluctuations, however, depending on the amount of water released from the dam. Benthic substrate in Conowingo Creek is also mainly composed of thick mud and detritus. Both sites contain abundant patches of sub-aquatic vegetation in summer.

***Method of capture and dietary sample collection*.**—We captured turtles with basking traps (Horne et al. 2003; Richards-Dimitrie et al. 2013) or opportunistically by hand in June and August 2018. We transported turtles to the Northern Map Turtle Research Center in Port Deposit, Maryland, and placed individuals in 558 × 419 × 330 mm plastic bins with 40 mm of distilled water. We held turtles for up to 24 h for fecal matter collection. We measured midline straight-line carapace length (SCL), midline straight-line plastron length (SPL), and maximum plastron length (MPL) with tree calipers to the nearest millimeter (Iverson and Lewis 2018). We measured mass using a 5 kg Pesola scale to the nearest 50 g. We decontaminated bins using a 10% bleach solution between turtle captures (Northeast Partners in Amphibian and Reptile Conservation [NEPARC]. 2014. Disinfection of field equipment to minimize risk of spread of chytridiomycosis and ranavirus. NEPARC. Available from http://www.northeastparc.org/products/pdfs/NEPARC_Pub_2014-02_Disinfection_Protocol.pdf [Accessed 16 September 2018]). We gave each turtle a unique identifying mark on marginal scutes with a power drill (Ernst et al. 1974).

We recorded the sex and size class of each turtle according to Lindeman (2006a); we classified turtles not determined as male but between 66–169 mm SPL as juvenile females, while we considered females ≥ 169 mm SPL to be adults. We recorded individuals not demonstrating male secondary sexual characteristics as juvenile (sex unknown) if < 66 mm SPL. We considered adult males as any individuals ≥ 66 mm SPL possessing male secondary sexual characteristics. Male secondary sexual characteristics include a larger, thicker tail with the cloacal opening extending beyond the carapace edge (Ernst et al. 1994). We released turtles at their site of capture after processing.

***Dietary sample processing and analysis*.**—We held all turtles once for sample collection in bins as previously described; however, we opportunistically obtained diet samples from two recaptures (one adult female and one juvenile female) held for a separate study. We collected dietary samples from fecal matter and filtered material through a 750 µm Nitex nylon mesh. We stored collections in 50 mL plastic vials filled with 70% ethanol (Lindeman 2006a; Richards-Dimitrie et al. 2013). We used fecal analysis instead of stomach flushing to minimize distress or harm potentially caused by flushing (Lindeman 2006a; Richards-Dimitrie et al. 2013). Inherently, fecal analysis could be biased towards revealing hard prey items; however, turtle stomach flush samples and fecal samples closely resemble one another (Rowe 1992). For molluscivorous Texas Map Turtles (*Graptemys versa*), Lindeman (2006b) could not detect mollusks in small female diets using stomach flushing but could detect them in fecal samples. Thus, flushing may not be effective for revealing hard prey items (Lindeman 2006b).

We collected 37 total diet samples from 37 individual turtles. Six samples, however, contained less than 0.1mL of total fecal matter and we did not include them in analysis (Lindeman 2006a; Richards-Dimitrie et al. 2013). The six unused samples included four adult males, one adult female, and one juvenile of unknown sex. The 31 analyzed samples included three from juveniles of unknown sex, six from juvenile females (including one recapture), 15 from adult males, and seven from adult females (including one recapture). Analyzed samples from June totaled 19 (two from juveniles of unknown sex, four from juvenile females, five from adult females, and eight from adult males); analyzed samples from August totaled 12 (one from juveniles of unknown sex, two from juvenile females, two from adult females, and seven from adult males). We separated samples into diet categories (Table 1) under a dissecting microscope and obtained category volumes via displacement in water using a 25 mL graduated cylinder within 0.1 mL accuracy. If a category displaced < 0.1 mL, we estimated it to be 0.05 or 0.01 mL. We stored separated diet items in one-dram glass vials and preserved them with 70% ethanol (Richards-Dimitrie et al. 2013).

