Assessment of Cranial Morphology and Function Underlying Dietary Diversity in Cryptodires

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This dissertation titled

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Abstract

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Assessment of Cranial Morphology and Function Underlying Dietary Diversity in Cryptodires

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Morphological, functional, and performance traits combine into a hierarchical sequence that determines how well an organism performs a behavior and interacts with its environment, and as such link to selective pressures and adaptation These three non-independent, hierarchical levels of traits set up an operative sequence connecting selective pressures to organismal form. The ultimate goal of this dissertation is to describe and quantify the interactions within this trait sequence using the feeding apparatus of Testudines as a model. Chapter 1 introduces the framework, goal, and model of the dissertation. Chapter 2 examines the morphological effect of the possible selective pressures from physiological diet, feeding mode, and feeding medium on the testudine skull across crytpodires. In more detail, this analysis investigates how the physical and mechanical properties of food items (operationalized through a novel method of categorizing diet data), as well as the feeding behaviors used by turtles, correlate with skull shape. This work is the first to fully and unrestrictively sample 3D testudine skull morphology with auto3DGM, resulting in novel support of previously hypothesized functional characteristics and their strong correlation to the direct pressure of cryptodire diets. Chapter 3 presents the direct effects of food properties on the intraspecific disparity of feeding morphology. This study compares two sexually dimorphic species: *Trachemys scripta*, which displays sexual size dimorphism but consume undifferentiated diets; and

Malaclemys terrapin, which displays sexual size dimorphis as well as trophic sexual dimorphism in which the sexes inhabit different dietary niches. This chapter reveals that adductor chamber dimensions scale with head size, and that this scaling occurs both intraspecifically and interspecifically. This scaling relationship differentiates male and female *M. terrapin* jaw adductor muscle size, indicating that ontogenetic trajectories of different lengths favor their respective trophic niches. These results suggest that bite force is primarily increased through absolute and relative size of the jaw adductors in turtles, but that muscle physiology plays an unknown role. Chapter 4 explores the interplay between the biomechanical, muscular, and physiological variation to generate static bite force in Testudines. This study focuses on quantifying how changes in muscle architecture and skull morphology alter theoretical bite force in three species with disparate bite strategies: *Trachemys scripta* (nonspecialized biting strategy), *Malaclemys terrapin* (forceful biting strategy), and *Chelydra serpentina* (fast and forceful biting strategy). The results of Chapter 4 demonstrate that, in spite of strong selective pressures to maintain a streamlined skull and neck retraction, aquatic turtles have a considerable ability to manipulate bite performance through intramuscular specialization of fiber lengths and contractile properties (i.e. specific tension), though absolute size of jaw adductors remains the variable with the largest effect on bite performance in the species studied. This work is the first to describe and compare jaw muscle morphology, architecture, leverage, and theoretical bite force interspecifically. Chapter 5 summarizes major conclusions, discusses the integrative implications of the dissertation, and outlines future directions. Sample size and taxonomic scope were major limitations of these works. Therefore, determining the role of morphological, functional, and performance traits in the predictability and repeatability of evolutionary change in the face of lineage diversification remains to be assessed by a much larger taxonomic sample. Ultimately, this dissertation discovered novel morphologies correlated to feeding behavior and biting strategy, explored their functional consequences, and evaluated their effects on performance in cryptodires.

Dedication

I dedicate this dissertation to my Board of Divas and Shad Bauer. I am the person I am today because of their intense support, dedication, and friendship.

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Chapter 1: Introduction

The relationships between form, function, and organismal performance are keys to understanding the diversity of life. Morphological, functional, and performance traits combine into a hierarchical sequence that determines how well an organism performs a behavior and interacts with its environment, and as such link to selective pressures and adaptation (Arnold, 2003; Wainwright, 2007). Morphological evolution can produce changes in the physiological and biomechanical properties arising from form (i.e., function, *sensu* Bock and von Wahlert, 1965). Functional differences, in turn, can alter performance traits (Wainwright et al., 1996). Because performance represents the interactions of a suite of functional traits with the constraints and demands of an organism's everyday life in its environment, it is a major target of natural selection leading to adaptation (Arnold, 2003; Wainwright, 2007). These three non-independent, hierarchical levels of traits set up an operative sequence connecting selective pressures to organismal form.

The ultimate goal of this dissertation is to describe and quantify the interactions within this trait sequence using the feeding apparatus of Testudines as a model. The Testudine clade includes all living turtles, terrapins, and tortoises, hereafter collectively referred to as either “testudines” or “turtles”. The testudine feeding apparatus was chosen because its morphology has been proposed as a fruitful system for exploring the relationships between morphology, function, performance, behavior, and ecology in the context of feeding (Schwenk, 2000; Lemell et al., 2019). Feeding is indeed one of the most important biological roles of the vertebrate skull, and feeding performance has been shown to be a determinant of survival and fitness (Stephens and Krebs, 1986; Benkman, 2003). By extension, diet, or the range of food resources an organism consumes for energy and nutrients, is also understood to have a major influence on skull evolution. The diversity in diet, feeding behavior, and feeding medium within Testudines highlights potentially stark differences in evolutionary selective pressures that have shaped the feeding apparatus among testudine species (Ernst and Barbour, 1989).

Indeed, the breadth of testudine morphological diversity at all trait levels -- morphological, functional, and performance -- is marked. More accurately, it is particularly astounding because the group is relatively taxon-poor. The order has a long evolutionary history dating back to the Triassic period (Schoch and Sues, 2016), and in spite of the age of the clade, there are only 357 modern species (Turtle Taxonomy Working Group, 2021). Among these species however, Testudines as a group displays a disparity of form and size comparable to much more speciose groups (Schwenk, 2000). This suggests that functional diversity and species richness may be more closely tied in testudines than in other groups, providing a relatively untapped substrate for functional morphology. Recent authors have leveraged the functional morphology of Testudines to understand the interactions between feeding traits and ecological parameters (e.g., bite force as it relates to dietary niche in diamond-backed terrapins, (e.g., Herrel et al., 2017), fitness (e.g., reproductive roles determining the need for the expanded niche of female map turtles, Bulté et al., 2008), and evolution (e.g., clade-wide key innovations leading to progressive correlation between the unique *Bauplan* of turtles and biomechanical adjustments in response, Ferreira et al., 2020).

The vast majority of testudines are constrained by a clade-specific defensive adaptation: the ability to retract the neck and head within the shell, a key innovation that evolved in near-synchrony with the turtle shell itself and initiated a suite of cranial modifications (Werneburg et al., 2015; Ferreira et al., 2020). The space constraint that the shell aperture places on the size, and especially the height of the testudine skull relative to the enlargement of the otic chamber through the evolution of early testudines, has necessitated the independent evolution of the trochlearis system in both extant clades, the Pleurodira and the Cryptodira (Werneburg, 2013)(Figure 1-1). The trochlearis system is an elaboration of the coronar aponeurosis, the tendinous framework that serves as the insertion site for adductor mandibulae externus, one of the three jaw adductors (Werneburg, 2011) (Figure 1-2). In cryptodires (the model for this dissertation), the system consists of a sesamoid made of cartilage (*cartilago transiliens*) or, more rarely, of bone (*os transiliens*) within the aponeurosis of the external mandibular adductor that is in contact with the cartilage-covered, bony trochlear process of the otic chamber (*processus trochlearis oticum*), often with a synovial cavity in between (Werneburg, 2013) (Figure 1-1 A). This configuration enables the force generated by longitudinally oriented muscle fibers originating in the posterior skull to be redirected around the enlarged otic chamber and applied vertically to affect rotation of the lower jaw (Schumacher, 1973). The trochlearis system has also long been implicated as a probable substrate for biomechanical adaptations and therefore morphofunctional diversification. Whereas other, non-Testudine, cranial systems utilize skull height to increase jaw adductor size (e.g., the tall parietal crests of mammalian carnivores), the simple mechanism of redirecting force in turtle jaws facilitates increases in skull length in addition to the more typical skull height. By releasing jaw adductor size from the constraint of skull height, it may allow species to increase bite force for, or maintain bite force through, adaptation to diverse selective pressures on the turtle skull dimensions. However, recent evidence suggests that this may not be a major driver of morphological evolution in the group (Ferreira et al., 2020).

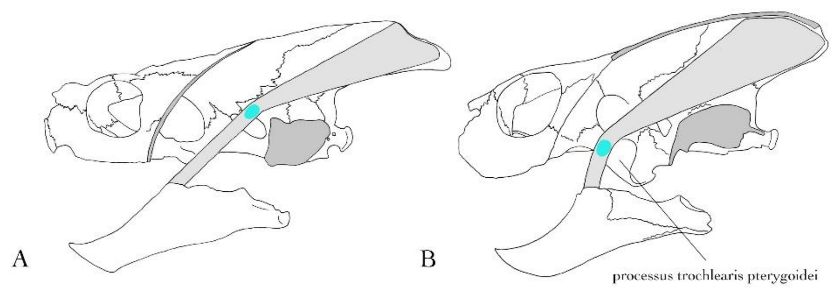

Figure 1-1. The trochlear system in turtles. A, the cryptodire condition (*Chelydra serpentina)* in which the external adductor musculature (light grey) is redirected by the otic chamber (dark grey), with the *cartilago transiliens* indicated by the blue dot; B, the pleurodire condition (*Elseya dentata)* in which the jaw musculature is redirected by the *processus trochlearis pterygoidei*. Text and figure modified from Anquentin (2009).

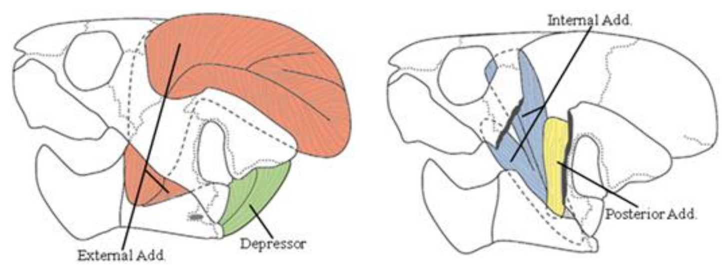

Figure 1-2. Testudine jaw opening and closing musculature.
Add. = adductor. Modified from Pfaller et al. (2011).

Testudine diets are diverse as foods consumed by turtles include fruits, the structural parts of plants, algae, as well as invertebrate and vertebrate animal prey, including hard-shelled mollusks, gastropods, jellyfish, sponges, even other turtles (Ernst and Barbour, 1989). The functional demands posed by such a variety of food items are reflected in the range of feeding behaviors utilized by the group. Testudine feeding behaviors also have to accommodate changes in feeding media since the group includes both terrestrial and aquatic species, as well as semi-aquatic species. While a number of species are capable of hunting and foraging in both environments, very few are capable of completing intra-oral transport in both media (Natchev et al., 2015). The disparate properties of water versus air have led to the evolution of diverse methods of food acquisition, prehension, and transport, hereafter collectively referred to as "feeding mode". These feeding modes are associated with critical changes in feeding morphologies specific to the environment where prehension and/or swallowing occurs (Bramble and Wake, 1985).

Aquatic feeding is plesiomorphic for the group (Heiss et al., 2011), and most aquatic species are reliant on the fluid properties of water for both food prehension and intraoral transport. These species first generate compensatory suction to minimize the effects of the bow wave created by the advancing head during the feeding strike. Subsequently, once the food item is caught between the jaws or in the oral cavity, they utilize hydrodynamics to position and transport the food item within the oral cavity before swallowing (Bramble and Wake, 1985). This method is elaborated into a form of inertial suction similar to ram-feeding in fishes. Ram-feeding is a mechanism of high-speed inertial suction during the head strike that allows the buccopharyngeal cavity to expand rapidly, creating a low-pressure area in the mouth into which the food item in drawn (Lauder and Prendergast, 1992; Ernst et al., 1994). The inertial suction of ram-feeding is limited by the pharyngeal expansion because turtles lack a secondary aperture for the evacuation of water (e.g., the operculum in fishes). Despite this limitation, some forms even utilize true hydrodynamic suction for prey capture in a manner referred to as suction-feeding (Lemell et al., 2019). These species retract a robust hyoid apparatus to generate a suction vortex, accommodating the water used to propel prey into the oral cavity by extensive esophageal expansion (Lemell et al., 2000).

The only strictly terrestrial family, Testudinidae (tortoises), have developed lingual prehension to capture food in environments where water dynamics cannot be used for completion. During lingual prehension, a large, fleshy tongue is used as a sensory apparatus, contacting the food to align the rhamphothecae for jaw prehension. The tongue is also a key factor during intra-oral transport and positioning as it holds food against the roof of the mouth during a series of jaw retractions during the contact phase of the gape cycle, packing the pharynx to create a bolus for swallowing (Bels et al., 2008; Natchev et al., 2015). The jaw is in contact with the food during this phase and undergoes some oral processing between rhamphothecae, which is highly textured in this group. Despite the name, lingual prehension still heavily involves the jaws to secure the food and appress the rhamphothecae during intraoral transport. As such, bite force is a non-negligible parameter. Some less derived terrestrial and semi-aquatic testudines utilize simple jaw prehension without the aid of the tongue, in which prey is grasped between the jaws directly, with or without lingual or hydrodynamic aid during intra-oral transport (Bramble and Wake, 1985; Natchev et al., 2015).

All of these modes of feeding influence the amount of time a food item is in contact with the skull as well as whether or not a species is capable of performing each of these tasks on land or in water, providing varied and sometimes opposing selective pressures on the feeding apparatus in testudines.

Within this framework, this dissertation comprises three data chapters. Chapter 2 examines the morphological effect of the possible selective pressures from physiological diet, feeding mode, and feeding medium on the testudine skull across crytpodires. In more detail, this analysis will investigate how the physical and mechanical properties of food items, as well as the feeding behaviors used by turtles, correlate with skull shape.

Chapter 3 presents the direct effects of food properties on the intraspecific disparity of feeding morphology. This study compares two sexually dimorphic species: *Trachemys scripta*, which displays sexual size dimorphism but consume undifferentiated diets; and *Malaclemys terrapin,* which displays additional trophic sexual dimorphism in which the sexes inhabit different dietary niches.

Chapter 4 explores the interplay between the biomechanical, muscular, and physiological variation to generate static bite force in Testudines. This study focuses on quantifying how changes in muscle architecture and skull morphology alter theoretical bite force in three species with disparate bite strategies.

Finally, Chapter 5 summarizes major conclusions, discusses the integrative implications of the dissertation, and outlines future directions.

Broader Significance

The relatively recent, though still contested, phylogenetic placement of Testudines as the sister group to Archosauria within Diapsida (i.e., Archelosauria; Hedges and Poling, 1999; Kumazawa and Nishida, 1999; Joyce, 2015; Thomson et al., 2021) makes a full biomechanical assessment of their cranial morphology of particular interest to those focused on diapsid evolution and behavior. While birds, crocodilians, and dinosaurs have received significant attention (Schwenk, 2000; Reilly et al., 2001), testudines are understudied as a whole (Schwenk, 2000). Detailed assessments of cranial morphology and biomechanics only exist in three species so far (Pfaller et al., 2011;

Jones et al., 2012). Thus, the data resulting from this research fill a large gap in our knowledge of diapsid anatomy, function, and evolution. Soft and hard tissue insights from this project could aid in the reconstruction of tissues, function, and behavior of extinct archosaurs. These insights could also aid in investigations of basal amniote function and phylogenetics, and could be used to address the position of Testudines itself.

Over 60% of turtle and tortoise species are listed as threatened or endangered on the IUCN Red List. Testudine conservation is hampered by a lack of knowledge about the natural history of many species (Ernst and Barbour, 1989). The present research contributes to our understanding of the biomechanics behind flexibility or constraint in the feeding behavior of some testudine species that are threatened, which may be useful for conservation efforts involving these species. Results from this research may also facilitate dietary inferences for species lacking detailed natural history information.

Finally, the many-to-one mapping of form to function (functional redundancy) has recently been implicated in the process of speciation as a possible avenue by which two populations of a parent species may respond differently to similar selection pressures on performance (Higham et al., 2016). With the quantification of divergent morphological, functional, and performance traits in testudines, the results of the proposed project will allow future studies to distinguish between similar or divergent selection in the evolutionary history of the group and determine the role of these traits in the predictability and repeatability of evolutionary change in the face of lineage diversification.

Chapter 2: Patterns of Skull Shape Variation in Cryptodires

Introduction

Turtles (Order Testudines, Batsch, 1788) are a diverse group of vertebrates dating back to the Late Triassic (Schoch and Sues, 2016). In spite of the age of the clade, it is relatively taxon-poor, comprised of approximately 356 modern species (Rhodin et al., 2017). Yet despite being relatively species-poor as a group, testudines display great disparity in ecology comparable to more speciose groups (Ernst and Barbour, 1989). For example, living turtles have colonized terrestrial, aquatic, estuarine, and marine habitats spanning temperate to tropical regions on all continents except Antarctica (Ernst and Barbour, 1989). This ecological diversity is paralleled in their trophic diversity: turtles access and even specialize on a broad range of foods, including fruits, the structural parts of plants, algae, as well as invertebrate and vertebrate animal prey, including hard-shelled mollusks, gastropods, jellyfish, sponges, even other turtles (Ernst and Barbour, 1989). Moreover, because they span aquatic and terrestrial habitats, with some species inhabiting both, testudine feeding occurs in water and air, media which typically impart very different requirements for prey capture and transport (See Lemell et al., 2019, for a current review). The functional demands posed by such a variety of food items, feeding media, and environmental constraints may provide an explanation for the great disparity of form in turtles, especially regarding the morphology of the skull.

Turtle skull shape has been previously compared to ecological factors in analyses within Testudinoidea (Claude et al., 2004) and among all clades of Testudinata including extant and extinct forms (Foth et al., 2016; Souza, 2021). In the more restricted analysis of Testudinoidea, Claude et al. (2004) demonstrated that the primary level of variance in skull shape was determined by habitat, followed by diet and cladogenesis, and postulated that habitat differences could be related to differences in feeding modes between the habitats. In the expanded analysis by Foth et al. (2016), there is a high degree of correlation with phylogeny as well as centroid size, indicating strong allometry in their dataset. Once their results are corrected for the effect of phylogeny, it is still difficult to distinguish diet or habitat groupings. In fact, some species with convergent ecologies occupy different parts of the skull morphospace. Moreover, Foth et al. (2016) argue that the expanded area of morphospace covered by each group is sufficient to increase the likelihood of group overlap. These ambiguous correlations between skull shape and ecology are in part attributed to the taxonomically unrestricted nature of their dataset including all Testudines, suggesting that more phylogenetically restricted analyses may demonstrate significant ecological correlations within particular clades (Foth et al. 2016). In a three-dimensionally landmarked, but similarly phylogenetically broad analysis, Souza (2021) demonstrated that skull shape in turtles is best explained by the combination of multiple traits and sources, including allometry, neck retraction, durophagy, and use of a suction-feeding mechanism, and that these traits demonstrate a moderately strong phylogenetic signal. Souza (2021) also suggested that some ecological traits, such as terrestrial herbivory in tortoises, maybe be ancestral to some clades, supporting a hypothesis that these ecological traits have been a driver of cranial diversification among turtle clades.

In addition to the differences in phylogenetic focus of the studies, these studies also differ in their approach to selecting landmarks. The 2D landmarks in Claude et al. (2004) are primarily homologous contacts between individual bones with only a few landmarks defining the maxima of curves. The use of homologous landmarks may emphasize phylogenetic information over functional information, since these landmarks are, by definition, the same point on the same structure as modified by evolution (i.e., phylogenetically identical points). The 2D landmark work by Foth et al. (2016) extends the previous study by defining additional semilandmark curves on the edges of bony features, such as the outline of the palate, eye, or skull emarginations. However, neither study took into account the full complexity of the curves nor the surfaces of other structures with functional importance to feeding, such as the attachment points of the jaw closing musculature, the jaw joint, and the trituration surface of the palate. Souza (2021) was a significant improvement in this area, using a series of homologous landmarks in addition to semilandmark curves over the skull emarginations, outlines of the palate, eye, tympanum, nares, and condylar surface of the jaw joint, as well as surface semilandmarks distributed on the trituration surface of the palate and the condylar surface of the jaw joint. Still unaddressed, however, are the attachment surfaces of the jaw closing and opening muscles in the adductor chamber and on the quadrate, as well as the unique trochlear surface that serves to redirect the force of the external mandibular adductor in turtles.

The present study attempts to reconcile the conflicting results of Foth et al. (2016) and Claude et al. (2004) on the relative importance of phylogeny versus ecological variables in shaping the testudine skull. Indeed, their results suggest that correlations between ecology and skull shape can be recovered in more phylogenetically limited analyses across the order. The same habitats and diets are often converged upon by different clades of turtles, but these ecological factors may only produce convergent morphologies, and therefore significant ecological correlations with specific morphologies, within a clade. Because of the three-dimensional complexity of the turtle skull, this chapter also advances the analysis of variation in turtle cranial shape by using 3D geometric morphometrics across all functional aspects of the skull. Specifically, in order to relate the shape of the turtle skull to the specific functional demands of feeding and habitat, the present study will incorporate auto3DGM-generated pseudolandmarks (automatically generated three-dimensional geometric morphometrics algorithm, Boyer et al., 2015), which are not constrained to identifiable points on bone sutures in favor of pure shape. By using an automated landmarking approach, variation in skull morphology can be identified independent of the particular sutures or edges that underlie that morphology. This focuses the shape data collection on the other aspects of skull shape, such as unrestricted contours and surfaces that are likely important to the function of the feeding system as well as the demands of feeding and living in habitats with vastly differing fluid forces. Finally, this analysis will attempt to identify morphological correlates to diet and feeding behavior.

Material and Methods

Taxon Sampling and Landmarks

The sample consisted of adult individuals of 39 extant cryptodire turtle species spanning 9 of the 15 extant turtle families representing extremes of dietary and habitat variation within each family. One specimen of unknown sex or age was used from each species. The head of each specimen was CT-scanned at either Ohio University μCT facility, the University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center, or the University of Arkansas MicroCT Imaging Consortium for Research and

Outreach (MICRO). Specimen details and associated scan parameters are provided inAppendix A. Additional CT data were sourced from DigiMorph.org. Each specimen was subsequently reconstructed as 3D digital models using Avizo (v. 8.1, Thermo Fisher Scientific, Waltham, MA) and cleaned for further use in MeshLab (Cignoni et al., 2008). To avoid problems associated with damage to some specimens, the most complete half of each skull (reflected in MeshLab if needed to match the orientation of the other specimens) was exported as the final model used in the analysis.

Cranial shape variation was quantified via 3D geometric morphometrics using an automated landmarking procedure which coated the surfaces of the 3D digital skull models in mathematically equivalent, not phylogenetically homologous, points (i.e., pseudolandmarks). Pseudolandmarks were generated using auto3DGM (Boyer et al., 2015) in the program 3DSlicer (Fedorov et al., 2012) utilizing the suggested 128 initial points and 1024 final points following the outcomes of Vitek et al., 2017, and pruned to exclude landmarks placed on internal surfaces of the skull in SlicerMorph (Rolfe et al., 2021).

Ecological and Behavioral Data

To visualize differences in ecology in behavior in further analyses, generalized diet category (herbivorous, carnivorous, omnivorous), feeding mode, and feeding medium were scored for each species using categorizations and qualitative observations from Ernst et al., (1994) and Souza (2021). Feeding mode represents broad functional suites of characters, similar to the classification of Foth et al. (2016). Species that crush hard-shelled prey were scored in the ‘hard’ feeding mode. Species scored in the ‘lingual’ feeding mode utilized lingual food prehension, which is obligatory in all tortoises

(Wocheslӓnder et al., 1999; Bels et al., 2008; Lemell et al., 2019). Species that utilized some form of suction for aquatic prey capture were scored in the ‘suction’ feeding mode. ‘Nonspecialized’ feeding mode scores represented the species that were not scored in the other feeding mode categories. Feeding medium describes where a turtle completes a feeding sequence, including intraoral transport and swallowing, to distinguish terrestrial and aquatic feeders, and those that can feed in both media (Natchev et al., 2015).

Not reflected within traditional categories is important functional information that, if considered separately, could lead to greater insights on morphological variation. For instance, food items may be orally processed or simply swallowed, and jaw contact may impose different functional demands on the cranium, potentially influencing shape differently or even to a greater extent than items that are merely transported prior to the swallow. Thus, a closer examination of the functionally important aspects of testudine diets is warranted beyond the traditional dietary categories. This is supported by the range of measured biomechanical properties of testudine food items and their influence on the skull morphology and jaw musculature in the few species that have been studied (e.g., *Psammobates geometricus:* Balsamo et al., 2004*; Malaclemys terrapin:* Herrel et al., 2017*; Graptemys geographica:* Lindeman, 2000; Lindeman and Sharkey, 2001; *Sternotherus minor:* Pfaller et al., 2011). To this end, separately from the other categorizations, each species was coded for the proportion of its diet represented by different food sizes and mechanical/material properties as well as the relative amount of contact the jaw makes with the food. This coding was operationalized to categorize diet data for animal-based and vegetation-based (including fungi) diets according to Figure 2-1. Within both categories, it was determined whether the item is simply swallowed with no intentional jaw contact, which only occurs under water, or whether it must be orally processed using the jaw in some way. It is assumed that all strictly terrestrial species must make some jaw-food contact to initially capture or prehend the food item. Swallowing versus oral processing in aquatic and semi-aquatic species was only assumed when the items were non-discrete or minute enough that a turtle would not have to position the item a certain way in order to swallow them. Personal observations of submerged feeding videos (e.g. https://www.youtube.com/watch?v=MBXvATaxsb0) for a variety of species demonstrated that submerged turtles suck most vegetation pieces and small, even soft-bodied, prey in and out of the oral cavity, presumably to position the item for suction-based intraoral transport (e.g. (Natchev et al., 2011; Stayton, 2011; Kummer et al., 2017). Between each positioning cycle, the item is held in the jaws while the water used in the cycle is ejected through the oral cavity, which indicates that even items that fit completely inside the oral cavity have at least some jaw-food contact during positioning. Live, large, or fast prey as well as large, unanchored vegetation, are first captured with jaw prehension, then torn with the aid of the forelimbs such that the pieces may be positioned for swallowing in the same way. Some armored prey, such as medium-sized arthropods, small mollusks and gastropods, or nuts or fruit, tend to be positioned first between the trituration surfaces for crushing, then the fragments are positions for swallowing.

The categorization of each food item was determined as follows (final categories italicized):

For animal-based foods, oral processing is characterized by either *particle-size reduction* if the prey is too large to swallow and not protected by a shell, or if there is a shell, by crushing. Crushed food items are further divided based on inferred fracture strength of the shell. If the prey is hard-shelled or well defended, like a mollusk or large crab, it requires *forceful crushing*. If the prey item requires crushing, but is not well defended, such as small arthropods, it merely requires *comminuting*. If the prey is small enough to swallow without positioning, like minute arthropods, most amphibian eggs and some larvae, and small fish or fry, the prey is simply *swallowed.*

Vegetation-based foods were sorted into four categories based on the inferred difficulty of processing: *coarse* vegetation like grasses and woody or fibrous plants with high levels of cellulose which resists fracture; *resistant* vegetation including forbs, annuals, fruits with an expanded, toughened pericarp (e.g., figs or olives), succulents and cactus pads; *soft* foods that require little force to reduce particle size, like the fruiting bodies of fungus, soft fruits (i.e., those that possess soft, fleshy pericarp, like berries), flowers, and delicate greens like stonewort algae; and unaltered vegetative matter that did not require contact with the jaw apparatus to ingest, such as filamentous algae, duck weed, and detritus is simply *swallowed*.

Representation within the categories was recorded as proportions of the whole diet for each reference and averaged in proportion to the number of individuals in each study to compute a species mean, creating a matrix of scores for each category. Diet data were recorded from sources using (in order of preference) bulk diet data measures, quantitative observational data, or, in the absence of those options, occurrence data (see Appendix B-1 for final species scoring, Appendix B-2 for source data groups, Appendix B-3 for raw and categorized diet data; and Appendix C for a partial bibliography of turtle diet data). Since the frequency and manner of interaction between individual food items and the testudine skull are of highest interest, measures that approximated the number of jaw-food interactions for a given food item were prioritized and generalized across an entire species over their entire lives. As such, in an effort to approximate bulk diet data, occurrence data were converted to a proportion of all occurrences by dividing each food item occurrence by the sum of all occurrences of all food items. This measure was not shown to be highly correlated with volumetric data in a study of omnivorous badger scats (Zabala and Zuberogoitia, 2003), but diet data sources for turtles used a wide variety of bulk measures that have not yet been tested for correlation. Therefore, it is unknown if the variance among bulk measures is greater than the variance between bulk measures and proportion of all occurrences.

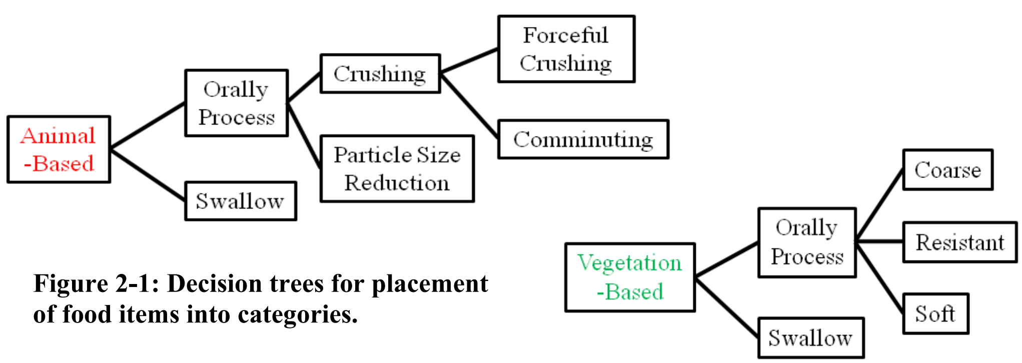

Figure 2-1: Decision trees for placement of food items into categories.

Analysis

All analyses were performed in the R-package Geomorph (Adams and Otárola-Castillo, 2013; Adams and Collyer, 2016). All plots were generated within the R tidyverse (Wickham et al., 2019). A generalized procrustes fit (GPA) of the pseudolandmarks was performed before all downstream analyses. A phylogenetic tree from (Thomson et al., 2021) was pruned for use in downstream analyses. Multivariate effects sizes were reported as z-score for all correlative analyses (Adams & Collyer, 2016).

The GPA coordinates were tested for: 1) phylogenetic signal (for each PC axis and globally) using the function 'physignal', reported as a Kmult value (Adams, 2014) in which the closer the value is to K=1, the closer the species fit a Brownian motion, or random, model of evolution, whereas values of K<1 indicate a lesser effect of phylogeny than expected, and K>1 indicates a larger effect of phylogeny; 2) allometric signal using the function 'procD.pgls' to perform a phylogenetically informed ANOVA of the model skull shape ~ centroid size, reported as an R^2 value, in which R^2=1 would indicate that 100% of the variation in shape is explained by size; and 3) morphological disparity among families, diet, feeding mode, and feeding medium using the function 'morphol.disparity', reported as Procrustes variance.

Principal component analyses (PCA) were run on all specimens (Full Dataset) for uncorrected data, phylogenetically corrected data (Revell, 2009), phylogenetically aligned (Collyer and Adams, 2021) data, and repeated for a subset of the data (Non-Tortoise Dataset) that excluded tortoises (Testudinidae) due to their strong effects in the full dataset. Only PC axes with 10% or more explained variation were reported, unless notable patterns were present in axes with less than 10%. Adams and Collyer (2019) suggest against "correcting" shape data for allometry because it makes the resultant PCA difficult to interpret with any biological reality, and, indeed, allometric traits may be adaptive or functionally relevant. Uncorrected and phylogenetically corrected two-block partial least squares analyses (2BPLS;Rohlf and Corti, 2000) were performed comparing the GPA shape to the diet data (averaged for each species). The correlation coefficient is reported as r_{PLS} for which 1 would be perfect correlation.

Results

Full Dataset

Phylogenetic Signal, Allometric Signal, and Morphological Disparity. Phylogenetic signal was measured in the full dataset as K= 0.1995 (P=.005, z=2.62), indicating that the phylogenetic signal is low. Nonetheless, this small Kmult value was significant, either implying that there is "a weak signal for many variables or a strong signal for few variables" (Adams and Collyer, 2019). This is not discernable in this dataset because of the limited samples size, which lacks the statistical power needed to compare among phylogenetically distinct groups. The low K of 0.1995 implies that there is a directional model of evolution in turtle skull morphology as opposed to a Brownian model, and that the selection factors are not phylogenetic (Adams, 2014).

Parsing the phylogenetic signal of the uncorrected PCA by component reveals that principal component 4 is the only one of the first four components to carry significant phylogenetic signal (K=0.4, P=.001, z= 3.85). Since significant phylogenetic signal was found within the first four components, phylogenetic correction was deemed appropriate for this dataset, despite the low signal for the dataset as a whole.

Fitting a Phylogenetic Procrustes ANOVA of skull shape to log centroid size returned R^2= 0.082 (P=0.001) suggesting that (1) 8.2% of the variation in skull shape is size-correlated, and (2) such allometric signal is significant.

The morphological disparity in the dataset, measured as the Procrustes variance, was 0.028, and no group (family, diet, feeding mode, feeding medium) was significantly different from any other group. Therefore, group variances and pairwise significance values are not reported here.

Uncorrected PCA Loadings and Phylogenetic Patterns. The first four components of the uncorrected PCA explain ~62% of the skull shape variation in the dataset (Figure 2-2). When regressed against centroid size, it was found that both PC1 (24.5%) and PC4 (9.7%) capture both significant size and shape variation, while PC2 (14.7%) and PC3 (13.6%) components capture only shape variation.

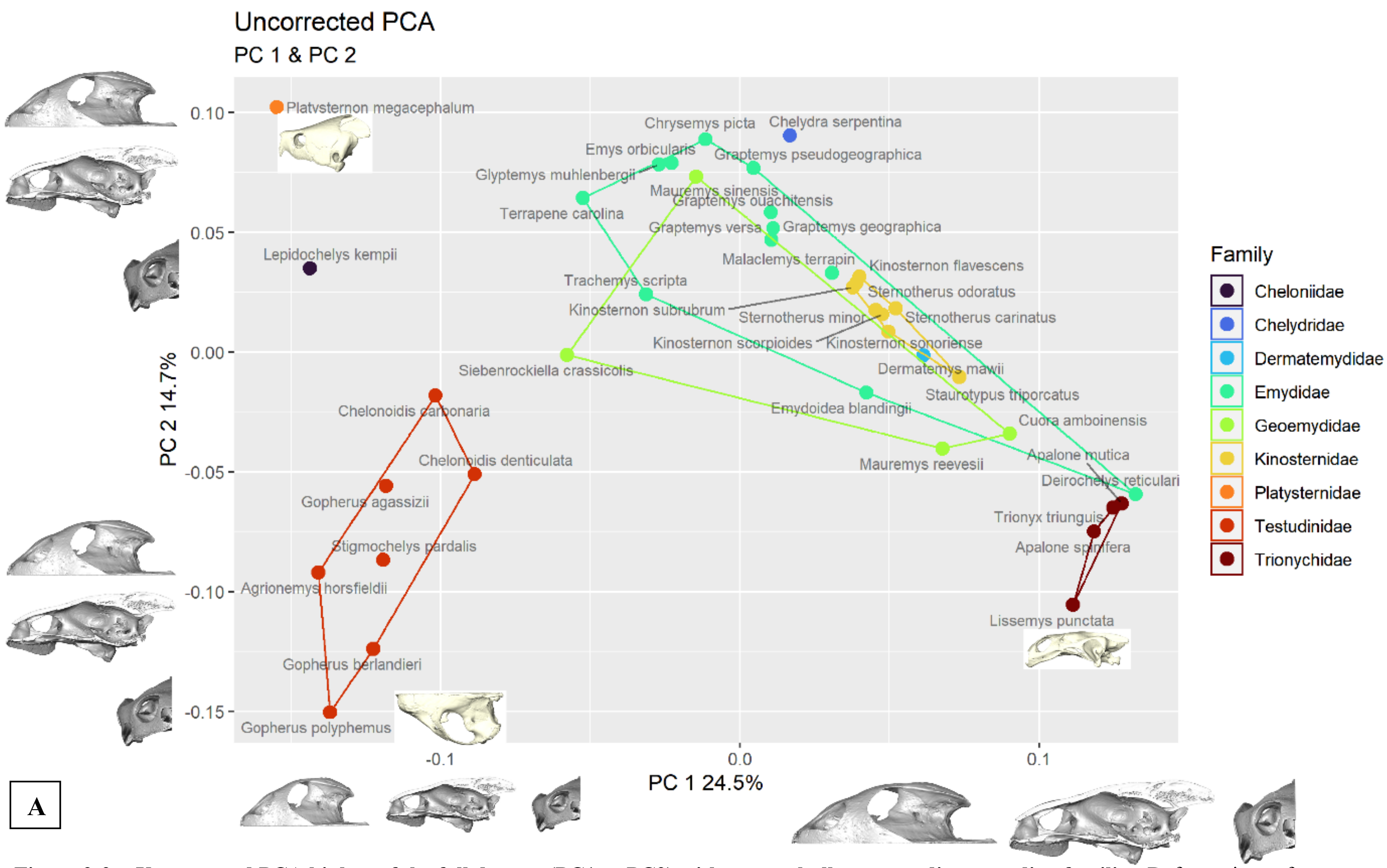

Figure 2-2a: Uncorrected PCA biplots of the full dataset (PC1 vs PC2) with convex hulls surrounding testudine families. Deformations of an averaged mesh display the hemiskull shape at the extremes of each axis magnified two times for emphasis in (top-bottom, left-right) dorsal, medial, and anterior view.

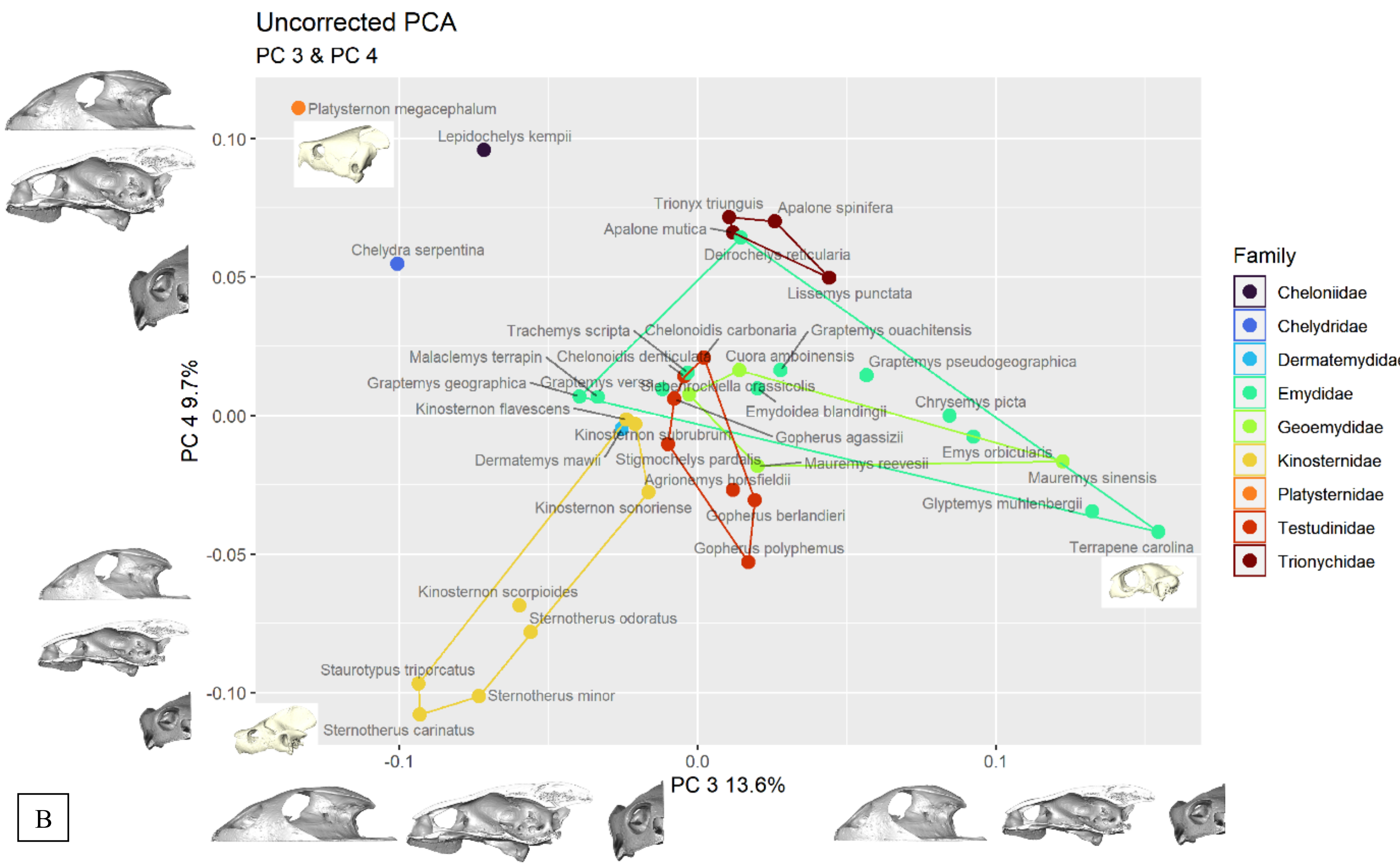

Figure 2-2b: Uncorrected PCA biplots of the full dataset (PC3 vs PC4) with convex hulls surrounding testudine families. Deformations of an averaged mesh display the hemiskull shape at the extremes of each axis magnified two times for emphasis in (top-bottom, left-right) dorsal, medial, and anterior view.

At the positive extreme of PC1, the skull is narrower, with a taller squamosal eminence, greater temporal emargination, and a trochlear process that is more anterior relative to the jaw articulation. At the negative extreme of PC1 the skill is flatter and wider and has a more convex adductor chamber, a posteriorly flared maxilla and palate, and a longer supraoccipital crest and squamosal eminence. Tortoises (Testudinidae) and the two sole representatives of their families, *Platysternon megacephalum* and *Lepidochelys kempii* from the remainder of cryptodire species are separated along PC1.

The cranial shape at the negative end of PC2 is slightly longer posteriorly, with a slightly flatter skull roof and lower temporal emargination, and a slightly deeper labial ridge than the shape at the positive end of PC2, though the difference between them is not strong. Tortoises are represented along the negative end of PC2, whereas there is little distinction between families on the positive end.

The gradient along PC3 is somewhat similar to PC1, except it is the positive shape that is wider and flatter, possessing more temporal and cheek emargination, while the negative shape is slightly longer with a narrower orofacial region, flatter palate with a deep labial ridge, and an articular process of the quadrate that projects more inferiorly below the basicranium and has a narrower, more medially directed articular surface. PC3 distinguishes the three sole representatives of their families and Kinosternidae from the remainder of cryptodire families.

Skull shape at the negative extreme of PC4 is flatter than that at the positive extreme, which is much taller in all areas, particularly evident in the deeper labial ridge and over the otic chamber between the squamosal eminence and quadrate. PC4 contains significant phylogenetic signal and does roughly separate families, primarily, the three sole representatives of their families on the positive end, Kinosternidae on the negative end, and the remaining cryptodire families grouped centrally on the axis.

Phylogenetically Corrected PCA Loadings and Phylogenetic Patterns. The first four components of the pPCA explain ~66% of the shape variation in the dataset, while more variation is captured in pPC1 (28%) and pPC2 (16.7%) than the same axes of the uncorrected analysis. In this analysis, pPC1 and pPC4 (8.3%) again capture shape along with most of the size variation, though the effects are magnified compared to the uncorrected PCA (see Figure 2-2), while pPC2 and pPC3 (12.6%) capture shape variation.

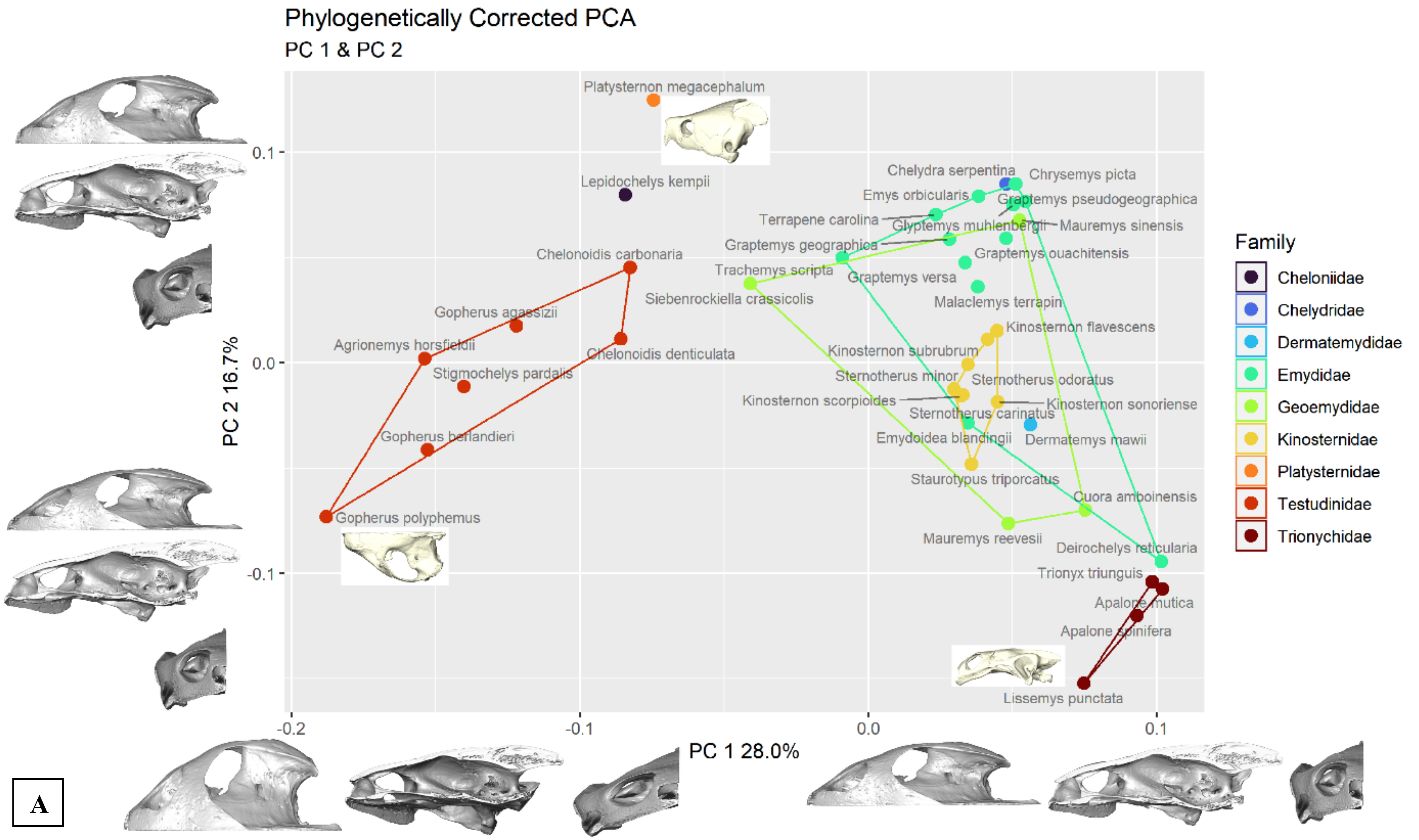

Figure 2-3a: Phylogenetically corrected PCA biplots of the full dataset (pPC1 vs pPC2) with convex hulls surrounding testudine families. Deformations of an averaged mesh display the hemiskull shape at the extremes of each axis magnified two times for emphasis in (top-bottom, left-right) dorsal, medial, and anterior view.

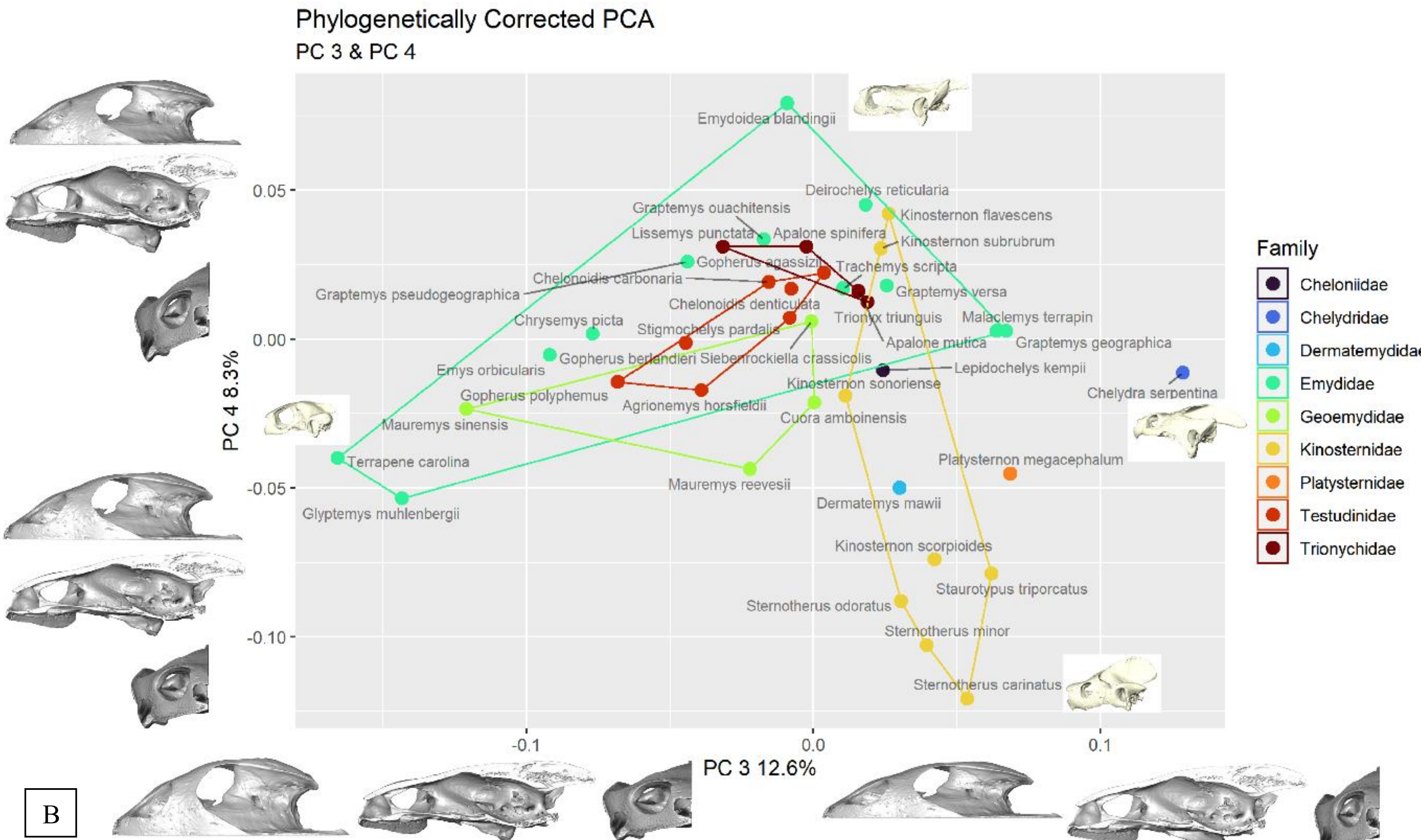

Figure 2-3b: Phylogenetically corrected PCA biplots of the full dataset (pPC3 vs pPC4) with convex hulls surrounding testudine families. Deformations of an averaged mesh display the hemiskull shape at the extremes of each axis magnified two times for emphasis in (top-bottom, left-right) dorsal, medial, and anterior view.

Phylogenetic correction of the dataset results in a pPC1 that separates by size in addition to the shape separation of the uncorrected analysis PC1: the negative end may be summarized as tortoise-like in shape (see further descriptions in this paragraph) and much smaller than average while the positive end is non-tortoise-like and larger than average. At the negative end of pPC1, skulls are short, flat, and wide, have a wide adductor chamber with a trochlear process positioned far anterior of the jaw joint, and a wide oral region. The palate is vaulted and has deep labial ridges. The articular surface of the quadrate is wide, faces medially and ventrally, and projects well below the basicranium, which contributes to the height of the palate relative to the jaw. Finally, the mandibular condyles are aligned perpendicular to the long axis of the skull. The shape at the positive extreme of pPC1 is average in width and height, and essentially all the above-described features are similar to the average shape of the sample. Phylogenetic correction results in an even greater divide among tortoises, *L. kempii*, and *P. megacephalum* and all other cryptodire families along pPC1.

Size variation is not represented along pPC2 but rather reflects the shape that is similar to the positive end of pPC1: dorsal features appear swept posteriorly relative to the ventral features, and there is a narrowing of the adductor chamber and narrow, anteriorly pointed premaxillary portion of the labial ridge. This contrasts with the shape a the positive extreme of pPC2, which is slightly wider and taller in all these aspects with a slightly deeper temporal emargination. pPC2 seems to draw out Trionychidae to the negative extreme, while Testudinidae is now in a centralized location along this axis, grouped with the bulk of cryptodire families and the species with tall, armored skulls forming the positive extreme.

The shape at the negative extreme of pPC3 trends towards a very flat but wide posterior skull with a high cheek emargination and deeper temporal emargination, wide but shallow and short palate/maxilla and anterior face, and a trochlear process that is far anterior of the jaw articulation. This contrasts with the positive end of pPC3, in which these features are similar to the average shape in the sample, but with the addition of a taller and more elongated adductor chamber and a quadrate articular process that projects below the basicranium and that has a narrow, ventromedially facing articular surface. This axis shows less pattern than pPC1 and pPC2. Tortoise-like and terrestrial emydids (*Terrapene carolina* and *Glyptemys muhlenbergii*) occupy the negative end of pPC3 while the largest emydid with the longest supraoccpital crest of the sample, *Chelydra serpentina*, anchors the positive extreme, though there is far less size effect in pPC3.

The shape at the negative end of pPC4 is similar to the mean shape of the sample, but much larger, while the shape at the negative end is much smaller. The shape at the positive extreme of pPC4 is similar to that at the negative end of pPC1 but lacks the greater width, possessing a deep labial ridge and a quadrate that projects below the basicranium contributing to the higher arch of the palate, and a ventromedially oriented quadrate articular surface and taller posterior skull with a deeper temporal emargination. This axis also shows less pattern than pPC1 and pPC2. With the largest size effect of the four axes, pPC4 has many of the larger species in Kinosternidae grouped towards the negative end, but that does not hold true for the entire family

Mapping of Ecological Categories on the PCA and pPCA. When feeding mode (Figure 2-4 and Figure 2-5 point shape), feeding medium (Figure 2-4 and Figure 2-5 point color), and traditional diet (Figure 2-4 and Figure 2-5 convex hull color) are mapped onto the PCA and pPCA, few patterns emerge. Herbivory primarily maps onto Testudinidae in both analyses, though in principal components 3 and 4, all herbivorous species are centralized and have lower disparity compared to carnivorous and herbivorous species. Most cryptodires are aquatic and all Testudinidae are terrestrial, so it is little surprise that feeding medium primarily reflects these families. The one interesting pattern is the location of the turtles that are confirmed to eat both in water and on land. This 'both' category maps opposite Testudinidae along component 1 in both analyses but overlaps Testudinidae along the remaining components. Feeding mode separates along the tortoise-like (lingual)/non-tortoise-like line (all other feeding modes) in the PCA (grouping in the negative quadrant in PC1 & PC2) and the pPCA (on the negative end of pPC1). Suction feeding species tend to plot near the positive end of PC1 or the negative end of pPC2, while showing little distinction from other species in principal components 3 and 4 in both analyses, though they do seem to occupy more restricted morphospace than other modes. Interestingly, a large component of hard prey in the diet of a species does not seem to form a distinct grouping in morphospace, since they largely overlap non-specialized feeding mode morphospace along all component axes.

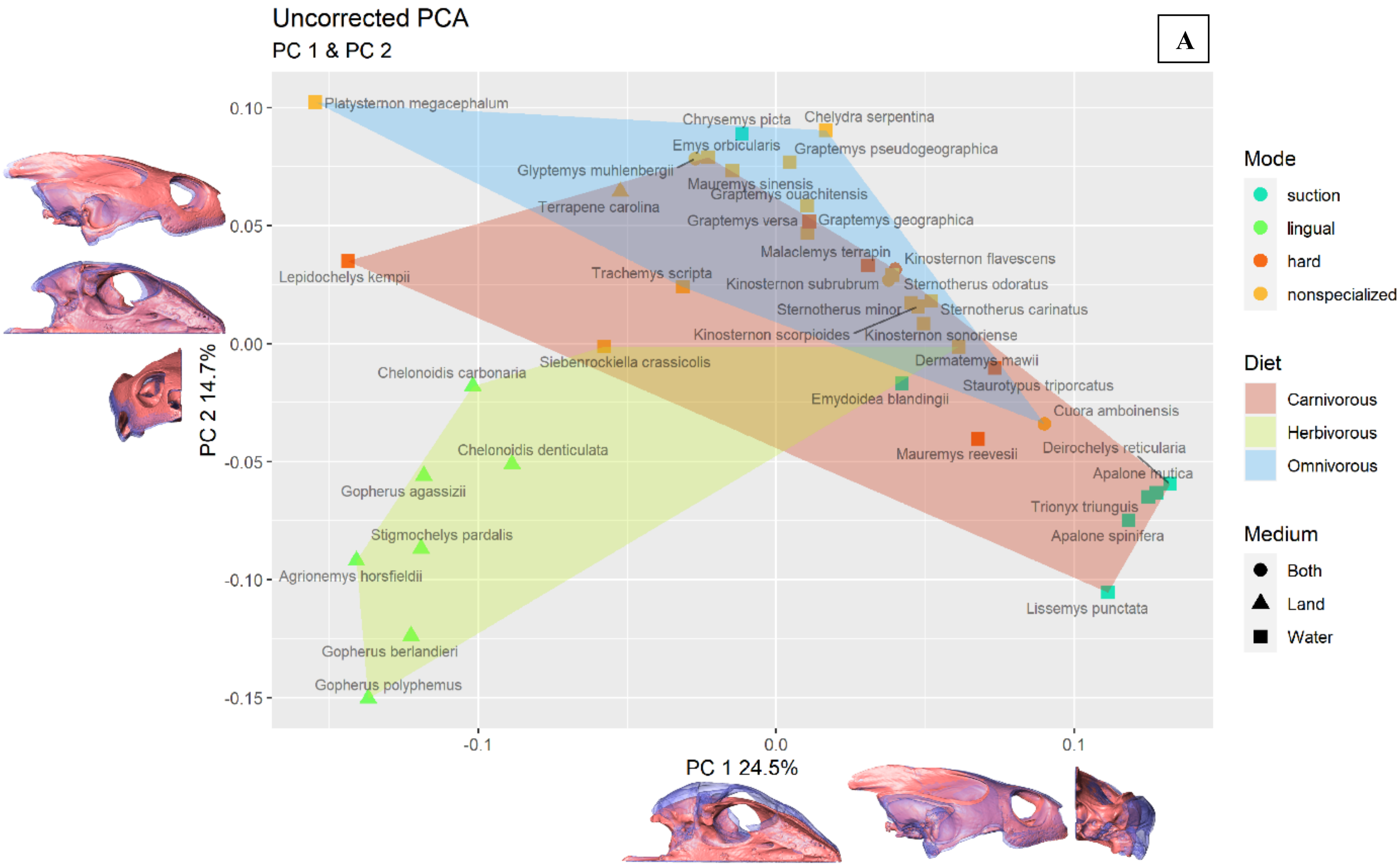

Figure 2-4a: Uncorrected PCA biplot of the full dataset with Mode, Diet, and Medium indicated, PC1 & PC2. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

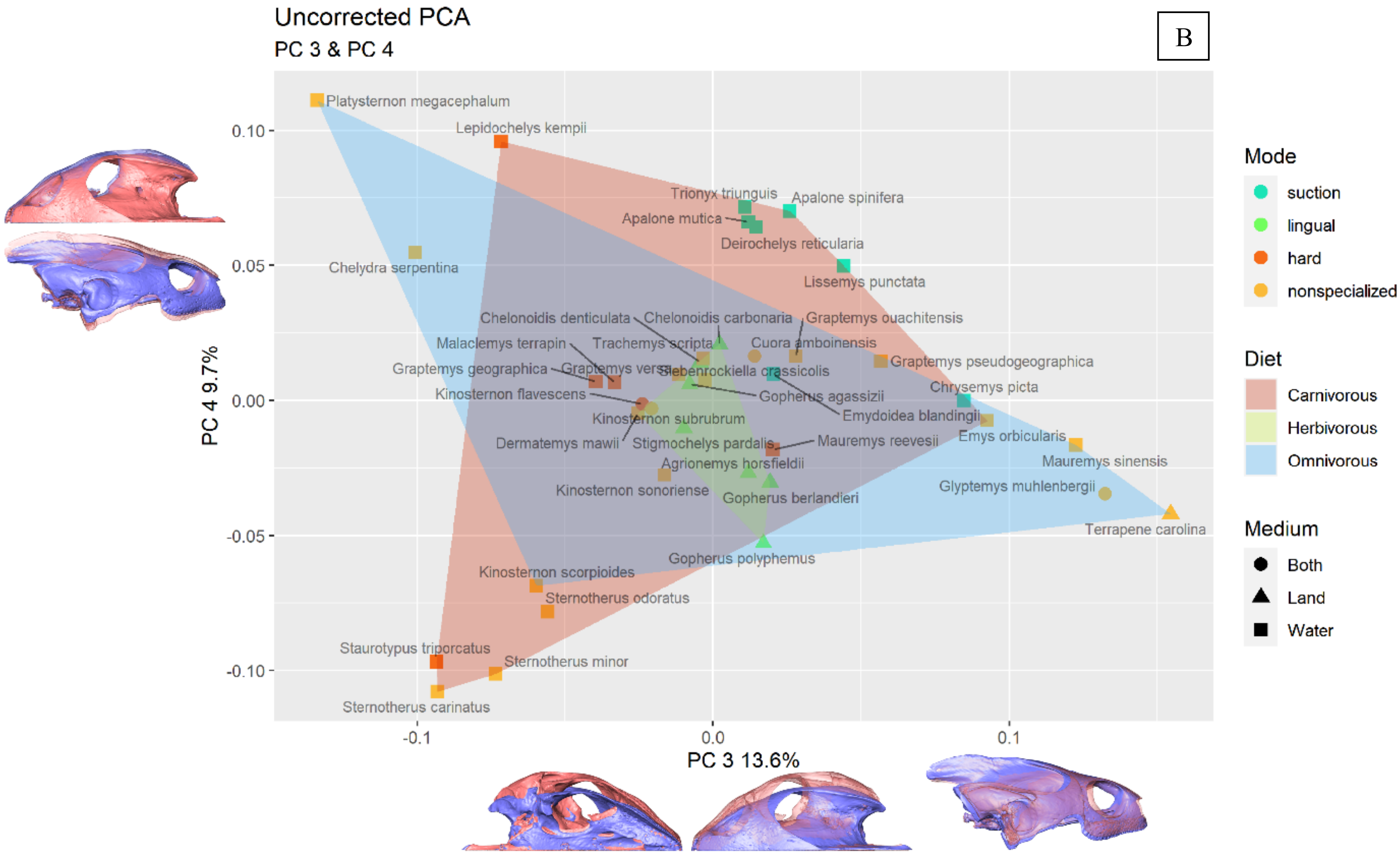

Figure 2-4b: Uncorrected PCA biplot of the full dataset with Mode, Diet, and Medium indicated, PC3 & PC4. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

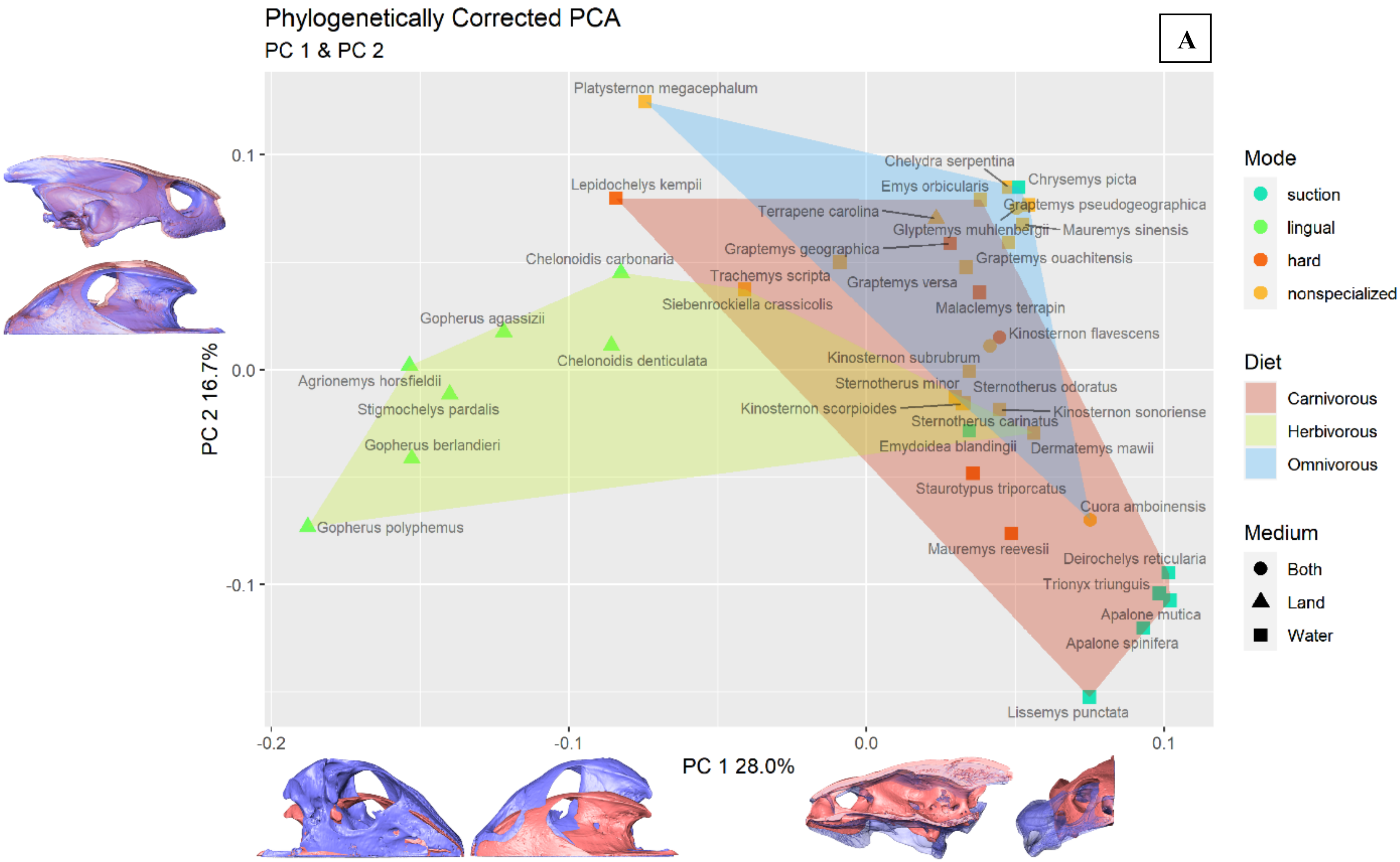

Figure 2-5a: Phylogenetically corrected PCA biplot of the full dataset with Mode, Diet, and Medium indicated, pPC1 & pPC2. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

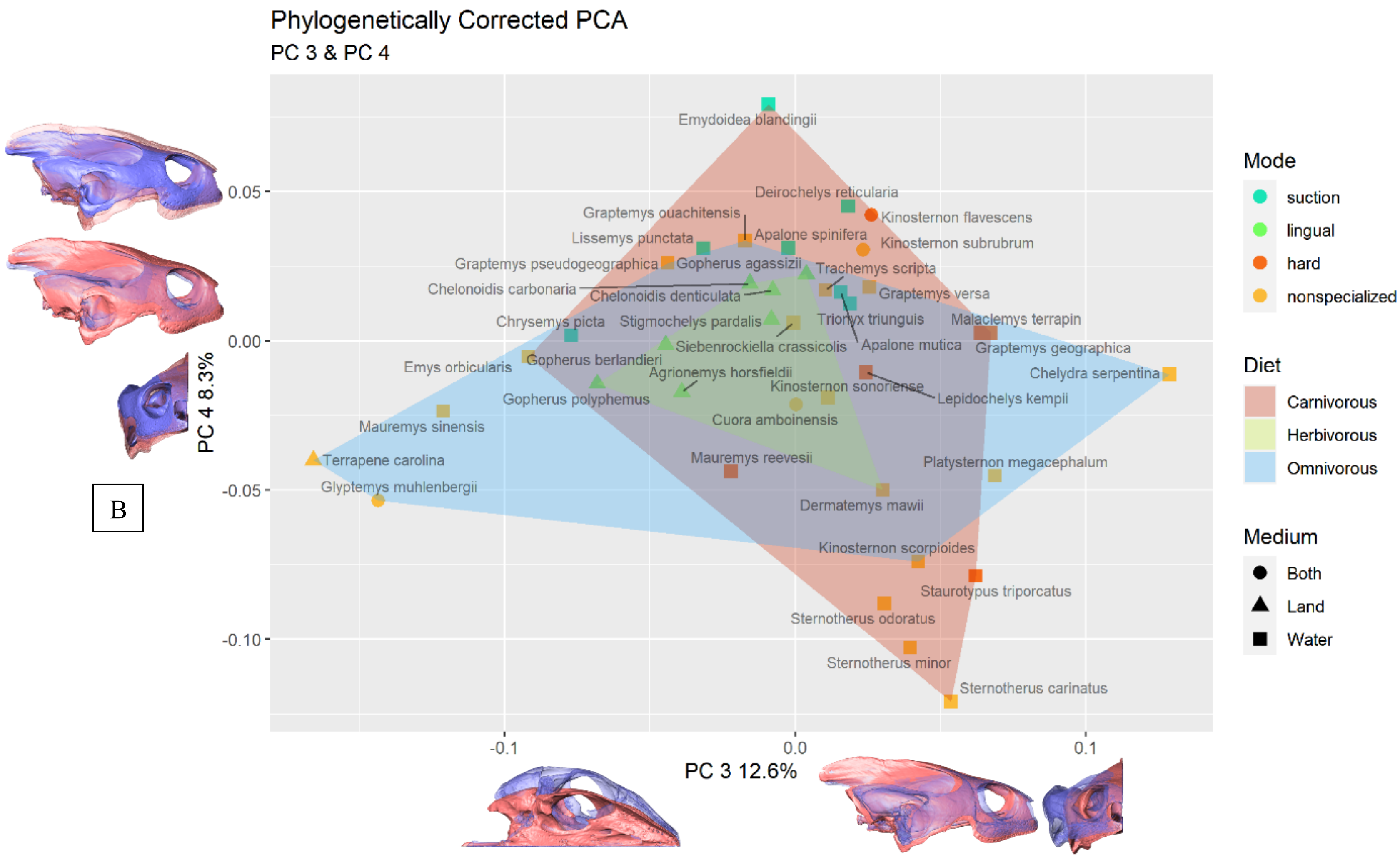

Figure 2-5b. Phylogenetically corrected PCA biplot of the full dataset with Mode, Diet, and Medium indicated, pPC3 & pPC4. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

2BPLS and Phylogenetically Corrected 2BPLS. The two-block partial least squares analysis comparing species-averaged proportional diet data to the shape of these 39 species produced significant covariation (*P*=0.002), with a correlation coefficient r_{PLS} =0.766 (*z*= 3.2589). Figure 2-6 shows that 29% of the variation in the blocks is shared along the first PLS axis. The shape (x-axis) loading is smaller at the negative end and larger at the positive end. Compared to the nearly average shape at the positive end, the shape at the negative is characterized by a deeper labial ridge, a wider and posteriorly flared palate/maxilla, a wider articular surface of the quadrate with the condyles that are very perpendicular to the long axis of the skull, a much wider adductor chamber with a lower posterior portion and an anterior portion that is anteroposteriorly shortened due to the location of the trochlear process, which is farther anterior of the jaw joint but lower in the adductor chamber. The diet (y-axis) is loaded as diets with a larger proportion of resistant vegetation towards the negative end, with coarse vegetation contributing less and soft vegetation even less to the loading. Diets with a larger proportion of animal matter requiring comminution loads the positive end, with low contribution of forceful crushing and particle size reduction modes to the loading. When plotted with convex hulls around species within traditional diet categories, herbivorous species tend towards the negative end of the axes, while carnivorous species plot near the positive end of the axes, with omnivorous species in between. As suspected by the similarity of the PLS shape loading with the shapes along the first principal component of the PCA, PC1 is the only axis with a significant correlation with the diet block (r_{PLS}=0.671, *P*=0.001, *z*=3.6249; not figured), with nearly identical diet loadings as reported for the entire shape data sample (Table 2-1).

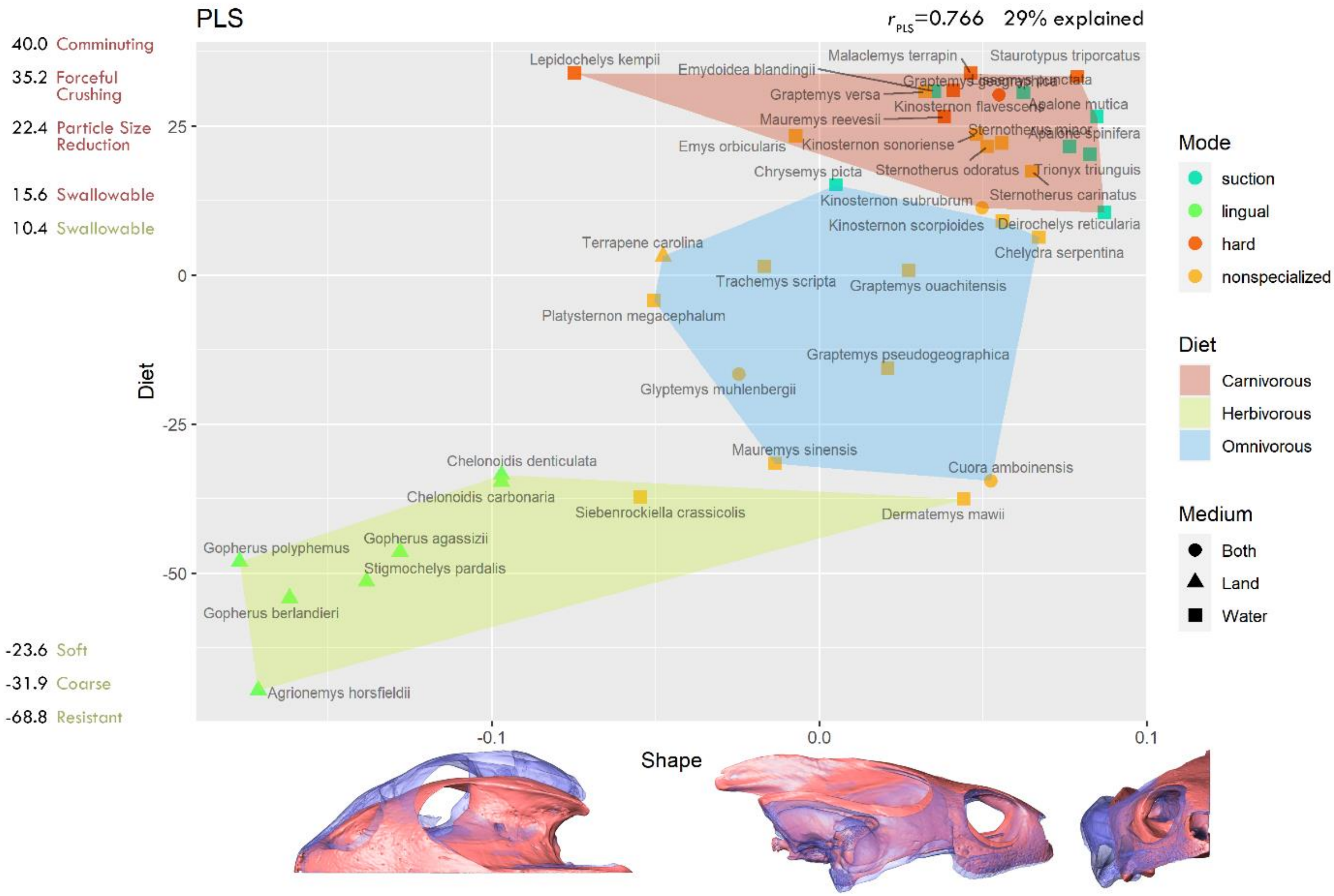

Figure 2-6. Uncorrected 2BPLS plot of the full dataset with feeding mode, diet, and feeding medium indicated. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red. Percent loadings of the diet axis display vegetation-based categories in green and animal-based categories in red.

Table 2-1: PCA axis 2BPLS Diet Loadings

PLS axis	*Negative diet loadings*		*Positive diet loadings*	
PC1	-70.4	Resistant (Vegetation)	42.6	Comminuting (Animal)
	-32.1	Soft (Vegetation)	27	Particle size reduction (Animal)
	-21.3	Coarse (Vegetation)	22	Forceful crushing (Animal)
			19.3	Swallow (Animal)
			12.3	Swallow (Vegetation)
pPC1	-60.9	Resistant (Vegetation)	47.5	Comminuting (Animal)
	-49.5	Coarse (Vegetation)	25	Particle size reduction (Animal)
	-10.9	Soft (Vegetation)	21.9	Forceful crushing (Animal)
			16	Swallow (Animal)
			10.3	Swallow (Vegetation)
pPC2	-77.7	Coarse (Vegetation)	48.3	Soft (Vegetation)
	-18	Particle size reduction (Animal)	31.9	Resistant (Vegetation)
	-8	Swallow (Vegetation)	12.3	Comminuting (Animal)
			8.3	Swallow (Animal)
			2.7	Forceful crushing (Animal)

The phylogenetically corrected 2BPLS (Figure 2-7) shows a similar pattern to the uncorrected PLS, but with a tighter, more significant correlation (r_{PLS} = 0.782, P=0.001, z=4.1234). Additionally, more of the variation in the datasets is shared along the PLS axis (36.5%), and there is a tighter grouping of species in traditional dietary categories. The loading of the positive extreme of the shape axis is virtually unchanged from its uncorrected counterpart, but the negative extreme is slightly magnified: slightly larger, slightly wider adductor chamber and palate/maxilla, a more vaulted palate and deeper labial ridge, slightly more perpendicular mandibular condyles, with a slightly flatter posterior adductor chamber. On the diet axis, higher proportions of resistant and coarse vegetation in the diet nearly contribute the same amount to the loading of the negative end, while higher proportions of animal matter requiring comminution contributes more to the loading of the positive extreme. Traditional diet category grouping is tighter, with herbivores now occupying the negative half, and carnivores and omnivores overlapping more. As suspected by the similarity of the shapes along the pPLS and pPC1 axes, the first principal component of the phylogenetically corrected pPCA has a significant correlation with the diet block (r-PLS= 0.709, *P*=0.001, *z*=3.8277; not figured), with nearly identical diet axis loadings to the full phylogenetically corrected dataset (Table 2-1). Additionally, pPC2 has a significant correlation with the diet block (r-PLS= 0.529, *P*=0.007, *z*=2.3632; not shown), but the loading of the dietary axis differs. The negative end represents diets with a larger proportion of coarse vegetation, with diets with a larger proportion of animal matter requiring particle size reduction contributing less to the loading. The positive end represents diets with a larger proportion of soft vegetation, with resistant vegetation contributing less to the loading.

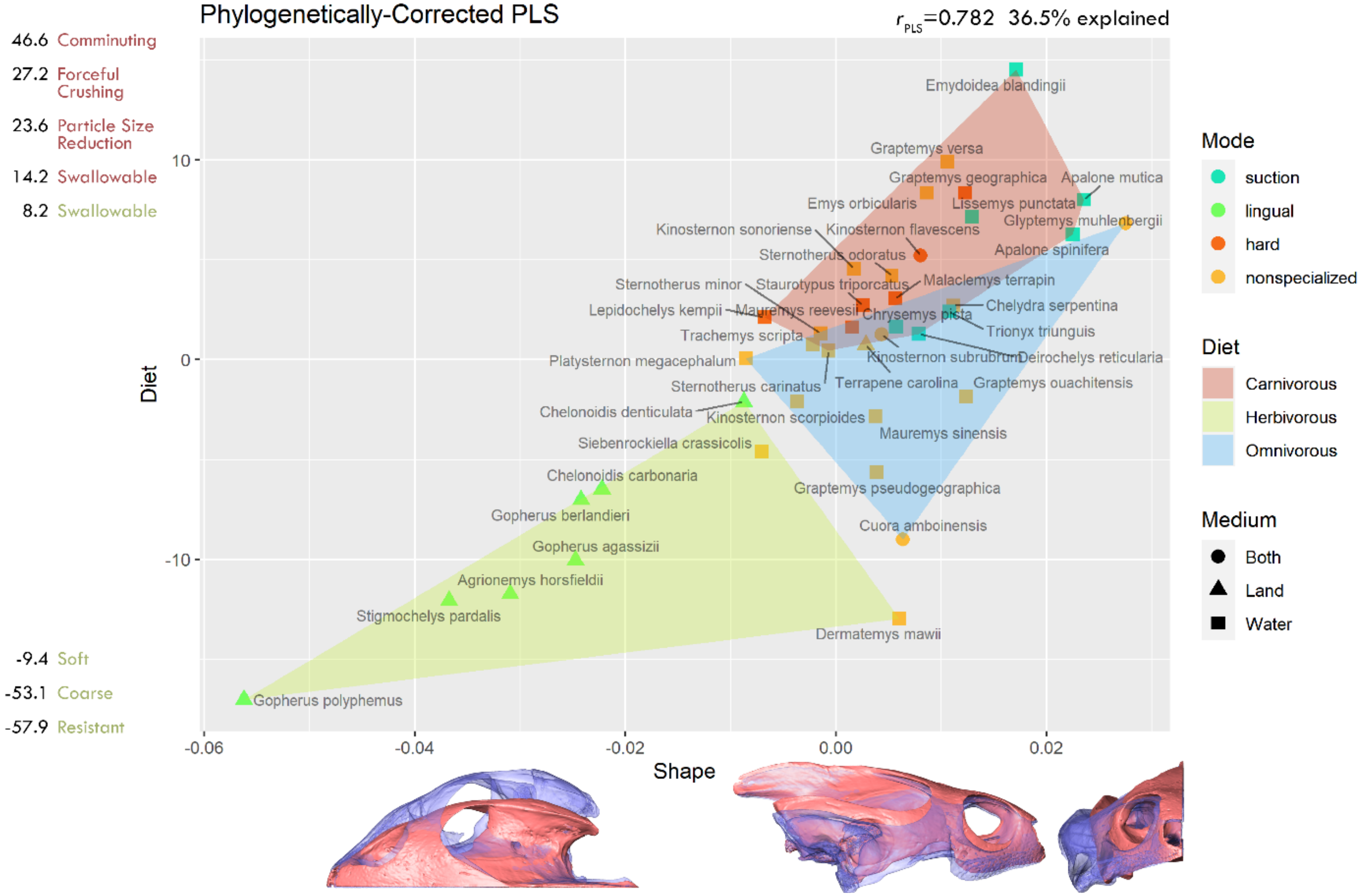

Figure 2-7. **Phylogenetically corrected 2BPLS plot of the full dataset with feeding mode, diet, and feeding medium indicated.** Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red. Percent loadings of the diet axis display vegetation-based categories in green and animal-based categories in red.

Non-Tortoise Dataset

Because of the strong effect of tortoises on the first principal components of the full dataset, the above analyses were repeated on a subset of the full data excluding Testudinidae.

Phylogenetic Signal, Allometric Signal. Phylogenetic signal in the non-tortoise subset was measured as K= 0.3204 (P=.001, z=6.4004), suggesting a weak phylogenetic signal, but a much stronger effect size. This is evident in the significant, moderate phylogenetic signal in all of the first four components of the uncorrected non-tortoise PCA (ntPCA): ntPC1 K= 0.4853, P=.001, z=4.0068; ntPC2 K= 0.3225, P=.006, z=2.5932; ntPC3 K= 1.1971, P=.001, z=5.679; ntPC4 K= 0.409, P=.002, z=3.0512. Therefore, phylogenetic correction was deemed appropriate for the non-tortoise subsample. When tortoises are removed, a linear model of skull shape to log centroid size returned R^2= 0.15689 (P=.001, z=3.9394), suggesting that 15.9% of the variation in skull shape is size correlated.

Non-tortoise PCA (ntPCA) Loadings and Phylogenetic Patterns. Only the first two components of the ntPCA (Figure 2-8) will be reported since these contain the majority of shape variation (ntPC1: 25.5%, ntPC2: 17.9%) and emergent patterns. Size is a major component of variation along both axes.

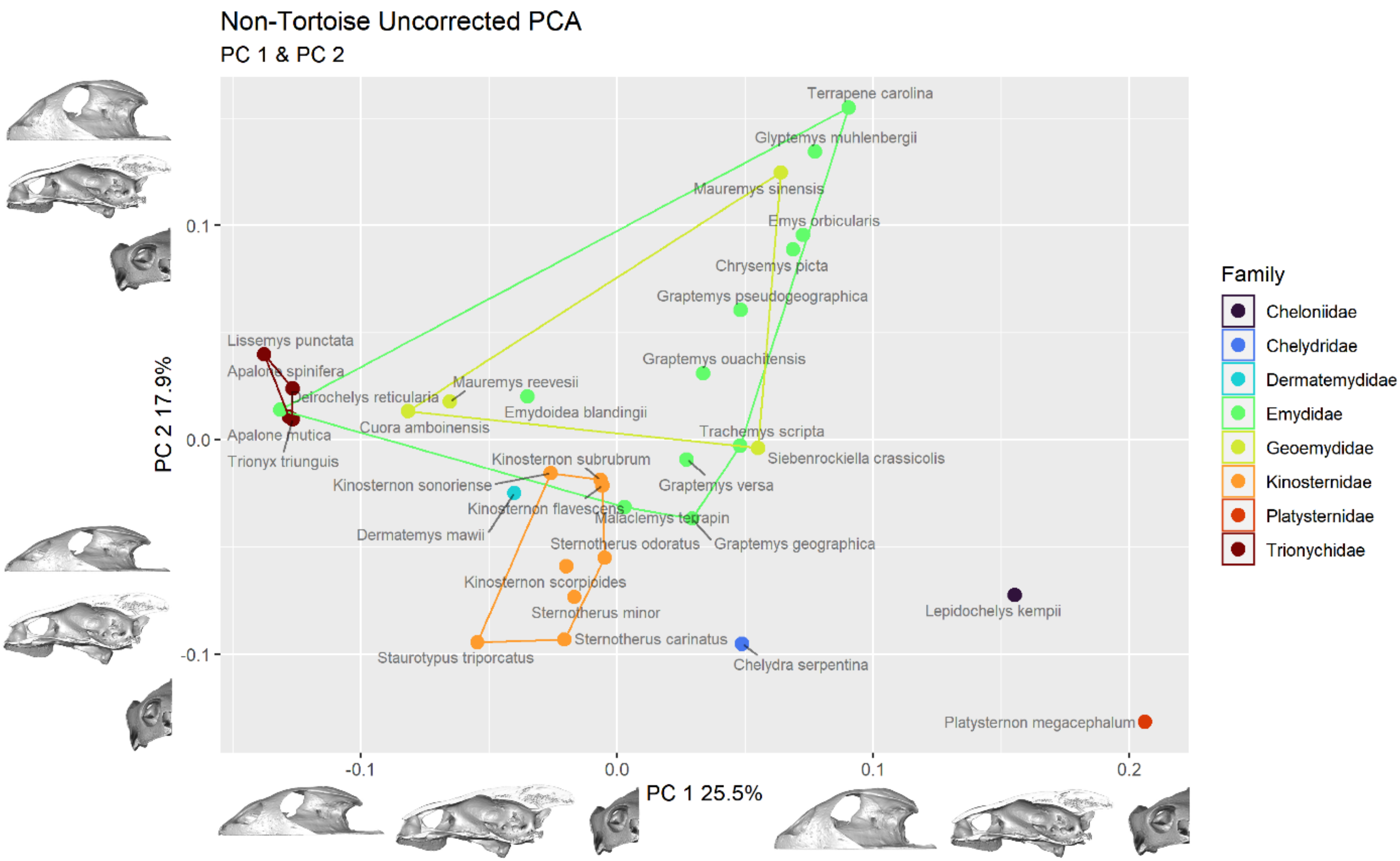

Figure 2-8. Uncorrected PCA biplot of the non-tortoise data subset with convex hulls surrounding testudine families. Deformations of an averaged hemiskull mesh display the shape at the extremes of each axis magnified three times for emphasis in (top to bottom, left to right) dorsal, medial, and anterior view.

Compared to the average shape, the larger shape at the negative end of ntPC1 (25.5%) is slightly narrowed. At the other extreme of ntPC1, skull shapes are shorter in height and length, have a posteriorly widened maxillary trituration surface, a wide adductor chamber with a trochlear process positioned far anterior to the jaw joint, a short supraoccipital crest, and mandibular condyles aligned perpendicular to the long axis of the skull. The larger effect size of phylogenetic signal of ntPC1 is clear, with most families plotting in relatively restricted morphospace, except for the pond turtle families Emydidae and Geoemydidae, two families that are often compared as convergent radiations. The trionychids anchor the negative end of ntPC1, while *L. kempii* and *P. megacephalum* plot some distance from other families on the positive end of the axis.

The average-sized shape at the positive end of ntPC2 (17.9%) is also shorter in height with a wider trituration surface and adductor chamber but has a shorter face with a shallower labial ridge and short quadrate articular process contributing to a shallow oral cavity, and a thin temporal bar as a result of encroachment by both emarginations. The trochlear process is far anterior to the jaw joint and the squamosal eminence is shortened considerably compared to both the average shape and the larger shape at the negative end of ntPC2. The negative extreme of ntPC2 has narrower than average oral cavity and adductor chamber, and a slightly deeper palate and associated structures, but the trochlear process is positioned more posteriorly than average. The negative half of ntPC2 is filled with Kinosternidae, *L. kempii, P. megacephalum,* and *C. serpentina* as well as *Malaclemys terrapin* and *Graptemys geographica,* while the positive end is anchored by *T. carolina* and *Glyptemys muhlenbergia.* Trionychids plot near the center of ntPC2.

Phylogenetically Corrected ntPCA (ntpPCA) Loadings and Phylogenetic Patterns. Only the first two components the phylogenetically corrected ntPCA (i.e., ntpPCA) (Figure 2-9). will be reported since these contain most of the shape variation (ntpPC1: 29.1%, ntPC2: 15.5%) and emergent patterns. The effects of centroid size are magnified in this analysis: the negative shapes of both ntpPC1 and ntpPC2 are very small and the positive shapes are very large.

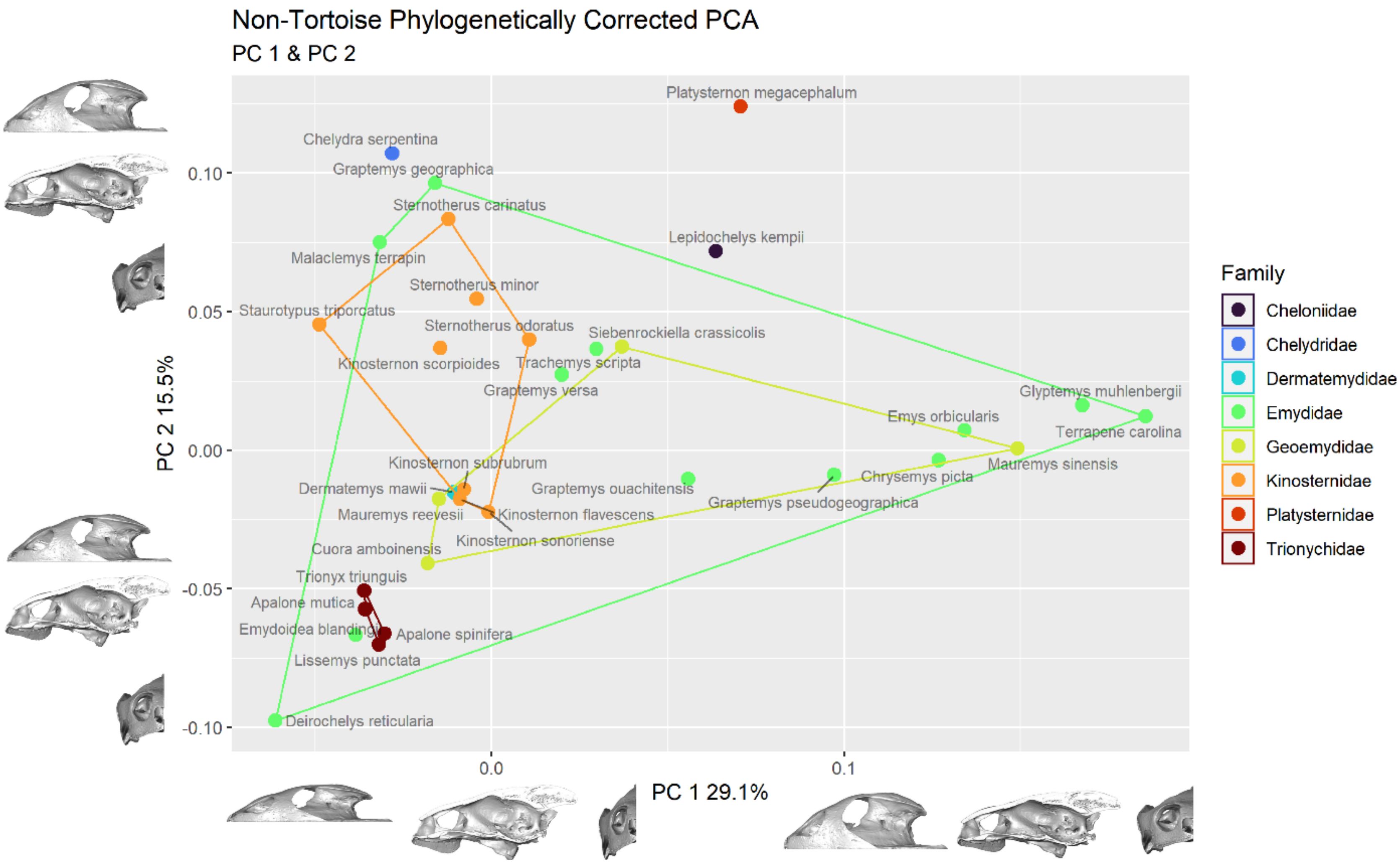

Figure 2-9. Phylogenetically corrected PCA biplot of the non-tortoise data subset with convex hulls surrounding testudine families. Deformations of an averaged hemiskull mesh display the shape at the extremes of each axis magnified two times for emphasis in (top to bottom, left to right) dorsal, medial, and anterior view.

Despite being much larger, the positive end of ntpPC1 is nearly average in shape yet slightly wider posteriorly and shorter in height with a slightly more anteriorly placed trochlear process. The negative shape of ntpPC1 is extremely narrow with a tall posterior half, with a deeper temporal emargination, longer and taller supraoccipital crest and squamosal eminence, a more posteriorly positioned trochlear process relative to the anteromedially directed articular surface of the quadrate, and a deeper labial ridge. Anterior deepening of the labial ridge contributes to a mediolaterally arched oral region mirroring the anteroposterior arching between the jaw joint and the tip of the labial ridges. The general spread of taxa indicates that phylogenetic correction brought the patterns of uncorrected ntPC2 to the fore, with the axis of variation separating *T. carolina* from *C. serpentina* now being captured in ntpPC1. Trionychids plus *Emydoidea blandingii* and *Deirochelys reticularia* anchor the negative end of ntpPC1, while the trio of *G. muhlenbergii, T. carolina,* and *Mauremys sinensis* once again anchor the positive of ntpPC1.

Besides being much larger, the shape at the positive extreme of ntpPC2 is nearly identical to the average shape exhibiting only a slightly narrower and taller face. The much smaller ntpPC2 negative shape is narrower, with a more posteriorly positioned trochlear process relative to a much more anteriorly placed and inferiorly projecting jaw articulation, but with a much more elongated skull and face, taller and longer supraoccipital crest and squamosal eminence, a shallower temporal emargination, and an anteroposterior arch to the skull between the jaw joint and the anterior tip of the labial ridges. The phylogenetic patterns of ntpPC2 are more similar to ntPC1. Trionychids plus *E. blandingii* and *D. reticularia* anchor the negative end of ntpPC2 while large headed species like *P. megacephalum, C. serpentina,* and *G. geographica* anchor the positive of ntpPC2. Mapping of Ecological Categories on the ntPCA and ntpPCA

Few patterns are evident when the traditional categories are overlaid on the uncorrected biplot (Figure 2-10 A) aside from feeding mode. The first principal axis separates suction feeders from the other feeding mode categories, while the second axis separates hard food specialists and species known for defensive biting and large, non-retractable heads from more generalist turtles. These patterns become more defined after phylogenetic correction (Figure 2-10 B). The suction feeding specialists plot in the negative quadrant of the phylogenetically corrected analysis and are opposed to the more terrestrial and herbivorous species are at the positive of ntpPC1 and the hard biters, either dietary or defensive, at the positive of ntpPC2. The species capable of feeding on both land and water plot between the suction feeders and the hard feeders.

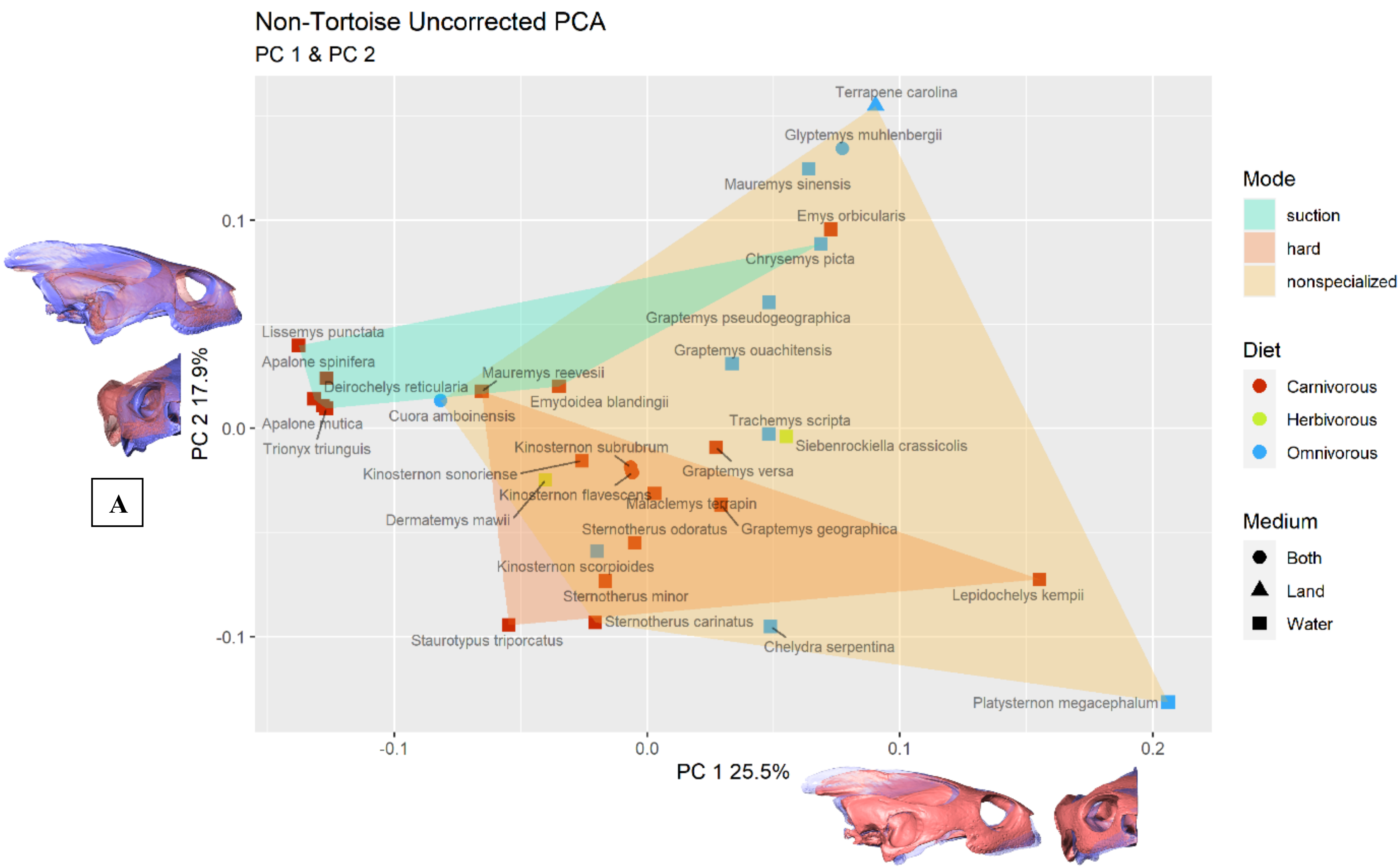

Figure 2-10a. PCA biplots of the non-tortoise subset with Mode, Diet, and Medium marked separately; uncorrected ntPCA. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

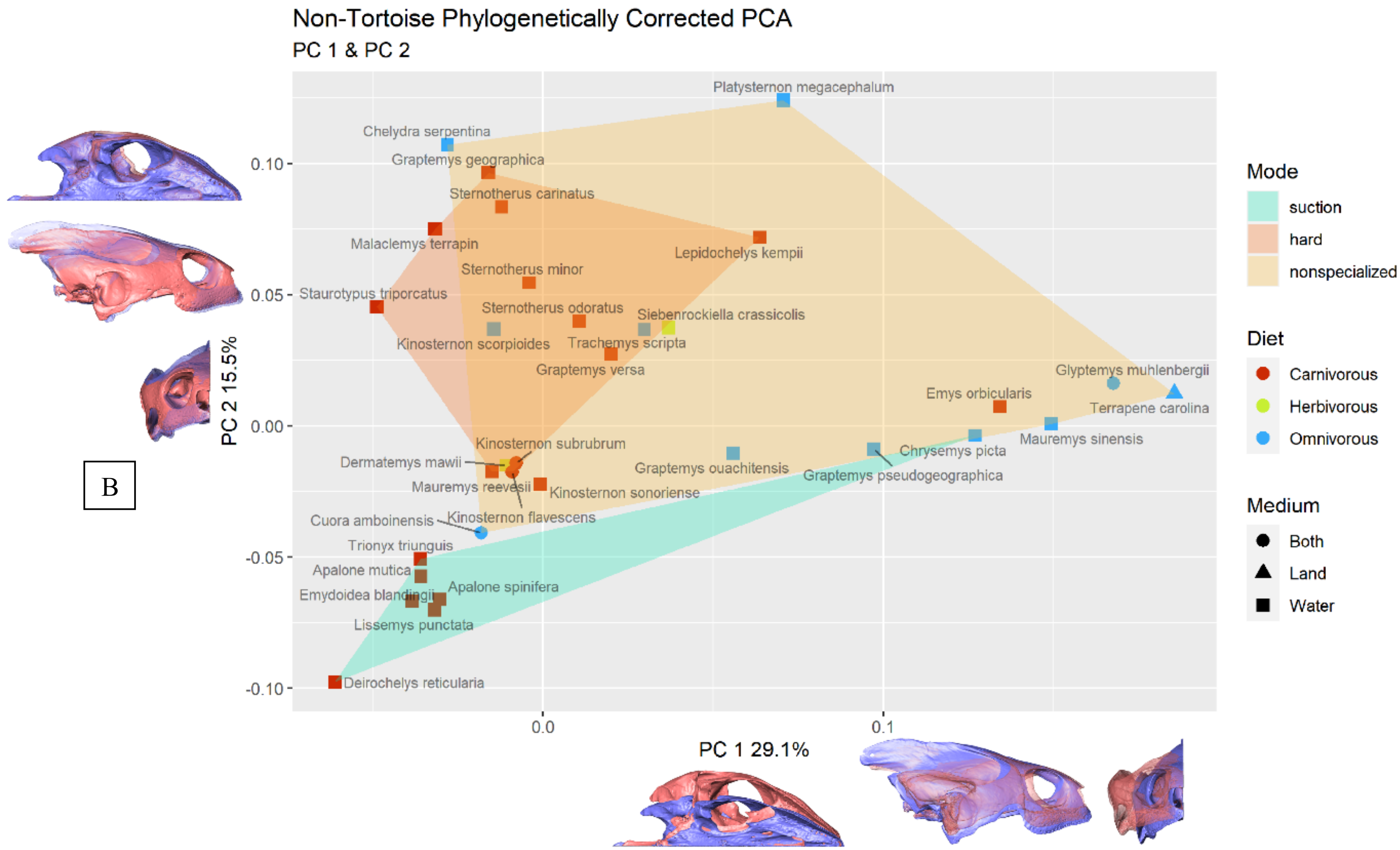

Figure 2-10b. PCA biplots of the non-tortoise subset with Mode, Diet, and Medium marked separately; phylogenetically corrected ntpPCA. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red.