We used a variety of reference sources (Smith 2001; Jessup et al. 2003; Gibb and Oseto 2005; Thorp and Covich 2010; Dillon R.T., Jr., M. Ashton, M. Kohl, W. Reeves, T. Smith, T. Stewart, and B. Watson. 2013. The Freshwater Gastropods of North America. Freshwater Gastropods of North America [FWGNA] project. Available from http://www.fwgna.org/ [Accessed 18 November 2018]; Bogan and Ashton 2016) as well as personal communication with Maryland Department of Natural Resources mollusk expert Matthew Ashton and Towson University staff to identify invertebrate dietary items. We calculated the percentage volume ($\%V_i$) and percentage frequency of occurrence ($\%F_i$) of each diet category for each turtle size/sex class. We used these data to calculate an Index of Relative Importance (IRI) to rank the importance of diet categories for each turtle class (Hyslop 1980; Bjorndal et al. 1997):

$$IRI_i = 100V_iF_i / \sum(V_iF_i)$$

with IRI_i values summing to 100 across all diet categories.

Results

The three most important dietary items for Northern Map Turtles of all size and sex classes in the Conowingo Hydroelectric Dam reservoir were Zebra Mussels (*Dreissena polymorpha*), Japanese/Chinese Mystery Snails (*Cipangopaludina japonica* and/or *C. chinensis*), and Phylactolaemate bryozoans (Fig. 1, Table 1). No meaningful differences in dietary item categories were seen between dietary samples taken in June and August 2018. Phylactolaemate bryozoans were seen more prominently in samples taken in August, however. Zebra Mussel consumption was most important for both juvenile females (IRI = 87.4) and adult females (IRI = 49.0) and was the second most important dietary item for both adult males (IRI = 16.7) and juveniles of unknown sex (IRI = 19.5; Table 1). Mystery snails were the most important dietary item for adult males (IRI = 18.2), the second most important for adult females (IRI = 22.9) and juvenile females (IRI = 4.6) and were the third most important for juveniles of unknown sex (IRI = 10.7; Table

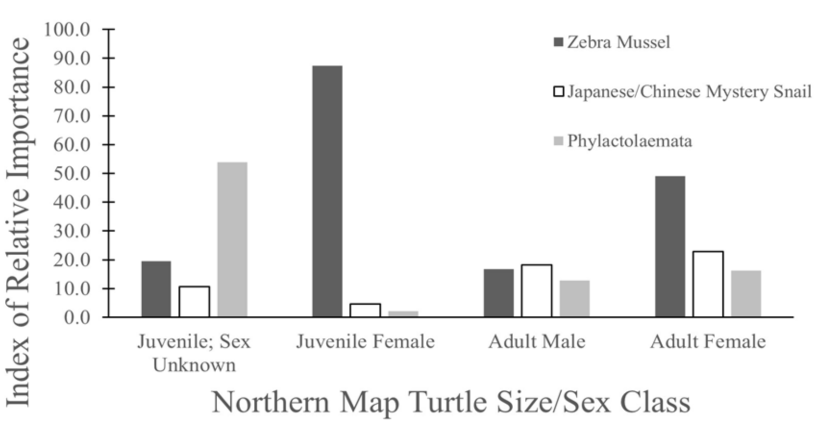

Figure 1. Index of Relative Importance (IRI) values for the three most important diet items of four size/sex classes of Northern Map Turtles (*Graptemys geographica*) captured upriver of the Conowingo Hydroelectric Dam, Maryland, USA.

Table 1. Percentage frequency of occurrence (%F), percentage volume (%V), and Index of Relative Importance (IRI) data for diet items in four size/sex classes of Northern Map Turtle (*Graptemys geographica*) captured upriver of the Conowingo Hydroelectric Dam, Maryland, USA. The abbreviation SU = sex unknown. Species listed are Zebra Mussels (*Dreissena polymorpha*), Japanese/Chinese mystery snails (*Cipangopaludina japonica* and/or *C. chinensis*), and Asian Clam (*Corbicula fluminea*).