Phylogenetically Corrected 2BPLS. The correlation of the uncorrected ntPLS was not significant (P=0.208) and thus will not be discussed. The ntpPLS of the non-tortoise dataset (Figure 2-11) demonstrates a significant and strong correlation (r_{PLS}=0.739, z=2.3714, P=0.007) which explains 34.4% of the covariation between phylogenetically corrected proportional diet data and skull shape. The shape at the negative extreme of the x-axis is larger than average while the shape at the positive extreme is smaller than average. The negative shape has an anterior-posterior arch and is wide and flat, especially posteriorly with a short supraoccipital crest and squamosal eminence, thin zygomatic bar, anteriorly positioned trochlear process, a very shallow, posteriorly swept labial ridge, and anteriorly directed eyes. The shape at the positive extreme is closer to the average shape but is narrower, with a medio-lateral arch to the palate and deeper labial ridge, and is much taller and more elongated, especially posteriorly, with a much longer supraoccipital crest, long and pointed squamosal eminence, and a more posteriorly positioned trochlear process. The loadings of the diet axis span from diets that are almost entirely made up of animal items that require forceful crushing at one end (negative) to diets with a large proportion of resistant vegetation with a smaller contribution from swallowable animal-based items at the positive end. This separation is reflected in feeding mode, with hard-diet specialists plotting in the negative quadrant and suction feeders and nonspecialized feeders plotting in the positive quadrant. However, note that the terrestrial *T. carolina* does not fit this pattern, plotting close to the hard-diet specialists on the diet axis but not on the shape axis.

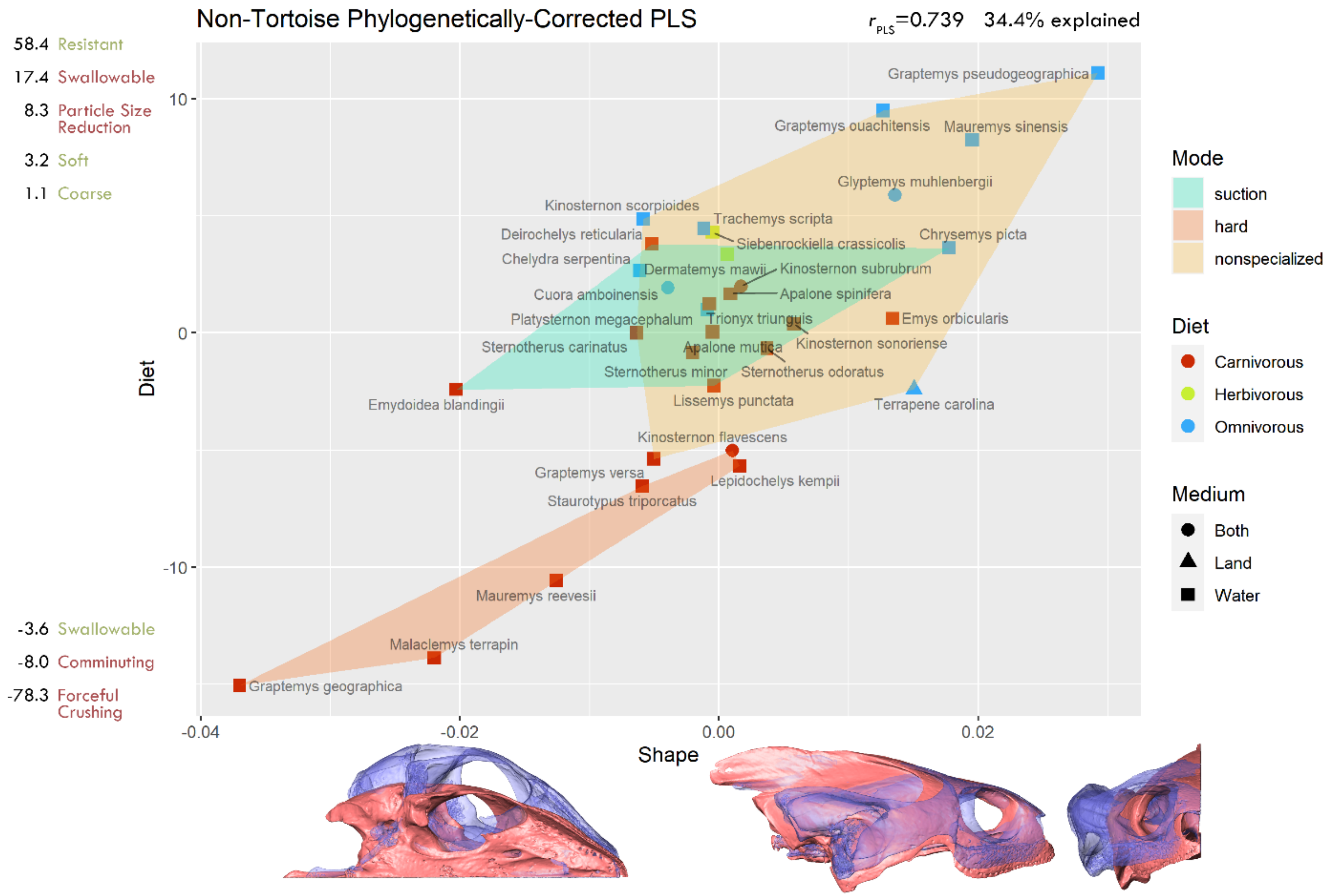

Figure 2-11. Phylogenetically corrected 2BPLS plot of the non-tortoise subset with feeding mode, diet, and feeding medium indicated. Informative views of warped hemiskull meshes that have been magnified two times, scaled, and superimposed display the minimum shape in blue and the maximum shape in red. Percent loadings of the diet axis display vegetation-based categories in green and animal-based categories in red.

Parsing the correlation with proportional diet by ntpPCA component, both the first (r_{PLS}=0.598, z=2.7554, P=0.002) and second (r_{PLS}=0.511, z=1.9493, P=0.023) principal component axes have a significant, but weaker, correlation with diet. The positive loading of the diet axis versus ntpPC1 (explaining 35.78% of the covariation) corresponds to diets made of largely resistant vegetation with swallowable animal-based items contributing less whereas the negative loading is dominated by animal-based diets with a large proportion of items requiring forceful crushing, with a smaller contribution from items requiring particle size reduction. This 2BPLS roughly separates carnivorous taxa at the negative end from omnivorous taxa at the positive end. The positive loading of the diet axis versus ntpPC2 (explaining 26.16% of the covariation) represents diets made almost entirely of items requiring forceful crushing, while the negative end is loaded with a mix of categories including resistant vegetation, animals requiring particle size reduction, and a smaller contribution by swallowable animal prey. This 2BPLS reflects the patterns of the ntpPLS, strongly separating hard-diet specialists at the positive end from suction and nonspecialized feeders, even defensive biting taxa, at the negative end.

Discussion

Functional Insights from the Full Dataset

The full dataset PCA and 2BPLS analyses largely define how different Testudinidae (tortoises) are from the rest of Cryptodira, in diet, habitat, feeding mode, and ultimately skull morphology. Tortoises are the only fully terrestrial clade capable of feeding on land. It has been suggested numerous times (Pritchard, 1979; Natchev et al., 2015; Lemell et al., 2019) that terrestrial feeding is ancestral to the group, thus their phylogeny and morphology are likely to be highly correlated in the skull. This manifests in two ways (1) skull shape evolution is free from the constraints of aquatic fluid pressures, whereas such constraints are maintained in other groups of turtles, and (2) skull shape evolution reflects the novel use of a fleshy tongue for intraoral transport, a solution to the change in medium since intra-oral transport in aquatic media relies on suction. This correlation is further compounded by the fact that tortoises are the only clade in which every member is herbivorous, making it difficult to distinguish the morphological reflections of terrestriality from those of herbivory in this group. This is evident in the broad similarity of the first and second principal components between the PCA and the pPCA: tortoises (outlined in purple in Figure 2-2 and Figure 2-3) cluster together, filling the negative quadrant formed by PC1 and PC2 in this analysis. In contrast, only pPC1 separates the herbivorous terrestrial tortoises from the remainder of cryptodira, which are all aquatic or semiaquatic turtles, suggesting that phylogenetic correction removed some, but not all, of this morphological correlation.

The morphological features that anchor these axes are hallmarks of the tortoise feeding functional morphology. The vaulted palate provides space for a fleshy tongue to support lingual prehension of food, which is a derived and obligatory characteristic of testudinids (with the exception of the basal *Manouria emys*, Natchev et al. 2015) who cannot use water as a feeding medium (Bels et al., 2008). The deep labial ridge supports a serrated rhamphotheca for cropping of vegetation, facilitating the grip as the tortoise pulls to tear vegetation instead of relying on a cutting edge. The broad trituration surface allows for some crushing of vegetation during intraoral transport during the pronounced retraction of the closed jaw (e.g., Bramble, 1974; Bramble and Wake, 1985), and an additional degree of freedom in the jaw joint that is enabled by the alignment of the mandibular condyles parallel with the direction of this movement. The strongest of the jaw closing muscles, the deep mandibular adductor, travels over the trochlear process forming a cartilaginous *cartilago transiliens* (Schumacher, 1973), which actually ossifies in *Gopherus* species (Bramble, 1974) due to the enhanced retraction of the jaw in these species. The anterior positioning of the trochlear process supports this sesamoid, allowing for a much more vertical insertion of the primary jaw adductor, which increases the force between the trituration surfaces throughout the retraction of the jaw to facilitate grinding of the toughest grasses (Bramble, 1974). The broader, but shorter origin area for the deep mandibular adductor may be tied to the need to generate higher forces to grind tough vegetation. Although bite forces in tortoises have not been extensively measured, with known data from only one individual of *Testudo horsfieldii* by Herrel et al., (2002), bite forces are generally larger in lepidosaurs that feed on vegetation (Isip et al., 2022). These morphological features are of course reflected nearly identically in the PLS and pPLS shape loadings, suggesting they have a strong correlation with diets high in resistant vegetation, though coarse vegetation did contribute some to the loading of those axes. Despite the strong correlation with diet, these results cannot separate these morphological features from those correlated to feeding on land. Accordingly, other terrestrial taxa may provide further insight.

Though tortoises plot in the center of PC3 and pPC3, the positive end is anchored by two highly terrestrial emydids, *T. carolina* and *G. muhlenbergii* and the shape that mimics some tortoise-features of the first principal components, namely head and oral cavity width, and a trochlear process placed far anterior to the jaw joint. Notably different are the lack of palate vaulting, indeed these species possess a much smaller tongue, and the lack of modified mandibular condyles presumably reflecting a lack of use in the use of significant jaw retraction. These species are in fact highly opportunistic in their feeding habits, but *G. muhlenbergii* is primarily herbivorous. The repetition of some tortoise-like features in these terrestrial emydids suggests that these features are associated with terrestriality, rather than terrestrial herbivory. This perhaps relates to the lack of fluidic constraint on the head in these turtles: if fluid dynamics are not a selective pressure on the head and shell, the head and shell aperture are free to expand in height and width to increase the origin of the major jaw closing musculature and insert it more advantageously onto the lower jaw.

Interestingly, the two species with more armored skulls (e.i. greater dermatocranial covering of the adductor chambers), *L. kempii* and *P. megacephalum*, lose their grouping with tortoises along pPC1, likely due to the much greater effect of hallmark terrestrial herbivore characteristics and less of an effect of overall dimensions. The relative position of *L. kempii* in the uncorrected analysis, being an herbivorous species that primarily feeds on coarse aquatic vegetation, was less surprising, but *P. megacephalum* has a generalized omnivorous diet, so diet may not be the greatest influence on the position of these species along PC1. The feature that both of these species share is the inability to retract the head into the carapace, and therefore both have an almost complete dermatocranial covering of the adductor chamber that has almost no temporal emargination. The evolution of temporal emarginations has been correlated to the evolution neck retraction in turtles, which evolved as a defensive mechanism after evolution of the carapace (Werneburg, 2015; Ferreira et al., 2020). With the lack of the carapace constraining the physical dimensions of the skull, it may be that these species take the testudinid path to forceful jaw closure, particularly the wide posterior adductor chamber. Similarly, in the uncorrected PLS analysis the phylogenetically distant *L. kempii* and *Dermatemys mawii* are the furthest off the line of correlation and also broaden the groupings of the herbivorous and carnivorous categories, but this distinction disappears with phylogenetic correction, suggesting that their unique skull morphologies are not solely associated with their dietary specialties, but also by their phylogenetic distance.

Opposite tortoises in both the principal components and partial least squares dimensions are virtually all other cryptodires, lessening the explanatory power of the full dataset results. The 2BPLS results summarize the skull shape of these non-tortoise cryptodires: a skull that is narrower and more streamlined than that of a tortoise is correlated with a more animal-based diet that requires comminuting (e.g., invertebrates). Only PC2 gives a hint of the pattern that will emerge strongly in the non-tortoise dataset: the most aquatic, streamlined, and suction feeding taxa are opposed to the hard-diet specialized and fast biting taxa.

Functional Insights from the Non-Tortoise Subset

The PCA of the uncorrected non-tortoise dataset appears to be highly affected by phylogeny apart from a few exceptions. The lesser phylogenetic signal in ntPC2 allows patterns that are indicative of function to become more obvious. The negative half of ntPC2 is filled with hard or fast biting taxa with high and wide skulls: Kinosternidae, *L. kempii, P. megacephalum,* and *C. serpentina* as well as *M. terrapin* and *G. geographica.* In contrast, the positive end is anchored by the most terrestrial emydids *T. carolina* and *G. muhlenbergia* with low and small skulls. *M. sinensis,* the geoemydid red-eared slider, which is primarily herbivorous, plots very near them, suggesting that the skull of this taxon has stronger similarity with the two emydids than its closer phylogenetic relatives, even though it is a typical semiaquatic pond turtle (Ernst & Barbour, 1989). Phylogenetic correction reveals this shape to be short with a shallow oral cavity and anteriorly positioned trochlear process where these taxa plot at the positive extreme of ntpPC1, repeating most of the features associated with terrestriality characteristic of these taxa in pPC3 in the full dataset. The position of the semi-aquatic pond turtles between these more terrestrial taxa and the much more aquatic taxa on the negative end of ntpPC1 likely reflects their flexibility. While they may not be able to complete a feeding cycle on land, many are capable of foraging on both land and in water, ultimately retreating to water to complete swallowing (Ernst and Barbour, 1989). The shallow oral cavity is unexpected, because though the tongue in these taxa is not as highly elaborate as tortoise tongues, all species that have been found to complete the feeding cycle on land do possess fleshy tongues to aid in intraoral transport (Lemell et al., 2019).

Paradoxically, the large and oceanic *L. kempii* and the small and semi-terrestrial *P. megacephalum* occupy the positive end of ntPC1 but the negative end of ntPC2, which are opposing in both centroid size and head width. This suggests that some elements of size-shape morphology may be adapted for separate maxima, but the greater phylogenetic signal in ntPC1 over ntPC2 and their phylogenetic distance from other taxa may be strongly affecting this pattern, as it disappears after phylogenetic correction. These taxa plot in the center of ntpPC1, and despite occupying different habitats, neither are capable of retracting the neck inside the carapace. Thus, it appears that release from the height and width constraints of the shell aperture results in similarities in skull morphology in these semiaquatic pond turtles.

Phylogenetic correction of the non-tortoise dataset clarifies the functional signal of the uncorrected PC2 axis considerably. The ntpPC2 strongly separates suction feeders from non-suction feeders, revealing that the morphology associated with this region of morphospace is functionally relevant to suction feeding in cryptodires. All turtles have an aquatic ancestry, and during aquatic feeding even terrestrial turtles demonstrate modulation of hyoid depression in compensatory suction of the bow wave created as the neck is extended for prey capture (Van Damme and Aerts, 1997; Summers et al., 1998). To this end, aquatic turtles tend to have triangular heads to reduce drag during prey capture (Lemell et al., 2010). Suction-feeding turtles rely on a high magnitude depression of a large hyoid apparatus and an extremely distensible esophagus to create inertial suction during the forward thrust of the head through water, and as such, streamlining of the skull is paramount to create an almost-pressure-wave-free capture strike (Lemell et al., 2010), which is most commonly accomplished through flat and/or acutely angled triangular heads. This analysis demonstrates that the skull shape of suction-feeders (mostly trionychids) is streamlined, being extremely narrow and pointed, but not flattened (when scaled to the same size) relative to other aquatic turtles as would be expected. Pleurodiran piscivorous suction-feeding specialists are known to expand the width of the posterior skull to expand the corresponding attachment surface further to increase jaw closing ability during fast neck extension to ensure capture of fast-moving prey (Lemell et al., 2010). The PLS loading of these PC axes include herbivorous as well as piscivorous aquatic feeders (associated here with in particle size reduction), perhaps explaining the lack of apparent skull flattening, which could be a result of increased width just as much as reduced height. The very mechanically poor insertion of the mandibular adductor into the jaw from the posteriorly positioned trochlear process is likely a byproduct of the streamlined profile, requiring compensatory posterior elongation of the adductor chamber to enlarge the attachment surface of the mandibular adductors and maintain jaw closing force while maintaining the streamlined profile of the skull (Lemell et al., 2010). Besides streamlining, the gross morphological commonality of these suction feeders is the anteroposterior as well as mediolateral arch of the skull, which may increase suction performance by making the oral cavity larger and more circular at wide gapes, a key suction feeding innovation in fish (Wainwright et al., 2015). The PLS loadings indicate that these Cryptodiran suction feeders may consume large fish, whatever vegetation falls or grows in the water, or whatever small animals that may be caught. A future analysis should further divide the particle size reduction category, which was based primarily on size, into the modes in which it is consumed to further separate these suction feeders.

Interestingly, the species capable of feeding on both land and water plot between the suction feeders and the hard-diet specialists along ntpPC2 and at the negative end of ntpPC1, suggesting that there is a skull morphology between arched and very streamlined and large yet minimally streamlined that is effective out of water. It would not be surprising if the other species plotting in the same region of morphospace, such as *Kinosternon sonoriense*, *D. mawii*, and *Mauremys reevesii,* are also capable of feeding in both media, but have not yet been observed to do so. The shape in the positive half of ntpPC2 is difficult to discern from average, but the negative loading of the ntpPLS reveals the morphology specific to hard-diet specialists, mainly including an enlarged adductor chamber and trituration surface width and much more mechanically advantageous jaw closing musculature facilitated by the anterior position of the trochlear process, which is similar to the morphological adjustments in tortoises. Unlike tortoises, posterior adductor chamber height and supraoccipital crest length are more maintained in the hard-diet specialists, likely to provide the greatest surface area for adductor muscle attachment while maintaining some streamlining and neck retraction capability.

Relative Importance of Factors Influencing Testudine Skull Morphology

The significant, yet low phylogenetic signal in the present analysis indicates that, contrary to Foth et al. (2016), phylogeny may have much less of an influence on pure shape as interpreted by auto3DGM-generated pseudolandmarks than it does on shape as interpreted by a homologous landmarking scheme (Foth and Joyce, 2016). The low phylogenetic signal is not surprising in a dataset consisting of mathematically homologous (i.e., not phylogenetically relevant) landmarks. A sample of 330 K_{mult} values in biological variation studies by Adams & Collyer (2019) possessed a mean of K= 0.65, suggesting that in most morphological data there was less phylogenetic signal than expected under a Brownian motion model of evolution. The turtles in this sample, therefore, had far less phylogenetic signal than expected under Brownian motion. This low phylogenetic signal often allowed the same functional associations to be visible in both the uncorrected analyses and phylogenetically corrected analyses, albeit slightly obscured in the uncorrected analyses. Phylogenetic correction clarified many relationships between groupings of species by behavioral categorization. Both Souza (2021) and Foth et al. (2016) demonstrated moderate phylogenetic signal and also had a high level (both 82%) of estimating the correct diet preference in herbivorous turtles, suggesting that herbivory, especially in tortoises, may have heavily influenced the full dataset results.

Skull size was still a significant effect, with tortoises and other testudine families differing in allometric trajectory, but, like Foth et al. (2016), the present analysis found this effect to be minor across Cryptodira as a whole (only 10% of the shape and size covary), and slightly higher (14.5%) in the non-tortoise families. Souza (2021) found some explanatory variables to only be significant when allometric effects are considered, such as aquatic feeding.

Out of all variables tested, the correlation with the functional diet data had the highest percent of explained shape variation, at 36.5% for the full dataset and 34.4% for the non-tortoise dataset, but some of that portion was clearly allometric as well. This is a stronger signal that in Souza (2021) who found that behavior (largely suction-feeding, durophagy, and neck retraction) explains up to 15% of shape variation in turtle skulls excluding the effect of allometry.

While habitat categories were not specifically tested, the feeding medium category approximated habitat categories by grouping species based on the environment in which they could complete a feeding cycle. Other than the tortoises, there was no clear pattern that pointed to habitat as correlated to a specific area of the skull morphospace. The species that can feed in both media are curiously not tortoise-like when tortoises dominate the weighting of the axes, suggesting that the unique shape of the tortoise skull is not shared with the species presumably closest in function. Instead, they plotted directly between suction-feeders and hard-diet specialists, all of whom feed exclusively in water. Souza (2021) was also able to discriminate between suction feeding, durophagy, and herbivory, but failed to discriminate between feeding on land and feeding in water, noting that many of the features associated with those ecological factors occurred in the palate and adductor chamber, areas not sampled in their analysis. The present analysis sampled those areas and found possible markers of feeding on land in the anterior position of the trochlear process in the adductor chamber and the high arch of the palate, but not in fully aquatic taxa that are capable of feeding on land. Considering that, aside from tortoises, most cryptodires are aquatic, the selection pressure of that fluid may just be too consistent along the group to tease out direct effects, other than those shown better by the effect of feeding mode.

Similarly, broad dietary categories were poorly distinguished in this analysis, apart from tortoises, but became well distinguished when proportional diet data was considered in the 2BPLS analysis of the full dataset. This suggests that the physiological content of the food is of less importance to skull shape evolution than the mechanics of food acquisition. Such a pattern is particularly well-demonstrated among the suction feeders in the non-tortoise dataset, which remained tightly grouped in morphospace, loading that end of the 2BPLS axis with both animal-based foods that need particle size reduction and resistant vegetation, which are equally well acquired through suction.

Feeding mode showed little non-phylogenetically related pattern in the full dataset but discriminated taxa quite well in the non-tortoise dataset. Feeding mode also aligned very well with the functional categories in the diet data in the 2BPLS, particularly for hard-diet specialists. More fine-grained and functionally informed feeding mode categories would likely show stronger patterns, though those patterns are likely to be similar to those using the functionally categorized diet.

Conclusion

Testudines have a unique *Bauplan* for which multiple morphological shifts were required to adjust to a key innovation: the turtle shell. The evolution of neck retraction constrained turtle skull dimensions, restricting the size of the jaw adductors and resulting in the evolution of the trochlearis system to maintain bite force capabilities (Ferriera et al., 2020). The present analysis confirmed the hypotheses of prior authors (Bramble, 1974; Reilly et al, 2002) that modification of the trochlearis system to be more mechanically advantageous is a major functional marker of testudine evolution, particularly when paired with widening of the trituration surface in terrestrial or durophagous turtles. Improving jaw adductor mechanical advantage has detrimental effects on the streamlining of the skull and this relationship potentially represents an evolutionary tradeoff for aquatic turtles. The trochlearis system is modified out of necessity for the high bite forces required of durophagous diets in aquatic turtles but appear similarly advantageous when the constraint of streamlining for aquatic feeding is released, such as in terrestrial testudinids and semi-aquatic/semi-terrestrial emydids and geoemydids. These more terrestrial species have a trochlear process that is positioned even more anteriorly, resulting in a nearly perpendicular insertion of the primary jaw adductor into the lower jaw. A wide trituration surface is shared between herbivorous tortoises and durophagous turtles, explaining to a certain extent how previous analyses struggled to separate these taxa in morphospace. This analysis has identified the anterior-posterior mobility in the jaw joint enabled by the orientation of the mandibular condyles as a major innovation of tortoises, one that enhances the ability to grind plant matter through retraction with the jaws appressed. When strong jaw closing is not selective among aquatic turtles, hydrodynamic constraints streamline the skull to varying degrees, culminating in the extremely pointed and elongate suction-feeding species. The diversity of testudine skull shapes has evolved under an inferred suite of both indirect (e.g., neck retraction) and direct (e.g. hydrodynamics, feeding media, and feeding mode) selection pressures. While other ecological variables and the turtle shell itself have also contributed to shaping the turtle skull, feeding mode and especially diets in which extensive food-jaw contact occurs have modified jaw mechanics to an enhanced degree, though their performance outcomes could not be assessed. This analysis is the first to fully and unrestrictively sample 3D testudine skull morphology with auto3DGM, resulting in novel support of previously hypothesized functional characteristics, and their strong correlation to the direct pressure of the physical and mechanical properties of cryptodire diets.

Chapter 3: Cranial Sexual Dimorphism in Two Species of Emydid Turtles: Size Dimorphism and Niche Partitioning in *Malaclemys terrapin* and *Trachemys scripta*

Introduction

Sexual dimorphism is a common trait in vertebrates that may evolve through myriad sexually dependent selection pressures (Shine, 1989). In Testudines, sexual size dimorphism is nearly universal and has been linked to environment-dependent mating behaviors as well as selection for increased fecundity of females (Berry and Shine, 1980; Bulté et al., 2008). For example, the fertility selection hypothesis posits that female-biased sexual size dimorphism (SSD) allows for greater reproductive output in the form of larger or more eggs (Pincheira-Donoso and Hunt, 2017). As an extension of the fertility selection hypothesis, the dimorphic niche selection hypothesis posits that this larger reproductive output likely comes with a higher energetic cost required to produce more eggs, resulting in differential selection among the sexes on structures used for energy acquisition (e.g., metabolic organs, trophic structures).

As a consequence of the reproductive role and the higher energetic requirement experienced by females, dietary specialization can illustrate the dimorphic niche selection hypothesis through trophic morphology dimorphism (TMD). Moreover, in extreme or specialized dietary modes, it is often the case that an organism's degree of specialization and its fitness are linked as well. For example, durophagy, or the consumption of animals with hard shells or exoskeletons, is associated with morphological specialization in the shape, size, and musculature of the vertebrate head. Some of these specializations include larger muscles with a greater physiological cross-sectional area (PCSA), changes to the lever mechanics of the jaw apparatus, and more robust bones (Lauder, 1983; Wainwright, 1988; Pfaller et al., 2011; Marshall et al., 2012; Schaerlaeken et al., 2012). These specializations enable higher and/or more efficient bite force production or increased resistance to reaction forces when processing well-defended prey. Ultimately, this may allow a durophagous species to occupy a less competitive dietary niche (Wainwright, 1987).

In turtles, energy acquisition may be even more important for reproductive females because egg production is energetically expensive (e.g., Congdon and Gatten, 1989; Thiem and Gienger, 2022). Evidence of the link between TMD and reproductive allocation via energy acquisition was recently demonstrated in the trophic structures of the durophagous turtle *Graptemys geographica* (Bulté et al., 2008). In this species, body condition and reproductive output of females scaled positively with head size and bite force. This link with fitness also supports the notion that energy intake is limited by the morphology of the feeding apparatus in durophagous turtles. Mechanically, larger individuals and more well-defended species of mollusk require more force to fracture (Herrel et al., 2017). Increasing head size and thus bite force increases the niche breadth of *G. geographica* by raising the upper size limit of accessible prey. Selection may favor a higher bite force because it allows these individuals to face even less competition for prey items and/or increase their energy intake relative to individuals with smaller heads. This pattern is hypothesized for other species, including other *Graptemys* species and *Malaclemys terrapin,* which also demonstrate TMD in their feeding structures. These are generally species in which the females have larger heads, allowing them to feed on larger and harder prey than males (Lindeman, 2000; Bulté et al., 2008; Underwood et al., 2013; Herrel et al., 2017).

The present analysis compares feeding apparatus morphology of two closely related emydid turtle species that demonstrate these two forms of sexual dimorphism -- *Trachemys scripta*, the generalist pond slider turtle, which displays only SSD, and *Malaclemys terrapin,* the durophagous diamondback terrapin, which displays TMD in addition to SSD -- in order to assess their impact on morphology and make inferences about function. *T. scripta* is a well-studied generalist species that demonstrates female biased SSD in all populations, though to varying degrees as limited by population dynamics and growth rates intrinsic to the population (Gibbons and Lovich, 1990). This freshwater aquatic species feeds on invertebrates, bryozoans, aquatic grasses, and algae (Moll and Legler, 1971; Dreslik, 1999). The exact content, the relative amount of plant versus animal matter, and whether or not there is a dietary shift from juvenile to adulthood varies by population in true generalist fashion. While the females in some populations occasionally take small freshwater mollusks or gastropods around laying season, possibly to supplement their calcium for egg production, there is no significant difference in the frequency of occurrence of dietary categories among size or sex grouping according to the most recent meta-analysis (Dreslik, 1999). Average *in vivo* bite forces for *T. scripta* are 14.59 ± 18.76 Newtons (N=33 individuals), and sex differences have not been reported (Herrel et al., 2002, 2017).

M. terrapin is a well-studied durophagous species that demonstrates female biased SSD and TMD with accompanying morphological differentiation. This estuarine species feeds mainly on marine mollusks, gastropods, and crustaceans. Large females are known to take larger and harder prey species and have larger bite forces than smaller females and males (Tucker et al., 1995; Underwood et al., 2013; Herrel et al., 2017). *In* *vivo* bite forces vary significantly with age and sex: juveniles average 17.02 ± 15.00 N; males average 37.11 ± 6.32 N; and females average 156.26 ± 46.40 N (Herrel et al., 2002, 2017). Herrel et al. (2017) further demonstrated that adult females are capable of crushing all prey types they measured but consumed the hardest prey items more frequently. Furthermore, the force required to crush the hardest prey items measured by Herrel et al. (2017) likely limits the ability of males to exploit them.

In a recent comparison between the two species, Herrel et al. (2017) also compare the external cranial skeletal morphology in the context of measured bite forces between the two species. Even accounting for size, all classes of *M. terrapin* have higher bite forces than *T. scripta* and the results of the morphological analyses reveals that the sexes of *M. terrapin* only differ in relative head width. Their work, which included dietary content and hardness analysis, clearly demonstrates that the larger heads and bite forces of female *M. terrapin* allow them to access harder and larger prey items than males. To bring out additional shape factors, they corrected their results for head width and found that *M. terrapin* individuals with longer jaw-closing in-levers (and thus greater mechanical advantage) bit harder. Importantly, by correcting for head width, they assumed that they had corrected for relative head size only and it was unacknowledged that they may have also removed the effects of other size-related factors, such as relative muscle size, which can be a function of other head dimensions. Both sexes of *M. terrapin* possess larger heads and, even when corrected for head width, a higher bite force than *T. scripta*. Therefore, they surmised that jaw in-lever biomechanics were responsible for the remaining bite force difference among the species, although they indicated that muscle architecture or physiology may also play a role. This is in direct contrast to the results of

Underwood et al. (2013) indicating no difference in mechanical advantage between male and female *M. terrapin*.

This study furthers the analysis of Herrel et al. (2017) and Underwood et al. (2013) to elucidate specific musculoskeletal factors contributing to differences in observed bite force among male and female *M. terrapin* and *T. scripta*. Informed by Herrel et al. (2017), Underwood et al. (2013), and the effects of SSD and TMD described in other species (Lindeman, 2000; Bulté et al., 2008), we predict that (1) skull and jaw adductor morphology will differ between males and females in *M. terrapin* but not in *T. scripta;* 2) therefore, that the disparity between males and females in skull morphology, jaw adductor leverage, and PCSA will be greater in *M. terrapin* than *T. scripta*; and (3) that overall, the jaw adductor leverage and PCSA of both male and female *M. terrapin* drive the greater bite force observed in *M. terrapin* compared to *T. scripta.* To test these predictions, we compare skull shape, relative adductor chamber and head dimensions, lever mechanics on a broad skeletal sample and jaw muscle volume, architecture, and PCSA on representative individuals of each sex and each species.

Materials and Methods

Specimen Sampling

Our sample consists of adult-sized individuals of 13 *M. terrapin* (6 male and 7 female) and 10 *T. scripta* (3 male and 7 female). The heads with included soft tissue of the 10 *T. scripta elegans* were sourced from Ward's Scientific ("large turtles" captured via pond dredging in Louisiana) and accessioned into the Ohio University Vertebrate Collections (OUVC). Skeletal specimens of *M. terrapin* and the head with included soft tissue of one female *M. terrapin* were collected post-mortem in Chesapeake Bay, Maryland, by Dr. Willem Roosenburg and accessioned into the OUVC. The head and included soft tissue of one male *M. terrapin* collected from the Chesapeake Bay population was sourced from the Smithsonian Institution Collection (USNM 574916). All wet specimens were fixed or had been fixed in 10% neutral buffered formalin.

The head or skull and jaw of each specimen was CT-scanned at either Ohio University µCT facility or the University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center. After the first scan, wet specimens were then washed of formalin in preparation for undergoing diceCT (Gignac et al., 2016). The specimens then underwent a 24-hour soak in a 20% sucrose solution in deionized water to rehydrate the tissues prior to staining. Specimens were stained in a 1% I_2KI solution in deionized water for a period of 3-8 months to enhance the contrast of the soft tissues, then CT-scanned again. Specimen details and associated scan parameters are provided in Appendix A.

Skeletal Model Preparation and Measurement

Unstained CT-scans of each specimen were reconstructed as 3D digital models using Avizo (v. 8.1, Thermo Fisher Scientific, Waltham, MA) and cleaned for downstream analysis in MeshLab (Cignoni et al., 2008). To avoid problems associated with damage to some specimens, the most complete half of each skull was exported as a final model. If needed, hemiskulls were then digitally reflected in MeshLab so that all analyses were conducted on the same half of the skull.

Cranial shape variation was assessed via 3D geometric morphometrics using an automated landmarking procedure which coated the surfaces of the 3D digital skull models in mathematically, not phylogenetically, homologous points (i.e., pseudolandmarks). These pseudolandmarks were generated in the R package auto3DGM (Boyer et al., 2015), utilizing 64 initial points and 512 final points.

The 3D models of the skull and jaw were digitally aligned to 5° gape (approximate gape of bony elements at minimum gape accounting for the presence of the rhamphotheca) and 2D morphological and biomechanical measurements were taken in Avizo (Figure 3-1). Turtles have akinetic skulls, so to remove the medial component of jaw adductor force, the levers of the jaw apparatus were measured in lateral view against the resultant vector of the external mandibular adductor, defined by a line marked from the trochlear process of the otic chamber on the skull to the most dorsal point of the coronoid bone of the jaw. Out-lever length (*OL*) was taken from the center of the jaw joint to the center of the trough of the trituration surface of the mandible. In-lever length (IL) was calculated from jaw measurements following Ostrom (1966; Figure 9; pg. 303) as $\sin(\theta + \delta)d$ where θ is the angle between the resultant vector and the out-lever and δ is the angle between the diagonal distance (d) from the coronoid apex to the center of the jaw joint and the out-lever.

Measurements of head and adductor chamber dimensions were taken to 1/100th of a millimeter digitally in Avizo**.** The following head dimensions were measured: maximum head width (*HW*), jaw length (*JL*) from the anterior tip of dentary or lower beak to the posterior tip of retroarticular process, head length (HL) in the longest dimension in lateral view from the anterior tip of the premaxilla to the posterior point of the supraoccipital crest, and head height (HH) from the jaw below the jaw joint to the level of the highest point of the skull perpendicular to the jaw out-lever, and basicranial length (*BL*) from the posterior tip of the occipital condyle to the anterior tip of the upper labial ridge. To approximate jaw adductor muscle size, the following dimensions of the adductor chamber were measured: anterior adductor chamber height (*AH*) perpendicular to the OL from the deepest point of the adductor ridge of the jaw to the most superior point of muscle attachment surface on the parietal, anterior adductor chamber width (*AW*) perpendicular to the long axis of the skull in ventral view from the most medial point of the parietal to the level of the most lateral point of the internal surface of the zygomatic bar (not pictured in Figure 3-1), posterior adductor chamber length (*PL*), from the center of the trochlear process to the most posterior point of muscle attachment surface on the supraoccipital crest, and posterior adductor chamber width (*PW*) perpendicular to the long axis of the skull in dorsal view at the widest point of muscle attachment surface posterior to the trochlear process (not pictured). All measurements, illustrated and summarized in Figure 3-1, were scaled to basicranial length for direct comparisons. Basicranial length was chosen as a cranial size estimate that is the most independent of the jaw apparatus in the absence of a non-cranial size measure.

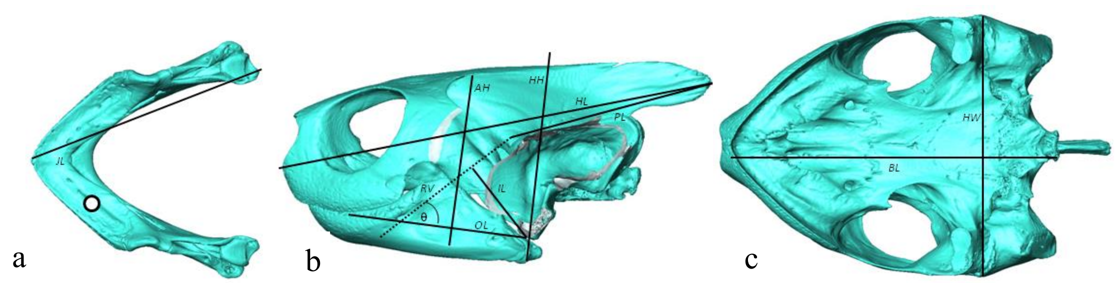

Figure 3-1: Morphological and lever measurements depicted on the skull and jaw of *Trachemys scripta*: a) jaw in dorsal view, b) skull and jaw in lateral view, the zygomatic bar and otic chamber have been clipped to expose the trochlear process, c) skull in ventral view. Solid line: physical measurement. *IL*: calculated in-lever measurement (Ostrom, 1966). Dotted line *RV*: MAME resultant force vector. Circle: center of trough of trituration surface to determine *OL* in lateral view. *JL*: jaw length. *HL*: head length. *PL*: Posterior chamber length. *HH*: head height. *AH*: Anterior chamber height. θ: angle between *OL* and *RV*. *HW*: head width. *BL*: basicranial length.

Muscle Model Preparation, Digital Dissection, and Measurement

Due to the time-consuming nature of digital dissection and measurement, one male and one female soft tissue specimen of each species was selected for further measurement. CT volume data from the pre- and post-staining scans of OUVC 10881 (female *T. scripta*), OUVC 10873 (male *T. scripta*), OUVC 10874 (male *T. scripta*), OUVC 10866 (female *M. terrapin*), and USNM 574916 (male *M. terrapin*) were imported into Volume Graphics VGStudio MAX v. 2022.2 (Volume Graphics GmbH, Heidelberg, Germany) for digital dissection (segmentation) and measurement. Following the anatomical divisions as defined in Werneburg (2011, numerical designation indicated for consistency) the following muscle portions and their respective tendons were dissected into non-overlapping digital volumes: *Musculus Adductor Mandibulae Externus* (MAME) *pars Profundus* (MAMEP, 19), *pars Superficialis* (MAMES, 21), and *pars Medialis* (MAMEM, 17); *Musculus Adductor Mandibulae Internus* (MAMI) *pars Pseudotemporalis* (MAMIS, 23-24) and *pars Pterygoideus* (MAMIT, 26-28); *Musculus Adductor Mandibulae Posterior* (MAMP, 29); and *Musculus Depressor mandibulae* (MDM, 45). Only MAMEP, MAMES, and MDM were able to be segmented in the male *M. terrapin* due to preservation. Though turtles have a unique tendon arrangement in the MAME, the tendon is assumed to redirect the contractile force of the muscle fibers posterior to the trochlea, and it is assumed that the trochlea is frictionless. Since the male specimen of *T. scripta* was larger than the female, the MAME volumes of an additional smaller male individual of *T. scripta* (OUVC 10874), subsequently labeled as M 2, were digitally dissected to observe size differentiation, but no architectural measurements were taken.

Since MAMEM represented a small proportion of overall MAM Externus volume and was oriented nearly parallel with the OL in these specimens, it was excluded from the following measurements and calculations. Within MAMEP and MAMES a minimum of ten fiber length measurements were taken by marking a single fascicle through the volume from its origin to its insertion. Unfortunately, the male *M. terrapin* specimen preservation was such that fiber architecture measurements were unable to be taken in the anterior adductor chamber, thus, only five fibers were recorded for each of the portions in the posterior adductor chamber. Fiber angle was measured at the insertion of the marked length into the digitally dissected tendon or bony attachment. Fiber length and insertion angle are dependent on gape (Gans and de Vree, 1987), and the use of fixed museum specimens necessitated that these measurements were taken on specimens with variable gapes. To calculate normalized fiber length, Anapol and Barry (1996) multiplied measured fiber length by the percentage difference of the measured sarcomere length from resting sarcomere length. A recent analysis (Moo et al., 2016) found that sarcomere elongation through the range of motion of a joint was not uniform across an intact muscle, ranging from 10%–25%. This is similar to the range found in *Alligator mississippiensis* MAMES from 0°-22° gape, ranging from 12%-23% from anterior to posterior fibers (Busbey, 1989). Since resting sarcomere length is approximately 50% of joint motion range, a value of 17.5% is assumed to be the amount of averaged elongation in a muscle at maximum gape. To approximate the method of fiber length normalization as described in Anapol and Barry (1996) in the absence of sarcomere measurement, sarcomere elongation is assumed to be linear such that 17.5% is used in the following equation:

$$Fiber\ normalization\ ratio = \frac{1}{(0.175\ \times PGM) +\ 1}$$

where *PGM* is the ratio of specimen gape angle (-5° to account for the keratinous rhamphotheca) to maximum gape angle (~70° in the specimens that were preserved at maximum gape as observed by the authors of the present study), multiplied by the residual proportion of maximum elongation beyond resting fiber length. This produced a ratio by which the measured fiber length would be multiplied to normalize to resting lengths. Similarly, fiber angle was normalized as in Anapol and Barry (1996) by the following equation:

$$Normalized\ fiber\ angle = \arcsin\left(\frac{a}{fl}\right)$$

where *a* is the width of the muscle perpendicular to the tendon that a single fiber travels from origin to insertion and *fl* is the normalized fiber length. Note that fiber angles in the female *Trachemys scripta* at an original gape angle of 5° (i.e., closed mouth) averaged 34.3° and yet the normalized value was 128% larger at 43.9°, suggesting that all calculated PCSA from normalized values will be a slight underestimate.

As shown in Table 3-1, the above measurements were used to calculate a number of functional and performance traits. Fiber length, fiber insertion angle, and muscle portion volume were used to calculate physiological cross-sectional area (PCSA).

Table 3-1: Measured and calculated traits for MAM Externus and jaw closing

Measurements	Functional Traits
Muscle volume (*V*, cm^3)*	Physiological Cross-Sectional Area* $PCSA = \frac{V}{FL} \times cos\theta$
Normalized mean muscle fiber length (*FL* or *fl*, cm)*	
Normalized mean fiber pennation angle (θ, degrees)*	
Muscle belly width (*a,* cm)	
In-lever length in lateral view (*IL*, cm)	Mechanical Advantage $MA = \frac{IL}{OL}$
Out-lever length in lateral view (*OL*, cm)	

Statistical Analyses

Generalized Procrustes Analysis (GPA) on the skull shape pseudolandmark coordinates followed by principal components analyses (PCA) on Procrustes coordinates were performed in the R package Geomorph (Adams and Otárola-Castillo, 2013; Adams and Collyer, 2016).

The Procrustes coordinates for each species were also separately tested for pairwise differences in morphological disparity between species and between sexes within a species, using the function 'morphol.disparity', and reported as Procrustes variance.

The Procrustes coordinates were also tested for allometry by fitting a linear model of skull shape ~ centroid size * sex, reported as an R^2 value, in which R^2=1 would indicate that 100% of the variation in shape is explained by size. Two-block partial least squares analyses (2BPLS; Rohlf and Corti, 2000) were performed comparing the principal components to centroid size to assess the effect of size on the principal axes of shape variation. The correlation coefficient is reported as r_{PLS} for which 1 is a perfect correlation. Multivariate effects sizes were reported as *z*-score for all correlative analyses (Adams & Collyer, 2016).

All linear measurements were evaluated for significant differences among species and sex using two-sample one-tailed T-tests. Percent difference is reported to assess the magnitude of linear and muscular differences, using the following equation:

$$\% \, difference = 100 \times \frac{a - b}{\left(\frac{(a+b)}{2}\right)}$$

All plots were generated within the r tidyverse (Wickham et al., 2019).

Results

Skull Shape

Shape in Male versus Female *T. scripta*. In the PCA, the male specimens are distributed evenly amongst the female specimens (Figure 3-2) demonstrating that there is little difference in shape between the sexes. All shape variation is therefore intraspecific variation that cannot be distinguished by sex, and thus shape differentiation along the component axes is not reported.

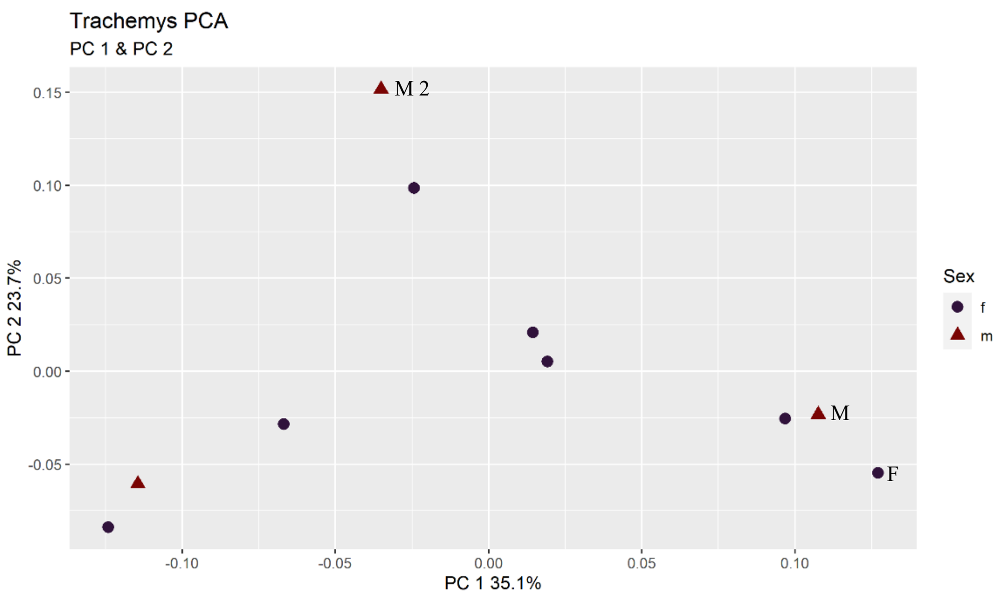

Figure 3-2: PCA biplot of *Trachemys scripta*, highlighting the lack of differentiation between males and female specimens. Soft tissue specimen points are labeled as follows: F= OUVC 10881; M=OUVC 10873; M 2=OUVC 10874.

Disparity, reported as Procrustes variance, for all *T. scripta* specimens was 0.02067. The partial disparity of male specimens, at 0.01825, was less than that of female specimens, at 0.02631. This pairwise absolute difference of 0.00807 was non-significant (P=0.119).

At two-block partial least squares analysis of the PC axes and centroid size did not find a significant correlation for PC1 (P=0.238) or PC2 (P=0.698). Furthermore, fitting a linear model of skull shape to centroid size found a non-significant effect of allometry (P=0.354) among the *T. scripta* specimens, with a non-significant effect (P=0.286) when grouped by sex.

Skull Shape in Male versus Female *M. terrapin*. In the PCA, while there is one female that is grouped with the male specimens along PC1 (43% of shape variation in the sample), female specimens largely occupy the negative half of PC1 while male specimens plot on the positive half of PC1 (Figure 3-3). Since there is a significant allometric effect, this suggests that PC1 is describing size-shape differences between the sexes[1], such that the skull shape at the negative extreme of PC1 (blue warp in Figure 3-3) is associated with larger female specimens and the skull shape at the positive extreme of PC1 (red warp in Figure 3-3) is associated with smaller male specimens. The female *M. terrapin* skull is wider than the male skull, though in the zygomatic aperture, it is clear that the increase in width includes the braincase and is not limited to the adductor chamber.

Also, the supraoccipital crest is shorter in the female skull, though the basicranial length of the skull is longer, indicating that skull length is influenced by a combination of modifications. Increases in length of the female skull can be observed in the labial ridge of the maxilla, the anterior adductor chamber, and from the jaw joint to the bite point along the trituration surface of the maxilla. Relative to the male skull, the articular condyle of the quadrate in the female skull is located further posteriorly, while the trochlear process shows little change, a configuration which would alter the angle at which the external mandibular adductor inserts on the lower jaw.

[1] No such distinction occurs along PC2, as such shape differentiation along this component axis is not discussed.

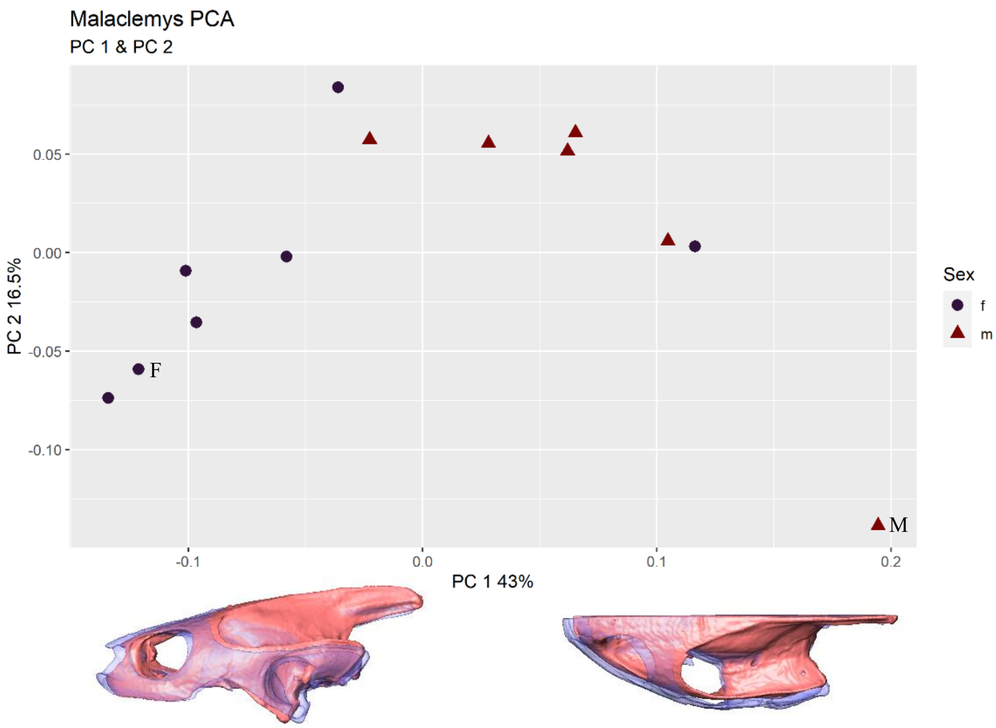

Figure 3-3: PCA biplot of *Malaclemys terrapin*. Meshes of lateral (left) and dorsal (right) views warped to the minimum shape (in blue) and the maximum shape (in red) along PC1. Soft tissue specimen points are labeled as follows: F= OUVC 10866; M= USNM 574916.

Disparity, reported as Procrustes variance, for all *M. terrapin* specimens was 0.02299. The partial disparity of male specimens, at 0.02255, was slightly less than that of female specimens, at 0.02338. This pairwise absolute difference of 0.00083 was also non-significant (P=0.945). Fitting a linear model of skull shape to centroid size found a significant effect of allometry (R^2=0.21674, P=0.015, z=2.14) among *M. terrapin* samples, with a non-significant effect (P=0.407) when grouped by sex.

A two-block partial least squares analysis of the PC axes and centroid size found a significant correlation for PC1 (r_{PLS} = -0.658, P= 0.014, z=-2.3478) and a non-significant correlation for PC2 (P=0.726). A total of 43.27% of the covariation between PC1 shape and centroid size is explained by the PLS, indicating that size is a significant contributor to variation along PC1.

Relative Head and Adductor Chamber Dimensions

Counter to predictions, male and female *T. scripta* do show some significant difference in relative head size, specifically in anterior adductor chamber width and head height (Table 3-2). Females have relatively wider anterior adductor chambers and taller heads than males.

In contrast to *T. scripta*, and consistent with predictions, male and female *M. terrapin* differ significantly in all adductor chamber and head dimension apart from posterior adductor chamber length (Table 3-2). Females of *M. terrapin* are relatively larger in all dimensions than males. The difference is particularly strong in the anterior adductor chamber width, head width, head length, and head height. The lack of significant difference in posterior adductor length is reflective of the supraoccipital crest morphology along PC1.

Counter to predictions, *M. terrapin* and *T. scripta* do not differ significantly in most dimensions. *T. scripta* and *M. terrapin* differ significantly in anterior adductor chamber height, posterior adductor chamber length and width (Table 3-2). The difference is moderately strong between the species in anterior adductor chamber height. Contrary to what would be expected for relative jaw adductor size, *M. terrapin* have smaller adductor chamber dimensions than *T. scripta.* When male and female *M. terrapin,* are respectively compared to all of *T. scripta,* it is revealed that *M. terrapin* are indeed significantly different from *T. scripta* but in opposite directions depending on sex. Counter to prediction 3, female *M. terrapin* have smaller adductor chamber dimensions for their size than *T. scripta* across nearly all measurements. Consistent with prediction 3, male *M. terrapin* have larger adductor chamber dimensions for their size than *T. scripta.* Since female *M. terrapin* are larger than *T. scripta*, while male *M. terrapin* are smaller than *T. scripta*, these dimensions appear to correlate with size.

Table 3-2: Two-sample t-test results comparing skull dimensions in *M. terrapin* and *T. scripta*

Prediction	DF	Standardized to *BL*						
		AH	*AW*	*PL*	*PW*	*HW*	*HL*	*HH*
Intraspecific comparisons								
Female = Male *T. scripta*	4	*t*=0.68 P=0.27	***t*=3.35 P<0.05**	*t*=0.63 P=0.3	*t*= 0.55 P=0.31	*t*=2.91 P=0.05	*t*=0.79 P=0.26	***t=2.83 P<0.05***
Female > Male *M. terrapin*	9	**t=4.19 P<0.01**	**t=9.77 P<0.01**	t=1.81 P=0.05	**t=4.14 P<0.01**	***t*=10.97 P<0.01**	***t*=9.6 P<0.01**	***t*=10.3 P<0.01**
Interspecific comparisons								
M. terrapin* > *T. scripta	19	**t=4.64 P<0.01**	t=0.44 P=0.33	**t=3.09 P<0.01**	**t=2.45 P<0.05**	t=0.02 P=0.49	t=0.98 P=0.17	t=0.62 P=0.27
Female *M. terrapin* > *T. scripta*	9	**t=2.27 P<0.05**	***t*=2.96 P<0.01**	***t*=3.13 P<0.05**	t=0.74 P=0.24	**t=7.68 P<0.01**	**t=5.32 P<0.01**	**t=6.98 P<0.01**
Male *M. terrapin* > *T. scripta*	13	**t=10.14 P<0.01**	**t=4.89 P<0.01**	t=1.79 P=0.05	***t*= 4.19 P<0.01**	***t*=7.32 P<0.01**	***t*=7.93 P<0.01**	***t*=7.56 P<0.01**

BL= basicranial length; JL= jaw length; AH= anterior adductor chamber height; AW= anterior adductor chamber width; PL= posterior adductor chamber length; PW= posterior adductor chamber width; HW= head width; HL= head length; HH= head height. Bold values are significant. Light gray values are consistent with predictions.

While the sample sizes are not sufficient to definitively conclude growth types, nearly all patterns in Figure 3-4 are suggestive of isometric and negative allometric growth in all dimensions measured among all groups (full model details can be found in Appendix D).

Most adductor chamber and head dimensions scale with slight negative allometry to near isometry in both male and female *T. scripta* (Figure 3-4).

The adductor chamber dimensions scale with negative allometry in both male and female *M. terrapin*. Notably, both posterior adductor chamber dimensions scale more negatively in females than in males. Unexpectedly, both male and female *M. terrapin* scale with extremely negative allometry in all head dimensions.

The male *M. terrapin* adductor chamber slopes are visually similar to the *T. scripta* slopes, while both differ from the female *M. terrapin*. *T. scripta* are clearly scaling with near isometry in head dimensions while *M. terrapin* scales with extreme negative allometry.

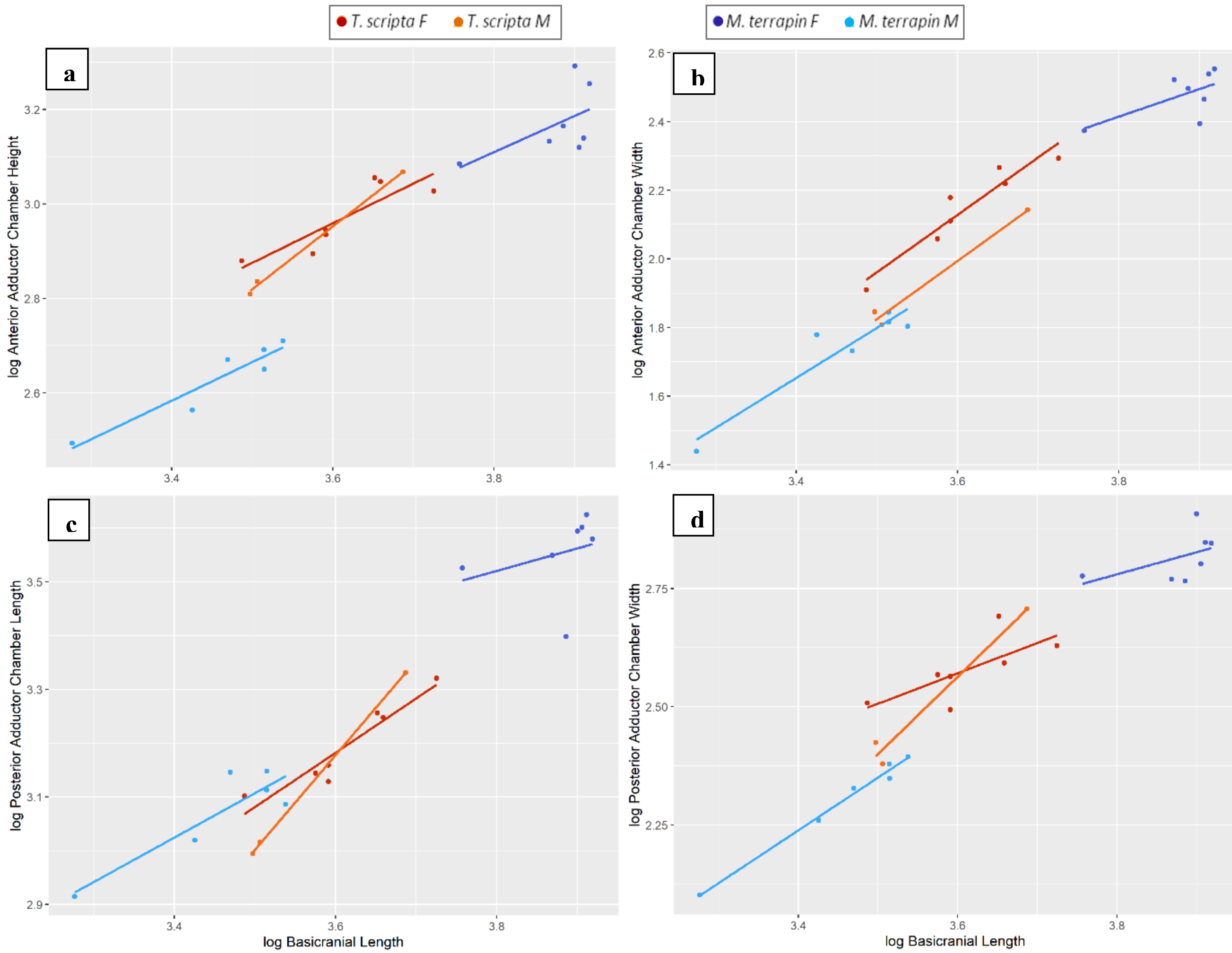

Figure 3-4 a-d: Adductor chamber dimensions regressed on basicranial length.

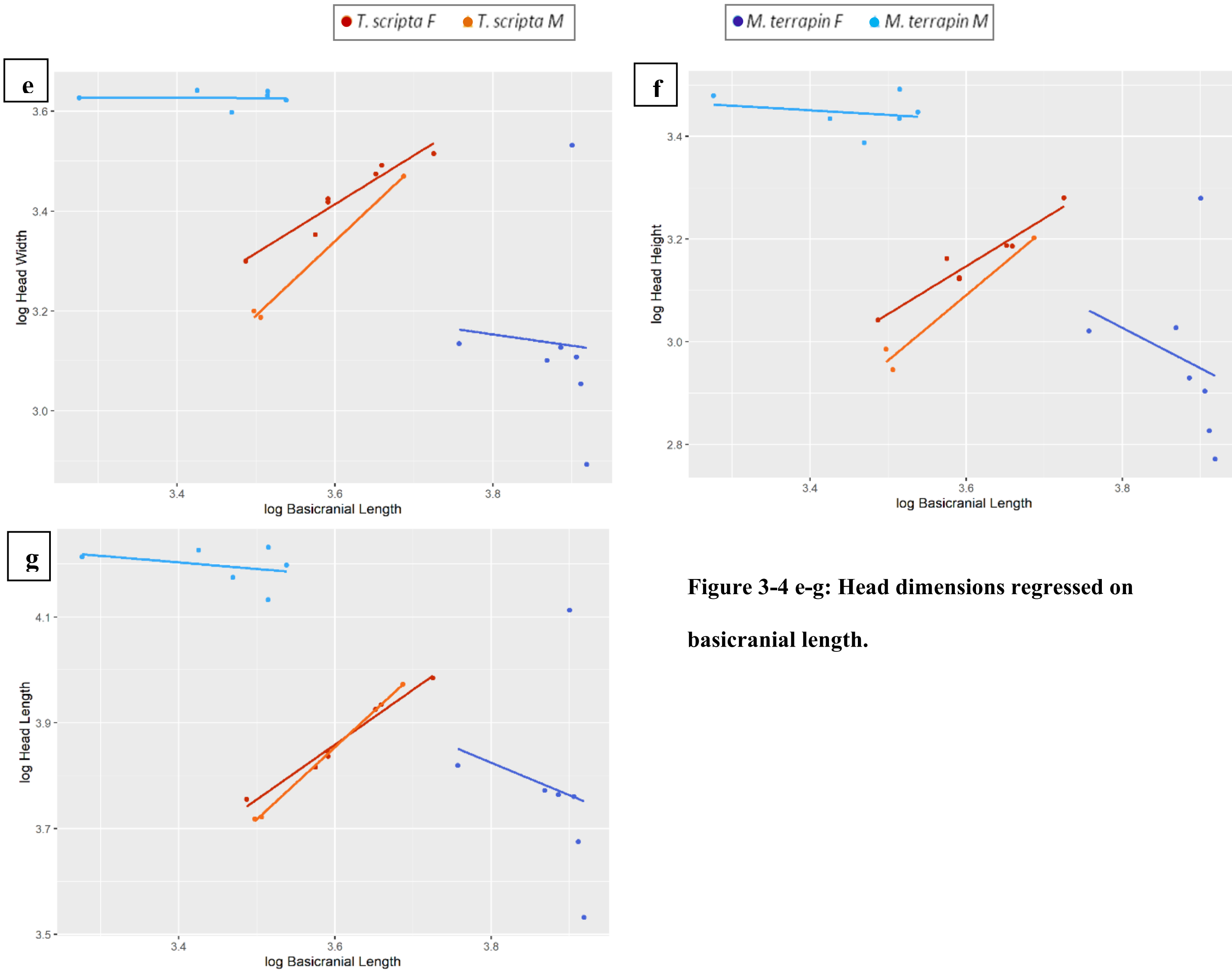

Figure 3-4 e-g: Head dimensions regressed on basicranial length.

Lever Mechanics

On average, female *T. scripta* were 4% larger than male *T. scripta* based on basicranial length but had 12% longer out-levers and 14% longer in-levers. Surprisingly, this did not strongly affect mechanical advantage (MA). The average MA in females is only slightly, but not significantly, greater than the average MA in males ($t(6)=0.886$; $P=0.205$) (Table 3-3, Figure 3-5).

On average, female *M. terrapin* were 42% larger than male *M. terrapin* as measured by basicranial length but had 51% longer out-levers and 63% longer in-levers. Average MA in the female is significantly greater than in the average MA of males ($t(9)=2.482$; $P=0.017$) (Table 3-3, Fig. 5).

When grouped by species, *M. terrapin* and *T. scripta* did not differ significantly in mechanical advantage ($t(20)=0.611$; $P=0.274$). When the sexes of *M. terrapin* were tested individually against *T. scripta*, female *M. terrapin* did not differ significantly ($t(15)=0.755$; $P=0.231$) but male *M. terrapin* nearly differed significantly ($t(10)=1.789$; $P=0.052$).

Table 3-3: Comparative Lever Mechanics in *M. terrapin* and *T. scripta*

Group *Average (Standard Deviation)*	***Malaclemys***				***Trachemys***			
	BL	***OL***	***IL***	***MA***	***BL***	***OL***	***IL***	***MA***
Species	40.75 (8.99)	20.83 (4.60)	10.63 (2.74)	0.507 (0.03)	36.60 (3.04)	18.42 (1.91)	9.49 (1.22)	0.514 (0.028)
Male	32.04 (6.52)	16.31 (4.6)	7.94 (2.55)	0.487 (0.03)	35.42 (3.9)	17.09 (1.74)	8.63 (1.2)	0.504 (0.021)
Female	45.60 (6.99)	24.70 (1.65)	12.93 (1.09)	0.523 (0.021)	37.11 (2.8)	19.00 (1.79)	9.85 (1.1)	0.519 (0.031)

BL= basicranial length; OL= out-lever length; IL= in-lever length; MA= mechanical advantage.

Mechanical advantage spanned a wide range in female *T. scripta*, but the three male *T. scripta* do not provide an appropriately sampled comparison to assess disparity (Figure 3-5). Mechanical advantage was more disparate between males and females in *M. terrapin* than the male and female samples of *T. scripta* (Figure 3-5).

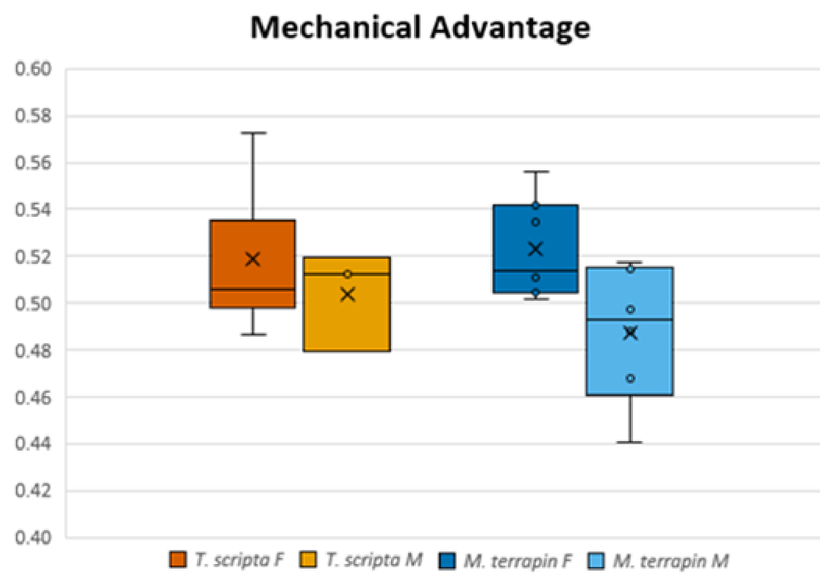

Figure 3-5: Box and whisker plot of mechanical advantage variation n *T. scripta* and *M. terrapin*, demonstrating the significant difference between male and female *M. terrapin*, but the insignificant difference between male and female *T. scripta*.

In-lever and out-lever lengths increased at similar rates in male and female *T. scripta* but increased at different rates in male and female *M. terrapin* (Figure 3-6). Male *M. terrapin* in-levers increase in length at a slower rate than female *M. terrapin* in-levers. Relative to *T. scripta*, male *M. terrapin* in-levers increase in length at a slower rate and female *M. terrapin* in-levers increase at a faster rate (Figure 3-6).

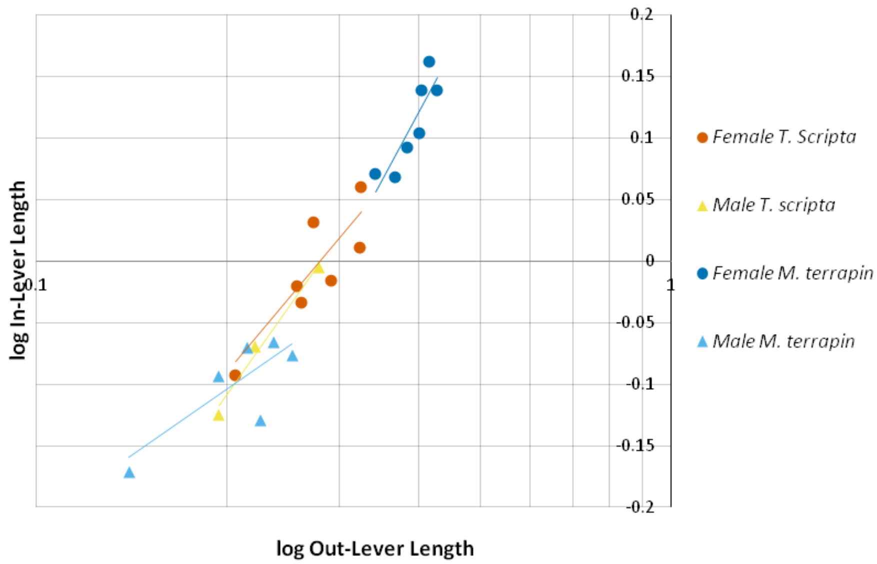

Figure 3-6: Regression of log-transformed in-lever length to out-lever length in *T. scripta* and *M. terrapin.*

Muscle Volume, Fiber Length, and Fiber Angle

The relationship between MAMEP muscle volume and fiber length is similar in male and female *T. scripta,* but differs in MAMES (Table 3-4, Figure 3-7). In MAMEP, the female has a larger relative volume but relatively shorter fibers. In MAMES, the female has both smaller relative volume and relatively shorter fibers, demonstrating a scaling relationship. In both volume and fiber length, the female is much larger relatively than the male. The fiber angle of the MAMEP in *T. scripta* is similar in male and female (Table 3-4). The fiber angle of MAMEP is slightly higher in the male specimen and this pattern is repeated in MAMES.

The relationship between muscle volume and fiber length is similar in male and female *M. terrapin* (Table 3-4, Figure 3-7). In both volume and fiber length, the female is much larger relatively than the male, demonstrating a scaling relationship. The fiber angles in the posterior MAMEP (the only part that could be measured on the male) are similar (Table 3-4, Figure 3-7), indicating that the muscle architecture of MAMEP is similar between the sexes of *M. terrapin* (Figure 3-7). The fibers of the MAMES, on the other hand, insert at a lower angle in the female *M. terrapin* (Table 3-4, Figure 3-7).

Table 3-4: MAME Volume and Architecture in Male and Female *T. scripta* and *M. terrapin*

Specimen	Original Gape Angle (°)	MAME pars Profundus			MAME pars Superficialis		
		V (cm³)	*fl* (cm)	θ°	*V* (cm³)	*fl* (cm)	θ°
T. scripta F	0	0.987	1.116 *1.16*	43.9 *34.3*	0.467	0.752 *0.752*	61.2 *23.49*
T. scripta M	0	1.866	1.339 *1.339*	47.8 *29.4*	0.630	0.97 *0.97*	76 *19.6*
M. terrapin F	15	1.859	1.468 *1.505*	59.0 *22.5*	0.944	0.918 *0.941*	62.7 *15.4*
M. terrapin M	8	0.231	0.934 *0.941*	59.7 *22.5*	0.110	0.664 *0.669*	77 *10.4*

Normal text = value normalized to 0% gape; *italicized text = measured value at specimen gape*

Overall, *M. terrapin* and *T. scripta* demonstrate similar scalar relationships in muscle volume and fiber length. *M. terrapin* has relatively higher fiber angle in MAMEP compared to *T. scripta*. Surprisingly, the females of each species have more similar MAMES fiber angles to each other than their conspecific males, and vice versa.

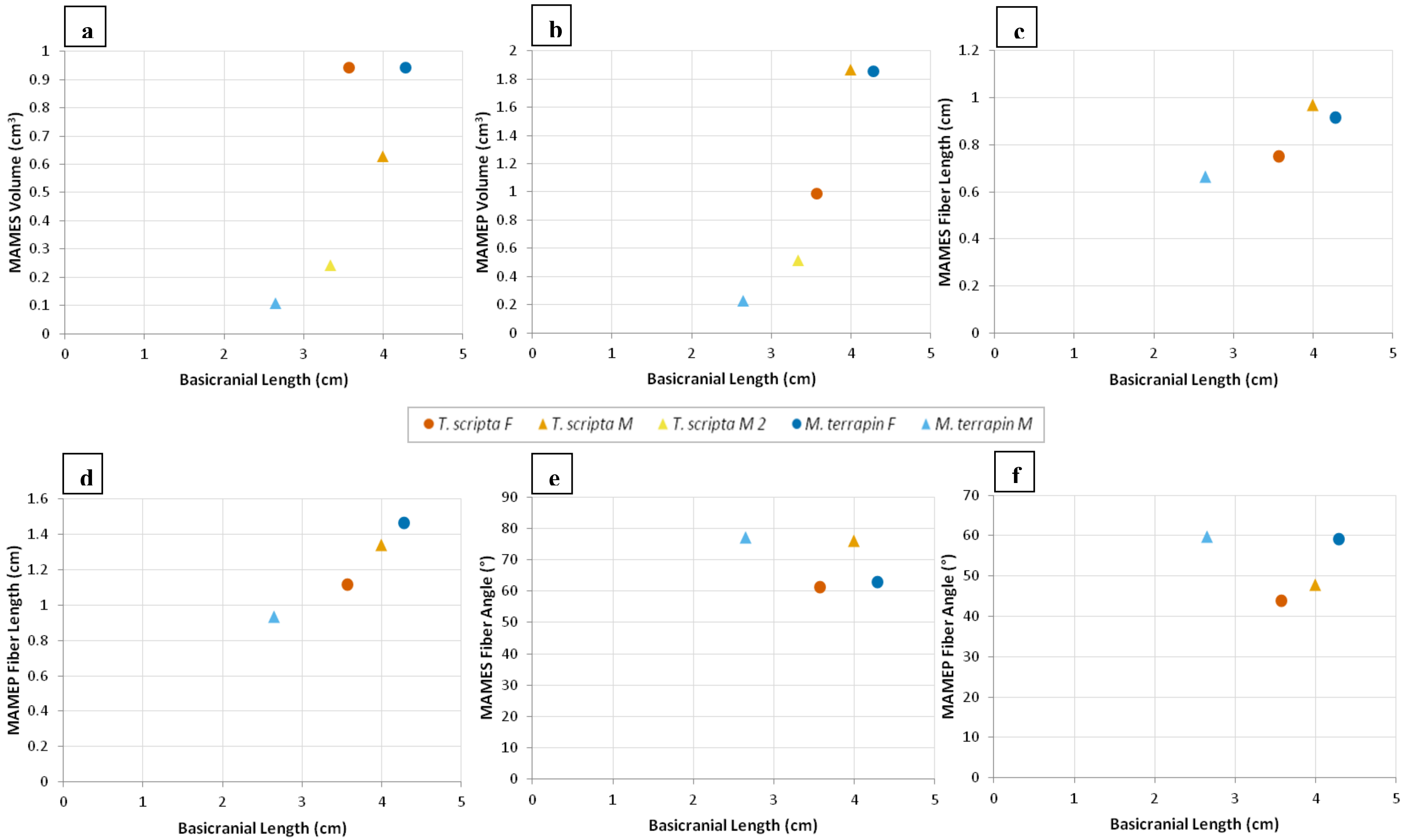

Figure 3-7: Comparative MAMES and MAMEP volume, fiber length, and fiber angle. MAMES= *musculus adductor mandibulae pars superificialis.* MAMEP= *musculus adductor mandibulae pars profundus*.

PCSA

PCSA is closely related to MAME volume, which scales with approximately isometric growth in both species (the pattern as shown in Figure 3-7).

The male *T. scripta* has 42.21% relatively (71.65% absolutely) greater muscle volume but only 6.67% (4.60% absolutely) greater relative PCSA than the female.

Because of the much greater size disparity in *M. terrapin*, this translates to an exaggerated difference between male and female MAME volume and PCSA (Table 3-5). The female *M. terrapin* has 134.23% relatively (721.61% absolutely) greater muscle volume and 114.1% relatively (491.29% absolutely) greater PCSA than the male. With similar muscle architecture between the male and the female, the source of variation in PCSA in *M. terrapin* is primarily muscle volume.

Table 3-5: Soft Tissue Specimen Leverage, Muscle Volume, and PCSA

Species	Sex	Jaw Length (mm)	Basicranial Length (cm)	MAME *MA*	% Diff MA	MAME *V* (cm^3)	Scaled % Diff V	MAME *PCSA* (cm^2)	Scaled % Diff PCSA
Trachemys scripta	F	26	3.57	0.51	1.98	1.4540	42.21	0.6217	6.67
Trachemys scripta	M	28.3	3.99	0.50		2.4958		0.6503	
Malaclemys terrapin	F	32.7	4.28	0.52	5.94	2.8025	134.23	2.4414	114.1
Malaclemys terrapin	M	18.71	2.65	0.49		0.3411		0.4129	

MAME= musculus adductor mandibulae externus (sum superficialis and profundus portions). MA=mechanical advantage V= volume. PCSA = physiological cross-sectional area. % Diff=percent relative difference as scaled to basicranial length

Discussion

Prediction 1: Male and Female M. terrapin Differ, Male and Female T. scripta Do Not

T. scripta **Intraspecific Variation.** SSD is associated with only minor differences in anterior adductor chamber width and MAMES architecture in *T. scripta*. Variation across all areas tested is largely attributable to a pattern of isometric growth.

Consistent with the prediction, the strictly size-dimorphic male and female *T. scripta* exhibit only minor and isolated differences in skull shape, relative adductor chamber and head dimensions, lever mechanics, and jaw muscle volume and architecture. In the PCA, the male specimens were distributed evenly amongst the female specimens demonstrating that there is little difference in skull shape between the sexes. Contrary to expectation, anterior adductor chamber width and head height are larger relative to their basicranial length in females than in males, but the effect sizes of these differences are small, indicating that these differences are minor. Additionally, most adductor chamber features appear to scale isometrically in *T. scripta*, therefore, any observed differences can likely be attributed to scaling relationships within the skull.

In contrast to what would be expected from the differences in linear dimensions, the muscle volume in the female individual fell between the two males measured. Again, this is likely an effect of size. Since the architectural data come from the larger male, the relative differences between male and female architecture may be confounded by size effects. Indeed, log fiber length increases as basicranial length increases, suggesting that fiber length scales with isometry. Regardless, the female individual had more effective fiber angles in both portions of MAME. This suggests that fiber angle is less optimal with increased head size. With greater sample sizes, this may prove to be driven by either size or sexual dimorphism.

The lack of significant allometric effect in the shape data for *T. scripta* translated to apparent isometric scaling in muscle volume and architecture with head size in *T. scripta,* likely explaining the small differences this analysis did find between males and females. The sexes in *T. scripta* grow at the same rate but achieve maturity at different sizes (Gibbons and Lovich, 1990). It is not known whether male and female *T. scripta* have different bite forces, but their size dimorphism may prove that to be the case, though it is also possible that they are sexually dimorphic in carapace dimensions but not head dimensions.

***M. terrapin* Intraspecific Variation.** SSD and TMD are associated with significant and in many cases major differences between male and female *M. terrapin* in all areas tested. Surprisingly, muscle architecture is largely similar between males and females. Also unexpected is the fact that most variation between the sexes is largely attributable to pattern of negative allometric to isometric growth.

In terms of skull shape, females have wider skulls and a jaw joint that is located more posteriorly relative to the trochlear process, yet shorter supraoccipital crests compared to males. These differences qualitatively confirm the results of Herrel et al. (2017) who found that head width (and not head length) as well as in-lever length are significantly different between male and female *M. terrapin.*

When scaled to basicranial length, female and male *M. terrapin* are significantly different in all linear measurements apart from posterior adductor chamber length, quantitatively confirming the results of the shape analysis. The lack of a significant difference in posterior adductor chamber length is consistent with morphological difference in supraoccipital crest length in the PCA. These measurements do appear to scale with negative allometry across the whole species, with the females generally scaling with more negative slopes.

Females also have significantly better mechanical advantage, supporting the hypothesis that their TMD affects jaw biomechanics, as predicted by the significant effect of in-lever length on bite force in Herrel et al. (2017). Lever lengths appear to scale with isometry, though the slopes are slightly different, reflecting the difference in mechanical advantage. The difference in mechanical advantage quantitatively reflects the morphological variation in trochlear process position between males and females. Since the *cartilago transiliens* develops in response to pressure of the tendon on the bone (Tsai and Holliday, 2011), it is likely that the trochlear process develops similarly. This leverage difference may be a plastic response to the greater muscle force generated by female adductor muscles. Herrel et al. (2017) were necessarily restricted to an approximate in-lever length that could be measured externally, and still found in-lever length to discriminate male and female *M. terrapin*. Curiously, the opposite was found in Underwood et al. (2013), who measured levers in a manner similar to the present analysis in a larger sample. They found no significant difference in in:out-lever ratio, and even found that males had a slightly larger average. This could be due to the fact that their out-lever was measured to the jaw tip, while the out-lever in the present analysis was measured to the trough of the trituration surface, where *M. terrapin* have been shown to position prey for crushing (Bels et al., 1998).

As expected, based on the differences in linear dimensions, the female specimen has a much larger absolute and relative muscle volume. Muscle volume likely scales isometrically or with slight positive allometry, though the pattern is not as indicated by the adductor chamber dimensions. Controlling for head width led Herrel et al. (2017) to conclude that the sexes did not differ in muscle architecture. Apart from slight differences in MAMES architecture, this analysis confirms that males and females do not differ much in muscle architecture. The fiber lengths of MAME appear to scale isometrically, consistent with volumetric scaling. Interestingly, the fibers of the MAMES scale with size but a different slope and are relatively more effective in the female specimen. This suggests that fiber angle improves with increased head size.

Collectively, mechanical advantage, muscle volume, and slight improvements to MAMES muscle architecture appear to drive the large differences between male and female *in vivo* bite forces observed by Herrel et al. (2017). Combined with the differences between male and female skull shapes, these observations demonstrate that SSD and TMD contribute to near global divergence in the morphology associated with biting within this species.

Prediction 2: M. terrapin Are More Disparate Than T. scripta

The initial prediction was that trophic specialization, and in particular durophagy, would be associated with greater intraspecific morphological disparity in the skull of *M. terrapin* than in *T. scripta* because trophic dimorphism amplifies sexual dimorphism. The expectation is that disparity within *M. terrapin* would be high, and greater than between species. In fact, the shape analysis demonstrated that the disparity between species was less than within each species. Though evaluation of shape differences between male and female *M. terrapin* demonstrated apparent morphological distinctions (see above for a full discussion), these shape differences did not translate to greater disparity in *M. terrapin*. Furthermore, some of those morphological distinctions, in isolation, varied similarly in *T. scripta,* pointing to a common pattern between the species. This may be due to the fact that the morphological variation within both species could be accounted for by negative allometry, resulting in similar overall disparities. Though most adductor chamber features appear to scale allometrically in both species, the lack of significant allometry in overall skull shape in *T. scripta* suggest that this is an unlikely cause of the similar disparity. A more likely explanation may be the relative strengths of selection on the trophic morphologies in these species. Without the direct selective pressure of a functionally demanding durophagous diet constraining it, skull morphology may be free to vary more overall, resulting in a higher overall disparity in *T. scripta.* Meanwhile, strong directional selection for durophagy in *M. terrapin* likely constrains skull shape variation to that most adaptive to the functional demands of their diet (e.g., Collar et al., 2014).

Outside of strict disparity, male and female *M. terrapin* demonstrated greater differences than male and female *T. scripta*. Often, the distinct clusters of male and female *M. terrapin* bracketed the sole cluster comprised of both sexes of *T. scripta*. Additionally, the relative intraspecific difference in MAME volume was more than three times larger in *M. terrapin* and the same in PCSA was more than 16 times larger than in *T. scripta*. This provides clear supporting evidence for the vast disparities among *in vivo* bite forces in *M. terrapin* (Herrel et al., 2017).

Prediction 3: Jaw Adductor Leverage and PCSA Do Not Drive Greater Bite Force in M. terrapin

This analysis did not find a significant difference in lever mechanics between the species. However, male *M. terrapin* had significantly worse mechanical advantage than both *T. scripta* and female *M. terrapin*. Therefore, leverage does not drive the bite force advantage of *M. terrapin*.

Importantly, this analysis did not discover major differences in muscle architecture between the species outside of isometric scaling. This is surprising since male *M. terrapin* still bite harder than all *T. scripta.* Therefore, muscle physiology, specifically contractile properties, is a highly likely cause of the observed disparity in *T. scripta* and *M. terrapin in vivo* bite forces

Conclusion

Preliminary evidence suggests that jaw muscles scale with isometry or slight negative allometry in *T. scripta* and *M. terrapin*. Jaw muscle size is correlated with dietary disparity in lizards among species (Isip et al., 2022) and between sexes within a species (Herrel et al., 2007). This is similar to recent evidence that alterations to ontogenetic trajectory produce the trophic morphological disparity among species of sea turtles, including modifications of the adductor chamber to produce the higher bite forces associated with durophagy in some species (Chatterji et al., 2022). This is a pattern that has been found repeatedly in other groups outside of Testudines (e.g., Gray et al., 2019; Morris et al., 2019). Similarly, isometric and slight negative allometric scaling through ontogeny of levers, bite force and head dimensions appear repeatedly in turtles (Guzman, 2010; Pfaller et al., 2011; Marshall et al., 2012, 2014).

While *T. scripta* do achieve maturity at different sizes – the females extend their ontogenetic growth longer than the males -- this SSD does not constitute a major distinction in PCSA on the scale of *M. terrapin* such that males are excluded from the trophic niche of females. The fact that female *M. terrapin* are, on average, much larger than male *M. terrapin* indicates that different ontogenetic scaling favors their respective trophic niches, a pattern that is not observed in the SSD *T. scripta*. The present analysis concludes that the sexes arising from TMD in *M. terrapin* are also likely differentiated through ontogenetic trajectories of different lengths. Among these species, SSD is only distinguished from TMD by the relative magnitude of differentiation in ontogenetic trajectory.

Chapter 4: Estimating Bite Force in Three Aquatic Turtle Species with Disparate Bite Strategies: Exploring the Impact of Assumptions on Theoretical Bite Force Modelling and Interpretation

Introduction

Bite force is a performance trait that can have a direct effect on fitness (Anderson et al., 2008). In the absence of *in vivo* data, bite force is commonly estimated using relatively static bite force models (Thomason, 1991; Anderson et al., 2008). While these estimates are theoretically comparable to maximum tetanic force generated by the jaw musculature, facilitating comparative studies, they fall short of accurately predicting bite forces measured *in vivo* (Huber and Motta, 2004). Recent advances that enable more detailed measurements of relevant musculoskeletal parameters for these models, such as functional MRI (e.g., Cagnie et al., 2011), diceCT (Gignac et al., 2014), and computational muscle fiber tracking (e.g., Sullivan et al., 2019) should increase accuracy of bite force estimations. Nevertheless, theoretical bite force estimates still fall short of accurately replicating *in vivo* measurement (Curtis et al., 2010; Davis et al., 2010; Gröning et al., 2013). Often overlooked is that biomechanical models used to estimate theoretical bite force may be highly sensitive to the input variables (and constants), some of which involve significant assumptions (Hutchinson, 2012; Gröning et al., 2013; cf., Holmes and Taylor, 2021).

Three critical parameters in static bite force models are specific tension, physiological cross-sectional area, and mechanical advantage. Specific tension (P_o) is the whole muscle force per unit area (Close, 1972; Schiaffino and Reggiani, 2011). Physiological cross-sectional area (PCSA) is the ratio of the area of the muscle fibers to their length as modified by their insertion angle (Powell et al., 1984). Mechanical advantage (MA) is a measure of leverage that assumes the jaw apparatus acts as a class-three lever and estimates how much of the applied muscle force becomes resultant bite force as the ratio of the in-lever of the muscle force to an out-lever of the jaw (Huber and Motta, 2004). Of these parameters, only MA can be measured from dry skulls, though muscle cross-sectional area may be grossly estimated from skeletal landmarks (e.g., Thomason, 1991). PCSA, on the other hand, requires dissection of muscle tissue. Finally, P_o requires *in vitro/vivo* measurement, either by direct measurement of fiber contractile characteristics or by the ratio of *in vivo* muscle force to PCSA.

In Chapter 3, I demonstrated that mechanical advantage and PCSA did not explain the disparity in bite forces measured *in vivo* between *Malaclemys terrapin* and *Trachemys scripta*. In the present study, I investigate possible explanations for this disparity in bite forces by examining the relative effects of input variables on estimates of theoretical bite force in the jaw apparatus of three related, yet functionally diverse turtle species. To provide comparative context, I calculate and manipulate theoretical bite force in three aquatic cryptodiran species, *T. scripta*, *M. terrapin*, and *Chelydra serpentina*, which utilize distinct bite strategies to capture and ingest prey. While understanding how different species "rank" relative to each other in terms of estimated bite force is a first step in interspecific comparisons of functional differences relating to morphology, the ability to estimate *in vivo* bite forces more accurately from models enables greater understanding of organismal performance in the context of behavior and ecology. This is particularly important when *in vivo* bite forces cannot be obtained. Indeed, for turtles, *in vivo* bite forces are available for only a small subset of the 357 extant species (Turtle

Taxonomy Working Group, 2021). Additionally, understanding assumptions going into the models used to estimate bite force facilitates cross-study comparisons using different parameters or models.

Rationale and Background for Input Variables Examined in the Context of Turtle Cranial Evolution

The present study includes measurements of MA and PCSA, but specifically lacks information on P_o, for which measurements are only available for a handful of well-studied vertebrate species (summarized in Table 1 of Holmes and Taylor, 2021). Mounting evidence from different vertebrate groups suggests that accurate predictions of bite force rely on not only accurate biomechanical models but also accurate specific tension values (Anderson et al., 2008; Gröning et al., 2013; Holmes and Taylor, 2021; Charles et al., 2022). Due to the dearth of specific tension measurements (or *in vivo* bite force data matched with PCSA), a standardized value, often between 25-40Ncm^{-2} for jaw muscles, is still regularly used in bite force models (Cleuren et al., 1995; Herrel et al., 1998; see p. 47 in Pfaller, 2009 for a discussion), though it has long been known that specific tension is not a constant (Buchanan, 1995).

The contractile properties of a whole muscle (i.e., P_o) are determined by muscle physiology on a fiber-by-fiber basis. The phenotype of a fiber is determined by the type and relative proportion of various myosin heavy-chain (MHC) isoforms, which are the molecular motors that enable contraction within sarcomeres (Pette, 2006). These MHC isoforms determine the contractile velocity, endurance, and tension cost of each sarcomere (Toniolo et al., 2008). The length and operating range of the sarcomeres themselves determine the maximum tension of a sarcomere because there is an optimal overlap of sarcomeres, i.e., resting length, at which the maximum number of actin-myosin cross-bridges are formed and thus peak tension is produced (Gordon et al., 1966). Changing the length of the sarcomeres thus determines the overall fiber stretch (e.g., through changing jaw gape in the case of jaw muscle) at which this peak tension is produced. Due to the delay in cross-bridge formation, there is an inverse relationship between muscle fiber force and velocity, such that as velocity is increased, fewer cross-bridges are formed and as such force is reduced (Gans, 1982). The number of sarcomeres in series, i.e., fiber length, thus determines the shape of the force-velocity curve at the fiber level, such that longer fibers shorten faster by the additive nature of their greater number of sarcomeres. It is well known, however, that these fiber-level characteristics are not constant across a muscle (Infantolino et al., 2010; Moo et al., 2016; Anderson and Roberts, 2019; Sullivan et al., 2019; Taylor et al., 2019; Holmes and Taylor, 2021).

Variation in muscle physiology can explain some differences between *in vivo* bite performance despite similarity in morphology and biomechanics and vice versa. On a whole-muscle level, this variation forms a dimension for selection that can create functional equivalence. That is, different combinations of muscle fiber phenotypes and architectures can achieve the same functional result in spite of morphological variation in the skull (e.g., Anderson and Patek, 2015). Alternatively, this variation can produce functional diversity such that different combinations of muscle fiber phenotypes and architectures overcome similarities in mechanics or skull morphology to achieve different functional results (as exemplified in Taylor and Holmes, 2021).

In models used to predict turtle bite forces, changes in skull morphology throughout evolution have been inferred to have implications at the level of muscle fibers for muscles involved in producing bite force, i.e., the jaw adductors. Dissection-based descriptions of cranial musculature are available for a number of turtles (see Werneburg, 2011, for a complete list), but few species have reported intramuscular characteristics (Pfaller et al., 2011) or biomechanical measurements (Dalrymple, 1977, 1979; Pfaller et al., 2011; Underwood et al., 2013; Herrel et al., 2017) for the jaw apparatus. Based on all these studies, it has been repeatedly hypothesized that posterior elongation of the adductor chamber, and particularly the supraoccipital crest, should result in longer and more numerous muscle fibers and thus higher bite forces. Yet, Ferreira et al. (2020) found no such increase in predicted bite force over the evolution of this structure. This is in contrast to evidence that bite force scales approximately isometrically or with positive allometry with most head dimensions in the five turtle species studied (Pfaller et al., 2010; Marshall et al., 2012, 2014; Herrel and O'Reilly, 2014; Gagnon, 2021) and in Lepidosauria (Isip et al., 2022). *In vivo* bite forces have been measured empirically in only 48 species and span from ~1-1766N (and likely higher in the largest sea turtles) in taxa spanning a size range from ~0.1- 450kg (Herrel et al., 2002, 2017; Bulté et al., 2008; Guzman, 2010; Pfaller et al., 2010; Marshall et al., 2012, 2014; Butterfield et al., 2021; Gagnon, 2021). These studies imply that greater muscle mass is the primary determinant of bite force in turtles. However, how that mass is arranged relative to the jaw joint has never been investigated beyond a single species (Pfaller et al., 2011).

In turtles, this arrangement is impacted by the trochlearis system. The trochlearis system is hypothesized to provide a biomechanical advantage to bite force production that triggered their Middle Jurassic diversification (Joyce, 2007). The trochlearis system is an elaboration of the coronar aponeurosis, the tendinous framework that serves as the insertion site for adductor mandibulae externus, one of the three jaw adductors (Werneburg, 2011). In cryptodires, the system consists of a sesamoid made of cartilage (*cartilago transiliens*) or, more rarely, of bone (*os transiliens*) within the aponeurosis of the external mandibular adductor that is in contact with the cartilage-covered, bony trochlear process of the otic chamber (*processus trochlearis oticum*), often with a synovial cavity in between (Werneburg, 2013). This configuration enables the force generated by longitudinally oriented muscle fibers originating in the posterior skull to be redirected around the enlarged otic chamber and applied vertically to affect rotation of the lower jaw (Schumacher, 1973). The trochlearis system has also long been implicated as a probable substrate for biomechanical adaptations and therefore morphofunctional diversification. However, Ferreira et al. (2020) did not find an increase in simulated bite forces during the evolution of the trochlear system.

Herrel et al. (2002) measured bite forces in 28 species of turtles, observing that head height was the linear dimension with the most explanatory power for high bite force in turtles. Herrel et al. (2002) proposed increased contraction speed from longer muscle fibers as well as greater mechanical advantage in the primary jaw adductor as an explanation for this finding. A trade-off between force and speed exists in muscle fiber length which has been shown to alter jaw biomechanics in other groups (e.g., synapsids, DeMar and Barghusen, 1972), but this has never been investigated in turtles nor have fiber lengths or their placement in the muscle ever been reported. Nevertheless, Ferreira et al. (2020) speculated that greater contraction speed may explain the posterior elongation of the adductor chamber where increased bite force apparently does not, though they were not clear on how they calculated bite forces for their sample. Within the species studied, the mechanical advantage of the primary jaw adductor does not appear to vary with allometry (Pfaller et al., 2011), or with sexual size and trophic dimorphism (Underwood et al., 2013), suggesting an alternate explanation for the considerable *in vivo* bite force variation in turtles, though mechanical advantage has never been reported for more than a handful of species (Dalrymple, 1979; Pfaller, 2009).

The effect of muscle architecture on bite force in turtles has also yet to be evaluated across turtle species. PCSA and theoretical bite forces have only been reported for one species (Pfaller et al., 2011), so the impact of morphological diversity in jaw adductor muscle architecture on bite performance is unknown. Wernberg (2011) proposed two hypotheses for the evolution of the long tendon of the primary jaw adductor. First, it allows some fibers to maintain length for speed at larger gapes. This has been suggested as an explanation for the elongated supraoccipital crest of the snapping turtle, *C. serpentina,* which presumably forms an elongated attachment surface for these long fibers of the primary jaw adductor in the posterior adductor chamber (Werneburg, 2011). Second, the tendon enables high pennation angles for force production at smaller gapes. This is demonstrated by the wide zygomatic aperture (anterior adductor chamber) which contributes to lateral expansion of the skull of the durophagous female *Malaclemys terrapin* and its putative correlation with higher bite forces (Herrel et al. 2017). These hypotheses have been expanded upon on in *C. serpentina* and *M. terrapin* by Herrel et al. (2002) and Herrel et al. (2017). Specifically, they allude to an association between elongated fibers and the elongated supraoccipital crest of *C. serpentina* and greater mechanical advantage in *C. serpentina* relative to other turtles and female *M. terrapin* relative to male *M. terrapin* and the closely related *Trachemys scripta.*

Yet we know from studies of aquatic turtles, particularly suction feeders, that hydrodynamic constraints have been important in the evolution of turtle morphology (Aerts et al., 2001; Stayton, 2011, 2019). The need for a streamlined head and carapace (i.e., implying shorter cranial aperture of the carapace) produces packing constraints in the skull of suction-feeding turtles (Dalrymple, 1979). Even in these turtles who capture prey through rapid hyoid depression to create suction, high forces and fast jaw closing are required to rapidly secure the prey within the oral cavity against the resistance of water. Posterior elongation of the skull (e.g., Trionychidae, Dalrymple, 1979) and in extreme forms, lateral expansion of the skull (e.g. *Chelus fimbriatus*, Lemell et al., 2010) are thought to have evolved to meet these hydrodynamic demands. Therefore, the apparent strategy to increase bite force via lateral expansion of the skull (i.e., greater head width) is shared between specialized suction-feeders and unspecialized aquatic turtles despite being clearly optimized for separate feeding strategies (Lemell et al., 2019). The purported purposes of posterior elongation, however, appear to be at odds. Specifically, research on non-suction feeding taxa suggests that posterior elongation is associated with longer fibers whereas in suction feeders it facilitates increasing muscle mass without increasing head height.

The present analysis sets out to test the variables used in the calculation of theoretical bite force to evaluate their range of variation and relative importance in three aquatic cryptodiran species utilizing three disparate bite strategies. In doing so, this analysis may discriminate between the three hypotheses set forth for the functional purpose of posterior elongation of the adductor chamber: 1) muscles and fibers optimized for increased bite force (trionychids, Dalrymple, 1979); 2) muscles and fibers optimized for increased contractile speed (*Chelydra serpentina*, Herrel et al., 2002); or 3) a combination of both (*Chelydra serpentina*, Werneburg, 2011).

Materials and Methods

Specimen Selection and Rationale

Detailed measurements for bite force calculations were gathered from three species of turtle native to North America from the Order Cryptodira: *Chelydra serpentina*, *Malaclemys terrapin*, and *Trachemys scripta*. These species were chosen for their comparable and simple muscle divisions, the availability of *in vivo* bite force data tied to morphological measurements (Herrel et al., 2002), the availability of multiple fixed specimens, and the fact that all three are well studied in all areas of their natural history, feeding kinematics, and general morphology (e.g., Rieppel, 1990; Lauder and Prendergast, 1992; Bels et al., 1998; Bouchard and Bjorndal, 2006; Pérez-Santigosa et al., 2011; Herrel et al., 2017). While sharing an aquatic habitat and phylogenetic closeness, therefore reducing confounding factors affecting the morphology of the jaw apparatus, these species represent three distinct diets and bite force strategies.

Chelydra serpentina, the common snapping turtle, is a large-bodied turtle in the family Chelydridae that is incapable of retracting its head fully inside its shell. It prefers shallow freshwater habitats in which it ambushes and captures prey underwater through ram-feeding. Ram-feeding involves high-speed inertial pharyngeal suction during the head strike, where the rapid expansion of the buccopharyngeal cavity compensates for the bow-wave of the forward movement of the head itself. The rapid advancement of the head creates a low-pressure area in the mouth to draw in the food item after which the jaws close quickly (Lauder and Prendergast, 1992; Ernst et al., 1994). The snapping turtle has a generalist omnivorous diet, feeding on whatever food is common in its natal habitat, including large amounts of plant matter and whatever animal prey it can catch or scavenge (Ernst et al., 1994). *C. serpentina* is often cited for its large head, extremely large bite force and "snapping" defense mechanism, and is hypothesized to have jaw muscles optimized for speed as well as force (Herrel et al., 2002). Compared to other species sampled by Herrel et al. (2002), it has an extremely high bite force relative to all head dimensions but low bite force relative to body mass. Although it is not durophagous in its diet (Ernst et al., 1994), it represents a fast and forceful bite strategy in the present analysis.

Malaclemys terrapin, the diamond-backed terrapin, is a medium-sized turtle in the family Emydidae that is capable of full neck retraction. The terrapin prefers estuarine habitats and is very aquatic, actively foraging for sedentary or slower moving prey (Ernst et al., 1994). It is durophagous and feeds on well-defended molluscan or crustacean prey. It is also female-biased sexually size-dimorphic and sexually dimorphic in its trophic morphology, with females possessing larger heads, higher bite forces, and feeding on more well-defended prey (Underwood et al., 2013; Herrel et al., 2017). This species uses only enough suction to compensate for its head movements in water via pharyngeal distension to apprehend its prey, then engages suction to precisely position the prey between broad trituration surfaces of the jaws before crushing it (Bels et al., 1998). It is not known in the literature what morphology causes the large discrepancy between male and female bite forces other than the difference in head width reported by (Herrel et al., 2017). Compared to other species, it has a high bite force relative to body mass, head width, and head length (Herrel et al. 2002). This species represents the static forceful bite strategy in the present analysis.

Trachemys scripta, the red-eared slider, is a medium-sized turtle in the family Emydidae that prefers quiet freshwater habitats and that is capable of full head retraction. Its feeding kinematics are minimally described but it is considered a generalist with generally fast gape cycles and is invasive in many areas of the world (Nishizawa et al., 2014). They are opportunistic omnivores but are more carnivorous when young, actively foraging in shallow water for a variety of plants and invertebrates (Ernst et al., 1994). Compared to other species sampled by Herrel et al. (2002), it has a very low bite force relative to its head dimensions, and therefore represents the non-specialized bite strategy in the present analysis.

Specimen Sampling

The head, including the skull and the associated soft tissues, of one male (OUVC 10873) and one female (OUVC 10881) *T. scripta elegans* of approximately similar size were sourced from Ward's Scientific ("large turtles" captured via pond dredging in Louisiana) and accessioned into the Ohio University Vertebrate Collections (OUVC). The head with included soft tissue of one female *M.terrapin* (OUVC 10866) was collected post-mortem under permit in Chesapeake Bay, Maryland, by Dr. Willem Roosenburg and accessioned into the OUVC. The head and included soft tissue of one male *M.terrapin* collected from the Chesapeake Bay population was sourced from the Smithsonian Institution Collection (USNM 574916). The head with included soft tissue of one male *C. serpentina* (OUVC 10867) collected post-mortem under permit in Athens, Ohio and accessioned into the OUVC. All wet specimens were fixed or had been fixed in 10% neutral buffered formalin. No live animals were collected, obtained, used, or euthanized for any aspect of this study.

The head of each specimen was CT-scanned at Ohio University μCT facility, the University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center, or the University of Arkansas MicroCT Imaging Consortium for Research and Outreach. After the first scan, the specimens were the washed of formalin in preparation for undergoing diceCT (diffusible-iodine contrast-enhanced computed tomography; Gignac et al., 2016). The specimens then underwent a 24-hour soak in a 20% sucrose solution in deionized water to rehydrate the tissues prior to staining. Specimens were stained in a 1% I_2KI solution in deionized water for a period of 3-8 months to enhance the contrast of the soft tissues, then CT-scanned again. Specimen details and associated scan parameters are provided in Appendix A.