	Juvenile; SU (n=3)			Juvenile female (n=6)			Adult male (n=15)			Adult female (n=7)		
Diet Item	%F	%V	IRI	%F	%V	IRI	%F	%V	IRI	%F	%V	IRI
Zebra Mussel	66.7	25.9	19.5	100.0	84.0	87.4	46.7	23.6	16.7	85.7	44.8	49.0
Japanese/Chinese Mystery Snail	100.0	9.5	10.7	83.3	5.3	4.6	86.7	13.8	18.2	71.4	25.1	22.9
Pleurocerid snail				33.3	1.0	0.3	13.3	0.4	0.1	57.1	7.2	5.2
Diptera	100.0	1.3	1.5	66.7	0.3	0.2	60.0	6.7	6.1	71.4	0.2	0.2
Phylactolaemata	100.0	47.8	53.9	66.7	3.0	2.1	66.7	12.6	12.8	85.7	14.9	16.3
Plant matter	100.0	3.0	3.4	100.0	1.9	2	100.0	6.3	9.6	100.0	0.5	0.6
Insecta	100.0	1.3	1.5	66.7	0.3	0.2	66.7	11.5	11.7	42.9	0.1	0.1
Physidae	66.7	4.7	3.5	33.3	0.8	0.3	66.7	7.5	7.6			
Planorbidae	33.3	0.4	0.2	16.7	0.1	0.02	66.7	5.2	5.3			
Mollusca	100.0	1.3	1.5	100.0	1.3	1.4	60.0	1.7	1.5	71.4	0.4	0.4
Gastropoda							6.7	0.2	0.02			
Gerridae							6.7	0.2	0.02			
Menetus dilatatus							20.0	0.6	0.2	28.6	0.1	0.04
Trichoptera	66.7	0.9	0.7				33.3	1.7	0.9	28.6	0.1	0.04
Hymenoptera							20.0	1.3	0.4			
Ostracoda				50.0	0.2	0.1				71.4	0.2	0.2
Isoptera	33.3	0.4	0.2									
Aphididae				16.7	0.1	0.02						
Unknown arthropod				16.7	0.3	0.1						
Asian Clam	33.3	0.4	0.2							28.6	3.4	1.2
Unknown worm (Annelida)				16.7	0.1	0.02	13.3	0.4	0.1			
Unknown	100.0	3.0	3.4	100.0	1.3	1.4	93.3	6.3	8.9	100.0	3.0	3.8

1). Phylactolaemate bryozoans were the most important dietary item for juveniles of unknown sex (IRI = 53.9) and were the third most important for adult males (IRI = 12.8), adult females (IRI = 16.3), and juvenile females (IRI = 2.1; Table 1).

Among the two recaptured turtles, no meaningful difference in diet was observed between recaptures. A juvenile female recaptured in August had a similar dietary sample compared to its dietary sample from a June capture; however, we observed more snails in the Physidae family in the August recapture sample for this juvenile female. Our second recaptured turtle, an adult female, had a dietary sample in June composed primarily of mystery snails and Pleurocerid snails. This turtle had little dietary matter from its recapture sample in August, being mostly composed of unidentifiable matter. Adult males exhibited the most dietary breadth among the size/sex classes examined, feeding additionally on small snails (Planorbidae, IRI = 5.3; Physidae, IRI = 7.6), insects (composed of fragments identified to class Insecta, IRI = 11.7), and plant matter (IRI = 9.6; Table 1). Compared to other turtle classes, adult males did not rely on any one of the three major dietary items (Fig. 1).