Unstained CT-scans of each specimen were reconstructed as 3D digital models using Avizo (v. 8.1, Thermo Fisher Scientific, Waltham, MA). The 3D models of the skull and jaw were digitally aligned to 5° gape (approximate gape of bony elements at minimum gape accounting for the keratinous beak) and 2D lever measurements were taken in Avizo (Figure 4-1). Turtles have akinetic skulls, so to remove the medial component of jaw adductor force, the levers of the jaw apparatus were measured in lateral view against the resultant vector of the external mandibular adductor, defined by a line drawn from the trochlear process of the otic chamber on the skull to the most dorsal point of the coronoid bone of the jaw (*RV*). Out-lever length (*OL*) was taken from the center of the jaw joint to the center of the trough of the trituration surface of the mandible. In-lever length (*IL*) was measured perpendicular to the line of *RV* as the distance from the center of rotation of the jaw joint to the *RV*.

For comparison to published works, measurements of head dimensions were taken to 1/100th of a millimeter digitally in Avizo for all species. These measurements were repeated digitally on the skeletal models as well as the stained soft tissue models, since the presence of the soft tissue around the bone may produce larger measurements comparable to those from living specimens recorded by Herrel et al. (2002, 2017). The following dimensions were measured on skeletal and tissue models: maximum head width (*HW*), head length (HL) in the longest dimension in lateral view from the anterior tip of the premaxilla to the posterior point of the supraoccipital crest, and head height (HH) from the jaw below the jaw joint to the level of the highest point of the skull perpendicular to the jaw out-lever, and jaw length (*JL*) from the anterior tip of dentary or lower beak to the posterior tip of retroarticular process.

The following dimensions were measured in three dimensions on the skeletal models only: basicranial length (*BL*) from the posterior tip of the occipital condyle to the anterior tip of the upper labial ridge, anterior adductor chamber height (*AH*) perpendicular to the OL from the deepest point of the adductor ridge of the jaw to the most superior point of muscle attachment surface on the parietal, anterior adductor chamber width (*AW*) perpendicular to the long axis of the skull in ventral view from the most medial point of the parietal to the level of the most lateral point of the internal surface of the zygomatic bar (not pictured), posterior adductor chamber length (*PL*), from the center of the trochlear process to the most posterior point of muscle attachment surface on the supraoccipital crest, and posterior adductor chamber width (*PW*) perpendicular to the long axis of the skull in dorsal view at the widest point of muscle attachment surface posterior to the trochlear process. All measurements are illustrated and summarized in Figure 4-1.

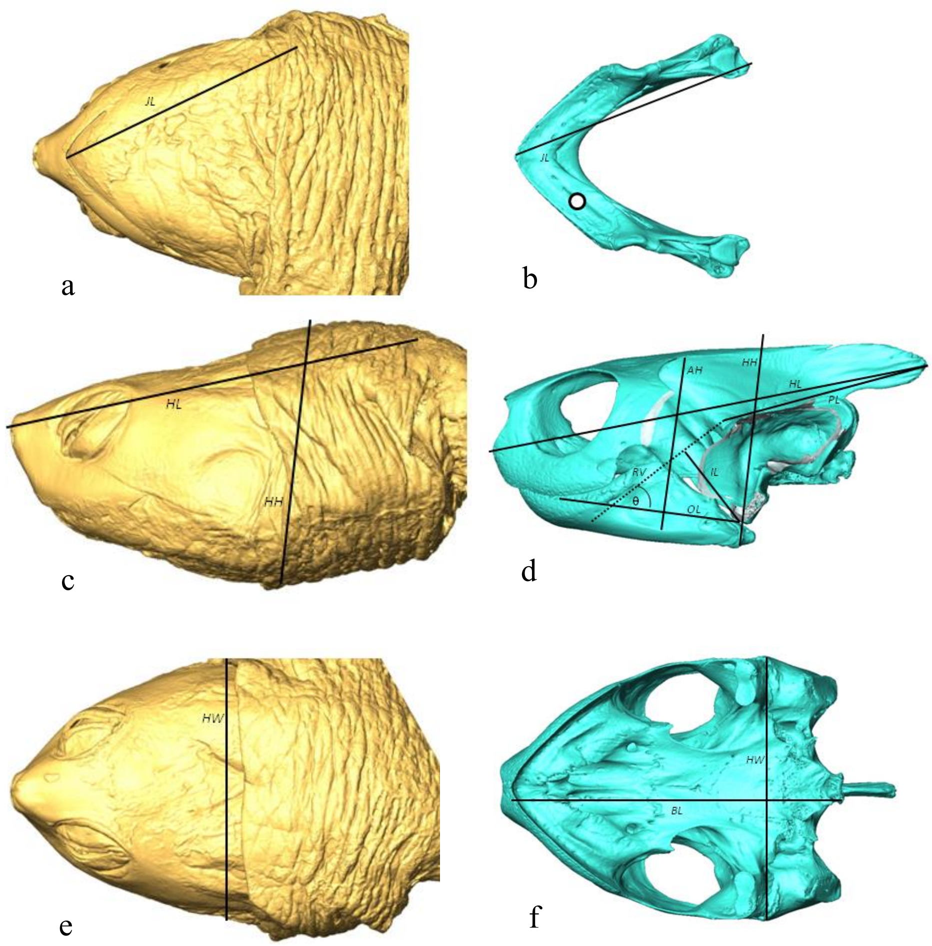

Figure 4-1: Morphological and lever measurements depicted on the skull and jaw of *Trachemys scripta*: a) whole specimen in ventral view, b) jaw in dorsal view, c) whole specimen in lateral view, d) skull and jaw in lateral view, the zygomatic bar and otic chamber have been clipped to expose the trochlear process, e) whole specimen in dorsal view, f) skull in ventral view. Solid line: physical measurement. Dashed line *IL*: calculated in-lever measurement (Ostrom, 1966). Dotted line *RV*: MAME resultant force vector. Circle: center of trough of trituration surface to determine *OL* in lateral view. *JL*: jaw length. *HL*: head length. *PL*: Posterior chamber length. *HH*: head height. *AH*: Anterior chamber height. θ: angle between *OL* and *RV*. *HW*: head width. *BL*: basicranial length.

Muscle Model Preparation, Digital Dissection, and Measurement

The development and homology of cranial musculature in turtles was described in detail in a recent review by Werneburg (2011). The trigeminally innervated jaw adductor apparatus in turtles is divided into three adductors: *Musculus Adductor Mandibulae Externus* (MAME), *MAM Internus* (MAMI), and *MAM Posterior*, with an additional fourth (*M. Zygomaticomandibularis*) plesiomorphically found in Carettochelydae and Trionychidae. Of these, MAM Externus is the largest in nearly all species described and makes the greatest contribution to bite force (e.g., 98% of bite force in *Sternotherus minor*, the only taxon with a comprehensive description and analysis of bite force and muscle architecture, Pfaller et al., 2011). The remaining adductors are small and have extremely low mechanical advantage, so only MAM Externus was digitally dissected for use in calculations of estimated bite force. MAME *pars profundus* originates on the parietal and supraoccipital crest and inserts mostly on the medial side of the coronar aponeurosis. In taxa with a strong zygomatic arch, the squamosal head of MAME *pars superficialis* originates on the dorsal surface of the quadrate, opisthotic, and in taxa with a strong zygomatic bar, an additional postorbital head originates on the medial surface of the zygomatic bar, both inserting largely into the lateral side of the coronar aponeurosis. *MAME pars medialis* originates on the anterior surface of the quadrate and inserts laterally on the lower jaw and/or coronar aponeurosis. (Werneburg, 2011)

CT volume data from the pre- and post-staining scans of OUVC 10881 (female *T. scripta*), OUVC 10873 (male *T. scripta*), OUVC 10866 (female *M. terrapin*), USNM 574916 (male *M. terrapin*) and OUVC 10867 (male *Chelydra serpentina*) were imported into Volume Graphics VGStudio MAX v. 2022.2 (Volume Graphics GmbH) for digital dissection (segmentation) and measurement. Following the anatomical divisions as defined in Werneburg (2011, numerical designation indicated for consistency) the following muscles portions and their respective tendons were dissected into non-overlapping digital volumes: *Musculus Adductor Mandibulae Externus* (MAME) *pars Profundus* (MAMEP, 19), *pars Superficialis* (MAMES, 21), and *pars Medialis* (MAMEM). After fiber measurements (see below), regionalization within MAMEP was observed in some specimens, prompting further dissection of the MAME into anterior adductor chamber and posterior adductor chamber subvolumes in these specimens. All fibers that originated posterior to the *cartilago transiliens* (the cartilaginous sesamoid within the MEME tendon complex located where the muscle force is redirected over the trochlear process of the otic chamber) were termed MAMEPp, whereas fibers originating within the anterior adductor chamber are termed MAMEPa. Though turtles have a unique tendon arrangement in the MAME, the tendon is assumed to redirect the contractile force of the muscle fibers posterior to the trochlea, and it is assumed that the trochlea is frictionless.

Since MAMEM represented a small proportion of overall MEM Externus volume and was oriented nearly parallel with the out-lever in these specimens, it was excluded from the following measurements and calculations. Within MAMEP and MAMES a minimum of ten fiber length measurements were taken by marking a single fascicle through the volume from its origin to its insertion. Unfortunately, the male *M. terrapin* specimen preservation was such that fiber architecture measurements were unable to be taken in the anterior adductor chamber, thus, only five fibers were recorded for each of the portions in the posterior adductor chamber. Specimen fiber angle was measured at the insertion of the marked length into the digitally dissected tendon or bony attachment. Fiber length and insertion angle are dependent on gape (Gans and de Vree, 1987) and the use of fixed museum specimens necessitated that these measurements were taken on specimens with variable gapes. To calculate normalized fiber length, Anapol and Barry (1996) multiplied measured fiber length by the percentage difference of the measured sarcomere length from resting sarcomere length. Recent analyses have found that sarcomere elongation through the range of motion of a joint is not uniform across an intact muscle, ranging from 10%-25% in the tibialis anterior of a mouse (Moo et al., 2016), 30% in temporalis and up to 43% in superficial masseter of macaques (Taylor et al., 2019). A similar range is found at conservative gapes of *Alligator mississippiensis* MAMES from 0°-22° gape, ranging from 12%-23% from anterior to posterior fibers (Busbey, 1989). No specimen in the present analysis was preserved beyond 15° of gape, so the elongation values from alligator MAMES, the most homologous muscle to MAME in turtles, was modified for use in the present analysis. Since resting sarcomere length is approximately 50% of joint motion range, a conservative value of 17.5% is assumed to be the amount of averaged elongation in turtle MAME at maximum gape. To approximate the method of fiber length normalization as described in Anapol and Barry (1996) in the absence of sarcomere measurement, sarcomere elongation is assumed to be linear such that 17.5% is used in the following equation:

$$Fiber\ normalization\ ratio = \frac{1}{(0.175 \times PGM) + 1}$$

where *PMG* is the ratio of specimen gape angle (-5° to account for the keratinous beak) to maximum gape angle (~70° in the specimens observed by this author that were preserved at maximum gape), multiplied by the residual proportion of maximum elongation beyond resting fiber length. This produced a ratio by which the measured fiber length would be multiplied to normalize measured values to resting lengths. Similarly, fiber angle was normalized as in Anapol and Barry (1996) by the following equation:

$$Normalized\ fiber\ angle = \arcsin\left(\frac{a}{fl}\right)$$

where *a* is the width of the muscle perpendicular to the tendon that a single fiber travels from origin to insertion and *fl* is the normalized fiber length. Note that fiber angles in the female *Trachemys scripta* at an original gape angle of 5° (i.e., closed mouth) averaged 34.3° and yet the normalized value was 128% larger at 43.9°, suggesting that all calculated PCSA from normalized values will be a slight underestimate (see results section examining the effect of fiber angle).

As shown in Table 4-1, the above measurements were used to calculate a number of functional and performance traits. Fiber length, fiber insertion angle, and muscle portion volume were used to calculate physiological cross-sectional area (PCSA), maximum tetanic muscle force at 100% fiber recruitment (F, after Powell et al., 1984) and theoretical static bite force (multiplied by two to account for both left and right MAME musculature).

Table 4-1: Measured and Calculated Traits for MAM Externus and Jaw Closing

<table>
<tr><th>Measurements</th><th colspan="2">Functional Traits</th><th>Performance Traits</th></tr>
<tr><td>Muscle volume (V, cm^3)*</td><td rowspan="5">Physiological Cross-Sectional Area*
$PCSA = \frac{V}{FL} \times cos\theta$</td><td rowspan="5">Maximum Tetanic Muscle Force at 100% Recruitment*
$F = PCSA \times Po$</td><td rowspan="7">Theoretical Bilateral Static Bite Force
$BF = \sum F \times MA \times 2$</td></tr>
<tr><td>Normalized mean muscle fiber length (FL or fl, cm)*</td></tr>
<tr><td>Normalized mean fiber pennation angle (θ, degrees)*</td></tr>
<tr><td>Muscle belly width (a, cm)</td></tr>
<tr><td>Specific Tension (P_o, Ncm^{-2})**</td></tr>
<tr><td>In-lever length in lateral view (IL, cm)</td><td colspan="2" rowspan="2">Mechanical Advantage
$MA = \frac{IL}{OL}$</td></tr>
<tr><td>Out-lever length in lateral view (OL, cm)***</td></tr>
</table>

**taken for individual muscle portions (heads); **multiple values tested at intervals of 5 from 10-60; ***taken for jaw tip and trough of trituration surface*

In the absence of *in vivo* muscle physiology data, it is possible to calculate a whole-muscle P_o average by using cross-products to solve the static bite force model for specific tension if all other metrics are known (Buchanan, 1995). No study to date has done this in turtles but published *in vivo* bite forces exist for the three species used in this study (Herrel et al., 2002, 2017). I therefore calculated P_o from a combination of published bite force values and morphometrics and the measured PCSA of the specimens as follows:

$$Estimated\ Po = \frac{SB}{2} \times \frac{MA}{PCSA}$$

where SB is the estimated bite force for an individual with the same jaw length as the specimen, and MA and $PCSA$ as calculated for the specimen following Table 4-1. The SB value for each specimen was calculated using the ratio of specimen jaw length to average published jaw length multiplied by the average published bite force. The species means from Herrel et al. (2017) were used for *C. serpentina* and *T. scripta* while the adult female means were used for the female *M. terrapin*. The male *M. terrapin* specimen falls just inside the upper size limit of the Juvenile class from Herrel et al. (2017), so the juvenile means were utilized in that case. I compare the calculated P_o and *SB* to estimated bite forces calculated over the range of P_o known in vertebrate muscle fibers and whole muscles, from 5-60 Ncm^{-2}.

Tests were run on the proportional effect of each variable by determining the average of each variable in the sample, and then using those averages as a constant in bite force equations where the test variable was the actual value of that variable for each specimen. For each test variable, the effect was determined by the ratio of the standard deviation of the test bite forces to the average test bite force (hereby referred to as 'test ratio' and expressed as a percentage).

Results

Interspecific Comparison

An in-depth discussion and comparison between male and female *Trachemys* and *Malaclemys* musculature can be found in the preceding chapter, and all comparisons in this section refer to only the females of each species

Compared to *T. scripta*, *M. terrapin* has only slightly higher anterior adductor chamber dimensions and posterior adductor chamber width (Figure 4-2). In contrast, the posterior adductor chamber is elongated in *M. terrapin* compared to *T. scripta*, possibly reflected in the greater relative head length measurement in Figure 4-2. Compared to the other species, *C. serpentina* demonstrates an increase in all adductor chamber dimensions, but relatively less overall disparity among chamber dimensions.

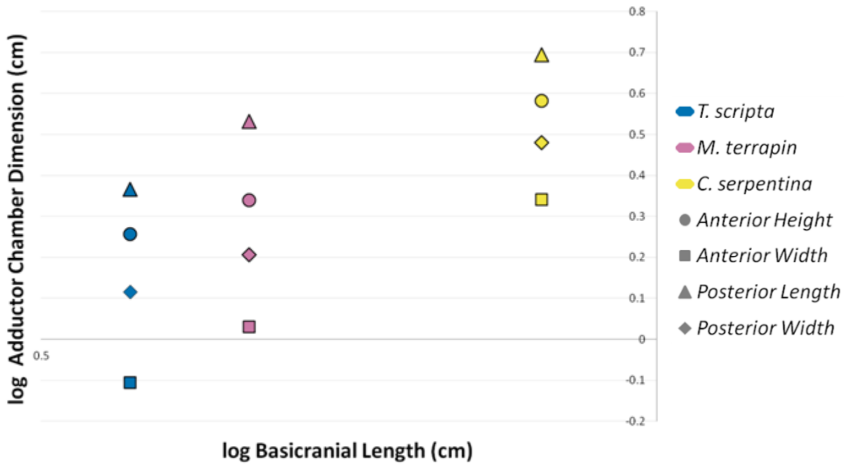

Figure 4-2: Comparative adductor chamber dimensions relative to basicranial length.

True to their body and head size disparity, *C. serpentina* had greater absolute volume and fiber length than *M. terrapin*, which had greater absolute volume and fiber length than *T. scripta* (Table 4-2, Figure 4-3). When scaled to jaw length, *C. serpentina* still had a much greater relative muscle volume: 4.2x more than *M. terrapin* and 6.5x more than *T. scripta*. Still, across all three species the distribution of MAMES and MAMEP relative to total MAME volume was quite similar, while the MAMEM of *C. serpentina* is a relatively larger proportion of total MAME volume (Figure 4-4). Fiber length scaled similarly to muscle volume demonstrating the tight linkage between fiber length and muscle volume (Figure 4-3). On average, all species had shorter and higher angle fibers in MAMES than in MAMEP, though the fiber length difference was not as extreme in *C. serpentina,* and the angle difference was not as extreme in *M. terrapin* (Table 4-2, Figure 4-3). In MAMEP, both *M. terrapin* and *C. serpentina* were characterized by heterogeneous muscle architecture in the region anterior, but not posterior, to the *cartilago transiliens*. No such differentiation was found in *T. scripta*. In both *M. terrapin* and *C. serpentina*, MAMEP anterior fibers normalized to closed gape were 38.8% and 36.6% longer, respectively (Figure 4-3), and they inserted at a more acute angle (97% and 73% of posterior angle, respectively) than posterior fibers (Figure 4-3), while fibers inserted more acutely than either species throughout the volume in *T. scripta* (Table 4-2). At original specimen gapes, the posterior fibers of *C. serpentina* had smaller angles than the anterior fibers at the original gape of 20°, while the opposite was true in *M. terrapin* at a similar specimen gape of 15° (Table 4-2). In light of these findings, the MAMEP volume was subdivided into anterior and posterior volumes in these species and treated separately for PCSA calculations.

Table 4-2: MAME Muscle Architecture Variation

Species	MAMEP *V* cm³	MAMEP fl cm	MAMEP θ°	MAMEPa V cm³	MAMEPa fl cm	MAMEPa θ°	MAMEPp V cm³	MAMEPp fl cm	MAMEPp θ°	MAMES V cm³	MAMES fl cm	MAMES θ°
Trachemys scripta (f)	0.987	1.116 *1.16*	43.9 *34.3*	*NA*	1.151 *1.151*	43.9 *32.7*	*NA*	1.08 *1.08*	43.9 *35.9*	0.467	0.752 *0.752*	61.2 *23.49*
Malaclemys terrapin (f)	1.859	1.468 *1.505*	59.0 *22.5*	0.337	1.732 *1.775*	58.8 *18.1*	1.523	1.248 *1.28*	60.7 *26.2*	0.944	0.918 *0.941*	62.7 *15.4*
Chelydra serpentina	10.429	3.262 *3.384*	59.2 *20.8*	5.069	3.766 *3.907*	50.7 *27.6*	5.361	2.757 *2.861*	69.1 *14*	4.585	2.719 *2.821*	73 *11.7*

Normal = value normalized to 5% gape; *italicized = measured value at specimen gape*

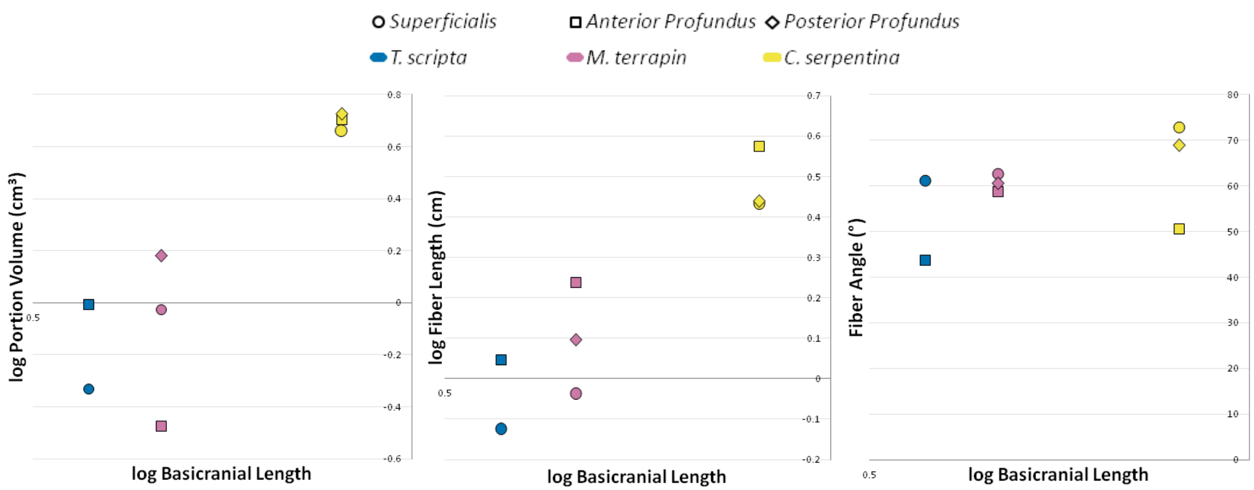

Figure 4-3: Scatterplots of comparative volumes, fiber lengths, and fiber angles among MAME portions.

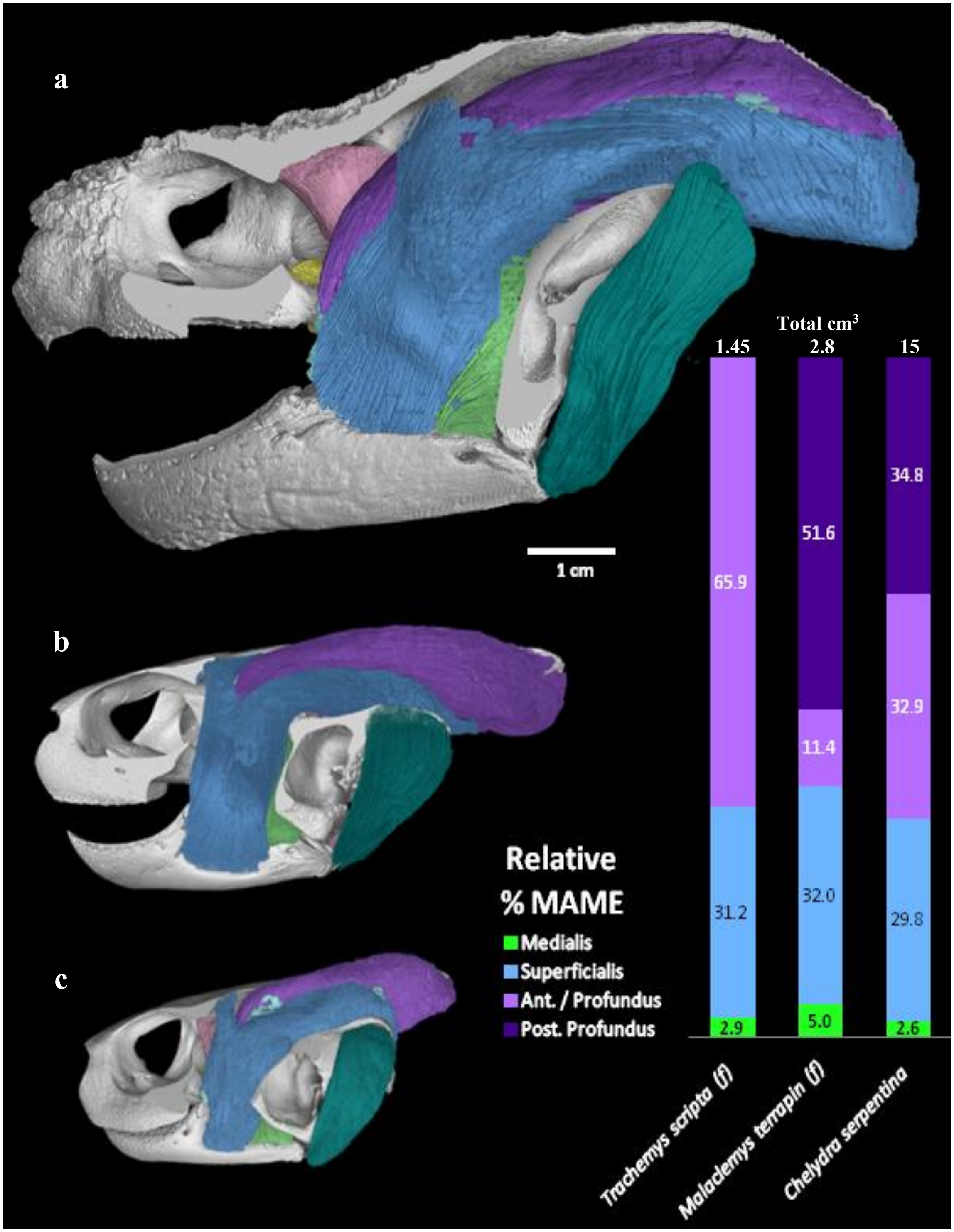

Figure 4-4: Digital jaw muscle dissections of a) *Chelydra serpentina* (male), b) *Malaclemys terrapin* (female), and c) *Trachemys scripta* (female), with relative proportions of *Musculus Adductor Mandibulae Externus pars Medialis*(light green), *pars Superficialis*(light blue), *pars Profundus* (undifferentiated and anterior in light purple, posterior in dark purple) graphed to the right and displayed on the 3D models; additional musculature visible on 3D models: *Musuclus Depressor Mandibulae* (dark teal), *Musculus Adductor Mandibulae Internus pars Pterygoideus* (yellow), and *pars Pseudotemporalis* (pink).

C. serpentina demonstrates a number of anterior adductor chamber modifications in addition to its much larger relative muscle volume. It has more anterior chamber muscle volume, with a greater proportion of MAME concentrated in the MAMEPa and MAMEM (Figure 4-4), resulting in roughly equal proportions of MAMES, MAMEPa and MAMEPp (Figure 4-3). Additionally, the MAMES and MAMEPp in *C. serpentina* have extremely similar relative fiber lengths and angles, which are both longer (but in proportion with volume) and insert at a higher angle than other species (Figure 4-3). Meanwhile, MAMEPa has longer fibers and those fibers are at a more acute angle (Figure 4-3). Additionally, the anterior adductor chamber contains a larger proportion of MAMEP as well as MAMES and MAMEM (Figure 4-4).

M. terrapin has a much larger percentage of its muscle volume concentrated in the posterior adductor chamber, whereas the anterior chamber contains little of MAMEP (Figure 4-3 & Figure 4-4). The relative differences in fiber length between MAMEPa and MAMEPp were similar to *C. serpentina*, but there was a much smaller proportion of MAMEPp, reducing the contribution of the longer MAMEPa to overall PCSA. The preponderance of fibers in the anterior chamber belonged to MAMES and were comparable to *T. scripta* muscles in length relative to MAMEPp fibers (Figure 4-3). Compared to both *C. serpentina* and *T. scripta*, *M. terrapin* demonstrated considerable homogeneity of muscle fiber angle in all portions of MAME (Figure 4-3).

All skeletal vs soft tissue head dimension measurements were within 5% of each other, indicating that the soft tissue did not inflate head dimension measurements of the skull as expected. As such, this is not considered a large source of error. Comparing MAME volume and PCSA to head dimensions (Figure 4-5) reveals that, although volume plays a large role in PCSA, muscle architecture clearly differentiates the metrics in the case of *C. serpentina* and *T. scripta*, whereas it does little in *M. terrapin*.

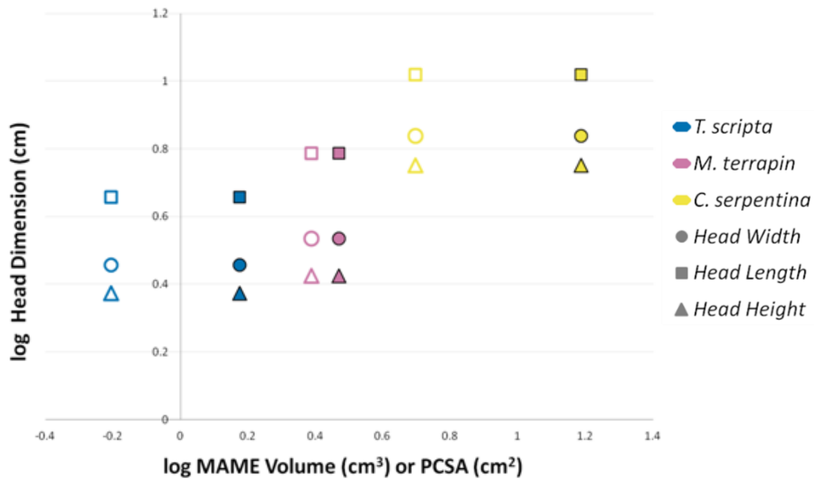

Figure 4-5: MAME volume (filled points) and PCSA (open points) relative to head width, head length, and head height.

Effect of Variables in Static Bite Force Model

Muscle PCSA is determined primarily by the ratio of muscle volume to fiber length (Table 4-3). The ratio of volume to fiber length ranged between 0.2575-3.1975 in MAMES and 0.1653-1.6802 in MAMEP. This ratio had a proportionately large effect on bite force calculations, with the standard deviation of the test bite forces being 68.2% of the average test bite force. This is similar to the effect of overall head size: scaling PCSA to jaw length produced a test ratio of 78.8%. Fiber angle ranged from 22.5 to 72 degrees in the present sample, producing a large range from 94% to 34% of the contractile force of the fibers being transferred to the muscle resultant vector. Though this seems a large effect, in contrast to volume/fiber length, the standard deviation of the test bite forces was only 5.8% of the average test bite force.

Mechanical advantage (MA) is one of the variables with the strongest contribution in the equation for bite force but the range in our sample was limited, varying between 0.45 and 0.52. Accordingly, the effect of MA on bite force calculations was similarly small, producing a test ratio of only 5.8%. Due to the commonalities in habitat and phylogenetic distance of the species chosen for this analysis, these data do not preclude mechanical advantage from having a larger effect in a broader taxonomic sample. Indeed, previous results (see Chapter 2) suggest that only a part of the jaw adductor complex may be under selection or possibly released from selection in some groups, in association with some diets and feeding media. It is a hypothesis that remains to be explored, but a cursory examination of available specimens of other species produced a larger range of lateral trituration surface MA, from 0.396 in *Glyptemys muhlenbergia* to 0.638 in *Gopherus polyphemus*.

Bite force was also strongly affected by specific tension (P_o), the standard deviation of the test bite forces modeled with P_o values ranging from 5-60Ncm^{-2} being 45.1% of the average bite force produced by those models. These results indicate that the largest single determinant of bite force in turtles is the ratio of volume to fiber length, followed by the specific tension value chosen for the calculation.

Table 4-3: Comparative effects of test variables on bite forces using the variation present in the sample while holding the other variables to a constant average value. All values calculated with P_o = 30 Ncm^{-2} for comparative purposes, except for the effect of P_o, which was calculated using unaltered values from *Chelydra serpentina.*

Test variable:	Effect of v/fl	Effect of V	Effect of FA	Effect of MA	Effect of P_o = 5-60 cm^{-2}
Scaling/Constant:	*Same FA*	*PCSA/JLx30mm*	*Same v/fl*	*Same PCSA*	*Chelydra values*
***Trachemys scripta* F**	22.0836	21.0365	32.6688	32.6688	
***Trachemys scripta* M**	31.8722	21.5067	34.7546	34.7546	
***Malaclemys terrapin* F**	36.0261	70.3563	34.9903	34.9905	
***Malaclemys terrapin* M**	6.0693	19.4633	32.7499	32.7495	
Chelydra serpentina	66.2877	98.9402	30.2405	30.2403	
Standard Deviation	22.1445	36.4789	1.9232	1.9233	81.1768
Average	32.4678	46.2606	33.0808	33.0807	180.1152
St. Dev/Ave	**0.682**	**0.789**	**0.058**	**0.058**	**0.451**

Modeling specific tension values from 5-60Ncm^{-2} produced a large range of bite forces, only just exceeding published in vivo ranges for each species/sex (Table 4-4). When specimen PCSA and literature-reported *in vivo* bite force (scaled to specimen jaw length) are used to calculate specific tension, it suggests that contractile properties vary among species, but not between sexes within a species. The large difference in estimated specific tension between *T. scripta* and female *M. terrapin* likely explains the order of magnitude difference in bite force, whereas absolute muscle volume does not. It also explains the parity in bite force between *T. scripta* and male *M. terrapin* despite the latter's much smaller size/PCSA. On the other hand, greater PCSA makes *C. serpentina* a more effective biter than *T. scripta.* Still, the lower specific tension relative to *M. terrapin* means that female *M. terrapin* bite nearly as hard as *C. serpentina*, despite the latter's much larger MAME volume and PCSA.

Table 4-4: Relevant specimen measurements and specific tension

Species	Sex	Jaw Length (mm)	MAME *MA*	MAME *V* (cm^3)	MAME *PCSA* (cm^2)	*BF* range P_o 20 - 60 (N)	Scaled *BF* range P_o 20 - 60 (N)	Published *in vivo BF* mean ± st. dev	Estimated *BF* for specimen	Estimated P_o
Trachemys scripta	F	26	0.49	1.4540	0.6217	12.15 - 36.46	14.02 - 42.07	14.59 ± 18.76*	21.34	35.11
Trachemys scripta	M	28.3	0.52	2.4958	0.6503	13.56 - 40.58	14.34 - 43.01	14.59 ± 18.76*	23.22	34.34
Malaclemys terrapin	F	32.7	0.52	2.8025	2.4414	51.13 - 153.38	46.90 - 140.71	156.26 ± 46.40**	134.25	52.52
Malaclemys terrapin	M	18.71	0.49	0.3411	0.4129	8.09 - 24.28	12.98 - 38.93	17.02 ± 15.00***	21.80	53.87
Chelydra serpentina	M	40.96	0.45	15.0139	4.9760	90.06 - 270.17	65.96 - 197.88	208 ± 226.10*	182.04	40.43

*species mean from (Herrel et al., 2002); **female mean and *** juvenile mean from (Herrel et al., 2017)

Discussion

Jaw Apparatus Specialization Varies with Bite Strategy

The static-forceful biting species, *M. terrapin*, shows a number of specializations in the jaw apparatus over the non-specialized biting species, *T. scripta*. In summary, *M. terrapin* has relatively greater muscle volume, achieved through posterior adductor chamber elongation, contributing to a higher PCSA. *M. terrapin* also has less heterogeneity in fiber length and pennation angle between muscle fibers in the anterior and posterior chambers, resulting in relatively shorter MAMES fibers and more MAMES fibers being packed into a similar anterior adductor chamber area. Consequently, the anterior chamber has a greater influence on bite force production. Because of these architectural differences, *M. terrapin* has a greater PCSA relative to muscle volume than either *T. scripta* or *C. serpentina*. Additionally, a small amount of anterior MAMEP fibers in *M. terrapin* are dedicated to increased length and likely jaw-closing speed, signaling a somewhat greater emphasis on apprehending prey in this actively hunting species.

The fast and forceful biting species, *C. serpentina*, also demonstrates a number of specializations over the non-specialized biting species. Of greater importance in *C. serpentina* than in *M. terrapin* is the functional regionalization of the MAME into long anterior chamber and short posterior chamber fibers, indicating a greater proportion of jaw adductor musculature dedicated to fast jaw-closing. In addition to fiber length regionalization, the posterior fibers of *C. serpentina* had smaller angles than the anterior fibers at the original gape of 15°, while the opposite was true in *M. terrapin* at a similar specimen gape of 10°, indicating that the posterior fibers are likely to be more effective at wider gapes in *C. serpentina*. These are likely important features for capturing elusive prey during ram-feeding. Additionally, overall muscle volume is increased not only through an increase in relative head size, but also through a relative increase in all dimensions of the adductor chamber, resulting in less disparity among adductor chamber measurements where the other species show restrictions. This much larger muscle volume ensures that *C. serpentina* can close its jaws at high velocity against the fluid pressure of the water it is feeding in, but also that the bite is forceful enough for both prey-capture and defensive bites. Overall, these architectural modifications result in a PCSA that is much smaller relative to muscle volume in *C. serpentina* than *M. terrapin,* and even slightly worse for its size than *T. scripta*.

Relative Importance of Static Bite Force Variables in Turtles

The above results suggest that mechanical advantage (MA) does not have a large effect on bite force, though the range of this variable is yet to be determined more broadly across turtles. Additionally, the bite point evaluated in the present study is at the center of the trough of the trituration surface, and many turtle species that do not have extensive food-jaw contact (e.g., suction-feeding specialists) and some do not even have a trituration surface. Because positioning of the food item is of such importance to the out-lever of the jaw closing muscles, a behavioral shift in the out-lever is likely to have more immediate impact than a morphological shift in the MAME in-lever. Therefore, the inherent variability of the contribution of mechanical advantage to feeding behavior remains to be fully explored in turtles not only from a taxonomic perspective but a behavioral one as well.

Muscle volume, being the largest determinant of PCSA, is the largest determinant of bite force in the species studied, though diversity in effect of this parameter is also present. For instance, the MAME architecture in *C. serpentina*, particularly the high fiber angle, affected PCSA in this species more strongly than in the other species Muscle architecture may create refinement in estimations of bite force but is not as primary a determinant as sheer muscle volume.

Specific tension is the second most impactful variable in the static bite force model and is estimated to vary among species. It does not appear to vary between sexes within a species, suggesting that it is consistent within a species and may be tied to phylogenetic history. The large disparity in specific tension estimates provides an explanation for the large disparities in bite force whereas PCSA does not. These results indicate that specific tension is a highly important dimension of diversity that is as of yet entirely unexplored in turtles, and likely other vertebrate groups.

Where does specific tension variability come from? Varying fiber type and relative proportions of those types optimizes different muscles to different tasks (Buchanan, 1995; Schiaffino and Reggiani, 2011). Skeletal muscle fibers are subject to a trade-off between endurance and speed which is based on an energy-saving mechanism in slow-tonic fibers that allow them to maintain tension for high endurance activities (like postural control), while fast twitch fibers can contract quickly but fatigue quickly (common in muscles used for fast reactions). Among cranial muscles, mammal jaw muscles are known to have a greater variety of fiber types in addition to those found in postcranial skeletal muscle. This includes two additional types of fibers that modify this gradient with force capacity (P_o), including a type with low P_o but extremely high endurance (found in muscles with highly repetitive tasks such as the heart, down to 5 $N.cm^{-2}$ in some bovine jaw muscle fibers), and a unique masticatory myosin with extremely high P_o (e.g. 39.8 Ncm^{-2} in carnivore jaw muscle) that is highly conserved across vertebrate jaw muscles (Reiser et al., 2010).

Though muscle fiber types have been described for some turtle muscles (Callister et al., 2005), only masticatory myosin has so far been confirmed in the jaw muscle of five turtle species. These muscles were not tested for the presence of other isoforms (Reiser et al., 2010). Little has been published on reptilian jaw muscles, but evidence from lizards suggests that reptiles, in contrast to mammals, have only one muscle fiber type with two MHC isoforms, masticatory and slow-tonic (fewer than in limb muscles), contributing to the force and extreme endurance of some reptilian bites (Nguyen et al., 2020). On the other hand, whole-muscle P_o in the jaw muscle of six species of *Anolis* lizards was found to vary from 17.5-30 $N.cm^{-2}$ (Anderson and Roberts, 2019). Another study of jaw biomechanics in a turtle species characterized by high bite force *Sternotherus minor* (Pfaller et al., 2011), used a standardized whole-muscle value of $30N.cm^{-2}$ to test their model with a small spectrum of values against their *in vivo* bite force measurements. This is in the realm of variation currently known in reptiles but remains to be experimentally validated in other species. From the results of the present analysis, it is likely that turtles adapt that single jaw muscle fiber type to different functional priorities (i.e., bite strategies) by altering the relative proportions of masticatory and slow-tonic myosin within the fiber, resulting in differing values of P_o for a muscle.

Conclusion

The forceful biting strategy did differentiate *M. terrapin* muscle architecture from that of *T. scripta. M. terrapin* homogenized the fiber angles of the respective muscle portions and, along with greater relative muscle volume, these changes resulted in a high PCSA for its muscle volume. However, these architectural specializations still did not explain how female *M. terrapin* bite 1071% harder than *T. scripta*. In order to overcome the fracture properties of its highly armored molluscan prey, *M. terrapin* likely generates greater bite force through a different proportion in masticatory versus slow/tonic myosin resulting in much higher specific tension. Specific tension has been shown to vary by bite strategy in *Anolis* (Anderson and Roberts, 2019) but not to the extreme value reached by *M. terrapin.* Specific tension, more than jaw muscle architecture or size, is likely the primary contributor to forceful biting specialization in *M. terrapin.*

The fast and forceful biting strategy did differentiate *C. serpentina* muscle architecture from that of *T. scripta* and *M. terrapin*. *C. serpentina* demonstrated not only a larger relative size, but a large proportion of fibers dedicated to speed. Perhaps unsurprisingly, this translates to a lower PCSA relative to volume in *C. serpentina* than *M. terrapin,* and even slightly lower for its size than *T. scripta*. Yet, unnormalized MAMEPp fiber angles suggest that this portion is more effective at higher gapes than *M. terrapin.* This may indicate diversity in functional optimization to gape since *C. serpentina* may have more contractile force at greater fiber elongations than the other species. In other groups of vertebrates, gape is widely known to affect bite force (e.g., Herring and Herring, 1974; Eng et al., 2009; Williams et al., 2009; Meyers et al., 2018). The differential architecture of MAMEPa in *C. serpentina* compared to other taxa in this analysis resembles the modification of the superficial masseter in common marmosets (Taylor and Vinyard, 2004), but for a different function. The elongated fibers of the superficial masseter in the common marmoset facilitates muscle stretching at large gapes and may allow them to produce exceptional force at wider gapes (Eng et al., 2009). *C. serpentina* feeding does not require especially large gapes, but it does likely require exceptional force production at wider gapes. To effectively catch prey in an aquatic feeding medium, *C. serpentina* does not only have to envelop the prey in its oral cavity, but also close the jaws to prevent escape. This creates a particular requirement to overcome the fluid resistance of water, necessarily increased due to the momentum of the closing jaws. The common snapping turtle must snap close its jaws quickly and against resistance, requiring architectural modifications for both speed -- a large proportion of long MAMEPa fibers -- and force -- total enlargement of the head to increase the volume of the force-specialized muscles, MAMES and MAMEPp -- to capture prey. This analysis has confirmed such architectural specializations in *C. serpentina*, though they are not in the arrangement predicted by either Herrel et al. (2002) or Werneburg (2011). Finally, the probable change in the proportion of masticatory to slow/tonic myosin in the muscle fibers results in a slightly higher specific tension in *C. serpentina* compared to *T. scripta*, but much lower than in *M. terrapin*, likely to increase bite force relative to an unspecialized biting species yet maintain the endurance capabilities necessary for defensive bites.

There is a reliance on the ability to use theoretical bite force calculations to predict feeding strategies, either from dry skulls measurements or even from soft tissue measurements. The analysis presented here demonstrates that, while theoretical bite force models are useful for comparing the biomechanics among species, they are less useful for predicting actual feeding performance without an understanding of the specific tension of the jaw musculature in the organisms being studied. Among just three species, the present study predicts large heterogeneity in specific tension. This variation is non-negligible, making comparisons to real-world fracture forces and *in vivo* measurements uninformative without the ability to predict P_o. This significantly reduces the predictive power of theoretical bite force in turtles until there is a much greater understanding and a much wider sampling of the muscle physiology and/or *in vivo* bite forces relative to PCSA in this group. Still, examinations of theoretical bite force, when discussed in the context of morphological modifications of the oral cavity and pharynx, provide a promising first attempt at investigating changes and variation in turtle feeding behavior. The challenge remains in understanding how well this variation reflects selection pressures on the testudine feeding system throughout evolution when it does not reflect the true performance these animals use to interact with their environment.

Chapter 5: Conclusion

Testudines have a unique *Bauplan* for which multiple morphological shifts were required to adjust to a key innovation: the turtle shell. The evolution of neck retraction constrained turtle skull dimensions, restricting the size of the jaw adductors and resulting in the evolution of the trochlearis system to maintain bite force capabilities (Ferreira et al., 2020). Because of this unique arrangement, I expected the functional morphology of this system to be a major determinant of bite performance and thus to vary in concert with the physical demands of testudine diets.

Indeed, Chapter 2 first appeared to confirm these expectations. Modifications to the trochlearis system demonstrated high correlation with durophagous diets but appear similarly advantageous when the constraint of streamlining for aquatic feeding is released, such as in terrestrial tortoises and semi-aquatic/semi-terrestrial New and Old-World pond turtles. Tortoises apparently have high mechanical advantage in the absence of the demands of an aquatic environment, suggesting that greater mechanical advantage of the jaw adductors are advantageous even without a higher bite performance demand. Thus, there is likely an evolutionary tradeoff between greater mechanical advantage of the external jaw adductor muscle and streamlining of the skull in aquatic environments. Yet, if the functional demands of the diet are strong, as in durophagy, then my results in Chapter 2 suggest that the environmental selective pressure may be overcome. This work is the first to fully and indiscriminately sample 3D testudine skull morphology with auto3DGM, resulting in novel support of previously hypothesized functional characteristics and their strong correlation to the direct pressure of cryptodire diets. Future work should include broader taxonomic sampling, especially outside of

Cryptodira. Additionally, greater refinement of the dietary classification system to discriminate feeding mode in addition to the physical and mechanical properties of testudines diets should garner a clearer picture of cranial features that are influenced by food-jaw contact.

In light of these results, I expected to find vast differences in jaw adductor mechanical advantage between durophagous aquatic turtles and aquatic turtles with non-specialized diets. The results of Chapters 3 and 4 proved this not to be the case. The jaw adductor mechanical advantage of three aquatic turtles with disparate biting strategies, *Malaclemys terrapin*, *Trachemys scripta*, and *Chelydra serpentina*, is generally similar. Indeed, variation was nearly within the standard deviation of mechanical advantage within just the durophagous species, *M. terrapin*. Furthermore, I concluded in Chapter 4 that this variation in mechanical advantage had an extremely small effect on theoretical bite force estimates in turtles. The dual selective pressures of the aquatic environment and sometimes neck retraction, even when the demands of the diet are great, still likely limits the mechanical advantage of this system. Apparently, turtle jaws evolve one exceptional mechanical strategy 250 million years ago and then that was enough of that, though a much broader survey of jaw adductor mechanical advantage in Testudines is a clear future direction of this work.

So, if the mechanics of the trochlearis system is not a likely source of the vast bite performance disparity among turtle species, what is? In Chapter 3, I uncovered that adductor chamber dimensions scale with head size, and that this scaling occurs both intraspecifically and interspecifically, though further ontogenetic work is needed to fully support the growth trajectories in both *T. scripta* and *M. terrapin*, especially measuring

PCSA in more specimens. This scaling relationship differentiates male and female *M. terrapin* jaw adductor muscle size, indicating that ontogenetic trajectories of different lengths favor their respective trophic niches. Indeed, the nine modern species of sea turtle demonstrate similar variation in ontogenetic trajectory, which likely produces their dietary (and functional) disparity. Adults of species with paedomorphic skulls have diets with low functional demands on bite performance, while durophagous species appear to develop features associated with high bite force in an ontogenetic sequence to adulthood (Chatterji et al., 2022).

Thus, it appears that bite force is primarily increased through absolute and relative size of the jaw adductors in turtles. Indeed, this was the variable with the largest effect on bite performance in Chapter 4. Yet this still did not explain how much smaller male *M. terrapin* still bite harder *in vivo* than *T. scripta*. Chapter 3 and Chapter 4 revealed that *M. terrapin* have more muscle fibers with architecture dedicated to forceful biting, yet this still did not explain the advantage of the male *M. terrapin*, who had greatly smaller external mandibular adductor PCSA. As discovered in Chapter 4, there appears to be significant adaptation to durophagy in the fiber phenotype, giving *M. terrapin* an extremely high whole muscle specific tension value. The majority of the fibers in jaw musculature of *M. terrapin* are likely to have a high proportion of masticatory myosin relative to those in *T. scripta*. The high specific tension of the jaw adductor in *M. terrapin* explains their much greater bite force relative to size as compared to *T. scripta*, which is enhanced in the females through a longer ontogenetic trajectory to achieve relatively large jaw adductor volumes.

This pattern is likely repeated in *C. serpentina*, but with an additional feeding specialization: speed of jaw closure. As reported in Chapter 4, *C. serpentina* possesses a large proportion of long muscle fibers, located in the architecturally distinct anterior region of the profundus portion the external mandibular adductor. The heterogeneity gives this species its characteristically high velocity snapping bite, allowing capture of elusive prey after the feeding strike. Yet, this fast closing must occur against water pressure during feeding, so *C. serpentina* must also produce a forceful bite. This is achieved, once again, through ontogenetic scaling to achieve relatively greater mass in regions architecturally dedicated to forceful jaw closing (which may also be more efficient at larger gapes than *M. terrapin*). Both priorities may not be able to be met within the space confines of the turtle shell aperture, therefore providing a likely functional basis for the megacephaly and subsequent loss of full neck retraction in *C. serpentina*. Indeed, the hardest biting turtle species tend to be both large and incapable of neck retraction. Considering the calculated specific tension of *C. serpentina* was middling between *T. scripta* and *M. terrapin*, I would not be surprised if the specific tension of the force-dedicated portions is similar to that of *M. terrapin*, while the speed-dedicated portions are much lower in contractile force ability, and possibly even containing a faster fiber phenotype.

The results of Chapter 4 demonstrate that, in spite of strong selective pressures to maintain a streamlined skull and neck retraction, aquatic turtles have a considerable ability to manipulate bite performance through intramuscular specialization of fiber lengths and contractile properties. This work is the first to describe and compare jaw muscle morphology, architecture, leverage, and theoretical bite force interspecifically.

My results provide a strong motivator for future work identifying turtle jaw musculature fiber types and contractile properties.

Interestingly, released from the constraints of the aquatic environment, tortoises may achieve both gigantism (Ernst and Barbour, 1989) and apparently high mechanical advantage of their primary jaw adductors, suggestive of high bite forces in the pattern of the aquatic species examined in this dissertation. Yet tortoises consume tough, but not well-defended food items, have jaw joints with greater anterior-posterior mobility, and possess relatively reduced posterior adductor chambers, all suggestive of poor biting performance, though no large species have published *in vivo* bite forces. In light of this mystery, future work should also include much broader taxonomic sampling to describe the full extent of jaw adductor architectural variation and constituent fiber phenotypes in the context of feeding behavior and habitat.

Finally, this dissertation identified a few key areas worthy of further exploration in the feeding apparatus of this functionally and ecological diverse group: the effect of jaw joint mobility in Testudinidae and its correlation with the apparent greater mechanical advantage of the jaw adductor and the ossification of the sesamoid in the trochlearis system, especially in the context of the bite performance of tortoises; the variation of jaw muscle fiber phenotypes and its correlation to the variation in bite performance evident from the dietary diversity of the group; and the repeatability and/or diversity of jaw adductor architecture and relative scaling in relation to feeding behaviors. The ultimate goal of this dissertation was to describe and quantify the interactions within the sequence of morphology, function, and performance in the feeding apparatus of Testudines. This dissertation discovered novel morphologies correlated to feeding behavior and biting strategy, explored their functional consequences and evaluated their effects on performance. Still, sample size and taxonomic scope were major limitations of these works. Therefore, determining the role of these traits in the predictability and repeatability of evolutionary change in the face of lineage diversification remains to be assessed by a much larger taxonomic sample.

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Appendix A

Appendix Table A-1: Specimen Details and Scan Parameters

Specimen Number	Species	Sex	Age	Locality	Collector	Scan Type	Scanning Facility	Technician	Year	kV	uA	Exposure	Resolution	Rotation Step	µm	Chapter
CM 105814	*Kinosternon scorpioides*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	44.7	**2**
CM 107465	*Mauremys reevesii*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	2240	0.3	34.1	**2**
CM 108721	*Chelonoidis carbonaria*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	63.2	**2**
CM 108723	*Chelonoidis denticulata*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem	Jasmine Croghan	2017	65	123	1000	1120	0.3	63.2	**2**

							Bioimaging Center									
CM 117798	*Dermatemys mawii*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 118578	*Graptemys versa*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 118600	*Siebenrockiella crassicolis*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	58.2	**2**
CM 119164	*Carettochelys insculpta*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	58.2	**2**
CM 124275	*Graptemys pseudogeographica*		Adult			Skeletal	University of Washington	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**

							Friday Harbor Labs Karel F. Liem Bioimaging Center									
CM 159430	*Kinosternon subrubrum*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	64.6	**2**
CM 159431	*Kinosternon flavescens*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	64.6	**2**
CM 26405	*Lissemys punctata*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 33423	*Lepidochelys kempii*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**

							Bioimaging Center									
CM 35621	*Graptemys geographica*	F	Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	63.2	**2**
CM 37754	*Gopherus berlandieri*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	56.1	**2**
CM 58898	*Sternotherus minor*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	44.7	**2**
CM 60424	*Sternotherus carinatus*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 60987	*Deirochelys reticularia*		Adult			Skeletal	University of Washington	Jasmine Croghan	2017	65	123	1000	1120	0.3	58.2	**2**

							Friday Harbor Labs Karel F. Liem Bioimaging Center									
CM 66395	*Mauremys sinensis*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	44.7	**2**
CM 84699	*Graptemys ouachitensis*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 88508	*Apalone spinifera*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**
CM 91075	*Staurotypus triporcatus*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem	Jasmine Croghan	2017	65	123	1000	1120	0.3	49.7	**2**

							Bioimaging Center									
CM 91284	*Gopherus agassizii*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	56.1	**2**
CM 96223	*Emydoidea blandingii*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	56.1	**2**
CM 96325	*Kinosternon sonoriense*		Adult			Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	1120	0.3	44.7	**2**
OUVC 10861	*Stigmochelys pardalis*		Adult	Captive	Steve O'Reilly	Skeletal	Ohio University µCT	Ryan Ridgely	2016						96.7559	**2**
OUVC 10864	*Terrapene carolina*		Adult			Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37793	**2**
OUVC 10865	*Sternotherus odoratus*		Adult			Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.3779	**2**
PCHP ? Digimorph A1060	*Chrysemys picta*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		45	**2**

PCHP 2022	*Emys orbicularis*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		55	**2**
PCHP 2746	*Apalone mutica*		Adult			Skeletal	Digimorph	Matthew Colbert	2004						93.6	**2**
PCHP 2929	*Agrionemys horsfieldii*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		55	**2**
PCHP 3358	*Platysternon megacephalum*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		145	**2**
PCHP 4559	*Trionyx triunguis*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		145	**2**
PCHP 5077	*Cuora amboinensis*		Adult			Skeletal	Digimorph	Matthew Colbert	2004						68	**2**
PCHP 7667	*Gopherus polyphemus*		Adult			Skeletal	Digimorph	Matthew Colbert	2004				1024		72.3	**2**
UF 22159	*Chelydra serpentina*		Adult	Alachua County, Florida	J.M. Pylka	Skeletal	Digimorph	Matthew Colbert	2004				1024		246	**2**
UF 85274	*Glyptemys muhlenbergii*		Adult			Skeletal	Digimorph	Matthew Colbert	2003						53.9	**2**
OUVC 10872	*Trachemys scripta*	M	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 9	**3**
OUVC 10873	*Trachemys scripta*	M	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 8	**3**
OUVC 10874	*Trachemys scripta*	M	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 86	**3**
OUVC 10875	*Trachemys scripta*	F	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 78	**3**
OUVC 10876	*Trachemys scripta*	F	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 98	**3**
OUVC 10877	*Trachemys scripta*	F	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 82	**3**
OUVC 10879	*Trachemys scripta*	F	Adult	Louisiana , USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.37 8	**3**

OUVC 10880	*Trachemys scripta*	F	Adult	Louisiana, USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.3787	**3**
OUVC 10933	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**
OUVC 10936	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**
OUVC 10940	*Malaclemys terrapin*	M	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.3	65	**3**
OUVC 10943	*Malaclemys terrapin*	M	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.3	65	**3**
OUVC 10947	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**

							Washington Friday Harbor Labs Karel F. Liem Bioimaging Center									
OUVC 10949	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**
OUVC 10952	*Malaclemys terrapin*	M	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.3	65	**3**
OUVC 10955	*Malaclemys terrapin*	M	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.3	65	**3**
OUVC 10957	*Malaclemys terrapin*	M	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem	Jasmine Croghan	2017	65	123	290	1120	0.3	65	**3**

							Bioimaging Center								
OUVC 10966	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**
OUVC 10968	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	290	1120	0.25	50	**3**
OUVC 10874	*Trachemys scripta*	M	Adult	Louisiana, USA	Ward's Scientific	diceCT	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	80	90	1000	2240	0.3	24.8	**3**
OUVC 10867	*Chelydra serpentina*	M	Adult	Athens, Ohio	Catherine Early	Skeletal	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	65	123	1000	2240	0.3	50.002063	**4**
OUVC 10867	*Chelydra serpentina*	M	Adult	Athens, Ohio	Catherine Early	diceCT	University of Arkansas MicroCT	Manon Wilson	2018	210	390	1000	2000		50.0018921	**4**

							Imaging Consortium for Research and Outreach									
OUVC 10866	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.378	**2; 3; 4**
OUVC 10881	*Trachemys scripta*	F	Adult	Louisiana, USA	Ward's Scientific	Skeletal	Ohio University µCT	Ryan Ridgely	2016						48.378	**2; 3; 4**
USNM 574916	*Malaclemys terrapin*	M	Adult	Maryland		Skeletal	Ohio University µCT	Ryan Ridgely	2018	120	32	NA	NA	0.3	49.3	**3; 4**
OUVC 10866	*Malaclemys terrapin*	F	Adult	Maryland	Willem Roosenburg	diceCT	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	80	90	1015	2240	0.3	35	**3; 4**
OUVC 10873	*Trachemys scripta*	M	Adult	Louisiana, USA	Ward's Scientific	diceCT	University of Washington Friday Harbor Labs Karel F. Liem Bioimaging Center	Jasmine Croghan	2017	80	90	1000	2240	0.3	28	**3; 4**
OUVC 10881	*Trachemys scripta*	F	Adult	Louisiana, USA	Ward's Scientific	diceCT	University of Washington Friday Harbor Labs Karel F. Liem	Jasmine Croghan	2017	80	90	1000	2240	0.3	24.8	**3; 4**

							Bioimaging Center									
USNM 574916	*Malaclemys terrapin*	M	Adult	Maryland		diceCT	Ohio University µCT	Ryan Ridgely	2018	12 0	32				24.7	**3; 4**

Appendix B

Appendix Table B-1: Final compiled diet data proportions used in Chapter 2 Analyses
1=Coarse Vegetation; 2=Resistant Vegetation; 3=Soft Vegetation; 4=Swallow Vegetation; 5=Swallow Animal; 6=Particle Size Reduction Animal; 7=Comminuted Animal; 8=Forceful Crushing Animal

Species_SpecimenNumber	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Agrionemys_horsfieldii_Digimorph2929	0	100	0	0	0	0	0	0
Apalone_mutica_Digimorph2746	0	0	0	13	20	42	18	6
Apalone_spinifera_CM88508	0	1	0	18	19	24	37	1
Carettochelys_insculpta_CM119164	0	38	54	0	0	1	6	0
Chelonoidis_carbonaria_CM108721	3	23	73	0	0	0	1	0
Chelonoidis_denticulata_CM108723	2	24	69	0	2	0	2	0
Chelydra_serpentina_UF22159	0	17	0	22	8	19	33	1
Chrysemys_picta_DigimorphA1060	0	12	0	12	29	40	3	5
Cuora_amboinensis_Digimorph5077	78	13	2	6	0	0	0	0
Deirochelys_reticularia_CM60987	10	14	0	0	24	50	2	0
Dermatemys_mawii_CM117798	72	21	0	7	0	0	0	0
Emydoidea_blandingii_CM96223	1	2	0	4	6	56	13	19
Emys_orbicularis_DigimorphA1056b	0	8	0	0	13	46	18	15
Glyptemys_muhlenbergii_UF85274	0	36	26	0	0	37	0	1
Gopherus_agassizii_CM91284	63	37	0	0	0	0	0	0
Gopherus_berlandieri_CM37754	30	65	0	0	6	0	0	0
Gopherus_polyphemus_Digimorph7667	58	41	2	0	0	0	0	0
Graptemys _versa_CM118578	0	1	1	5	11	40	4	38
Graptemys_geographica_F_CM35621	0	1	0	0	14	18	7	61
Graptemys_ouachitensis_CM84699	5	23	0	9	18	25	19	3
Graptemys_pseudogeographica_CM124275	0	42	0	0	23	3	12	19
Kinosternon_flavescens_CM159431	0	4	0	0	1	32	10	53
Kinosternon_scorpioides_CM105814	12	15	0	8	9	50	2	4
Kinosternon_sonoriense_CM96325	0	8	0	10	7	55	7	12
Kinosternon_subrubrum_CM159431	0	22	0	0	0	32	14	32
Lepidochelys_kempii_CM33423	0	0	0	0	0	0	1	98
Lissemys_punctata_CM26405	0	0	0	0	0	17	36	47
Malaclemys_terrapin_OUVC10866	0	0	0	2	0	7	0	90
Mauremys_reevesii_CM107465	0	0	1	22	7	0	3	67
Mauremys_sinensis_CM66395	14	49	0	1	23	3	5	4
Platysternon_megacephalum_Digimorph3358	0	17	33	0	0	18	19	13
Siebenrockiella_crassicolis_CM118600	9	52	7	27	1	0	1	2
Staurotypus_triporcatus_CM91075	0	0	0	0	4	0	2	94
Sternotherus_carinatus_CM60424	0	10	0	22	4	18	12	35
Sternotherus_minor_CM58898	0	8	0	1	24	25	1	41
Sternotherus_odoratus_OUVC10865	0	9	4	2	6	36	6	36
Stigmochelys_pardalis_OUVC10861	46	53	0	0	1	1	0	0
Terrapene_carolina_OUVC10864	9	24	0	0	0	20	9	38
Trachemys_scripta_f_OUVC10881	10	16	4	16	11	20	13	9
Trionyx_triunguis_Digimorph	0	3	0	5	18	14	51	8
Total count in each column	**423**	**808**	**277**	**213**	**309**	**748**	**371**	**852**

ID	Species	Reference	Locality	Time of Year	Data Type	Sample Size	Demography	Type	Units	Used	Notes	Page Reference
2	*Phrynops geoffroanus*	Souza, F. L., & Abe, A. S. (2000). Feeding ecology , density and biomass of the freshwater turtle , Phrynops geoffroanus , inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology, 252(4), 437–446.	in RibeiraÄo Preto city, SaÄo Paulo state, south-eastern Brazil.	All seasons	Stomach flushing	30	Male	% volume	%			
3	*Phrynops geoffroanus*	Souza, F. L., & Abe, A. S. (2000). Feeding ecology , density and biomass of the freshwater turtle , Phrynops geoffroanus , inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology, 252(4), 437–446.	in RibeiraÄo Preto city, SaÄo Paulo state, south-eastern Brazil.	All seasons	Stomach flushing	19	Female	% volume	%			
4	*Phrynops geoffroanus*	Souza, F. L., & Abe, A. S. (2000). Feeding ecology , density and biomass of the freshwater turtle , Phrynops geoffroanus , inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology, 252(4), 437–446.	in RibeiraÄo Preto city, SaÄo Paulo state, south-eastern Brazil.	All seasons	Stomach flushing	8	Juvenile	% volume	%			
5	*Carettochelys insculpta*	Georges, A., & Kennett, R. (1989). Dry-season Distribution and Ecology of Carettochelys insculpta (Chelonia :	Kakadu National Park, Northern Australia	Dry season	Stomach flushing	24	Mix	% weight	%			

		Carettochelydidae) in Kakadu National Park, Northern Australia. Australia Wildlife Research, 16, 323–335. http://doi.org/10.1071/WR9890323										
6	*Malaclemys terrapin*	Herrel, A., Petrochic, S., & Draud, M. (2017). Sexual dimorphism, bite force and diet in the diamondback terrapin. Journal of Zoology. http://doi.org/10.1111/jzo.12520	Mill Neck Crek or Center Island Beach (Long Island, NY)	May 15-September 28	Fecal samples	37	Large Females	% weight	%	1		
7	*Malaclemys terrapin*	Herrel, A., Petrochic, S., & Draud, M. (2017). Sexual dimorphism, bite force and diet in the diamondback terrapin. Journal of Zoology. http://doi.org/10.1111/jzo.12520	Mill Neck Crek or Center Island Beach (Long Island, NY)	May 15-September 28	Fecal samples	14	Medium Females	% weight	%	1		
8	*Malaclemys terrapin*	Herrel, A., Petrochic, S., & Draud, M. (2017). Sexual dimorphism, bite force and diet in the diamondback terrapin. Journal of Zoology. http://doi.org/10.1111/jzo.12520	Mill Neck Crek or Center Island Beach (Long Island, NY)	May 15-September 28	Fecal samples	11	Small Females	% weight	%	1		
9	*Malaclemys terrapin*	Herrel, A., Petrochic, S., & Draud, M. (2017). Sexual dimorphism, bite force and diet in the diamondback terrapin. Journal of Zoology.	Mill Neck Crek or Center Island Beach (Long Island, NY)	May 15-September 28	Fecal samples	37	Males	% weight	%	1		

		http://doi.org/10.1111/jzo.12520										
10	*Elseya albagula*	Armstrong, G., & Booth, D. T. (2005). Dietary ecology of the Australian freshwater turtle (Elseya sp.: Chelonia: Chelidae) in the Burnett River, Queensland. Australian Wildlife Research, 32, 349–353. Retrieved from papers3://publication/uuid/272ED325-2F11-404B-816D-74F90860E969	Burnett River, Queensland	September 2002-January 2004	Stomach flushing	22	Males	IRI	n/a	1	Was Elseya dentata until 2006 and has very similar diet	
11	*Elseya albagula*	Armstrong, G., & Booth, D. T. (2005). Dietary ecology of the Australian freshwater turtle (Elseya sp.: Chelonia: Chelidae) in the Burnett River, Queensland. Australian Wildlife Research, 32, 349–353. Retrieved from papers3://publication/uuid/272ED325-2F11-404B-816D-74F90860E969	Burnett River, Queensland	September 2002-January 2004	Stomach flushing	25	Females	IRI	n/a	1	Was Elseya dentata until 2006 and has very similar diet	
12	*Stigmochelys pardalis*	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife …, 23(3), 63–70. Retrieved from	Cape Province, South Africa	September-April 1987-1988	Observed bites			% use	%	1	Use is expressed as the number of bites of a species divided by the total number of bites taken of all species	Table 1

		http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1								multiplied by 100 to give relative percentage use	
13	*Psammobates oculiJer*	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife …, 23(3), 63–70. Retrieved from http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1	Cape Province, South Africa	September -April 1987-1988	Observed bites			% use	%		Use is expressed as the number of bites of a species divided by the total number of bites taken of all species multiplied by 100 to give relative percentage use	Table 4
14	*Stigmochelys pardalis*	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife …, 23(3), 63–70. Retrieved from http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1	Cape Province, South Africa	September -April 1988-1989	Observed bites			% use	%	1	Use is expressed as the number of bites of a species divided by the total number of bites taken of all species multiplied by 100 to give relative percentage use	Table 2
15	*Psammobates oculiJer*	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African	Cape Province, South Africa	September -April	Observed bites			% use	%		Use is expressed as the number of	Table 3

		tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife, 23(3), 63–70. Retrieved from http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1		1988-1989							bites of a species divided by the total number of bites taken of all species multiplied by 100 to give relative percentage use	
16	*Stigmochelys paradalis*	Milton, S. J. (1992). Plants Eaten and Dispersed by Adult Leopard Tortoises Geochelone-Pardalis (Reptilia, Chelonii) in the Southern Karoo. South African Journal Of Zoology, 27(2), 45–49.	Karoo, South Africa	All seasons	Fecal samples	51		Raw abundance	raw counts	1	"Total incidence" as counted by dissecteng fecal samples under a microscope. Assumed to be raw abundances, though % volume grass, forbs, woody material expressed in text	'total incidence'
17	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97.	Tonacito, Estado de Mexico	Dry season	Stomach flushing and Fecal samples	12	Males	% abundance	%		Also included frequency of occurrence, percent of numeric frequency, and index of relative importance for female, male, and	use %N in Table 1

		http://doi.org/10.2744/CCB-0782.1									immature; "numeric frequency" = percentage of each item in each diet category in relation to the total number of categories across all samples	
18	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1	Tonacito, Estado de Mexico	Dry season	Stomach flushing and Fecal samples	8	Females	% abundance	%		Also included frequency of occurrence, percent of numeric frequency, and index of relative importance for female, male, and immature; "numeric frequency" = percentage of each item in each diet category in relation to the total number of categories across all samples	
19	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010).	Tonacito, Estado de Mexico	Dry season	Stomach flushing and Fecal samples	5	Immature	% abundance	%		Also included frequency of occurrence,	

		Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1									percent of numeric frequency, and index of relative importance for female, male, and immature; "numeric frequency" = percentage of each item in each diet category in relation to the total number of categories across all samples	
20	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1	Tonacito, Estado de Mexico	Rainy season	Stomach flushing and Fecal samples	10	Males	% abundance	%		Also included frequency of occurrence, percent of numeric frequency, and index of relative importance for female, male, and immature; "numeric frequency" = percentage of each item in each diet category in relation to the total number of	

											categories across all samples	
21	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1	Tonacito, Estado de Mexico	Rainy season	Stomach flushing and Fecal samples	5	Females	% abundance	%		Also included frequency of occurrence, percent of numeric frequency, and index of relative importance for female, male, and immature; "numeric frequency" = percentage of each item in each diet category in relation to the total number of categories across all samples	
22	*Kinosternon integrum*	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1	Tonacito, Estado de Mexico	Rainy season	Stomach flushing and Fecal samples	14	Immature	% abundance	%		Also included frequency of occurrence, percent of numeric frequency, and index of relative importance for female, male, and immature; "numeric frequency"	

											= percentage of each item in each diet category in relation to the total number of categories across all samples	
23	*Mauremys reevesii*	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	Seomjin and Nam rivers, South Korea	June-September 2009	Stomach flushing	3	Males	Raw abundance	raw counts	1		Add all of the data for each sub group
24	*Mauremys reevesii*	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	Seomjin and Nam rivers, South Korea	June-September 2009	Fecal samples	2	Males	Raw abundance	raw counts	1		
25	*Mauremys reevesii*	Lee, H.-J., & Park, D. (2010). Distribution, habitat	Seomjin and Nam rivers,	June-September 2009	Stomach flushing	3	Females	Raw abundance	raw counts	1		

		characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	South Korea									
26	*Trachemys scripta elegans*	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	Seomjin and Nam rivers, South Korea	June-September 2009	Stomach flushing	3	Males	Raw abundance	raw counts	1		
27	*Trachemys scripta elegans*	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	Seomjin and Nam rivers, South Korea	June-September 2009	Stomach flushing	2	Females	Raw abundance	raw counts	1		

28	*Rhinoclemmys annulata*	Moll, D., & Jansen, K. P. (1995). Evidence for a role in seed dispersal by two tropical herbivorous turtles. Biotropica, 27(1), 121–127.	Tortuguero National Park, NE Costa Rica	May-June 1990, February-April 1991, June-July 1992	Stomach flushing	12	Adult (8 male, 4 female)	% volume	%			Table 3.
29	*Peltocephalus dumerilianus*	Pérez-Emán, J. L., & O, A. P. (1997). Diet of the pelomedusid turtle Peltocephalus dumerilianus in the Venezuelan Amazon. Journal of Herpetology, 31(2), 173–179.	Yagua riverand Atacavi river, Amazonas State, Venezuela		Stomach flushing	23	All demographics	% volume	%		Also includes a breakdown of data with coarser categories into male, female, and fife size classes, but only as raw occurence and frequency of occurence. Much more detailed breakdown in raw occurence and a variety of non-measured techniques (interviews, etc)	Percentage volume from Table 4
31	*Elseya albagula*	Armstrong, G., & Booth, D. T. (2005). Dietary ecology of the Australian freshwater turtle (Elseya sp.: Chelonia: Chelidae) in the Burnett River, Queensland. Australian Wildlife	Burnett River, Queensland	September 2002-January 2004	Fecal samples	21	Adult	IRI	n/a	1	Was Elseya dentata until 2006 and has very similar diet	

		Research, 32, 349–353. Retrieved from papers3://publication/uuid/272ED325-2F11-404B-816D-74F90860E969										
32	*Graptemys geographica*	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.	Mississippi River, 5 km south of LaCrosse, Wisconsin (T14N R7W)	30th of May-2nd of September, 1972, 1974	Dissected stomach contents	21	All demographics	% volume	%	1	Also includes % frequency of occurence; stated that 38 males of all species were examined and all found to be carnivorous	Estimate base on the bar graph in Fig. 1
33	*Graptemys pseudogeographica*	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.	Mississippi River, 5 km south of LaCrosse, Wisconsin (T14N R7W)	30th of May-2nd of September, 1972, 1975	Dissected stomach contents	38	All demographics	% volume	%	1	Also includes % frequency of occurence; stated that 38 males of all species were examined and all found to be carnivorous	
34	*Graptemys ouachitensis*	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.	Mississippi River, 5 km south of LaCrosse, Wisconsin (T14N R7W)	30th of May-2nd of September, 1972, 1976	Dissected stomach contents	54	All demographics	% volume	%	1	Also includes % frequency of occurence; stated that 38 males of all species were examined and all found to be carnivorous	

35	*Trachemys scripta elegans*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Portil Pond, Southern Spain	April-August 2003	Dissected stomach contents combined with fecal contents	12	Adults	% volume	%	1	Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 1
36	*Trachemys scripta elegans*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Portil Pond, Southern Spain	April-August 2003	Dissected stomach contents combined with fecal contents	6	Juveniles	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 1
37	*Trachemys scripta elegans*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C.	El Acebuche Pond,	April-August 2003	Dissected stomach contents combined	8	Adults	% volume	%	1	Also inludes % frequency of	Table 1

		(2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	Southern Spain		with fecal contents						occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	
38	*Trachemys scripta elegans*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Acebuche Pond, Southern Spain	April-August 2003	Dissected stomach contents combined with fecal contents	6	Juveniles	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 1
39	*Mauremys leprosa*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for	El Portil Pond, Southern Spain	April-August 2003	Fecal samples	16	Adults	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach	Table 2

		food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.									(dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	
40	*Mauremys leprosa*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Portil Pond, Southern Spain	April-August 2003	Fecal samples	5	Juveniles	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 2
41	*Mauremys leprosa*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad.	El Acebuche Pond, Southern Spain	April-August 2003	Fecal samples	15	Adults	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture	Table 2

		Amphibia-Reptilia, 32(2), 167–175.									capture) and fecal contents after finding no significant difference between them.	
42	*Mauremys leprosa*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Acebuche Pond, Southern Spain	April-August 2003	Fecal samples	6	Juveniles	% volume	%		Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 2
43	*Emys orbicularis*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Portil Pond, Southern Spain	April-August 2003	Fecal samples	2	Adults	% volume	%	1	Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after	Table 3

											finding no significant difference between them.	
44	*Emys orbicularis*	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	El Acebuche Pond, Southern Spain	April-August 2003	Fecal samples	18	Adults	% volume	%	1	Also inludes % frequency of occurance and IRI; combined stomach (dissected contents a few days after capture) and fecal contents after finding no significant difference between them.	Table 3
45	*Trachemys scripta*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	8	Males	% volume	%	1		Table 1 (after references), use the values in parentheses (#)
46	*Trachemys scripta*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois.	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	13	Females	% volume	%	1		Table 1 (after references), use the values in parentheses (#)

		Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.										
47	*Trachemys scripta*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	6	Juveniles	% volume	%			Table 1 (after references), use the values in parentheses (#)
48	*Pseudemys concinna*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	4	Males	% volume	%	1		Table 2 (after references), use the values in brackets [#] -
49	*Pseudemys concinna*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	6	Females	% volume	%	1		Table 2 (after references), use the values in brackets [#].
50	*Pseudemys concinna*	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys	Round Pond, Gallatin County, Illinois, USA	Summers of 1994-1995	Fecal Contents	6	Juveniles	% volume	%			Table 2 (after references), use the

		concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.										values in brackets
51	*Hydromedusa tectifera*	Alcalde, L., Derocco, N. N., & Rosset, S. D. (2010). Feeding in Syntopy: Diet of Hydromedusa tectifera and Phrynops hilarii (Chelidae). Chelonian Conservation and Biology, 9(1), 33–44. http://doi.org/10.2744/CCB-0794.1	Arroyo Bunirigo, Buenos Aires Province, Argentina	December 2006-November 2008	Stomach flushing	25	Adults	% volume	%		Also includes numeric frequency, occurance frequency, as well as ranking of food items by relative importance	Table 1 (use the column %TV)
52	*Phrynops hilarii*	Alcalde, L., Derocco, N. N., & Rosset, S. D. (2010). Feeding in Syntopy: Diet of Hydromedusa tectifera and Phrynops hilarii (Chelidae). Chelonian Conservation and Biology, 9(1), 33–44. http://doi.org/10.2744/CCB-0794.1	Arroyo Bunirigo, Buenos Aires Province, Argentina	December 2006-November 2008	Stomach flushing	64	All demographics	% volume	%		Also includes numeric frequency, occurance frequency, as well as ranking of food items by relative importance	Table 1 (use the column %TV)
53	*Emydura krefftii*	Trembath, D. F. (2005). The comparative ecology of Krefft's River Turtle Emydura krefftii in Tropical North Queensland, MSc Thesis	Ross River, North Queensland Australia	Februrary-April, 2005	Stomach flushing	30	Males	% volume	%			Page 58 in text, (2nd paragraph listed under percentage amount)
54	*Emydura krefftii*	Trembath, D. F. (2005). The comparative ecology of Krefft's River Turtle Emydura krefftii in Tropical	Ross River, North Queensland Australia	Februrary-April, 2005	Stomach flushing	30	Females	% volume	%			Page 58 in text, (3rd paragraph listed under

		North Queensland, MSc Thesis										percentage amount)
55	*Emydura krefftii*	Trembath, D. F. (2005). The comparative ecology of Krefft's River Turtle Emydura krefftii in Tropical North Queensland, MSc Thesis	Townsville Creeks, North Queensland Australia	Februrary-April, 2005	Stomach flushing	35	Males	% volume	%			Page 62 in text, (2nd paragraph listed under percentage amount).
56	*Emydura krefftii*	Trembath, D. F. (2005). The comparative ecology of Krefft's River Turtle Emydura krefftii in Tropical North Queensland, MSc Thesis	Townsville Creeks, North Queensland Australia	Februrary-April, 2005	Stomach flushing	32	Females	% volume	%			Page 62 in text, (3rd paragraph listed under percentage amount).
57	*Graptemys geographica*	Richards-Dimitrie, T., Gresens, S. E., Smith, S. A., & Seigel, R. A. (2013). Diet of Northern Map Turtles (Graptemys geographica): Sexual Differences and Potential Impacts of an Altered River System. Copeia, 3(3), 477–484. http://doi.org/10.1643/CE-12-043	Susquehanna River, Maryland, USA	May-September of 2009 and 2010	Fecal Contents	20	Males	Mean % volume	%	1	Also includes % frequency	Table 2 % V
58	*Graptemys geographica*	Richards-Dimitrie, T., Gresens, S. E., Smith, S. A., & Seigel, R. A. (2013). Diet of Northern Map Turtles (Graptemys geographica): Sexual Differences and Potential Impacts of an Altered River System. Copeia, 3(3), 477–484. http://doi.org/10.1643/CE-12-043	Susquehanna River, Maryland, USA	May-September of 2009 and 2010	Fecal Contents	21	Females	Mean % volume	%	1	Also includes % frequency	Table 2 %V

59	*Emys orbicularis*	Ottonello, Dario; Salvidio, Sebastiano; Rosecchi, E. (2005). Feeding habits of the European pond terrapin Emys orbicularis in Camargue (Rhône delta, Southern France). Amphibia-Reptilia, 26(4), 562–565. http://doi.org/10.1163/156853805774806241	Tour du Valat estate, Camargue, Franche	April-August 2003	Fecal Contents	27	Adults	% Abundance	%	1	Also includes % frequency	Table 1 %A
60	*Emys orbicularis*	Ottonello, Dario; Salvidio, Sebastiano; Rosecchi, E. (2005). Feeding habits of the European pond terrapin Emys orbicularis in Camargue (Rhône delta, Southern France). Amphibia-Reptilia, 26(4), 562–565. http://doi.org/10.1163/156853805774806241		April-August 2003	Fecal Contents	4	Juveniles	% Abundance	%		Also includes % frequency	Table 1 %A
61	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Belize River, Belize		Stomach flushing	82	Adults	% volume	%	1	Also includes % frequency	Table 1 % vol
62	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Progresso Lagoon, Belize		Stomach flushing	58	Adults	% volume	%	1	Also includes % frequency	Table 1 % vol

63	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Rio Grande Estuary, Belize		Stomach flushing	24	Adults	% volume	%	1	Also includes % frequency	Table 1 % vol
64	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Belize River, Belize		Stomach flushing	28	Juveniles	% volume	%		Also includes % frequency	Table 2 % vol
65	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Progresso Lagoon, Belize		Stomach flushing	26	Juveniles	% volume	%		Also includes % frequency	Table 2 % vol
66	*Dermatemys mawei*	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	Rio Grande Estuary, Belize		Stomach flushing	16	Juveniles	% volume	%		Also includes % frequency	Table 2 % vol
67	*Chelodina rugosa*	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.	Adelaide River or Knuckey's Lagoon, Darwin, Northwest Territory, Australia	Wet Season (February) 1990	Stomach flushing	18	Adults	% mass	%		Also includes % frequency & % Abundance	Table 1 Mass(%) W
68	*Chelodina rugosa*	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the	Adelaide River or Knuckey's Lagoon, Darwin, Northwest	Dry Season (August-October) of 1991	Stomach flushing	41	Adults	% mass	%		Also includes % frequency & % Abundance	Table 1 Mass(%) D

		Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.	Territory, Australia									
69	*Elseya dentata*	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.	Douglas River, Northern Territory, Australia	Wet Season (March) of 1991	Stomach flushing	32	Adults	% mass	%		Also includes % frequency	Table 2 Mass(%) W
70	*Elseya dentata*	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.	Douglas River, Northern Territory, Australia	Dry Season (Septembe r) of 1991	Stomach flushing	34	Adults	% mass	%		Also includes % frequency	Table 2 Mass(%) D
71	*Emydura krefftii*	Georges, A. (1982). Diet of the Australian freshwater turtle Emydura krefftii (Chelonia: Chelidae) in an unproductive lentic environment. Copeia, 1982(2), 331–336.	Lake Coomboo, Fraser Island, Australia	September , 1978- may 1979	Stomach flushing	81	Adults	% volume	%		Also includes % abundance and % occurence; separates by sex and season but only in pie charts	Table 1 Percentage by volume
72	*Emydura krefftii*	Wilson, M., & Lawler, I. R. (2008). Diet and digestive performance of an urban population of the omnivorous freshwater turtle (Emydura krefftii) from Ross River, Queensland.	Ross River, NE Australia	September -October 2006	Stomach flushing	18	Adults	IRI	n/a		Separates by section on the river, examining importance of public-fed bread on diet.	Table 1

		Australian Journal of Zoology, 56(3), 151–157. http://doi.org/10.1071/ZO08007										
73	*Chelodina burrungandjii*	FitzSimmons, N. N., Featherston, P., & Tucker, A. D. (2015). Comparative dietary ecology of turtles (Chelodina burrungandjii and Emydura victoriae) across the Kimberley Plateau, Western Australia, prior to the arrival of cane toads. Marine and Freshwater Research. Retrieved from http://dx.doi.org/10.1071/MF15199	Kimberley Plateau, Western Australia	Dry seasons 2002-2008	Stomach flushing	155	All demographics	IRI	n/a		Kept separate demographics but did not present data as such	Table 1
74	*Emydura victoriae*	FitzSimmons, N. N., Featherston, P., & Tucker, A. D. (2015). Comparative dietary ecology of turtles (Chelodina burrungandjii and Emydura victoriae) across the Kimberley Plateau, Western Australia, prior to the arrival of cane toads. Marine and Freshwater Research. Retrieved from http://dx.doi.org/10.1071/MF15199	Kimberley Plateau, Western Australia	Dry seasons 2002-2008	Stomach flushing	390	All demographics	IRI	n/a		Kept separate demographics but did not present data as such	Table 1
75	*Chelydra serpentina osceola*	Punzo, F. (1975). Studies on the feeding behavior , diet , nesting habits and temperature telationships of Chelydra serpentina	Sarasota County, Florida, USA	May-October, 1970	Dissected gastrointestinal tract contents	59	34 male and 25 female	Raw abundance	raw counts	1	Male and female data lumped in paper; data also available % frequency	Table 2 N

		osceola (Chelonia : Chelydridae). Journal of Herpetology, 9(2), 207–210. Retrieved from http://www.jstor.org/stable/1563038								of occurrence	
76	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Wintergreen, Sherman, and East Twin Lakes plus 67 more, fish hatcheries, 17 streams in Michigan	May-September 1937-1938	Dissected Stomachs	173	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; less granular whole sample data from this paper; % frequency of occurence also available	Table 4 Composition by Volume
77	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Wintergreen, Sherman, and East Twin Lakes plus 67 more, fish hatcheries, 17 streams in Michigan	May-September 1937-1939	Dissected Colons	261	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; less granular whole sample data from this paper; % frequency of occurence also available	Table 4 Composition by Volume
78	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of	Fish Hatcheries, Michigan	May-September	Dissected Stomachs	18	Adults (presumed)	% volume	%	1	Some raw abundances as well as species	Table 3 Composition by Volume

		Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist		1937-1940							identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	
79	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Fish Hatcheries, Michigan	May-September 1937-1941	Dissected Colons	10	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 3 Composition by Volume
80	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The	Wintergreen Lake, Michigan	May-September 1937-1942	Dissected Stomachs	13	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from	Table 2 Composition by Volume

		American Midland Naturalist									this paper; % frequency of occurence also available	
81	*Chelydra serpentina*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Wintergreen Lake, Michigan	May-September 1937-1943	Dissected Colons	17	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 2 Composition by Volume
82	*Chelydra serpentina*	Alexander, M. M. (1943). Food Habits of the Snapping Turtle in Connecticut. The Journal of Wildlife Management, 7(3), 278–282. Retrieved from http://www.jstor.org/stable/3795533	Connecticut lakes, ponds, streams, and swamps	Summers of 1939-1941	Dissected Stomachs	470	All demographics	% volume	%	1	% Frequency also available, as is data by broad habitat category	Table 1 Totals Vol.
83	*Sternotherus oderatus*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist,	Michigan lakes and streams	Late summer 1937-1938	Dissected Stomachs	73	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular	

		29(2), 257–312. Retrieved from The American Midland Naturalist								locality-specific data from this paper; % frequency of occurence also available	
84	*Sternotherus oderatus*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Late summer 1937-1938	Dissected Colons	66	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identificatio n avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	
85	*Emydoidea blandingii*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1938	Dissected Stomachs	51	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identificatio n avaialble in text; more granular locality-specific data from this paper; % frequency of occurence	Table 5 pg. 289 Composition by Volume

											also available	
86	*Emydoidea blandingii*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1938	Dissected Colons	41	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 5 pg. 289 Composition by Volume
87	*Graptemys geographica*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1938	Dissected Stomachs	12	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 6 pg. 293 Composition by Volume
88	*Graptemys geographica*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to	Michigan lakes and streams	Summers of 1937-1938	Dissected Colons	24	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble	Table 6 pg. 293 Composition by Volume

		Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist									in text; more granular locality-specific data from this paper; % frequency of occurence also available	
89	*Chrysemys picta*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1938	Dissected Stomachs	394	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 8 pg. 302 Composition by Volume
90	*Apalone spinifera*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1938	Dissected Stomachs	11	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; %	Table 9 p g. 304 Composition by Volume

											frequency of occurence also available	
91	*Apalone spinifera*	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	Michigan lakes and streams	Summers of 1937-1939	Dissected Colons	6	Adults (presumed)	% volume	%	1	Some raw abundances as well as species identification avaialble in text; more granular locality-specific data from this paper; % frequency of occurence also available	Table 9 p g. 304 Composition by Volume
92	*Chrysemys picta*	Lindeman, P. V. (1996). Comparative life history of painted turtles (Chrysemys picta) in two habitats in the inland Pacific Northwest. Copeia. https://doi.org/10.2307/1446947	waste-water lagoons Latah County, Idaho	1986-1987	Stomach flushing	45	All demographics	% vloume	%	1	% abundance available for animal prey; FO available for April, June, August sampling bouts; Volume scaled to account for individual variation in size by multiplying each sample total volume by the natural	Table 3 Syringa Trailer Court Average proportion by Volume pg. 119

											log of plastron length.	
93	*Chrysemys picta*	Lindeman, P. V. (1996). Comparative life history of painted turtles (Chrysemys picta) in two habitats in the inland Pacific Northwest. Copeia. https://doi.org/10.2307/1446947	Middle Findley Lake, Spokane County, Washington	1987	Stomach flushing	42	All demographics	% volume	%	1	% abundance available for animal prey; FO available for April, June, August sampling bouts; Volume scaled to account for individual variation in size by multiplying each sample total volume by the natural log of plastron length.	Table 3 Middle Findley Lake Average proportion by Volume pg. 119
94	*Batagur baska*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	Perak River, Malaysia	Summers 1975, 1976, 1978	Fecal contents	12	All demographics	% volume	%		%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 3 Perak %TV
95	*Batagur baska*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles.	Trengganu River, Malaysia	Summers 1975, 1976, 1978	Fecal contents	3	All demographics	% volume	%		%FO and %Individual volume (percent total	Table 3 Trengganu %TV

		Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111									volume of given food type found in all samples having that particular food item.	
96	*Batagur borneoensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Perak River, Malaysia	Summers 1975, 1976, 1979	Dissected Digestive Tracts	18	All demographics	% volume	%		%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 4 Perak %TV
97	*Batagur borneoensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3113	Trengganu River, Malaysia	Summers 1975, 1976, 1980	Dissected Digestive Tracts	1	Adult	% volume	%		%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 4 Trengganu %TV
98	*Cuora amboinensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Perak River, Malaysia	Summers 1975, 1976, 1979	Dissected Digestive Tracts	11	All demographics	% volume	%	1	%FO and %Individual volume (percent total volume of given food type found in all samples having that	Table 8 Perak %TV

											particular food item.	
99	*Cuora amboinensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3113	Pahang River, Malaysia	Summers 1975, 1976, 1980	Dissected Digestive Tracts	3	All demographics	% volume	%	1	%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 8 Pahang %TV
100	*Cuora amboinensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Trengganu River, Malaysia	Summers 1975, 1976, 1979	Dissected Digestive Tracts	2	Adult	% volume	%	1	%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 8 Trengganu %TV
101	*Siebenrockiella crassicollis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Perak River, Malaysia	Summers 1975, 1976, 1979	Dissected Digestive Tracts	5	Adult	% volume	%	1	%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 9 Perak %TV
102	*Siebenrockiella crassicollis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles.	Pahang River, Malaysia	Summers 1975, 1976, 1980	Dissected Digestive Tracts	5	Adult	% volume	%	1	%FO and %Individual volume (percent total	Table 9 Pahang %TV

		Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3113								volume of given food type found in all samples having that particular food item.	
103	*Siebenrockiella crassicollis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Trengganu River, Malaysia	Summers 1975, 1976, 1979	Dissected Digestive Tracts	9	All demographics	% volume	%	1	%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 9 Trengganu %TV
104	*Cyclemys dentata*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Trengganu River, Malaysia	Summers 1975, 1976, 1979	Fecal contents	2	Adult	% volume	%		%FO and %Individual volume (percent total volume of given food type found in all samples having that particular food item.	Table 12 %TV
105	*Orlitia borneensis*	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3112	Perak River, Malaysia	Summers 1975, 1976, 1979	Fecal contents	1	Adult	% volume	%		%FO and %Individual volume (percent total volume of given food type found in all samples having that	Table 12 %TV

											particular food item.	
106	*Emydoidea blandingii*	Kofron, C. P., & Schreiber, A. A. (1985). Ecology of Two Endangered Aquatic Turtles in Missouri: Kinosternon flavescens and Emydoidea blandingii. Journal of Herpetology, 19(1), 27–40.	Goose Pond march, Missouri	September 1980-November 1981	Stomach Flushing	15	All demographics	Raw abundance	raw count s	1	Raw occurence (number of turtles from which particular food item was obtained) also available	Table 1 E. blandingii n Prey
107	*Kinosternon flavescens*	Kofron, C. P., & Schreiber, A. A. (1985). Ecology of Two Endangered Aquatic Turtles in Missouri: Kinosternon flavescens and Emydoidea blandingii. Journal of Herpetology, 19(1), 27–40.	Goose Pond march, Missouri	September 1980-November 1982	Fecal contents	50	All demographics	Raw abundance	raw count s	1	Raw occurence (number of turtles from which particular food item was obtained) also available	Table 1 K. flavescens n Preu
108	*Emydoidea blandingii*	Rowe, J. W. (1992). Dietary Habits of the Blanding's Turtle (Emydoidea blandingi) in Northeastern Illinois. Journal of Herpetology, 26(1), 111–114.	Chain of Lakes State Park in Lake McHenry counties, Northeastern Illinois	March-November 1986	Stomach Flushing	22	All demographics	% volume	%	1	Mean individual volume % and Frequency of occurence % also available	Table 1 Total Volume S. pg. 113
109	*Emydoidea blandingii*	Rowe, J. W. (1992). Dietary Habits of the Blanding's Turtle (Emydoidea blandingi) in Northeastern Illinois. Journal of Herpetology, 26(1), 111–114.	Chain of Lakes State Park in Lake McHenry counties, Northeastern Illinois	March-November 1987	Intestinal Flushing	15	All demographics	% volume	%	1	Mean individual volume % and Frequency of occurence % also available	Table 1 Total Volume F, pg 113

110	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;2	South Llano River, Kimble County, Texas, USA	May 1998 & May 1999	Stomach Flushing	21	Males	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 1 Males %V pg. 27
111	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;3	South Llano River, Kimble County, Texas, USA	May 1998 & May 2000	Stomach Flushing	7	Small females (overlapping with male plastral length)	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 1 Small females %V pg. 27
112	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an	South Llano River, Kimble County, Texas, USA	May 1998 & May 2001	Stomach Flushing	10	Large females (exceeding male plastral length)	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 1 Large females %V pg. 27

		Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;4										
113	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;2	South Llano River, Kimble County, Texas, USA	May 1998 & May 1999	Fecal contents	25	Males	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 2 Males %V pg. 27
114	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;3	South Llano River, Kimble County, Texas, USA	May 1998 & May 2000	Fecal contents	8	Small females (overlapping with male plastral length)	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 2 Small females %V pg. 27

115	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;4	South Llano River, Kimble County, Texas, USA	May 1998 & May 2001	Fecal contents	16	Large females (exceeding male plastral length)	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 2 Large females %V pg. 27
116	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;5	South Llano River, Kimble County, Texas, USA	30th April 1949	Dissected Digestive Tracts	7	Males	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 3 Females %V pg. 28
117	*Graptemys versa*	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an	South Llano River, Kimble County, Texas, USA	30th April 1950	Dissected Digestive Tracts	12	Females	% volume	%	1	% frequency of occurence and index of relative importance also available	Table 3 Males %V pg. 28

		Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;6										
118	*Graptemys ouachitensis*	Moll, D. (1976). Food and Feeding Strategies of the Ouachita Map Turtle (Graptemys pseudogeographica ouachitensis). American Midland Naturalist, 96(2), 478. https://doi.org/10.2307/2424089	Mississippi River, Lake County, Tennesse, USA	May 1971-November 1972	Dissected Digestive Tracts	80	All demographics	% volume	%	1	% frequency of occurence also available	Table 1 Miss. R. % Tot. vol.
119	*Graptemys ouachitensis*	Moll, D. (1976). Food and Feeding Strategies of the Ouachita Map Turtle (Graptemys pseudogeographica ouachitensis). American Midland Naturalist, 96(2), 478. https://doi.org/10.2307/2424089	Meredosia Lake, Cass County, Illinois, USA	June-September 1972	Dissected Digestive Tracts	35	All demographics	% volume	%	1	% frequency of occurence also available	Table 1 Meredosia L. % Tot. vol.
120	*Agrionemys horsfieldi*	Lagarde, F., Bonnet, X., Corbin, J., Henen, B., Nagy, K., Mardonov, B., & Naulleau, G. (2003). Foraging Behaviour and Diet of an Ectothermic Herbivore : Testudo horsfieldi. Ecography, 26(2), 236–242.	Djeiron Ecocenter of Bukhara, Repubic of Uzbekistan	2nd March-April 15 1999	Focal observation	7	Adult (4 male, 3 female)	% mass	%	1	Estimated fresh mass by observing number and which plant parts consumed and using the mean mass of plant parts	Table 2 Dietary portion (% of fresh mass consumed)

121	*Agrionemys horsfieldi*	Lagarde, F., Bonnet, X., Corbin, J., Henen, B., Nagy, K., Mardonov, B., & Naulleau, G. (2003). Foraging Behaviour and Diet of an Ectothermic Herbivore : Testudo horsfieldi. Ecography, 26(2), 236–242.	Djeiron Ecocenter of Bukhara, Repubic of Uzbekistan	April 15-30th 1999	Focal observation	7	Adult (3 male, 4 female)	% mass	%	1	Estimated fresh mass by observing number and which plant parts consumed and using the mean mass of plant parts	Table 1 Dietary portion (% of fresh mass consumed)
122	*Gopherus berlandieri*	Scalise, J. L. (2011). Food habits and selective foraging by the Texas Tortoise (Gopherus berlandieri). Texas State University-San MArcos.	South Texas, USA	Summers of 2007 & 2008	Fecal contents	51	All demographics	% identified fragments	%	1	point frame sampling of 50 points pers fecal, assigning to one of five forage classes; locality specific data available but without animal matter.	
123	*Chelonoidis carbonaria*	Moskovits, D. K., & Bjorndal, K. A. (1990). Diet and Food Preferences of the Tortoises Geochelone carbonaria and G . denticulata in Northwestern Brazil. Herpetologica, 46(2), 207–218.	Ilha de Maraca, Roraima, Brazil	March 1981-November 1982	Feeding observation	95	All demographics	% foraging observations	%	1		Table 2a C bold
124	*Chelonoidis denticulatus*	Moskovits, D. K., & Bjorndal, K. A. (1990). Diet and Food Preferences of the Tortoises Geochelone carbonaria and G . denticulata in	Ilha de Maraca, Roraima, Brazil	March 1981-November 1983	Feeding observation	37	All demographics	% foraging observations	%	1		Table 2a D bold

		Northwestern Brazil. Herpetologica, 46(2), 207–218.									
125	*Chelonoidis denticulatus*	Guzmán, A., & Stevenson, P. R. (2008). Seed dispersal, habitat selection and movement patterns in the Amazonian tortoise, Geochelone denticulata. Amphibia Reptilia, 29(4), 463–472. https://doi.org/10.1163/156853808786230442	Madre de Dios, Peru	Rainy Season October 2006 - April 2007	Fecal contents	32	All demographics	% volume	%	1	visual estimate using pie chart guideline, 62 fecals samples from 31 tortoises	Table 3 Rainy Season
126	*Chelonoidis denticulatus*	Guzmán, A., & Stevenson, P. R. (2008). Seed dispersal, habitat selection and movement patterns in the Amazonian tortoise, Geochelone denticulata. Amphibia Reptilia, 29(4), 463–472. https://doi.org/10.1163/156853808786230443	Madre de Dios, Peru	Dry Season June 2006 - September 2006	Fecal contents	30	All demographics	% volume	%	1	visual estimate using pie chart guideline, 62 fecals samples from 31 tortoises	Table 3 Dry Season
127	*Gopherus agassizii*	Hansen, R. M., Johnson, M. K., & Van Devender, R. T. (1976). Foods of the Desert Tortoise , Gopherus agassizii , in Arizona and Utah. Herpetologica, 32(3), 247–251.l 1976	Lower Grand Canyon, Mohave County, Arizona	May 1973-March 1975	Fecal contents	66	All demographics	% dry weight	%	1	visual microhistological estimate of dry volume after 200 pieces identified	Table 1 Lower Grand Canyon
128	*Gopherus agassizii*	Hansen, R. M., Johnson, M. K., & Van Devender, R. T. (1976). Foods of the Desert Tortoise , Gopherus agassizii ,	New Water Mountains, Yuma County Arizona	May 1973-March 1976	Fecal contents	18	All demographics	% dry weight	%	1	visual microhistological estimate of dry volume after 200	Table 1 New Water Mountains

		in Arizona and Utah. Herpetologica, 32(3), 247–251.l 1977									pieces identified	
129	*Gopherus agassizii*	Hansen, R. M., Johnson, M. K., & Van Devender, R. T. (1976). Foods of the Desert Tortoise , Gopherus agassizii , in Arizona and Utah. Herpetologica, 32(3), 247–251.l 1978	Beaver Dam Wash, Washington County, Utah	May 1973-March 1977	Fecal contents	30	All demographics	% dry weight	%	1	visual microhistol ogical estimate of dry volume after 200 pieces identified	Table 1 Beaver Dam Wash
130	*Gopherus agassizii*	Jennings, W. B., & Berry, K. H. (2015). Desert tortoises (Gopherus agassizii) are selective herbivores that track the flowering phenology of their preferred food plants. PloS One, 10(1), e0116716. https://doi.org/10.1371/journal.pone.0116716	Easter Kern County, California, USA	Spring Activity Period, 24 March- 21 June 1992	Observed bites	18	Adult Male and Female	% Bites	%	1		Table 11 % Bites
131	*Gopherus agassizii*	Snider, J. R. (1993). Foraging ecology and sheltersite characteristics of Sonoran Desert tortoises. In Proceedings of the Desert Tortoise Council Symposium (Vol. 1992, pp. 82-84).	Little Shipp Wash, Arizona USA	May-October 1991	Observed bites	8	Adults	% Bites	%	1		Table 1 % Bites
132	*Gopherus agassizii*	Snider, J. R. (1993). Foraging ecology and sheltersite characteristics of Sonoran Desert tortoises. In Proceedings of the Desert Tortoise Council Symposium	Harcuvar Mountains, Arizona USA	June-October 1991	Observed bites	12	Adults	% Bites	%	1		Table 2 % Bites

		(Vol. 1992, pp. 82-84).										
133	*Gopherus polyphemus*	Carlson, J. E., Menges, E. S., & Marks, P. L. (2003). Seed dispersal by Gopherus polyphemus at Archbold Biological Station, Florida. Florida Scientist, 2003(2), 147–154.	Highlands County, Florida, USA	June-July 2001	Observed feeding	24	Adults	%F of all O	%	1	FO with scats and feeding observations, used this to calculate percent of all occurances (o*n/Σ o * n)	Table 1 Frequency in Foraging Observations
134	*Gopherus polyphemus*	Carlson, J. E., Menges, E. S., & Marks, P. L. (2003). Seed dispersal by Gopherus polyphemus at Archbold Biological Station, Florida. Florida Scientist, 2003(2), 147–154.	Highlands County, Florida, USA	June-July 2002	Fecal contents	91	Adults	%F of all O	%	1	FO with scats and feeding observations, used this to calculate percent of all observations (o*n/Σ o * n)	Table 1 Frequency in Scat
135	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2784	Hong Kong, China	Wet Seasons (April-September) 2009-2011	Fecal contents	6	Juveniles	%F of all O	%		converted to percentage of all occurrences	Table 2 Wet season J
136	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2785	Hong Kong, China	Wet Seasons (April-September) 2009-2012	Fecal contents	25	Females	%F of all O	%	1	converted to percentage of all occurrences	Table 2 Wet season F

137	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2786	Hong Kong, China	Wet Seasons (April-September) 2009-2013	Fecal contents	16	Males	%F of all O	%	1	converted to percentage of all occurrences	Table 2 Wet season M
138	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2787	Hong Kong, China	Dry Seasons (October-March) 2009-2014	Fecal contents	2	Juveniles	%F of all O	%		converted to percentage of all occurrences	Table 2 Dry season J
139	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2788	Hong Kong, China	Dry Seasons (October-March) 2009-2015	Fecal contents	5	Females	%F of all O	%	1	converted to percentage of all occurrences	Table 2 Dry season F
140	*Platysternon megacephalum*	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2789	Hong Kong, China	Dry Seasons (October-March) 2009-2016	Fecal contents	7	Males	%F of all O	%	1	converted to percentage of all occurrences	Table 2 Dry season M