Discussion

The diet of Northern Map Turtles in the Conowingo reservoir is consistent with the described diet habits of the species, particularly the more varied diet of males compared to more prominent molluscivory in female conspecifics (Lagler 1943; Lindeman 2006a; Bulte et al. 2008a; Lindeman and Rhodin 2013; Richards-Dimitrie et al. 2013). To study potential dietary discrepancies between Northern Map Turtle populations upriver and downriver of the Conowingo Hydroelectric Dam, however, we examined our data while considering a previous Northern Map Turtle dietary analysis conducted directly downriver of the dam (Richards-Dimitrie et al. 2013). Our results strongly contrast with dietary data for the downriver turtles. Richards-Dimitrie et al. (2013) did not report any Zebra Mussels, mystery snails, or bryozoans in turtles examined. Data from the reservoir do not indicate the extent of Pleurocerid snail or caddisfly larva consumption as reported downriver. The Asian Clam (*Corbicula fluminea*) was an unimportant food source upriver of the dam (only appearing as a few shell fragments) as opposed to downriver, where it was among the most important dietary items for males. It should be noted that Richards-Dimitrie et al. (2013) collected dietary data over multiple seasons/calendar years, whereas we collected dietary data over a single field season. A more temporally robust dietary sampling effort of Northern Map Turtles in the reservoir above the dam may therefore be more effective in comparing diets between studies.

Northern Map Turtles are often considered specialized feeders due to their molluscivorous habits (Vogt 1981; White and Moll 1992). Turtles with specialized diets are predicted to have stronger responses to prey base changes independent of natural changes in habitat condition or anthropogenic interference compared to diet generalists (Allanson and Georges 1999; Tucker et al. 2012); however, Northern Map Turtles can demonstrably adapt to anthropogenically influenced prey base alterations (Moll 1977). Likewise, prey base alterations including consumption of invasive species in our study population of Northern Map Turtles is consistent with consumption of invasive species reported for other map turtle populations (Moll 1977; Lindeman 2006a,b; Bulte and Blouin-Demers 2008; Richards-Dimitrie et al. 2013).

Bulte et al. (2008b) positively correlated body condition and reproductive output in Northern Map Turtles to head size, suggesting a link between head size/bite force and fitness. The trophic morphology dimorphism described for Northern Map Turtles (e.g., females possessing larger heads and body sizes) likely indicate that females have higher body maintenance costs compared to males (Bulte et al. 2008b). Females may counter this cost, however, by consuming large quantities of mollusks to increase the energy input allotted to reproduction (e.g., the production of larger egg sizes), thereby increasing their fitness (Lindeman and Rhodin 2013). Lindeman (2006a) demonstrated that Zebra and Quagga mussels (*Dreissena* sp.) found in Northern Map Turtle diets decreased the dietary diversity of females, although it is unknown how this diet shift affects Northern Map Turtles beyond this. Potentially, consumption of super-abundant invasive Zebra Mussels seen in females in our analysis and other Northern Map Turtle populations might relate to fitness, which is suggested to relate to increased Zebra Mussel populations in impounded areas of rivers (Bennett et al. 2009). The implications of this and other turtle life-history attributes related to Zebra Mussel consumption, especially in the context of river damming, needs further study.

A laboratory experiment illustrated that juvenile Northern Map Turtles eat Zebra Mussels (Serrouya et al. 1995), but the turtles in this experiment preferred eating a native snail, which provided 72% more energy to turtles per unit of time compared to Zebra Mussels. The high abundance of invasive Zebra Mussels may compensate for their lower energy per unit, however (Lindeman 2006a). In Lake Opinicon, Ontario, Canada, female Northern Map Turtles consumed considerable quantities of Zebra Mussels (Bulte and Blouin-Demers 2008). Bulte and Blouin-Demers (2008) estimated that Northern Map Turtles consume about 3,200 kg of Zebra Mussels per year in the lake, and both sexes exhibited increased Zebra Mussel consumption with size. Large populations of Northern Map Turtles could be an effective biological control of these invasive mollusks (Vogt et al. 2018), and Zebra Mussel consumption may benefit map turtle abundance (Lindeman 2006a). This may relate to impounded waterways, as Zebra Mussels are many times more likely to colonize impoundments compared to natural lakes and have been increasingly detected annually in the Conowingo Hydroelectric Dam reservoir since 2009 (Davis et al. 2000; Johnson et al. 2008; Ashton and Klauda 2015). Additionally, Zebra Mussels directly and indirectly exacerbate the loss of native mussels, which is already exacerbated by dam impoundments (van der Schalie 1939; Williams et al. 1992; Strayer and Smith 1996; Strayer et al. 1998; Strayer 1999). The broad-scale impact of Northern Map Turtle consumption on Zebra Mussel populations remains poorly understood, however (Lindeman and Rhodin 2013).