141	*Apalone spinifera*	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276	Wabash River and backwaters, Illinois, USA	April 17-October 1, 1989	Stomach flushing	4	All demographics	% volume	%	1	3 male 1 female; FO also available	Table 4 Total Volume S only smallest category that added to 100%
142	*Apalone mutica*	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1277	Wabash River and backwaters, Illinois, USA	April 17-October 1, 1989	Stomach flushing	50	All demographics	% volume	%	1	39 male 11 female; FO also availabe	Table 3 Total Volume S only smallest category that added to 100%
143	*Graptemys ouachitensis*	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1278	Wabash River and backwaters, Illinois, USA	April 17-October 1, 1990	Stomach flushing	3	Males	% volume	%	1	FO also available	Table 6 Total Volume F only smallest category that added to 100%
144	*Graptemys ouachitensis*	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1279	Wabash River and backwaters, Illinois, USA	April 17-October 1, 1991	Stomach flushing	10	Females	% volume	%	1	FO also available	Table 6 Total Volume M only smallest category that added to 100%
145	*Sternotherus peltifer*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13	Stomach flushing	28	Adults	% volume	%			Table 2

		in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.6		1978 & April 30 to August 4 1979								
146	*Pseudemys concinna*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.7	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	59	Adults	% volume	%			Table 2
147	*Trachemys scripta*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.8	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	10	Adults	% volume	%	1		Table 2

148	*Graptemys pulchra*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.9	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	11	Adults	% volume	%			Table 2
149	*Graptemys nigrinoda*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.10	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	75	Adults	% volume	%			Table 2
150	*Apalone mutica*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	9	Adults	% volume	%	1		Table 2

		Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.11										
151	*Apalone spinifera*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.12	Cahaba River near Sprott, Alabama, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	29	Adults	% volume	%	1		Table 2
152	*Sternotherus carinatus*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.13	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	41	Adults	% volume	%	1		Table 3
153	*Pseudemys concinna*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1-August 13 1978 &	Stomach flushing	8	Adults	% volume	%			Table 3

		United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.14		April 30 to August 4 1979								
154	*Trachemys scripta*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.15	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	14	Adults	% volume	%	1		Table 3
155	*Graptemys gibbonsi*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.16	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	18	Adults	% volume	%			Table 3
156	*Graptemys flavimaculata*	McCoy, C. J., Flores-Villela, O. A., Vogt,	Chickasaw hay River	10 day periods	Stomach flushing	14	Adults	% volume	%			Table 3

		R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.17	at Leakesville . Mississippi, USA	between July 1- August 13 1978 & April 30 to August 4 1979								
157	*Apalone mutica*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.18	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1- August 13 1978 & April 30 to August 4 1979	Stomach flushing	39	Adults	% volume	%	1		Table 3
158	*Apalone spinifera*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–	Chickasaw hay River at Leakesville . Mississippi, USA	10 day periods between July 1- August 13 1978 & April 30 to August 4 1979	Stomach flushing	23	Adults	% volume	%	1		Table 3

		208. https://doi.org/10.2744/CCB-1447.19										
159	*Sternotherus carinatus*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.20	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	68	Adults	% volume	%	1		Table 4
160	*Pseudemys concinna*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.21	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	93	Adults	% volume	%			Table 4
161	*Trachemys scripta*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30	Stomach flushing	63	Adults	% volume	%	1		Table 4

		Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.22		to August 4 1979								
162	*Graptemys pearlensis*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.23	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	28	Adults	% volume	%			Table 4
163	*Graptemys oculifera*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.24	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	47	Adults	% volume	%			Table 4
164	*Apalone mutica*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020).	Pearl River at Georgetown Water	10 day periods between	Stomach flushing	14	Adults	% volume	%	1		Table 4

		Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.25	Park, Mississippi, USA	July 1-August 13 1978 & April 30 to August 4 1979								
165	*Apalone spinifera*	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.26	Pearl River at Georgetown Water Park, Mississippi, USA	10 day periods between July 1-August 13 1978 & April 30 to August 4 1979	Stomach flushing	28	Adults	% volume	%	1		Table 4
166	*Kinosternon scorpiodes*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January-April 1984	Stomach flushing	80	Adults	% volume	%	1	FO also available	Table 1
167	*Kinosternon leucostomum*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January-April 1984	Stomach flushing	80	Adults	% volume	%		FO also available	Table 1

168	*Staurotypus triporcatus*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January 1985	Stomach flushing	40	Adults (5M 5F)	% volume	%	1	FO also available	Table 2
169	*Trachemys scripta*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January-April 1984	Stomach flushing	80	Adult Females	% volume	%	1	FO also available	Table 1
170	*Trachemys scripta*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January-April 1984	Stomach flushing	80	Adult Males	% volume	%	1	FO also available	Table 1
171	*Trachemys scripta*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	January-April 1984	Stomach flushing	80	Juveniles	% volume	%		FO also available	Table 1
172	*Staurotypus triporcatus*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	February 1984	Stomach flushing	40	Adults (5M 5F)	% volume	%	1	FO also available	Table 2
173	*Staurotypus triporcatus*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal	Chan Chen, Belize	March 1984	Stomach flushing	40	Adults (5M 5F)	% volume	%	1	FO also available	Table 2

		of Herpetology, 24(1), 48–53.										
174	*Staurotypus triporcatus*	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	Chan Chen, Belize	April 1984	Stomach flushing	40	Adults (5M 5F)	% volume	%	1	FO also available	Table 2
175	*Kinosternon subrubrum*	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	Oklahoma, USA	May-October of 1956-1960	Dissected Digestive Tracts	178	Adults	% volume	%	1	FO also available; monthly breakdowns available in figure	Table 1
176	*Kinosternon flavescens*	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	Oklahoma, USA	May-October of 1956-1960	Dissected Digestive Tracts	121	Adults	% volume	%	1	FO also available; monthly breakdowns available in figure	Table 1
177	*Sternotherus odoratus*	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	Oklahoma, USA	May-October of 1956-1960	Dissected Digestive Tracts	68	Adults	% volume	%	1	FO also available; monthly breakdowns available in figure	Table 1
178	*Sternotherus carinatus*	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	Oklahoma, USA	May-October of 1956-1960	Dissected Digestive Tracts	63	Adults	% volume	%	1	FO also available; monthly breakdowns available in figure	Table 1
179	*Sternotherus carinatus*	Kavanagh, B. T., & Kwiatkowski, M. A. (2016). Sexual dimorphism, movement patterns, and diets of Sternotherus carinatus (Razorback Musk Turtle). Southeastern Naturalist, 15(sp9), 117–133.	Bernaldo Creek and La Nana Creek, Nacogdoches County, Texas, USA	March-August, 2007-2008	Fecal contents	39	Males	% volume	%	1		Table 7 Proportional Volume

		https://doi.org/10.1656/058.015.0SP914										
180	*Sternotherus carinatus*	Kavanagh, B. T., & Kwiatkowski, M. A. (2016). Sexual dimorphism, movement patterns, and diets of Sternotherus carinatus (Razorback Musk Turtle). Southeastern Naturalist, 15(sp9), 117–133. https://doi.org/10.1656/058.015.0SP914	Bernaldo Creek and La Nana Creek, Nacogdoches County, Texas, USA	March-August, 2007-2008	Fecal contents	28	Females	% volume	%	1		Table 7 Proportional Volume
181	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Spring Creek, Jackson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	75	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 SCr-m-A
182	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Spring Creek, Jackson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	75	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 SCr-m-J
183	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk	Merritt's Mill Pond, Jackson County,	June 1-July 15, 1972	Dissected Digestive Tracts	27	Adults	% volume	%	1	adults and juveniles separate in Table 3 but	Table 3 MMP-m-A

		Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Florida, USA								not distinguished in sample size, listed grouped sample size as the sample for each.	
184	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Merritt's Mill Pond, Jackson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	27	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 MMP-m-J
185	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Ichetucknee River, Columbia County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	51	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Ich-m-A
186	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Ichetucknee River, Columbia County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	51	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the	Table 3 Ich-m-J

											sample for each.	
187	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Wacissa River, Jefferson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	17	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Wac-m-A
188	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Wacissa River, Jefferson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	17	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Wac-m-J
189	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Horn Spring, Leon County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	23	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 HSp-m-A
190	*Sternotherus minor*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern	Horn Spring, Leon County,	June 1-July 15, 1972	Dissected Digestive Tracts	23	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not	Table 3 HSp-m-J

		Florida. Copeia, 1975(4), 692–701.	Florida, USA								distinguished in sample size, listed grouped sample size as the sample for each.	
191	*Sternotherus odoratus*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Wacissa River, Jefferson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	85	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Wac-o-A
192	*Sternotherus odoratus*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Wacissa River, Jefferson County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	85	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Wac-o-J
193	*Sternotherus odoratus*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Horn Spring, Leon County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	24	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the	Table 3 HSp-o-A

											sample for each.	
194	*Sternotherus odoratus*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Horn Spring, Leon County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	24	Juveniles	% volume	%		adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 HSp-o-J
195	*Sternotherus odoratus*	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	Wakulla River, Wakulla County, Florida, USA	June 1-July 15, 1972	Dissected Digestive Tracts	42	Adults	% volume	%	1	adults and juveniles separate in Table 3 but not distinguished in sample size, listed grouped sample size as the sample for each.	Table 3 Wak-o-A
196	*Sternotherus minor peltifer*	Folkerts, G. W. (1968). Food Habits of the Stripe-Necked Musk Turtle, Sternotherus minor peltifer Smith and Glass. Journal of Herpetology, 2(3), 171–173.	East-central Alabama, USA	Summer 1966	Fecal contents	284	All demographics	% volume	%	1	estimated volume of what the intact organism would have taken up in the digestive tract, FO also available	Table 1 Estimated Percent Volume
197	*Sternotherus odoratus*	Patterson, J. C., & Lindeman, P. V. (2009). Effects of Zebra and Quagga Mussel (<i>Dreissena spp	Presque Isle State Park, Northwestern	May-September 2005-2006	Fecal contents	21	Males	Mean % volume	%	1	volume averaged across all samples; IRI and FO available	Table 1 Mean percent volume M

		.<\i>) Invasion on the Feeding Habits of Sternotherus odoratus (Stinkpot) on Presque Isle , Northwestern Pennsylvania. Northeastern Naturalist, 16(3), 365–374.	Pennsylvania, USA								
198	*Sternotherus odoratus*	Patterson, J. C., & Lindeman, P. V. (2009). Effects of Zebra and Quagga Mussel (<i>Dreissena spp .<\i>) Invasion on the Feeding Habits of Sternotherus odoratus (Stinkpot) on Presque Isle , Northwestern Pennsylvania. Northeastern Naturalist, 16(3), 365–374.	Presque Isle State Park, Northwestern Pennsylvania, USA	May-September 2005-2006	Fecal contents	13	Females	Mean % volume	%	1	volume averaged across all samples; IRI and FO available	Table 1 Mean percent volume F
199	*Sternotherus odoratus*	Wilhelm, C. E., & Plummer, M. V. (2012). Diet of radiotracked musk turtles, Sternotherus odoratus, in a small urban stream. Herpetological Conservation and Biology, 7(2), 258–264.	Gin Creek, White County, Arkansas, USA	12 May - 23 June, 2010	Fecal contents	45	Adults	% volume	%	1	15 radiotracked individuals captured and estimated three times; FO and IRI available	Table 1 Fecal Samples % volume
200	*Kinosternon sonoriense*	Hulse, A. C. (1974). Food Habits and Feeding Behavior in Kinosternon sonoriense (Chelonia : Kinosternidae). Journal of Herpetology, 8(3), 195–199.	Sycamore Creek, Maricopa County, Fossil Creek, Yavapai County, Tonto	1973	Dissected Digestive Tracts	101	All demographics	% volume	%	1	percent volume of each taxon per stomach was estimated based on the; original size of the	Table 1 % Total volume

			Creek, Gila County, and Tuley Stream, yavapai County, Arizona, USA								food item, not just the remains in the stomach.	
201	*Trionyx triunguis*	Akani, G. C., Capizzi, D., & Luiselli, L. (2001). Diet of the softshell turtle, Trionyx triunguis, in an Afrotropical forested region. Chelonian Conservation and Biology, 4(1), 200-201.	SE Nigeria	September 1996-May 2000	Dissected Stomach Contents	28	All demographics	%F of all O	%	1	Male, female and juvenile breakouts available, FO available, converted to percentage of all occurrences	
202	*Trionyx triunguis*	Akani, G. C., Capizzi, D., & Luiselli, L. (2001). Diet of the softshell turtle, Trionyx triunguis, in an Afrotropical forested region. Chelonian Conservation and Biology, 4(1), 200-201.	SE Nigeria	September 1996-May 2001	Fecal contents and Dissected Stomach Contents	41	All demographics	%F of all O	%	1	FO available, converted to percentage of all occurrences	
203	*Trionyx triunguis*	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	Tributary of the Sambreiro River, Rivers State, Southern Nigeria	2000-2002	Fecal contents and Dissected Stomach Contents	14	All demographics	%F of all O	%	1	Wet/Dry seasonal split available, FO available, converted to percentage of all occurrences	
204	*Pelusios castaneus*	Luiselli, L., Akani, G. C., Politano, E.,	Tributary of the	2000-2002	Fecal contents	217	All demographics	%F of all O	%		Wet/Dry seasonal	

		Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	Sambreiro River, Rivers State, Southern Nigeria		and Dissected Stomach Contents						split available, FO available, converted to percentage of all occurrences	
205	*Pelusios niger*	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	Tributary of the Sambreiro River, Rivers State, Southern Nigeria	2000-2002	Fecal contents and Dissected Stomach Contents	113	All demographics	%F of all O	%		Wet/Dry seasonal split available, FO available, converted to percentage of all occurrences	
206	*Pelomedusa subrufa*	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	Tributary of the Sambreiro River, Rivers State, Southern Nigeria	2000-2002	Fecal contents and Dissected Stomach Contents	9	All demographics	%F of all O	%		Wet/Dry seasonal split available, FO available, converted to percentage of all occurrences	
207	*Lissemys punctata*	Hossain, M. L., Sarker, S. U., & Sarker, N. J. (2012). Food Habits and Feeding Behaviour of Spotted Flapshell, Lissemys punctata (lacepede, 1788) in Bangladesh.	Chandpur, Naraynganj , Manikganj, Gopalganj and Madaripur districts and	March 1998 and February 2001	Dissected Stomach Contents	50	All demographics	% weight	%	1	Raw weights, FO, and % FO available	Table 1 "Occurrence relation to consumed food (%)

		Bangladesh Journal of Zoology, 40(2), 197–205.	Zoological garden of Dhaka University, Dhaka, Bangladesh.									
208	*Glyptemys muhlenbergia*	Melendez, N. A., Zarate, B., Fingerut, J., & McRobert, S. P. (2017). Diet of Bog Turtles (Glyptemys muhlenbergii) from Northern and Southern New Jersey, USA. Herpetological Conservation and Biology, 12, 272–278.	Sussex County, New Jersey, USA	14 April to 30 September 2014	Fecal contents	31	All demographics	%F of all O	%	1	Male and female split available, FO available	Table 2 %F NP
209	*Glyptemys muhlenbergia*	Melendez, N. A., Zarate, B., Fingerut, J., & McRobert, S. P. (2017). Diet of Bog Turtles (Glyptemys muhlenbergii) from Northern and Southern New Jersey, USA. Herpetological Conservation and Biology, 12, 272–278.	Salem County, New Jersey, USA	15 April to 30 September 2014	Fecal contents	29	All demographics	%F of all O	%	1	Male and female split available, FO available	Table 2 %F SP
210	*Mauremys sinensis*	Chen, T. H., & Lue, K. Y. (1998). Ecology of the Chinese Stripe-Necked Turtle, Ocadia sinenses (Testudines:Emydidae), in the Keelung River, Northern Taiwan. Copeia, 4, 944–952.	Keelung River, northern Taiwan	July-October 1995	Stomach flushing	23	Males	% volume	%	1	FO available, juveniles available FO only	Table 5 Males (in parentheses)
211	*Mauremys sinensis*	Chen, T. H., & Lue, K. Y. (1998). Ecology of the Chinese Stripe-	Keelung River, northern Taiwan	July-October 1995	Stomach flushing	25	Females	% volume	%	1	FO available, juveniles	Table 5 females (in parentheses)

		Necked Turtle, Ocadia sinenses (Testudines:Emydidae), in the Keelung River, Northern Taiwan. Copeia, 4, 944–952.									available FO only	
212	*Mauremys sinensis*	Chen TH, KY Lue. 1999. Food habits of the Chinese stripenecked turtle, Ocadia sinensis, in the Keelung River, northern Taiwan. J. Herpetol. 33: 463-471.	Keelung River, northern Taiwan	July-December 1995, February-May 1996, March-April 1997	Stomach flushing	64	Males	% volume	%	1	FO available, juveniles available FO only	Table 1 Males % Vol
213	*Mauremys sinensis*	Chen TH, KY Lue. 1999. Food habits of the Chinese stripenecked turtle, Ocadia sinensis, in the Keelung River, northern Taiwan. J. Herpetol. 33: 463-471.	Keelung River, northern Taiwan	July-December 1995, February-May 1996, March-April 1997	Stomach flushing	58	Females	% volume	%	1	FO available, juveniles available FO only	Table 1 Females % Vol
214	*Mauremys sinensis*	Wang, J., Shi, H., Hu, S., Ma, K., & Li, C. (2013). Interspecific differences in diet between introduced red-eared sliders and native turtles in China. Asian Herpetological Research, 4(3), 190–196. https://doi.org/10.3724/SP.J.1245.2013.00190	Wanquan River, Hainan, China	August 2011-January 2013	Stomach flushing and Dissected stomach contents	21	All demographics	% wet weight	%	1	FO available in bar graph	In text on Pg 192
215	*Trachemys scripta elegans*	Wang, J., Shi, H., Hu, S., Ma, K., & Li, C. (2013). Interspecific	Gutian Nature Reserve, Guangdong	August 2011-	Stomach flushing and	222	All demographics	% wet weight	%	1	FO available in bar graph	In text on Pg 192

		differences in diet between introduced red-eared sliders and native turtles in China. Asian Herpetological Research, 4(3), 190–196. https://doi.org/10.3724/SP.J.1245.2013.00190	, and Wanquan River, Hainan, China	January 2013	Dissected stomach contents and fecal samples							
216	*Terrapene carolina carolina*	Bush, F. M. (1959). Foods of Some Kentucky Herptiles. Herpetologica, 15(2), 73–77.	Kentucky, USA	1955-1956	Dissected Stomach Contents	10	All demographics	% volume	%	1	Summaries of other papers available	In text on Pg. 75
217	*Chelydra serpentina serpentina*	Bush, F. M. (1959). Foods of Some Kentucky Herptiles. Herpetologica, 15(2), 73–77.	Kentucky, USA	1955-1956	Dissected Stomach Contents	3	All demographics	% volume	%	1	Summaries of other papers available	In text on Pg. 75
218	*Terrapene carolina carolina*	Klimstra, W. N. D., & Newsome, F. (1960). Some Observations on the Food Coactions of the Common Box Turtle , Terrapene C . Carolina. Ecology, 41(4), 639–647.	Carbondale, Illinois, USA	March-October of 1955 & 1956	Dissected Digestive Tracts	117	All demographics	% volume	%	1	FO available in more granular categories	Table III % Volume
219	*Deirochelys reticularia*	Demuth, J. P., & Buhlmann, K. A. (1997). Diet of the turtle Deirochelys reticularia on the Savannah River Site, South Carolina. Journal of Herpetology, 31(3), 450–453. https://doi.org/10.2307/1565680	Dry Bay, Savannah River site, Aiken County, South Carolina, USA	June-July 1994	Fecal contents	29	All demographics	%F of all O	%	1	FO available, converted to percentage of all occurrences	Table 1 Dry Bay
220	*Deirochelys reticularia*	Demuth, J. P., & Buhlmann, K. A. (1997). Diet of the turtle Deirochelys	Lost Lake, Savannah River site, Aiken	June-July 1994	Fecal contents	8	All demographics	%F of all O	%	1	FO available, converted to	Table 1 Lost Lake

		reticularia on the Savannah River Site, South Carolina. Journal of Herpetology, 31(3), 450–453. https://doi.org/10.2307/1565681	County, South Carolina, USA								percentage of all occurrences	
221	*Deirochelys reticularia*	Demuth, J. P., & Buhlmann, K. A. (1997). Diet of the turtle Deirochelys reticularia on the Savannah River Site, South Carolina. Journal of Herpetology, 31(3), 450–453. https://doi.org/10.2307/1565682	Risher Pond, Savannah River site, Aiken County, South Carolina, USA	June-July 1994	Fecal contents	4	All demographics	%F of all O	%	1	FO available, converted to percentage of all occurrences	Table 1 Risher Pond
222	*Deirochelys reticularia miaria*	McKnight, D. T., Jones, A. C., & Ligon, D. B. (2015). The omnivorous diet of the western chicken turtle (Deirochelys reticularia miaria). Copeia, 103(2), 322–328. https://doi.org/10.1643/CH-14-072	Boehler Seeps and Sandhills Preserve, Atoka County, Oklahoma, USA	March-July 2012-2013	Fecal contents	43	Adults	%F of all O	%	1	FO available, converted to percentage of all occurrences	Table 1 Adults BSSP
223	*Deirochelys reticularia miaria*	McKnight, D. T., Jones, A. C., & Ligon, D. B. (2015). The omnivorous diet of the western chicken turtle (Deirochelys reticularia miaria). Copeia, 103(2), 322–328. https://doi.org/10.1643/CH-14-073	Ponds near Boehler Seeps and Sandhills Preserve, Atoka County, Oklahoma, USA	March-July 2012-2013	Fecal contents	11	Adults	%F of all O	%	1	FO available, converted to percentage of all occurrences	Table 1 Adults other sites

224	*Deirochelys reticularia miaria*	McKnight, D. T., Jones, A. C., & Ligon, D. B. (2015). The omnivorous diet of the western chicken turtle (Deirochelys reticularia miaria). Copeia, 103(2), 322–328. https://doi.org/10.1643/CH-14-074	Ponds in and near Boehler Seeps and Sandhills Preserve, Atoka County, Oklahoma, USA	March-July 2012-2013	Fecal contents	13	Juveniles	%F of all O	%		FO available, converted to percentage of all occurrences	Table 1 Juveinles all sites
225	*Lepidochelys kempii*	Schmid, J. R., & Tucker, A. D. (2018). Comparing Diets of Kemp's Ridley Sea Turtles (Lepidochelys kempii) in Mangrove Estuaries of Southwest Florida. Journal of Herpetology, 52(3), 252–258. https://doi.org/10.1670/16-164	Charlotte Harbor National Estuary, Florida, USA	March-May & August-November 2009-2013	Fecal contents	26	Juveniles <40 cm	% Dry mass	%		FO and IRI available	Table 1 Turtles <40 cm
226	*Lepidochelys kempii*	Schmid, J. R., & Tucker, A. D. (2018). Comparing Diets of Kemp's Ridley Sea Turtles (Lepidochelys kempii) in Mangrove Estuaries of Southwest Florida. Journal of Herpetology, 52(3), 252–258. https://doi.org/10.1670/16-165	Charlotte Harbor National Estuary, Florida, USA	March-May & August-November 2009-2013	Fecal contents	32	Adults >40 cm	% Dry mass	%	1	FO and IRI available	Table 1 Turtles >40 cm
227	*Lepidochelys kempii*	Seney, E. E., & Musick, J. A. (2005). Diet analysis of Kemp's ridley sea turtles (Lepidochelys kempii) in Virginia.	Virginia, USA	2000-2002	Dissected Digestive Tracts	18	Benthic Immature	% Number	%	1	FO and % weight available	Table 2 %N

		Chelonian Conservation and Biology, 4(4), 864–871.										

Appendix Table B-3: Raw Diet Data

Source Diet Group ID	Original Category	Amount	New Category	Decision Notes
4	Bradibena cf. similis	0.6		
4	Periplaneta americana	2.5		
4	Chironomus cf. plumosus (larvae)	8.2		
4	C. cf. plumosus (pupae)	32.3		
4	C. cf. plumosus (larvae+pupae)	40.5		
4	Meat	50		
4	Plant material	1.3		
4	Um	5.1		
3	Chironomus cf. plumosus (larvae)	61.1		
3	C. cf. plumosus (pupae)	15.6		
3	C. cf. plumosus (larvae+pupae)	76.6		
3	Plant material	3.6		
3	Um	19.8		
2	Periplaneta americana	2.5		
2	Chironomus cf. plumosus (larvae)	68		
2	C. cf plumosus (pupae)	14.4		
2	C. cf plumosus (larvae+pupae)	82.3		
2	Plant material	1.1		
2	Um	14.1		
5	Spirogyra sp.	34.6	3	
5	Ficus racemosa Fruit	19.3	3	
5	Ficus racemosa Leaves	38.1	2	
5	Misc (mushrooms, etc)	0.01	3	
5	O. Odonata (Corduliidae, Gomphidae)	0.01	5	
5	Palaemonidae (Macrobrachium rosenbergii)	1.5	6	
5	Pisces (Black bream (Hephaestus fuliginosus) Barramundi (Lates calcarifer) Catfish (Ariidae, Plotosidae))	6.5	7	
5	Misc (Formicidae, Murid faecal pellet)	0.01	5	
6	Illyanassa obsoleta	7.93	8	
6	Littorina saxatilis	1.52	8	
6	Gemma gemma	3.31	8	
6	Mya arenaria	7.99	8	
6	Macoma balthica	48.75	8	
6	Geukensia demissa	22.86	8	
6	Hydrobia sp	0.02	8	
6	Crabs	6.4	6	
6	Plant matter	0.71	4	
6	Melampus bidentatus	0.05	8	
6	Fish	0.19	7	
6	Crepidula sp.	0.27	8	
7	Ilyanassa obsoleta	9.97	8	
7	Littorina saxatilis	2.04	8	
7	Gemma gemma	8.93	8	

7	Mya arenaria	6.4	8	
7	Macoma balthica	25.17	8	
7	Geukensia demissa	30.45	8	
7	Hydrobia sp.	1.65	8	
7	Crabs	13.67	6	
7	Plant matter	1.24	4	
7	Melampus bidentatus	0.31	8	
7	Fish	0.13	7	
7	Crepidula sp.	0.04	8	
8	Ilyanassa obsoleta	1.19	8	
8	Littorina saxatilis	5.05	8	
8	Gemma gemma	32.66	8	
8	Mya arenaria	16.87	8	
8	Macoma balthica	3.88	8	
8	Geukensia demissa	26.45	8	
8	Hydrobia sp.	2.28	8	
8	Crabs	2.6	6	
8	Plant matter	4.88	4	
8	Melampus bidentatus	3.69	8	
8	Fish	0.43	7	
8	Crepidula sp	0	8	
9	Ilyanassa obsoleta	2.16	8	
9	Littorina saxatilis	27.87	8	
9	Gemma gemma	33.87	8	
9	Mya arenaria	2.6	8	
9	Macoma balthica	1.02	8	
9	Geukensia demissa	5.98	8	
9	Hydrobia sp.	12.45	8	
9	Crabs	4.61	6	
9	Plant Matter	3.02	4	
9	Melampus bidentatus	5.76	8	
9	Fish	0.65	7	
9	Crepidula sp.	0.01	8	
10	Algae	78	4	
10	Vallisneria sp.	11	2	
10	Cyperaceae sp.	7	1	
10	Castanospermum australe seed	2	2	
10	Celtis chinensis bud	1	4	
10	Celtis chinensis stem	0.3	1	
10	Celtis chinensis leaf	0.1	2	
10	Callistemon viminalis leaf	0.3	2	
10	Sponge	0	3	
10	Roots of terrestrial plants (bottlebrush and Chinese elm)	0.2	1	
10	Bufo marinus vertebrae	0	7	
10	Poaceae sp.	0	1	
11	Algae	65	4	
11	Vallisneria sp.	11	2	
11	Cyperaceae sp.	2	1	
11	Castanospermum australe seed	0.1	2	

11	Celtis chinensis bud	5	4	
11	Celtis chinensis stem	0	1	
11	Celtis chinensis leaf	6	2	
11	Callistemon viminalis leaf	0.4	2	
11	Sponge	10	3	
11	Roots of terrestrial plants (bottlebrush and Chinese elm)	0.7	1	
11	Bufo marinus vertebrae	0.1	7	
11	Poaceae sp.	0	1	
12	Mollugo cerviana	5.5	2	
12	Merremia verecunda	0.7	2	
12	Chamaesyce chamaesycoides	0.7	2	
12	Crotalaria sphaerocarpa	1	2	
12	Dipcadi papillatum	0.7	2	
12	Oxalis depressa	2.7	2	
12	Aristida congesta	4	1	
12	Cynodon dactylon	16.2	1	
12	Eragrostis lehmanniana	14.7	1	
12	Eragrostis pseudo-obtusa	2	1	
12	Heteropogon contortus	0.2	1	
12	Schmidtia kalahariensis	15.7	1	
12	Tragus racemosus	16.2	1	
12	Urochloa panicoides	0.7	1	
12	Portulaca oleracea	0.5	2	
12	Talinum caffrum	2.2	2	
12	Sutera campanulata	2.7	2	
12	Tribulus terrestris	14.5	2	
13	Alternanthera acyrantha	0.2	2	
13	Arctotis stoechadifolia	0.5	2	
13	Ijloga aristulata	5.5	2	
13	Wahlenbergia androsacea	5	2	
13	Chamaesyce chamaesycoides	5.4	2	
13	Chamaesyce inaequilatera	3.8	2	
13	Crotalaria sphaerocarpa	15.8	2	
13	Indigofera alternans	2.8	2	
13	Indigofera daleoides	0.9	2	
13	Indigofera filipes	0.3	2	
13	Lotononis crumanina	1	2	
13	Lotononis listii	3.2	2	
13	Tephrosia burchellii	1.4	2	
13	Monsonia angustifolia	0.4	2	
13	Salvia clandestina	0.1	2	
13	Homeria pallida	1.1	2	
13	Hibiscus pusillus	2.7	2	
13	Ruschia griquensis	0.5	2	
13	Oxalis depressa	5	2	
13	Cynodon dactylon	0.6	1	
13	Eragrostis lehmanniana	0.5	1	
13	Portulaca trianthemoides	2.4	2	
13	Nemesia fruticans	12.9	2	

13	Peliostomum leucorrhizum	2	2	
13	Sutera caerulea	1	2	
13	Hebenstretia integrifolia	0.3	2	
13	Hermannia bicolor	7.3	2	
13	Hermannia coccocarpa	5	2	
13	Hermannia comosa	0.2	2	
13	Tribulus terrestris	6.3	2	
14	Alternanthera acyrantha	0.1	2	
14	Arctotis stoechadifolia	3.2	2	
14	Sonchus oleraceus	2.9	2	
14	Heliotropium nelsonii	0.6	2	
14	Opuntia species	2.8	2	
14	Merremia verecunda	0.5	2	
14	Chamaesyce chamaesycoides	1.5	2	
14	Chamaesyce inaequilatera	0.8	2	
14	Crotalaria sphaerocarpa	0.6	2	
14	Crotalaria lotoides	1.2	2	
14	Dichilus lebeckioides	0.8	2	
14	Ingofera daleoides	7.6	2	
14	Lotononis crumanina	1	2	
14	Lotononis listii	2.2	2	
14	Tephrosia burchellii	2.9	2	
14	Herniaria erckertii	0.7	2	
14	Bulbine frutescens	0.4	2	
14	Dipcadi papillatum	1.2	2	
14	Scilla nervosa	2.5	2	
14	Trachyandra saltii	1.2	2	
14	Hibiscus pusillus	2.6	2	
14	Pavonia burchellii	3.8	2	
14	Oxalis depressa	1	2	
14	Anthephora pubescens	2.3	1	
14	Aristida congesta	1.6	1	
14	Cynodon dactylon	7.6	1	
14	Eragrostis lehmanniana	13.2	1	
14	Eragrostis pseudo-obtusa	9.1	1	
14	Fingerhuthia africana	1.8	1	
14	Heteropogon contortus	0.4	1	
14	Schmidtia kalahariensis	2	1	
14	Ziziphus mucronata	0.1	1	
14	Hermannia quartiniana	15.2	2	
14	Tribulus terrestris	4.6	2	
15	Limeum aethiopicum	1.1	2	
15	Mollugo cerviana	6.5	2	
15	Amaranthus thunbergii	1.1	2	
15	Chamaesyce chamaesycoides	1.1	2	
15	Indigofera daleoides	7.6	2	
15	Gladiolus edulis	1.4	2	
15	Homeria pallilia	2.2	2	
15	Ledebouria graminifolia	3.6	2	

15	Ruschia griquensis	6.9	2	
15	Oxalis depressa	2.5	2	
15	Aristida congesta	7.6	1	
15	Cynodon dactylon	4	1	
15	Eragrostis lehmanniana	5.8	1	
15	Schmidtia kalahariensis	2.2	1	
15	Portulaca trianthemoides	1.1	2	
15	Talinum caffrum	3.6	2	
15	Tribulus terrestris	9.4	2	
16	Arislida spp.	11	1	
16	Cynodon spp.	3	1	
16	Digitaria argyrograpla (Nees) Stapf	2	1	
16	Enneapogon scaber Lehm.	29	1	
16	Enneapogon devauxii Beauv	10	1	
16	Eragrostis obtusa Munro	6	1	
16	Fingeruthia africana Lehm	3	1	
16	Unidentified grass leaves	21	1	
16	Unidentified grass bases	18	1	
16	Hordeum murinum L.	2	1	
16	Karoochloa purpurea (L.f.) Con &. Tuer.	1	1	
16	Lolium sp.	1	1	
16	Oropetium capense Stapf	1	1	
16	Setaria verticillata (L.) Beauv.	1	1	
16	Tragus sp.	1	1	
16	Unidentified sedge	2	1	
16	Albuca sp.	1	2	
16	Haworthia glauca Baker	4	2	
16	Haworthia semiviva (V. Poelln.) B.M. Bayer	1	2	
16	Thesium lineatum L.f.	1	1	
16	Polygonum sp.	1	1	
16	Atriplex lindleyi Moq.*	2	2	
16	Atriplex semibaccata Aell.*	2	2	
16	Chenopodium sp.	6	2	
16	Amaranthus sp.	2	2	
16	Galenia papulosa (E. &Z.) Sond.	9	2	
16	Hypertelis salsoloides (Burch.) Adamson	6	2	
16	Limeum aethiopicum Burm.	19	2	
16	Tetragonia spicata L.f.	1	2	
16	Tetragonia echinata Ait.	5	2	
16	Trianthema trinquerta Willd.	1	2	
16	Ruschia spinosa (L.) H.E.K. Hartm.	3	2	
16	Malephora lutea (Haw.) Schwant.	2	2	
16	Pleiospilos compactus (Ait.) Schwant.	1	2	
16	Skeletium sp.	1	2	
16	Phyllobolus sp.	2	2	
16	Trichodiadema sp.	3	2	
16	Unidentifed mesembryanthema	19	2	

16	Portulacaria afra Jacq.	1	2	
16	Dianthus sp.	1	2	
16	Argemone mexicana L.*	1	2	
16	Heliophila sp.	2	2	
16	Lepidium spp.	8	2	
16	Adromischus spp.	4	2	
16	Crassula muscosa L.	7	2	
16	Crassula subaphylla (E.& z.) Harv.	5	2	
16	Tylecodon reticulaius (L.f.) Toelk.	1	2	
16	Tylecodon ventricosus (Burm.f.) Toelk.	1	2	
16	Tylecodon wallichi (Harv.) Toelk.	4	2	
16	Acacia karroo Hayne	3	2	
16	Indigofera pungens E. Mey.	5	2	
16	Lessertia annularis Burch.	1	2	
16	Lotononis sp.	16	2	
16	Medicago polymorpha L.	5	2	
16	Augea capensis Thunb.	1	2	
16	Tribulus terrestris L.	3	2	
16	Zygophyllum sp.	2	2	
16	Chamaesyche inequilatera (Sond.) Sojak	4	2	
16	Euphorbia sp.	1	2	
16	Euphorbia stellaspina Haw.	3	2	
16	Rhus sp.	1	2	
16	Malva parviflora L.*	2	2	
16	Hermannia spp.	10	2	
16	Opuntia ficus-indica (L.) Mill.*	1	2	
16	Datura sp.*	1	2	
16	Aptosiumum indivisum Burch.	8	2	
16	Nemesia sp.	2	2	
16	Zaluzianskya sp.	1	2	
16	Walafrida sp.	1	2	
16	Blepharis sp.	3	2	
16	Chrysocoma ciliata L.	1	2	
16	Cuspidia cernua (L.f.) B.L. Burtt	10	2	
16	Eriocephalus sp.	2	2	
16	Leysera tenella D.C.	5	2	
16	Osteospermum calenduclaceum L.f.	1	2	
16	Pteronia sp.	4	2	
16	Ursinia nana D.C.	2	2	
16	Unidentified succulent leaves	21	2	
16	Coleoptera: Tenebrionidae (>15mm)	5	6	
16	Homoptera: Cicadidae (>15mm)	1	6	
16	Heteroptera: Pentatomidae (<10mm)	1	6	
16	Hymenoptera: Formicidae (<10mm)	3	6	
16	Bone fragments (8-10mm)	2	5	
16	Stones (4-7mm diameter)	4	5	
17	Lemna sp.	4		
17	Grass seeds	4		

17	Gastropoda	7		
17	Cladocera	4		
17	Coleoptera	4		
17	Diptera	4		
17	Hemiptera	7		
17	Hymenoptera (ants)	4		
17	Odonata (larvae)	4		
17	Mixed animal matter (Arthropods)	11		
17	Mixed plant matter	18		
18	Filamentous algae	2		
18	Grass	2		
18	Argemone ocroleucra (roots and leaves)	4		
18	Grass seeds	7		
18	Mixed plant matter	12		
18	Gastropoda	2		
18	Coleoptera	5		
18	Diptera	5		
18	Hemiptera	2		
18	Hymenoptera (ants)	7		
18	Odonata (larvae)	4		
18	Mixed animal matter (Arthropods)	11		
18	Anura (eggs)	4		
18	Anura (adults)	2		
18	Trichoptera	2		
19	Filamentous algae	19		
19	Grass	6		
19	Lemna sp.	6		
19	Mixed plant matter	19		
19	Gastropoda	6		
19	Coleoptera	6		
19	Diptera	6		
19	Mixed animal matter (Arthropods)	13		
20	Filamentous algae	4		
20	Grass	7		
20	Argemone ocroleucra (roots and leaves)	7		
20	Grass seeds	4		
20	Mixed Plant matter	14		
20	Coleoptera	4		
20	Diptera	4		
20	Hemiptera	4		
20	Hymenoptera (wasps and bees)	4		
20	Hymenoptera (ants)	4		
20	Odonata (larvae)	7		
20	Orthoptera	4		
20	Mixed animal matter (Arthropods)	7		
20	Anura (tadpoles)	4		
20	Trichoptera	4		
21	Filamentous algae	2		

21	Argemone ocroleucra (roots and leaves)	5		
21	Argemone ocroleucra (seeds)	7		
21	Grass seeds	12		
21	Mixed Plant matter	19		
21	Hirudinea	2		
21	Cladocera	7		
21	Hymenoptera (wasps and bees)	2		
21	Odonata (larvae)	7		
21	Anura (adults)	5		
21	Trichoptera	2		
22	Filamentous algae	1		
22	Grass	1		
22	Argemone ocroleucra (roots and leaves)	3		
22	Argemone ocroleucra (seeds)	3		
22	Grass seeds	7		
22	Guava seeds	1		
22	Mixed Plant matter	15		
22	Copepoda	1		
22	Scorpionida	1		
22	Aranae	1		
22	Coleoptera	11		
22	Diptera	4		
22	Hemiptera	4		
22	Hymenoptera (wasps and bees)	3		
22	Hymenoptera (ants)	5		
22	Odonata (larvae)	1		
22	Orthoptera	1		
22	Mixed animal matter (Arthropods)	11		
22	Anura (tadpoles)	1		
22	Trichoptera	1		
23	Cyprinidae (fish)	2	7	
23	Mesogastropoda Main body	21	8	
23	Mesogastropoda Gill Cover	1	8	
23	Nympaeaceae flower	1	3	
24	Mesogastropoda Gill Cover	3	8	
24	Trichoptera nymph (caddisfly)	1	5	
24	Unknown Insects	2	5	
24	Cyperaceae seed	12	4	
25	Mesogastropoda Gill Cover	20	8	
25	Unknown Insects	1	5	
26	Mesogastropoda Main body	10	8	
26	Mesogastropoda Gill Cover	2	8	
26	Bradybaenidae (snail)	1	8	
26	Trichoptera nymph (caddisfly)	3	4	
26	Odonata adult (dragonfly)	2	6	
26	Nympaeaceae flower	9	3	
28	Pteridohpytes (Adiantum sp., Tectaria sp., Asplenium sp., Elaphoglossum	43.2		

	sp., Lycopodium sp., Other unidentifed sp.)			
28	Vines (Selaginella arthritica, Philodendron sp.)	12.5		
28	Fruit and seeds (Jacaratia dolichaula, Solanum siparanoides, Faramea suerrensis, Miconia affinis)	12.4		
28	Tree seedlings (Pentaclethra macroloba, Carapa guianensis, Astrocaryum alatum, Other unidentified sp.)	10.5		
28	Tree leaves	10.4		
28	Unidentifed vegetation	11		
29	Aquatic plants	9.4		
29	Fruits/Seeds	36		
29	Algae	0.4		
29	Fish	51.6		
29	Invertebrates	0.1		
29	Miscellaneous	2.4		
29	Unidentifed	0.1		
31	Algae	6	4	
31	Cyperaceae sp.	46	1	
31	C. australe seed	2	2	
31	C. chinensis leaf	12	2	
31	Roots	6	1	
31	Poaceae sp.	28	1	
32	Mollusks	68	8	
32	Fish	13	7	
32	Caddisfly cases	1	6	
32	Mayfly larvae	10	5	
32	Damselfly larvae	3	5	
32	Vegetation	3	2	
32	Misc.	3	5	
33	Mollusks	19	8	
33	Fish	12	7	
33	Caddisfly cases	3	6	
33	Mayfly larvae	16	5	
33	Damselfly larvae	2	5	
33	Vegetation	42	2	
33	Misc.	5	5	
34	Mollusks	3	8	
34	Fish	5	7	
34	Caddisfly cases	7	6	
34	Mayfly larvae	42	5	
34	Damselfly larvae	1	5	
34	Vegetation	33	2	
34	Misc.	10	5	
35	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamen-tous algae)	59.6	2	
35	Heteropters	10.8	6	
35	Odonata	8.5	7	

35	Hymenopters	1.7	6	
35	Dipterans	1.7	5	
35	Coleopterans	1	6	
35	Crustaceans	3.3	6	
35	Gastropods	11.8	8	
35	Worms	0	7	
35	Fish	0	7	
35	Others	1.7	5	
36	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamen-tous algae)	15	2	
36	Heteropters	4	6	
36	Odonata	16.4	7	
36	Hymenopters	1.5	6	
36	Dipterans	1	5	
36	Colepterans	6.8	6	
36	Crustaceans	9.3	6	
36	Gastropods	32.5	8	
36	Worms	0	7	
36	Fish	0	7	
36	Others	13.5	5	
37	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamen-tous algae)	26.1	2	
37	Heteropters	1.6	6	
37	Odonata	0.6	7	
37	Hymenopters	0.9	6	
37	Dipterans	0.6	5	
37	Coleopterans	16	6	
37	Crustaceans	41.6	6	
37	Gasteropods	0	8	
37	Worms	0	7	
37	Fish	0	7	
37	Others	12.5	5	
38	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamen-tous algae)	15	2	
38	Heteropters	5.6	6	
38	Odonata	37.3	7	
38	Hymenopters	1.3	6	
38	Dipterans	6	5	
38	Coleopterans	10.3	6	
38	Crustaceans	16.5	6	
38	Gastropods	0	8	
38	Worms	0	7	
38	Fish	0.3	7	
38	Others	7.7	5	
39	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamen-tous algae)	84.61	2	
39	Heteropters	0.44	6	

39	Odonata	2.98	7	
39	Hymenopters	0.11	6	
39	Dipterans	0.77	5	
39	Coleopterans	1.73	6	
39	Crustaceans	5.94	6	
39	Gastropods	0	8	
39	Worms	1.55	7	
39	Fish	0.19	7	
39	Others	0.65	5	
40	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamentous algae)	49.3	2	
40	Heteropters	0	6	
40	Odonata	12	7	
40	Hymenopters	1	6	
40	Dipterans	8	5	
40	Coleopterans	9	6	
40	Crustaceans	0	6	
40	Gastropods	0.7	8	
40	Worms	0	7	
40	Fish	0	7	
40	Others	20	5	
41	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamentous algae)	31.8	2	
41	Heteropters	2	6	
41	Odonata	0	7	
41	Hymenopters	0	6	
41	Dipterans	0.6	5	
41	Coleopterans	4.6	6	
41	Crustaceans	53.5	6	
41	Gastropods	0	8	
41	Worms	0	7	
41	FIsh	6.7	7	
41	Others	0.3	5	
42	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamentous algae)	49.6	2	
42	Heteropters	10.5	6	
42	Odonata	13.4	7	
42	Hymenopters	3.1	6	
42	Dipterans	0.2	5	
42	Coleopterans	13.3	6	
42	Crustaceans	9.2	6	
42	Gastropods	0.3	8	
42	Worms	0	7	
42	Fish	0	7	
42	Others	0.3	5	
43	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamentous algae)	0	2	

43	Heteropters	7.5	6	
43	Odonata	47.5	7	
43	Hymenopters	2.5	6	
43	Dipterans	5	5	
43	Coleopterans	12.5	6	
43	Crustaceans	0	6	
43	Gastropods	25	8	
43	Worms	0	7	
43	Fish	0	7	
43	Others	0	5	
44	Plants (leaves, seeds or weeds of aquatic macrophytes, and filamentous algae)	25	2	
44	Heteropters	1	6	
44	Odonata	0.6	7	
44	Hymenopters	0.1	6	
44	Dipterans	0	5	
44	Coleopterans	0.9	6	
44	Crustaceans	71.5	6	
44	Gastropods	0	8	
44	Worms	0	7	
44	Fish	1	7	
44	Others	0	5	
45	Nuts, Seeds, Fruits	0	2	
45	Leaves, stems, roots, bark	0.13	1	
45	Higher Plant Material	0.28	2	
45	Algae	0.09	3	
45	MIsc. Plant Material	0.003	4	
45	Insects	0.002	6	
45	Crustaceans	0	6	
45	Mollusks	0	8	
45	Fish	0.03	7	
45	Bryozoans	0.44	5	
45	Unidentified/Detritus	0.02	5	
46	Nuts, Seeds, Fruits	0.02	2	
46	Leaves, stems, roots, bark	0.14	1	
46	Higher Plant Material	0.14	2	
46	Algae	0.06	3	
46	MIsc. Plant Material	0.06	4	
46	Insects	0.03	6	
46	Crustaceans	0	6	
46	Mollusks	0.06	8	
46	Fish	0.02	7	
46	Bryozoans	0.48	5	
46	Unidentified/Detritus	0	5	
47	Nuts, Seeds, Fruits	0.1	2	
47	Leaves, stems, roots, bark	0.52	1	
47	Higher Plant Material	0.06	2	
47	Algae	0.04	3	
47	MIsc. Plant Material	0	4	

47	Insects	0.1	6	
47	Crustaceans	0.01	6	
47	Mollusks	0.004	8	
47	Fish	0	7	
47	Bryozoans	0	5	
47	Unidentified/Detritus	0.17	5	
48	Aquatic Grasses	0	3	
48	Sagitaria and Algae	100	4	
49	Aquatic Grasses	2	3	
49	Sagitaria and Algae	98	4	
50	Aquatic Grasses	3	3	
50	Sagitaria and Algae	97	4	
51	Pimelodidae	10.5		
51	Characidae	3.41		
51	Poeciliidae	0.34		
51	Mental barbels, Chelidae (P. hilarii)	0.01		
51	Hydrobiidae	0.21		
51	Planorbidae	0.03		
51	Acari, Arrenuridae	0.0006		
51	Ostracoda, unidentified family	0.001		
51	Copepoda, unidentified family	0.13		
51	Amphipoda, Hyalellidae	1.58		
51	Decapoda, Sergestidae	0.99		
51	Heteroptera, Belostomatidae	10.64		
51	Heteroptera, Notonectidae	0.34		
51	Heteroptera, Corixidae	30.49		
51	Heteroptera, Ranatridae	0.12		
51	Larvae (Dysticidae, Hydrophilidae)	0.02		
51	Adult (Dysticidae, Hydrophilidae)	1.38		
51	Adult (Curculionidae and others) (terrestrial)	0.08		
51	Acrididae	0.04		
51	Formicidae	0.002		
51	Chironomidae (larvae)	34.8		
51	Ceratopogonidae (adult)	0.05		
51	Zigoptera larvae, unidentified family	2.41		
51	Larvae, unidentified family	2.31		
51	Larvae, unidentified family	0.03		
52	Loricaridae	0.14		
52	Characidae	2.98		
52	Poeciliidae	0.01		
52	Hylidae (larvae)	0.2		
52	Feathers, unidentified family	3.51		
52	Hair and skin rests, unidentified family	17.1		
52	Hydrozoa, Hydra spp.	0.007		
52	Turbellarea, unidentified family	0.003		
52	Ampullaridae	0.002		
52	Hydrobiidae	0.62		
52	Hyrudinea, unidentified family	2.19		

52	Oligochaeta, unidentified family (aquatic)	0.0001		
52	Araneidae, Lycosidae	0.008		
52	Acari, Arrenuridae	0.0002		
52	Cladocera, unidentified family	0.27		
52	Ostracoda, unidentified family	0.008		
52	Copepoda, unidentified family	0.21		
52	Amphipoda, Hyalellidae	0.83		
52	Decapoda, Brachyura, Trychodactylidae	0.002		
52	Isopoda, unidentified family (terrestrial)	0.22		
52	Heteroptera, Belostomatidae	12.29		
52	Heteroptera, Notonectidae	0.02		
52	Heteroptera, Corixidae	14.45		
52	Heteroptera, Ranatridae	0.0008		
52	Auchenorryncha, Cercopidea	0.01		
52	Larvae, unidentified family	0.66		
52	Larvae (Dysticidae, Hydrophilidae)	0.03		
52	Adult (Dysticidae, Hydrophilidae)	0.8		
52	Adult (Curculionidae and others) (terrestrial)	2.21		
52	Acrididae	0.0008		
52	Formicidae	0.001		
52	Hymenoptera, unidentified family	0.001		
52	Chironomidae (larvae)	39.77		
52	Culicidae (larvae)	0.009		
52	Culicidae (adult)	0.006		
52	Muscidae (larvae)	0.15		
52	Muscidae (adult)	0.01		
52	Sirphidae (larvae)	0.08		
52	Simulidae (adult)	0.0001		
52	Anisoptera larvae, unidentified family	0.27		
52	Zigoptera larvae, unidentified family	0.12		
52	Larvae, unidentified family	0.87		
52	Larvae, unidentified family	0.002		
57	Unionidae	0.1	8	
57	Corbicula	31.8	8	
57	Small gastropods	37.7	8	
57	Insect parts	1.2	6	
57	Trichoptera	24.6	6	
57	Plant material	2.3	2	
57	Mollusk soft tissue	0.05	8	
57	Unknown	2.3	5	
58	Pleuroceridae	93.4	8	
58	Unionidae	0.1	8	
58	Corbicula	2.4	8	
58	Small gastropods	0.2	8	
58	Insect parts	0.1	6	
58	Trichoptera	1.1	6	
58	Plant material	0.6	2	