Likewise, the literature concerning Northern Map Turtle prey switching to Zebra Mussels is scant but some evidence suggests that exotic species may benefit native predators. The invasive Round Goby (*Neogobius melanostomus*) in the Great Lakes, for instance, is beneficial to native Lake Erie Water Snakes (*Nerodia sipedon insularum*) as a primary food source by increasing growth rate and allowing snakes to attain larger body sizes (King et al. 2006). Zebra Mussel population structure may be reduced by abundant native predators, and consumption of invasive prey may recover certain aspects of invaded ecosystems (Carlsson et al. 2011). The effects of native predation may need substantial time to manifest as native predators adapt to changes in their prey base (Carlsson et al. 2011). Thus, given the recent nature of the spread of Zebra Mussels to the Conowingo Hydroelectric Dam reservoir, more time may be needed to detect how Map Turtle consumption of Zebra Mussels in the reservoir is affecting the local Zebra Mussel population.

We are unaware of any other published studies of Northern Map Turtle dietary ecology specifically reporting on consumption of mystery snails. Like Zebra Mussels, however, these snails potentially represent a novel dietary opportunity for map turtles by providing an additionally abundant invasive food supply; live mystery snail specimens and empty mystery snail shells were opportunistically observed in abundance while sampling in Broad and Conowingo creeks. Mystery snails may therefore provide another example of how the trophic structure of aquatic predators such as the Northern Map Turtle might be altered through anthropogenic restructuring of aquatic habitats promoting species invasions.

Besides invasive mollusks, Northern Map Turtle diets in the Conowingo Hydroelectric Dam reservoir largely consisted of bryozoans. Although bryozoan consumption has been reported for congeners (e.g., Black-Knobbed Sawback, *G. nigrinoda delticola*; Lahanas 1982, Texas Map Turtle; Lindeman 2006b), to our knowledge this is the first report of bryozoan consumption by Northern Map Turtles. Phylactolaemate bryozoans reproduce asexually by producing free-floating buds called statoblasts (Smith 2001). Statoblast germination might be favored in the lentic reservoir habitat of the Conowingo Hydroelectric Dam that is conducive to bryozoan establishment (Smith 2001). In the lotic downriver habitat, however, statoblasts might be easily swept away and fail to establish. This may explain why bryozoans are not found in map turtle diets downriver of the dam. Northern Map Turtles may also influence bryozoan dispersal in the reservoir, as statoblasts (observed intact in our dietary samples) will germinate after passing through the digestive tract of a turtle (Bushnell 1973).

Bryozoan colonies create suitable habitat for small animals like protozoans and midges, and small insects (e.g., caddisfly larvae and midges, both minor diet items in our study) and snails may graze upon them (Thorp and Covich 2010). Northern Map Turtles may feed upon bryozoans to consume the assorted organisms that congregate around colonies. Bryozoans are found in fish diets, for instance, but the insects housed within the colonies are thought to be of higher nutritional value (Dendy 1963). The apparent grazing behavior of Northern Map Turtles on bryozoans is expected considering such feeding behavior reported for congeners (Waters 1974; Lee et al. 1975; Moll 1976; Porter 1990; Kofron 1991).

To our knowledge there exists no historical pre-impoundment data for invertebrates in the Conowingo Hydroelectric Dam reservoir. Therefore, a comparison of the pre- and post-dam prey base is beyond the scope of our study. In comparison to Richards-Dimitrie et al. (2013), however, we provide evidence suggesting the prey base for Northern Map Turtles in the Conowingo Hydroelectric Dam upriver reservoir is different from that downriver of the dam. This is seen especially in Zebra Mussel consumption upriver of the dam, likely due to impoundment conditions favoring Zebra Mussel establishment. Impoundment conditions may have also created suitable habitat for mystery snails, which prefer still, turbid waters with sandy, silty, or muddy substrates (Kipp, R.M., A.J. Benson, J. Larson, and A. Fusaro. 2019. *Cipangopaludina japonica* (von Martens, 1861). U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available from https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1046 [Accessed 19 February 2019]). Conversely, the Asian Clam prefers moving waters due to high oxygen level requirements (Invasive Species Specialist Group. 2005. Global Invasive Species Database. International Union for Conservation of Nature. Available from http://www.iucngisd.org/gisd/species.php?sc=537 [Accessed 13 February 2020]). This may mean that Asian Clams are less available in the upriver reservoir than downriver of the dam. Yet, we opportunistically observed live Asian Clams as well as shells in the major tributaries of the Conowingo reservoir. If both Asian Clams and Zebra Mussels are established in this reservoir, an investigation targeted at understanding why the reservoir turtles might prefer the mussels over the clams could lend key insight into the nutritional value that Zebra Mussels hold to this turtle species and potentially other aquatic consumers.

It appears that in this anthropogenic watershed, Northern Map Turtles have experienced a trophic restructuring that may not have otherwise occurred naturally. Although we can infer that alterations in the diet ecology (and subsequently other potential life-history attributes) of a specialized riverine species such as the Northern Map Turtle are related to river damming, a crucial future goal is to investigate how this dietary/food web change may affect dietary specialists in the long term (Tucker et al 2012). This is particularly true of turtles because changes to diet ecology, and in turn other aspects of life-history, take a long time to manifest in long lived animals and are poorly understood in such species (Tucker et al 2012). The downriver dietary data collected by Richards-Dimitrie et al. (2013) for instance is about 10 y old at the time of this report. Since then, turtle diets below the Conowingo Hydroelectric Dam may have changed, especially considering the recent spread of Zebra Mussels throughout this region. Therefore, a re-characterization of the diet of Northern Map Turtles downriver of the dam may detect any recent trophic changes and provide a more recent comparison to our study. A more rigorous survey effort of the reservoir invertebrate community is also needed to characterize prey availability in this habitat as part of a comprehensive understanding of prey selection by this population of Northern Map Turtles.

Acknowledgments.—We wish to thank those who assisted us with turtle captures for fecal sample collection, particularly Kelly Hilton and Will Doughty, as well as Andrew Adams, Scott McDaniel, Emily Bueche, and Gabby Ross of Susquehannock Wildlife Society. We thank Scott Smith and the Maryland Department of Natural Resources for logistical support and for permitting for this work (permit # 53959). We greatly appreciate the town of Port Deposit for providing housing and space for turtle/sample processing at the Map Turtle Research Station during this project. Dr. Susen Gresens and Dr.

John LaPolla of Towson University and Matthew Ashton of the Maryland Department of Natural Resources were extremely helpful with identification of invertebrates found in diet samples. We thank Exelon Generation Corporation for their support, particularly Andrea Danucalov and Kim Long. Thanks also go to Dr. Alison McCartney of the Towson University Honors College for her guidance in completion of this project. We are grateful for the financial support provided by the Jess and Mildred Fisher College of Science and Mathematics Undergraduate Research Committee at Towson University. We additionally wish to thank The Jones Center at Ichauway for providing support while manuscript publication preparations were made. The Institutional Animal Care and Use Committee (IACUC) protocol # 06062012RS-01/1606000126R002 granted additional approval for this work.

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