58	Mollusk soft tissue	0.05	8	
58	Unknown	2	5	
59	Bithyniidae (Bithynia sp. Adults)	2.3	8	
59	Lymnaeidae (Galba sp. Adults)	4.1	8	
59	Physidae (Physella sp. Adults)	9.6	8	
59	Planorbidae (Adults)	2.3	8	
59	Undetermined remains (Adult)	0.4	8	
59	Acarina (Adult)	0.5	5	
59	Araneae (Adult)	0.5	5	
59	Conchostraca (Adult)	6.3	6	
59	Decapoda (Cambaridae (Procambarus clarkii)) Adults	7.8	6	
59	Dytiscidae (Larvae)	4.1	5	
59	Dytiscidae (Adult)	12.8	6	
59	Hydrophilidae (Larvae)	4.1	5	
59	Hydrophilidae (Adult)	18.7	5	
59	Noteridae (Adult)	0.5	6	
59	Chironomidae (larvae)	0.5	5	
59	Unidentified (Adult)	0.4	5	
59	Corixidae (Corixa sp. Adult)	13.7	6	
59	Notonectidae (Notonecta sp. Adults)	0.9	6	
59	Pleidae (Plea sp. Adults)	0.4	5	
59	Hymenoptera (Formicidae Adults)	3.2	5	
59	Aeshnidae (Larvae)	1.4	7	
59	Coenagrionidae (Adult)	1.4	7	
59	Libellulidae (Larvae)	0.4	6	
59	Libellulidae (Crocothemis erythraea Adult)	1.8	7	
59	Trichoptera (Larvae)	0.5	6	
59	Unidentified Insecta	0.9	5	
59	Vertebrata, undetermined remains	0.5	7	
60	Bithyniidae (Bithynia sp. Adults)	0	8	
60	Lymnaeidae (Galba sp. Adults)	0	8	
60	Physidae (Physella sp. Adults)	9.4	8	
60	Planorbidae (Adults)	3.1	8	
60	Undetermined remains (Adult)	0	8	
60	Acarina (Adult)	0	5	
60	Araneae (Adult)	3.1	5	
60	Conchostraca (Adult)	0	6	
60	Decapoda (Cambaridae (Procambarus clarkii)) Adults	0	6	
60	Dytiscidae (Larvae)	0	5	
60	Dytiscidae (Adult)	18.7	6	
60	Hydrophilidae (Larvae)	0	5	
60	Hydrophilidae (Adult)	6.3	5	
60	Noteridae (Adult)	0	6	
60	Chironomidae (larvae)	0	5	
60	Unidentified (Adult)	0	5	
60	Corixidae (Corixa sp. Adult)	0	6	
60	Notonectidae (Notonecta sp. Adults)	3	6	

60	Pleidae (Plea sp. Adults)	0	5	
60	Hymenoptera (Formicidae Adults)	31.3	5	
60	Aeshnidae (Larvae)	0	7	
60	Coenagrionidae (Adult)	15.7	7	
60	Libellulidae (Larvae)	0	6	
60	Libellulidae (Crocothemis erythraea Adult)	3.1	7	
60	Trichoptera (Larvae)	0	6	
60	Unidentified Insecta	6.3	5	
60	Vertebrata, undetermined remains	0	7	
61	Paspalum peniculatum	60.2	1	
61	Najas sp.	12.3	2	
61	Elodea densa	4.8	2	
61	Eichornea azurea	4.2	1	
61	Pontederia rotundifolia	2.8	2	
61	Ceratophyllum sp.	1	2	
61	Pisitia stratioides	1	2	
61	Myriophyllum sp.	0.8	2	
61	Lemma minor	1.6	4	
61	Spirodela polyrhiza	1.4	4	
61	Misc. tree leaves	0.9	2	
61	Ficus radula and sp. (fruit)	7	2	
61	Mangifera sp. (fruit)	0.5	2	
61	Insects	0.01	5	
61	Unidentified	1.5	4	
62	Paspalum peniculatum	62.2	1	
62	Najas sp.	6.8	2	
62	Elodea densa	6.4	2	
62	Pontederia rotundifolia	3.2	2	
62	Ceratophyllum sp.	3	2	
62	Pisitia stratioides	2.1	2	
62	Myriophyllum sp.	2.1	2	
62	Sagittaria latifolia	1	2	
62	Utricularia mixta	1	2	
62	Insects	0.01	5	
62	Unidentified	12.2	4	
63	Paspalum peniculatum	48	1	
63	Najas sp.	3.3	2	
63	Eichornea azurea	2.8	1	
63	Myriophyllum sp.	1.5	2	
63	Misc. tree leaves	1	2	
63	Thalassia testudinatum	1	2	
63	Mangrove leaves	38.5	1	
63	Insects	0.01	5	
63	Unidentified	3.9	4	
64	Paspalum peniculatum	85.2	1	
64	Najas sp.	2.4	2	
64	Elodea densa	1.8	2	
64	Potenderia rotundifolia	1.5	2	
64	Eichornea azurea	0.5	1	

64	Lemma minor	0.4	4	
64	Spirodela polyrhiza	0.4	4	
64	Ficus radula and sp. (fruit)	3.4	2	
64	Misc. tree leaves	2	2	
64	Insects	0.01	5	
64	Unidentified	2.4	4	
65	Paspalum peniculatum	65	1	
65	Najas sp.	12.2	2	
65	Potenderia rotundifolia	5.5	2	
65	Spirodela polyrhiza	2.4	4	
65	Misc. tree leaves	4.6	2	
65	Insects	0.01	5	
65	Unidentified	10.3	4	
66	Paspalum peniculatum	44.2	1	
66	Misc. tree leaves	10.5	2	
66	Mangrove leaves	38.6	1	
66	Unidentified	6.7	4	
67	Aeschnidae (Nymph)	13.3	5	
67	Corduliidae (Nymph)	25.7	6	
67	Dytiscidae (Adult)	6.3	6	
67	Cybister tripunctatus (Adult)	4.3	5	
67	Lethocerus distinctifemur (Adult)	0	6	
67	Diplonychus eques (Adult)	1.2	5	
67	Nematoda	0	5	
67	Macrobrachium sp. (Adult)	0	6	
67	Limnadia sp. (Adult)	17.6	5	
67	Lynceus sp. (Adult)	4.3	5	
67	Cyclestheria hislopi (Adult)	3.8	5	
67	Mollusca, Gastropoda (Adult)	1	8	
67	Hirudinea	0	5	
67	Amphibia (frog)	0	7	
67	Plotosidae (Eel-tailed catfish)	0	7	
67	Synbranchidae (Swamp eel)	0	5	
67	Unidentified fish	18.3	7	
67	Miscellaneous Aquatic Vertebrate Material	1.6	5	
67	Plant material	2.6	3	
68	Aeschnidae (Nymph)	1.3	5	
68	Corduliidae (Nymph)	0	6	
68	Dytiscidae (Adult)	0	6	
68	Cybister tripunctatus (Adult)	30.3	5	
68	Lethocerus distinctifemur (Adult)	1.1	6	
68	Diplonychus eques (Adult)	0.01	5	
68	Nematoda	0.01	5	
68	Macrobrachium sp. (Adult)	3.2	6	
68	Limnadia sp. (Adult)	0	5	
68	Lynceus sp. (Adult)	0	5	
68	Cyclestheria hislopi (Adult)	0	5	
68	Mollusca, Gastropoda (Adult)	0.01	8	
68	Hirudinea	0.01	5	

68	Amphibia (frog)	2.8	7	
68	Plotosidae (Eel-tailed catfish)	27.3	7	
68	Synbranchidae (Swamp eel)	20.1	5	
68	Unidentified fish	10.8	7	
68	Miscellaneous Aquatic Vertebrate Material	0	5	
68	Plant material	2.2	3	
69	Algae, (Spirogyra sp. & Vaucheria sp.)	0	4	
69	Vallisneria sp.	1	2	
69	Leaves (mostly Ficus racemosa)	10.1	2	
69	Fiscus racemosa (fruit/seeds)	13.9	2	
69	Nauclea orientalis (fruit/seeds)	54.3	2	
69	Terminalia erythrocarpa (fruit/seeds)	4.6	2	
69	Pandanus aquaticus (fruit/seeds)	0	2	
69	Morinda citrifolia (fruit/seeds)	0	2	
69	Acacia auriculiformes (fruit/seeds)	0	2	
69	Carallia brachiata (fruit/seeds)	0	2	
69	Flowers	0	3	
69	Bark and root material	3	1	
69	Palaemonidae (Macrobrachium sp.)	1	6	
69	Freshwater sponge	10.1	3	
69	Coleoptera, Dytiscidae (Adult)	0.4	5	
69	Heteroptera, Notonectidae (Adult)	0	5	
69	Trichoptera, Leptoceridae (Larvae)	0	5	
69	Lepidoptera (Larvae)	0.2	5	
69	Orthoptera, Acrididae (Adult)	0	5	
69	Araneomorphae, Heteropodidae	0.2	5	
69	Carrion Hair, (Sus scrofa, Pteropus sp.)	1.1	7	
69	Fecel pellet	0.01	7	
70	Algae, (Spirogyra sp. & Vaucheria sp.)	29.4	4	
70	Vallisneria sp.	0.4	2	
70	Leaves (mostly Ficus racemosa)	17	2	
70	Fiscus racemosa (fruit/seeds)	32.2	2	
70	Nauclea orientalis (fruit/seeds)	0	2	
70	Terminalia erythrocarpa (fruit/seeds)	0	2	
70	Pandanus aquaticus (fruit/seeds)	6.6	2	
70	Morinda citrifolia (fruit/seeds)	4.3	2	
70	Acacia auriculiformes (fruit/seeds)	7.7	2	
70	Carallia brachiata (fruit/seeds)	0.1	2	
70	Flowers	0.1	3	
70	Bark and root material	0.1	1	
70	Palaemonidae (Macrobrachium sp.)	1	6	
70	Freshwater sponge	0	3	
70	Coleoptera, Dytiscidae (Adult)	0	5	
70	Heteroptera, Notonectidae (Adult)	0.05	5	
70	Trichoptera, Leptoceridae (Larvae)	0.05	5	
70	Lepidoptera (Larvae)	0.5	5	
70	Orthoptera, Acrididae (Adult)	0.5	5	

70	Araneomorphae, Heteropodidae	0	5	
70	Carrion Hair, (Sus scrofa, Pteropus sp.)	0	7	
70	Fecel pellet	0	7	
71	Batrachospermum sp., Zoochlorella parasitica, Zygogonium ericetorum, Zygogonium kumaoense	7		
71	Baumea spp., Lepironia articulata, Utricularia sp.	23		
71	Ophrydium sp.	<1		
71	Cherax robustus, Caridina indistincta	25		
71	Dytiscidae, Gyrinidae	<1		
71	Ceratopogonidae, Chironomidae, Culicidae	1		
71	Leptophlebiidae	2		
71	Corixidae, Naucoridae	<1		
71	Sialidae	2		
71	Corduliidae, Libellulidae, Gomphidae, Miscellaneous Zygoptera	18		
71	Leptoceridae	9		
71	Miscellaneous Terrestrial Arthropods	11		
72	Windfall fruit	16.56		
72	Terrestrial vegetation	0.18		
72	Aquatic vegetation (Camboba)	75.53		
72	Terrestrial invertebrates	1.7		
72	Aquatic invertebrates	1.36		
72	Vertebrate carrion	0.59		
72	Bread	1.48		
72	Inorganic debris	0.08		
72	Organic debris	0.37		
72	Unidentifiable	2.15		
73	Sponge	0		
73	Spiders	0.071		
73	Insects	<0.001		
73	True bugs	0.134		
73	Water striders	0.125		
73	Orthopterans	0.002		
73	Caddis flies	0.002		
73	Caddis flies	0.001		
73	Snail shelled cf	0		
73	Stick cf	0.001		
73	Shrimps	0.46		
73	Prawns	0.35		
73	Crabs	3.16		
73	Fish	92.2		
73	Mussels	0		
73	Clams	<0.001		
73	Snails	0		
73	Animal tissue	2.74		
73	Green algae	0.001		
73	Seeds	0		

73	Figs	0		
73	Aquatic plant tissue	0.014		
73	Terrestrial plant tissue	0.41		
74	Sponge	9.32		
74	Spiders	0.23		
74	Insects	0.11		
74	True bugs	0.03		
74	Water striders	0.001		
74	Orthopterans	0.11		
74	Caddis flies	3.05		
74	Caddies flies	0.75		
74	Snail shelled cf	0.25		
74	Stick cf	2		
74	Shrimps	0.003		
74	Prawns	0.005		
74	Crabs	2.5		
74	Fish	0.8		
74	Mussels	1.27		
74	Clams	17.9		
74	Snails	0.43		
74	Animal tissue	2.07		
74	Green algae	19.7		
74	Seeds	1.45		
74	Figs	2.94		
74	Aquatic plant tissue	16.4		
74	Terrestrial plant tissue	14.5		
53	Submerged plants	73		
53	Windfall fruit	16		
53	Crustaceans	6		
53	Terrestrial Insects	4		
54	Submerged plants	35		
54	Molluscs	32		
54	Windfall fruit	15		
54	Terrestrial Insects	8		
54	Aquatic insects	5		
54	Vertebrates	3		
54	Crustaceans	2		
55	Windfall fruit	64		
55	Terrestrial insects	15		
55	Submerged plants	13		
55	Sponge	5		
55	Vertebrates	2		
56	Windfall fruit	53		
56	Terrestrial Insects	26		
56	Vertebrates	9		
56	Submerged plants	8		
56	Aquatic insects	3		
56	Molluscs	1		
56	Sponges	1		

75	Tricladida Adults	173	5	
75	Undet. Turbellaria Adults	83	5	same as above
75	Lumbriculidae Adults	207	5	
75	Undet. Oligochaeta Adults	111	5	same as above
75	Philobdella sp. Adults	14	5	
75	Undet. Hirudinea Adults	64	5	same as above
75	Anostraca Adults	16	5	
75	Cladocera Adults	27	5	
75	Eucopepoda Adults	79	5	
75	Sphaeromidae Adults	61	5	from feeding videos it appears head darting forward + suction is preferred mode, even on plants, so if smaller than head, most likely swallowed
75	Undet. Isopoda Adults	273	5	same as above
75	Gammaridae	61	5	
75	Cambarus sp Adults	84	6	
75	Procambarus clarki Adults	52	6	
75	Undet. Decapoda	31	6	same as above
75	Hydracarina	37	5	
75	Carabidae Adults	31	5	Though beetles are lightly defended, they are probably too small for snapping turtles to not swallow
75	Dytiscidae Adults	68	5	
75	Gyrinidae Adults	49	5	
75	Hydrophilidae Adults	37	5	
75	Undet. Coleoptera Adults	143	5	same as above
75	Diptera Larvae	29	5	
75	Ephemera sp. Larvae	63	5	
75	Potamanthus sp. Larvae	44	5	
75	Undet Ephemeridae Larvae	114	5	same as above
75	Belostomatidae Adults	54	5	
75	Corixidae (A)	97	5	
75	Gerridae (A)	27	5	
75	Ranatra sp. (A)	40	5	
75	Notonectidae (A)	131	5	
75	Undet. Hemiptera (A)	112	5	same as above
75	Lepidoptera	20	5	
75	Corydalidae (L)	16	5	
75	Sialidae (L)	31	5	
75	Aeshna sp. (L)	91	5	
75	Anax sp. (L)	18	5	
75	Agrionidae (L)	46	5	
75	Coenagrionidae (L)	76	5	
75	Gomphus sp. (L)	38	5	
75	Ophiogomphus sp. (L)	11	5	
75	Undet. Odonata (L)	81	5	same as above
75	Capniidae (L)	8	5	
75	Nemouridae (L)	3	5	
75	Perlidae (L)	46	5	

75	Undet. Plecoptera (L)	187	5	same as above
75	Trichoptera	54	5	
75	Ampullariidae (A)	12	8	
75	Lymnaeidae (A)	61	8	
75	Physidae (A)	84	8	
75	Undet. Gastropoda (A)	217	8	same as above
75	Bufonidae (L)	73	7	
75	Hylidae (L)	51	5	
75	Microhylidae (L)	12	5	
75	Pelobatidae (L)	69	5	
75	Ranidae (A)	37	7	
75	Ranidae (L)	84	5	
75	Undet Amphibia (L)	158	5	
75	Natrix sp.	19	7	
75	Thamnophis sp.	32	7	
75	Undet. Vertebrate Bone Fragments	387	7	
75	Elodea sp.	98.3	2	FO used, not N
75	Lemna sp.	33.8	4	FO used, not N
75	Najas sp.	45.7	2	FO used, not N
75	Nymphaea sp.	72.8	4	FO used, not N
75	Sagittaria sp.	50.8	2	FO used, not N
75	Typha sp.	37.2	2	FO used, not N
75	Vallisneria sp.	64.4	2	FO used, not N
75	Undet. Plant materal FO	100	2	FO used, not N
76	Fishes	35.4	7	Lumped all fishes
76	Other Vertebrates	1.1	7	
76	Carrion	19.6	7	
76	Invertebrates	7.8	6	Includes crayfish and snails
76	Vegetable matter	36.2	2	
77	Fishes	4.6	7	Lumped all fishes
77	Other Vertebrates	1.1	7	
77	Carrion	1.3	7	
77	Invertebrates	23.9	6	Includes crayfish and snails
77	Vegetable matter	69.2	2	
78	Fishes	85.3	7	Lumped all fishes
78	Frogs and Toads	1.2	7	
78	Crayfishes	8	6	
78	Insects	1	5	
78	Miscellaneous animals	0.4	7	meadow mouse and muskrat
78	Cryptograms	2.1	4	
78	Phanerogams	0.4	2	
78	Vegetable debris	1.6	4	
79	Fishes	1.5	7	Lumped all fishes
79	Frogs and Toads	0.5	7	
79	Crayfishes	41.6	6	
79	Insects	1.9	5	
79	Miscellaneous animals	0.4	8	water mites and snails
79	Cryptograms	6.1	4	
79	Phanerogams	10.6	2	

79	Vegetable debris	37.1	4	
80	Fishes	10.3	7	
80	Birds	28.2	7	Lumped all birds
80	Muskrat	0	7	
80	Carrion	5.3	7	
80	Crustaceans	0.4	6	
80	Insects	0.6	5	
80	Molluscs	1.7	8	
80	Cryptograms	49.3	4	
80	Phanerogams	0.3	2	
80	Vegetable debris	3.9	4	
81	Fishes	0.6	7	Lumped all fishes
81	Birds	4.4	7	Lumped all birds
81	Muskrat	5.6	7	
81	Carrion	0.3	7	
81	Crustaceans	0.1	6	
81	Insects	1.1	5	
81	Molluscs	0.5	8	
81	Cryptograms	70.3	4	
81	Phanerogams	1.8	2	
81	Vegetable debris	15.4	4	
82	Algae	12.8	4	
82	Elodea sp.	0.6	2	
82	Potamogeton sp.	9	2	
82	Najas sp.	0.3	2	
82	Pond lily	3.5	2	
82	Peltandra sp.	5.2	2	
82	Skunk cabbage	0.6	2	
82	Unknown aquatics	3.6	2	
82	Terrestrial plants	0.3	2	
82	Unidentified plants	0.6	4	
82	Insects	0.1	5	
82	Snail	0.01	8	
82	Crayfish	8	6	
82	Fiddler crab	2.7	6	
82	Shrimp	0.3	6	
82	Lamprey	2.5	7	
82	Eel	0.9	7	
82	Trout	0.1	7	
82	Sucker	3.2	7	
82	Bullhead	6.3	7	
82	Sunfish	7.5	7	
82	Perch	4.6	7	
82	Minnows	0.8	5	
82	Unknown fish	12.4	7	
82	Frog	0.6	7	
82	Salamander	0.01	7	
82	Snake	0.4	7	
82	Wood duck	0.5	7	

82	Red-wing blackbird	0.6	7	
82	Common mole	0.2	7	
82	Muskrat	0.9	7	
82	Unidentified animal	1.5	7	
82	Scavengings	4.6	7	
82	Non-food debris	4.8	0	Lumped paper, debris, and unclassified nonfood
83	Fishes	6.2	7	
83	Carrion	40.1	7	
83	Crayfishes	6.2	6	
83	Insects	16.9	6	
83	Snails and clams	23.2	8	
83	Cryptograms and Phanerogams	3.4	2	
83	Vegetable Debris	4	4	
84	Fishes	1.6	7	
84	Carrion	4.9	7	
84	Crayfishes	10.6	6	
84	Insects	23.6	6	
84	Snails and clams	34.7	8	
84	Cryptograms and Phanerogams	7.7	2	
84	Vegetable Debris	16.7	4	
85	Game fishes	1.6	7	
85	Forage fishes	2.7	7	
85	Fish remains	0.7	7	
85	Bird remains	5.6	7	
85	Carrion	4.7	7	
85	Leeches	0.1	5	
85	Crustaceans	56.6	6	
85	Insects	21.4	6	
85	Molluscs	2.6	8	
85	Cryptogams	1.2	2	
85	Phanerogams	0.5	2	
85	Vegetable debris	2.2	4	
86	Game fishes	0.01	7	
86	Forage fishes	0	7	
86	Fish remains	0.01	7	
86	Bird remains	1.8	7	
86	Carrion	0	7	
86	Leeches	0	5	
86	Crustaceans	60.1	6	
86	Insects	30.3	6	
86	Molluscs	0.5	8	
86	Cryptogams	0.01	2	
86	Phanerogams	0.3	2	
86	Vegetable debris	7	4	
87	Game fishes	1.8	7	
87	Forage fishes	11.3	7	
87	Fish remains	2.4	7	
87	Carrion	5	7	
87	Crayfishes	52.4	6	

87	Water mites	0	6	
87	Insects	8.6	5	
87	Snails	17.3	8	
87	Clams	1.3	8	
87	Plants	0	5	
88	Game fishes	0.01	7	
88	Forage fishes	0	7	
88	Fish remains	0.6	7	
88	Carrion	0	7	
88	Crayfishes	13	6	
88	Water mites	0.01	6	
88	Insects	12	5	
88	Snails	57.7	8	
88	Clams	12.5	8	
88	Plants	42	5	
89	Game fishes	1	7	
89	Forage fishes	0.3	7	
89	Fish remains	0.1	7	
89	Frog remains	0.4	7	
89	Carrion	2.5	7	
89	Spiders and water mites	0.01	5	
89	Leeches and "earthworms"	0.4	7	
89	Crustaceans	5	6	
89	Insects	16.5	6	
89	Molluscs	5.5	8	
89	Cryptogams	30.7	4	
89	Phanerogams	30.8	2	
89	Vegetable debris	3.7	4	
90	Fish remains	0.01	7	
90	Crayfishes	47.4	6	
90	Insects	52.4	5	
90	Snails	0.2	8	
90	Cryptogams	0.01	4	
90	Vegetable debris	0.2	4	
91	Fish remains	0	7	
91	Crayfishes	46.7	6	
91	Insects	53.3	5	
91	Snails	0	8	
91	Cryptogams	0.01	4	
91	Vegetable debris	0.01	4	
92	Diptera larvae	0.26	5	
92	Diptera pupae	0.26	5	
92	Diptera adults	0.01	5	
92	Gammarus	0	6	
92	Hyalella	0.01	6	
92	Zygoptera larvae	0	6	
92	Zygoptera adults	0.001	6	
92	Anisoptera larvae	0	6	
92	Corixidae	0.1	6	

92	Nabidae	0.001	6	
92	Notonectidae	0.03	6	
92	Coleoptera Larvae	0.002	6	
92	Coleoptera adults	0.001	6	
92	Trichoptera larvae	0.001	6	
92	Ephemeroptera larvae	0.01	6	
92	Isopoda	0.001	6	
92	Gastropoda	0	8	
92	Pelecypoda	0	8	
92	Hirudinea	0	7	
92	Aves (carrion)	0.05	7	
92	Vegetation	0.03	2	
92	Unidentified	0.22	5	
93	Diptera larvae	0.01	5	
93	Diptera pupae	0.001	5	
93	Diptera adults	0	5	
93	Gammarus	0.18	6	
93	Hyallela	0.14	6	
93	Zygoptera larvae	0.27	6	
93	Zygoptera adults	0	6	
93	Anisoptera larvae	0.02	6	
93	Corixidae	0.01	6	
93	Nabidae	0	6	
93	Notonectidae	0.01	6	
93	Coleoptera Larvae	0.05	6	
93	Coleoptera adults	0	6	
93	Trichoptera larvae	0.01	6	
93	Ephemeroptera larvae	0.002	6	
93	Isopoda	0	6	
93	Gastropoda	0.07	8	
93	Pelecypoda	0.001	8	
93	Hirudinea	0.001	7	
93	Aves (carrion)	0	7	
93	Vegetation	0.001	2	
93	Unidentified	0.07	5	
94	Leaves and stems	45.2	2	
94	Fruits	25.2	3	
94	Clams	29.6	8	
95	Leaves and stems	59.3	2	
95	Fruits	40.7	3	
95	Clams	0	8	
96	Leaves and stems	10.1	2	
96	Grasses and sedges	21.2	1	
96	Fruits	67.8	3	
96	Clams	0.2	8	
96	Snails	0.03	8	
96	Insect	0.07	5	
96	Unidentified	0.6	4	
97	Grasses and sedges	66.7	1	

97	Unidentified	33.3	4	
98	Leaves and stems	2.3	2	
98	Grasses and sedges	71	1	
98	Fruit	6.3	3	
98	Insect	0.9	5	
98	Fish	1	7	
98	Unidentified	18.5	4	
99	Grasses and sedges	100	1	
100	Leaves and stems	35.7	2	
100	Grasses and sedges	64	1	
100	Fish	0.3	7	
101	Leaves and stems	59	2	
101	Algae	22.7	4	
101	Fruits	10.1	3	
101	Insect	0	5	
101	Snail	6.1	8	
101	Clam	0.7	8	
101	Unidentified	1.4	4	
102	Leaves and stems	90.6	2	
102	Grasses and sedges	5.6	1	
102	Fruit	1	3	
102	Insect	2.8	5	
103	Leaves and stems	7.2	2	
103	Grasses and sedges	21.1	1	
103	Algae	29.4	4	
103	Fruits	11	3	
103	Fish	3.2	7	
103	Unidentified	28.1	4	
104	Leaves and stems	88.9	2	
104	Fruit	0	3	
104	Unidentified	11.1	4	
105	Leaves and stems	6.2	2	
105	Fruit	85.8	3	
105	Unidentified	8	4	
106	Decapoda	11	6	
106	Unidentified Insecta	2	6	
106	Unidentified Anisoptera	1	6	
106	Libellula sp.	1	6	
106	Trichoptera	1	6	
106	Unidentified Coleoptera	16	6	
106	Stratiomyidae	13	5	
106	Unidentified Osteichthyes	5	7	
106	Lepomis cyanellus	2	7	
106	Fish eggs	1	5	
106	Unidentified Anura	1	7	
106	Rana catesbeiana	1	7	
106	Rana sp.	2	7	
107	Sphaeriidae	5	8	
107	Unidentified Gastropoda	68	8	

107	Helisoma sp.	45	8	
107	Physa sp.	150	8	
107	Decapoda	11	6	
107	Unidentified Insecta	6	6	
107	Unidentified Anisoptera Larvae	2	6	
107	Unidentified Coleoptera Adult	3	6	
107	Chrysomelidae Adult	4	6	
107	Curculionidae Adult	1	6	
107	Unidentified Diptera	5	5	
107	Chironomidae	1	5	
107	Stratiomyidae	1	5	
107	Orthoptera	1	6	
107	Unidentified Osteichthyes	22	7	
108	Carex and Scirpus	2.3	1	
108	Ceratophyllum demersum	0	2	
108	Lemna minor	6.4	4	
108	seeds	0.9	2	
108	unidentified plant	2.7	4	
108	Stratiomyidae (l)	1.7	5	
108	Chironomidae (l)	0	5	
108	Belostomatidae (a)	0.4	6	
108	Dystiscidae (l)	7.3	6	
108	Hydrophilidae (a,l)	0	6	
108	Unidentified Coleoptera	0	6	
108	Anisoptera (n)	0.4	6	
108	Zygoptera (n)	0	6	
108	Trichoptera (a)	0	5	
108	unidentified insect eggs	0.5	5	
108	Arachnida	0	5	
108	Decapoda	19.3	6	
108	Hirudinea	0	7	
108	Oligochaeta	12.7	7	
108	Pelecypoda	0	8	
108	Gastropoda	35	8	
108	Aves	1.1	7	
108	Anura	0.5	7	
108	Osteichthys	4.3	7	
108	unidentified animal	4.5	7	
109	Carex and Scirpus	1.6	1	
109	Ceratophyllum demersum	1.2	2	
109	Lemna minor	0.4	4	
109	seeds	2.9	2	
109	unidentified plant	0.4	4	
109	Stratiomyidae (l)	1.3	5	
109	Chironomidae (l)	0	5	
109	Belostomatidae (a)	3.9	6	
109	Dystiscidae (l)	0.1	6	
109	Hydrophillidae (a,l)	0.3	6	
109	Unidentified Coleoptera	1.2	6	

109	Anisoptera (n)	0	6	
109	Zygoptera (n)	0	6	
109	Trichoptera (a)	0.3	5	
109	unidentified insect eggs	0.8	5	
109	Arachnida	0	5	
109	Decapoda	13.9	6	
109	Hirudinea	0	7	
109	Oligochaeta	0	7	
109	Pelecypoda	0.4	8	
109	Gastropoda	41.3	8	
109	Aves	3.3	7	
109	Anura	0	7	
109	Osteichthys	0.8	7	
109	unidentified animal	1.4	7	
110	Corbiculid clams	0	8	
110	Snails	11	8	
110	Crayfish	0	6	
110	Trichopteran larvae	32	6	
110	Ephemeropteran larvae	30.7	6	
110	Coleopteran adults	5.5	6	
110	Hemipteran adults	8.8	6	
110	Zygopteran adults	0	6	
110	Odonate larvae	0	6	
110	Lepidopteran adults	2.6	6	
110	Springtails	0.5	5	
110	unidentified insects	1.1	5	
110	Isopods	0	6	
110	Oligochaete worms	4.5	7	
110	Bryozoans	1	6	
110	Dicot leaves/stems	0.2	2	
110	Monocot leaves	0.2	1	
110	Grass seeds	1.1	4	
110	Filamentous algae	0.5	4	
110	Stonewort algae	0.2	3	
111	Corbiculid clams	0	8	
111	Snails	28.6	8	
111	Crayfish	0	6	
111	Trichopteran larvae	0	6	
111	Ephemeropteran larvae	21.4	6	
111	Coleopteran adults	14.3	6	
111	Hemipteran adults	0	6	
111	Zygopteran adults	0	6	
111	Odonate larvae	0	6	
111	Lepidopteran adults	0	6	
111	Springtails	0	5	
111	unidentified insects	14.3	5	
111	Isopods	0	6	
111	Oligochaete worms	0	7	
111	Bryozoans	0	6	

111	Dicot leaves/stems	0	2	
111	Monocot leaves	0	1	
111	Grass seeds	0	4	
111	Filamentous algae	21.4	4	
111	Stonewort algae	0	3	
112	Corbiculid clams	65.6	8	
112	Snails	4	8	
112	Crayfish	2	6	
112	Trichopteran larvae	6	6	
112	Ephemeropteran larvae	0	6	
112	Coleopteran adults	5.2	6	
112	Hemipteran adults	0	6	
112	Zygopteran adults	9.1	6	
112	Odonate larvae	4.8	6	
112	Lepidopteran adults	0	6	
112	Springtails	0	5	
112	unidentified insects	0	5	
112	Isopods	0.5	6	
112	Oligochaete worms	0	7	
112	Bryozoans	2	6	
112	Dicot leaves/stems	0.8	2	
112	Monocot leaves	0	1	
112	Grass seeds	0	4	
112	Filamentous algae	0	4	
112	Stonewort algae	0	3	
113	Corbiculid clams	1.2	8	
113	Snails	15.2	8	
113	Crayfish	0	6	
113	Trichopteran larvae	30.5	6	
113	Zygopteran adults	1.8	6	
113	Coleopteran adults	2.4	6	
113	Psephenid larvae	0.2	5	
113	Orthopteran adults	0.1	6	
113	Hemipteran adults	0.1	6	
113	Ephemeropteran larvae	0.1	6	
113	Megalopteran larvae	1.7	6	
113	unidentified insects	26.8	5	
113	isopods	6.6	6	
113	Sponges	1.1	7	
113	Leeches	0.5	7	
113	Fish	0	7	
113	Dicot leaves/stems	0.3	2	
113	Grass seeds	1.5	4	
113	Grass inflorescences	3	3	
113	Other flowers	1	3	
113	Filamentous algae	2.2	4	
113	Stonewort algae	3.7	3	
114	Corbiculid clams	33	8	
114	Snails	32	8	

114	Crayfish	0	6	
114	Trichopteran larvae	10.9	6	
114	Zygopteran adults	3.9	6	
114	Coleopteran adults	0	6	
114	Psephenid larvae	0	5	
114	Orthopteran adults	0	6	
114	Hemipteran adults	0	6	
114	Ephemeropteran larvae	0	6	
114	Megalopteran larvae	0	6	
114	unidentified insects	17.5	5	
114	isopods	0	6	
114	Sponges	0	7	
114	Leeches	0.5	7	
114	Fish	0	7	
114	Dicot leaves/stems	1.9	2	
114	Grass seeds	0	4	
114	Grass inflorescences	0	3	
114	Other flowers	0	3	
114	Filamentous algae	0.4	4	
114	Stonewort algae	0	3	
115	Corbiculid clams	94.7	8	
115	Snails	2.9	8	
115	Crayfish	0.2	6	
115	Trichopteran larvae	0.02	6	
115	Zygopteran adults	0	6	
115	Coleopteran adults	0.02	6	
115	Psephenid larvae	0	5	
115	Orthopteran adults	0	6	
115	Hemipteran adults	0	6	
115	Ephemeropteran larvae	0	6	
115	Megalopteran larvae	0	6	
115	unidentified insects	9.6	5	
115	isopods	0	6	
115	Sponges	0	3	
115	Leeches	0	7	
115	Fish	0.02	7	
115	Dicot leaves/stems	0.2	2	
115	Grass seeds	0.01	4	
115	Grass inflorescences	1	3	
115	Other flowers	0	3	
115	Filamentous algae	0.01	4	
115	Stonewort algae	0	3	
116	Sphaeriid clams	0	8	
116	Snails	0	8	
116	Sponges	0	7	
116	Bryozoans	0	6	
116	Trichopteran larvae	62.1	6	
116	Coleopteran adults	10	6	
116	unidentified insects	20	5	

116	Monocot leaves	2.1	1	
116	Dicot leaves	5.7	2	
116	Filamentous algae	0	4	
116	Stonewort algae	0	3	
116	Seeds	0	4	
117	Sphaeriid clams	16.3	8	
117	Snails	4.8	8	
117	Sponges	23.9	7	
117	Bryozoans	19.6	6	
117	Trichopteran larvae	21.1	6	
117	Coleopteran adults	3.3	6	
117	unidentified insects	1.1	5	
117	Monocot leaves	0.1	1	
117	Dicot leaves	0.3	2	
117	Filamentous algae	9.2	4	
117	Stonewort algae	0.2	3	
117	Seeds	0.2	4	
118	Chelone glabra leaves	50.8	2	
118	Wetland grass sp.	23.2	1	
118	Dicot seeds and leaves	0	2	
118	Ulmus americana fruits	0.5	4	
118	Uniden. plant material	1.2	4	
118	Chironomidae larvae	0	5	
118	Hymenoptera	2	6	
118	Coleoptera	1.8	6	
118	Diptera	0.7	5	
118	Odonata	0	6	
118	Unidentified insects	0.7	5	
118	Trap bait (fish)	16.1	7	
118	Gastropoda	0.3	8	
118	Pelecypoda	0.2	8	
118	Fish (other than trap bait)	0.02	7	
118	Bird fledglings	0.5	7	
118	Crayfish	0.08	6	
118	Uniden. animal material	0.4	5	
118	Detritus	0	4	
118	Unidentfied misc material	0.8	4	
119	Chelone glabra leaves	0	2	
119	Wetland grass sp.	0	1	
119	Dicot seeds and leaves	12.7	2	
119	Ulmus americana fruits	0	4	
119	Uniden. plant material	0	4	
119	Chironomidae larvae	27.7	5	
119	Hymenoptera	6	6	
119	Coleoptera	4.5	6	
119	Diptera	0.3	5	
119	Odonata	0.2	6	
119	Unidentified insects	0.2	5	
119	Trap bait (fish)	0	7	

119	Gastropoda	0.3	8	
119	Pelecypoda	0	8	
119	Fish (other than trap bait)	0.2	7	
119	Bird fledglings	0	7	
119	Crayfish	0	6	
119	Uniden. animal material	0	5	
119	Detritus	42.4	4	
119	Unidentfied misc material	5.5	5	
120	Centaurea	19.87	2	
120	Asteraceae	0.43	2	
120	Koelpinia	4.75	2	
120	Hypecoum	0.07	2	
120	Alyssum	0.03	2	
120	Papaveraceae	0.23	2	
120	Veronica	0.32	2	
120	Brassicaceae sp.2.	4.56	2	
120	Epilasia	4.86	2	
120	Ceratocephalus	64.84	2	
121	Hypecoum	0.36	2	
121	Asteraceae sp.	5.53	2	
121	Veronica	0.26	2	
121	Ceratocephalus	3.34	2	
121	Koelpinia	25.59	2	
121	Centaurea	1.17	2	
121	Epilasia	4.73	2	
121	Roemeria	1.72	2	
121	Brassicaceae sp.4.	20.73	2	
121	Papaver	36.51	2	
122	Forbs	36.7	2	
122	Cactus	28	2	
122	Grass	20.8	1	
122	Woody vegetation	8.71	1	
122	Animal matter	5.76	5	
123	Fruit	47.4	3	
123	Flower	23.2	3	
123	live vegetative plant parts (leaves stems roots)	17.7	2	
123	dead leaves (leaf litter) and bark	3.2	1	
123	fungi	4.2	2	
123	vertebrates	1	7	
124	Fruit	46	3	
124	Flower	29.7	3	
124	live vegetative plant parts (leaves stems roots)	8.1	2	
124	dead leaves (leaf litter) and bark	5.4	1	
125	Leaf and stems	21.9	2	
125	Fruit pulp	1.3	3	
125	Seeds	49.5	3	
125	Insects	3.3	5	
125	Flowers	1	3	

125	Fungi	19.9	3	
125	Vertebrate animals	2.8	7	
126	Leaf and stems	41.1	2	
126	Fruit pulp	7.3	3	
126	Seeds	28	3	
126	Insects	3.2	5	
126	Flowers	0.2	3	
126	Fungi	16	3	
126	Vertebrate animals	4.2	7	
127	Threeawn (Aristida spp.)	22	1	
127	Globemallow (Sphaeralcea spp.)	21	2	
127	Slim tridens (Tridens muticus)	20	1	
127	Foxtail brome (Bromus rubens)	19	1	
127	Red grama (Bouteloua trifida)	6	1	
127	Sedge (Carex spp.)	3	1	
127	Common sixweeksgrass (Vulpia octoflora)	1	1	
127	Cryptantha (Cryptantha spp.)	1	1	
127	Mormontea (Ephedra spp.)	1	1	
127	Wildbuckwheat (Eriogonum sp.)	1	2	
127	Cactaceae	1	2	
128	Threeawn (Aristida spp.)	16	1	
128	Globemallow (Sphaeralcea spp.)	6	2	
128	Slim tridens (Tridens muticus)	50	1	
128	Bush muhly (Mulenbergia porteri)	17	1	
128	Slender janusia (Janusia gracilis	11	2	
129	Foxtail brome (Bromus rubens)	64	1	
129	Redstem filaree (Erodium cicutarium)	23	2	
129	Comon winterfat (Eurotia lanata)	6	1	
129	Vetch (Astralagus + Oxytropis)	4	2	
130	Acmispon brachycarpus	29.7	2	
130	Mirabilis laevis	10.79	2	
130	Chamaesyce albomarginata	10.74	2	
130	Astragalus layneae	8.2	2	
130	Prenanthella exigua	5.59	2	
130	Astragalus didymocarpus	4.59	2	
130	Erodium cicutarium	3.93	2	
130	Eremothera boothii	3.86	2	
130	Chorizanthe brevicornu	2.6	2	
130	Phacelia tanacetifolia	2.01	2	
130	Amsinckia tessellata	1.93	2	
130	Mentzelia spp.	1.63	2	
130	Cryptantha circumcissa	1.59	2	
130	Eriastrum eremicum	1.46	2	
130	Plantago ovata	1.22	2	
130	Gilia minor	0.97	2	
130	Stylocline psilocarphoides	0.94	2	
130	Tetrapteron palmeri	0.75	2	
130	Schismus barbatus	0.69	1	
130	Malacothrix coulteri	0.61	2	

130	Lupinus odoratus	0.6	2	
130	Stephanomeria parryi	0.37	2	
130	Malacothrix glabrata	0.35	2	
130	Chaenactis fremontii	0.34	2	
130	Pectocarya spp.	0.25	2	
130	Loeseliastrum schottii	0.22	2	
130	Tropidocarpum gracile	0.21	2	
130	Linanthus dichotomus	0.19	2	
130	Allium fimbriatum	0.07	2	
130	Oxytheca perfoliata	0.07	2	
130	Unknown grass sp.	0.05	1	
130	Pholistoma membranaceum	0.04	2	
130	Chorizanthe rigida	0.03	2	
130	Eriogonum gracillimum	0.03	2	
130	Eriogonum pusillum	0.03	2	
130	Bromus madritensis	0.03	1	
130	Caulanthus inflatus	0.02	2	
130	Calycoseris parryi	0.02	2	
130	Astragalus acutirostris	0.01	2	
130	Ambrosia salsola	0.01	2	
130	Linanthus parryae	0.01	2	
130	Lomatium mohavense	0.01	2	
130	Chaenactis carphoclinia	0	2	
130	dead lizard (Gambelia wislizeni)	1.96	7	
130	unidentified plants	1.17	2	
130	tortoise scat	0.1	3	
131	Aristida purpurea	2.64	1	
131	Ayenia compacta	1.62	2	
131	Erioneuron pulchellum	23.17	1	
131	Euphorbia sp.	13.88	2	
131	Hilaria mutica	19.93	1	
131	Janusia gracilis	1.28	2	
131	Krameria parvifolia	2.38	2	
131	Opuntia englemannii	29.64	2	
131	Plantago insularis	3.66	2	
131	Sphaeralcea ambigua	1.19	2	
131	tortoise scat	0.6	3	
132	Schismus barbatus	15.34	1	
132	Plantago insularis	1.59	2	
132	Aristida purpurea	15.34	1	
132	Hilaria rigida	67.72	1	
133	Poaceae (Cyperaceae)	48.6	1	
133	Pinus ellotttii	5.7	1	
133	Galactia sp.	2.9	2	
133	Vaccinium myrsinites	5.7	2	
133	Roots	5.7	1	
133	Diodia teres	5.7	2	
133	Chamaesyce maculata	11.4	2	
133	Froelichia floridana	2.9	2	

133	Pityopsis graminifolia	2.9	2	
133	Tephrosia chrysophylla	2.9	2	
133	Mimosa quadrivalvis	2.9	2	
133	Licania michauxii (fruit)	2.9	3	
133	Commelina erecta	2.9	2	
134	Poaceae (Cyperaceae)	28.57	1	
134	Paspalum notatum	5.84	1	
134	Paspalum setaceum	4.22	1	
134	Pinus elliottii	14.29	1	
134	Galactia sp.	11.69	2	
134	Vaccinium myrsinites	9.09	2	
134	Quercus geminata	4.87	2	
134	Gaylussacia dumosa	4.55	2	
134	Roots	3.57	1	
134	Selaginella arenicola	2.92	2	
134	Diodia teres	2.27	2	
134	Smilax auriculata	1.62	2	
134	Myrica cerifera	1.62	2	
134	Digitaria sp.	0.97	1	
134	Quercus myrtifolia	0.65	2	
134	Unknown herb	0.65	2	
134	Chamaesyce maculata	0.65	2	
134	Quercus minima	0.32	2	
134	Carya floridana	0.32	2	
134	Lyonia lucida	0.32	2	
134	Lyonia fruticosa	0.32	2	
134	Opuntia humifusa	0.32	3	
134	Ximenia americana	0.32	2	
135	Fruit	33.33	3	
135	Other plant matter	25	2	
135	Mammal	0	7	
135	Bird	0	7	
135	Frog	0	7	
135	Lizard	0	7	
135	Crab	0	7	
135	Fish	0	7	
135	Mollusk	8.33	8	
135	Insect	33.33	6	
136	Fruit	29.31	3	
136	Other plant matter	17.24	2	
136	Mammal	0	7	
136	Bird	0	7	
136	Frog	1.72	7	
136	Lizard	1.72	7	
136	Crab	10.34	7	
136	Fish	1.72	7	
136	Mollusk	8.62	8	
136	Insect	29.31	6	
137	Fruit	31.58	3	

137	Other plant matter	15.79	2	
137	Mammal	0	7	
137	Bird	2.63	7	
137	Frog	0	7	
137	Lizard	0	7	
137	Crab	10.53	7	
137	Fish	5.26	7	
137	Mollusk	7.89	8	
137	Insect	26.32	6	
138	Fruit	33.33	3	
138	Other plant matter	33.33	2	
138	Mammal	0	7	
138	Bird	0	7	
138	Frog	0	7	
138	Lizard	0	7	
138	Crab	0	7	
138	Fish	0	7	
138	Mollusk	33.33	8	
138	Insect	0	6	
139	Fruit	30.77	3	
139	Other plant matter	15.38	2	
139	Mammal	0	7	
139	Bird	0	7	
139	Frog	0	7	
139	Lizard	0	7	
139	Crab	23.08	7	
139	Fish	0	7	
139	Mollusk	15.38	8	
139	Insect	15.38	6	
140	Fruit	40	3	
140	Other plant matter	20	2	
140	Mammal	6.67	7	
140	Bird	0	7	
140	Frog	0	7	
140	Lizard	0	7	
140	Crab	13.33	7	
140	Fish	0	7	
140	Mollusk	20	8	
140	Insect	0	6	
141	Ephemeroptera	7.7	5	
141	Decapoda	3.8	6	
141	Fish	3.9	7	
141	Unidentified Animal	61.5	7	
141	Plant	3.9	2	
142	Coleoptera	0.4	6	
142	Diptera	0.4	5	
142	Ephemeroptera	54.9	5	
142	Hymenoptera	0.4	5	
142	Lepidoptera	1.3	5	

142	Odonata	2.1	6	
142	Trichoptera	4.2	6	
142	Insect Unknown	8.4	5	
142	Fish	1.7	7	
142	Unidentified Animal	6.8	7	
142	Poaceae	0.4	1	
142	Dicot	0.4	2	
143	Coleoptera	8.3	6	
143	Fish	33.4	7	
143	Unidentified Animal	8.3	7	
143	Dicot	8.3	2	
144	Coleoptera	1.6	6	
144	Chironomidae	0.3	5	
144	Trichoptera	72.5	6	
144	Isopoda	0.8	6	
144	Gastropoda	8	8	
144	unidentified Animal	1.2	6	
144	Poaceae	0.1	1	
144	Dicot	1.7	2	
144	Algae	1	4	
144	unidentified plants	0.4	2	
145	Insect	19.5	6	
145	Crustacean	0	6	
145	Mollusk	18.7	8	
145	Fish	39.7	7	
145	Leaves and Algae	12.8	4	
146	Insect	3.1	6	
146	Crustacean	0	6	
146	Mollusk	0.1	8	
146	Fish	3.4	7	
146	Leaves and Algae	91.5	4	
147	Insect	6.8	6	
147	Crustacean	16.5	6	
147	Mollusk	0.5	8	
147	Fish	23.4	7	
147	Leaves and Algae	20	4	
148	Insect	90.3	6	
148	Crustacean	0	6	
148	Mollusk	0	8	
148	Fish	0	7	
148	Leaves and Algae	8.9	4	
149	Insect	42	6	
149	Crustacean	0	6	
149	Mollusk	0.2	8	
149	Fish	0.7	7	
149	Leaves and Algae	54	4	
150	Insect	52.1	6	
150	Crustacean	2.1	6	
150	Mollusk	13.5	8	

150	Fish	0	7	
150	Leaves and Algae	14.6	4	
151	Insect	11.9	6	
151	Crustacean	0.1	6	
151	Mollusk	0.4	8	
151	Fish	59.7	7	
151	Leaves and Algae	23.4	4	
152	Insect	4.8	6	
152	Crustacean	2.7	6	
152	Mollusk	12.4	8	
152	Fish	18	7	
152	Leaves and Algae	55.4	4	
153	Insect	0	6	
153	Crustacean	0	6	
153	Mollusk	1.3	8	
153	Fish	0	7	
153	Leaves and Algae	98.7	4	
154	Insect	4.8	6	
154	Crustacean	0	6	
154	Mollusk	0.6	8	
154	Fish	10	7	
154	Leaves and Algae	59.9	4	
155	Insect	5.1	6	
155	Crustacean	0	6	
155	Mollusk	82	8	
155	Fish	3.8	7	
155	Leaves and Algae	5.7	4	
156	Insect	31.9	6	
156	Crustacean	0	6	
156	Mollusk	3.5	8	
156	Fish	0.7	7	
156	Leaves and Algae	63.2	4	
157	Insect	23.7	6	
157	Crustacean	20	6	
157	Mollusk	1	8	
157	Fish	41	7	
157	Leaves and Algae	3.7	4	
158	Insect	4.6	6	
158	Crustacean	0.3	6	
158	Mollusk	1.4	8	
158	Fish	54.8	7	
158	Leaves and Algae	38.5	4	
159	Insect	8.1	6	
159	Crustacean	0.4	6	
159	Mollusk	15.1	8	
159	Fish	25.8	7	
159	Leaves and Algae	48.1	4	
160	Insect	2.1	6	
160	Crustacean	0	6	

160	Mollusk	1.7	8	
160	Fish	1.8	7	
160	Leaves and Algae	94	4	
161	Insect	13.3	6	
161	Crustacean	0	6	
161	Mollusk	2.9	8	
161	Fish	37.7	7	
161	Leaves and Algae	36.4	4	
162	Insect	23.5	6	
162	Crustacean	0	6	
162	Mollusk	24.1	8	
162	Fish	44.2	7	
162	Leaves and Algae	7.1	4	
163	Insect	33	6	
163	Crustacean	0	6	
163	Mollusk	22	8	
163	Fish	62	7	
163	Leaves and Algae	38	4	
164	Insect	38.9	6	
164	Crustacean	2.6	6	
164	Mollusk	7.6	8	
164	Fish	16.6	7	
164	Leaves and Algae	28.7	4	
165	Insect	22.7	6	
165	Crustacean	4.6	6	
165	Mollusk	3	8	
165	Fish	24.8	7	
165	Leaves and Algae	40.4	4	
166	Paspalum peniculatum	12.2	1	
166	Elodea densa	12.6	2	
166	Najas sp.	2.4	2	
166	Unidentified vegetation	7.8	4	
166	Insects	50.2	6	
166	Small snails	4	8	
166	Fish	1.5	7	
166	Unidentified animal	9.3	5	
167	Paspalum peniculatum	15.5	1	
167	Unidentified vegetation	12.1	4	
167	Insects	62.8	6	
167	Small snails	9	8	
167	Unidentified animal	0.6	5	
168	Large Snails (mainly Pomacea)	75.4	8	
168	Turtles	20.6	8	
168	Fish	2	7	
168	Unidentified	2	5	
169	Paspalum peniculatum	43.2	1	
169	Elodea densa	13.2	2	
169	Najas sp.	9.8	2	
169	Unidentified vegetation	2.9	4	

169	Insects	27.9	6	
169	Crustaceans	1	6	
169	Fish	1	7	
169	Unidentified animal	1	5	
170	Paspalum peniculatum	30.2	1	
170	Elodea densa	15.6	2	
170	Najas sp.	2	2	
170	Unidentified vegetation	6.2	4	
170	Insects	38	6	
170	Fish	3.2	7	
170	Unidentified animal	4.8	5	
171	Paspalum peniculatum	4.5	1	
171	Elodea densa	4	2	
171	Unidentified vegetation	4	4	
171	Insects	80.4	80.4	
171	Fish	1.2	1.2	
171	Unidentified animal	5.9	5.9	
172	Large Snails (mainly Pomacea)	85.2	8	
172	Turtles	10	8	
172	Unidentified	4.8	5	
173	Large Snails (mainly Pomacea)	60.2	8	
173	Turtles	30.8	8	
173	Fish	6	7	
173	Unidentified	3	5	
174	Large Snails (mainly Pomacea)	36.8	8	
174	Turtles	57.3	8	
174	Unidentified	5.9	5	
175	Insecta	30.4	6	
175	Crustacea	1.4	6	
175	Mollusca	31.8	8	
175	Amphibia	2.2	7	
175	Carrion	11.9	7	
175	Aquatic Vegetation	22.3	2	
176	Insecta	27.8	6	
176	Crustacea	27.7	6	
176	Mollusca	23.5	8	
176	Amphibia	9.2	7	
176	Carrion	3.2	7	
176	Aquatic Vegetation	8.5	2	
177	Insecta	46.4	6	
177	Crustacea	5	6	
177	Mollusca	23.7	8	
177	Amphibia	1.1	7	
177	Carrion	3.4	7	
177	Aquatic Vegetation	20.4	2	
178	Insecta	42.9	6	
178	Crustacea	2.8	6	
178	Mollusca	24.3	8	
178	Amphibia	2.5	7	

178	Carrion	10.6	7	
178	Aquatic Vegetation	16.6	2	
179	Mollusk	40	8	
179	Crustacean	14.9	6	
179	Arthropod	7.5	6	
179	Plant	23.6	2	
179	Other	16.4	5	
180	Mollusk	82	8	
180	Crustacean	2.5	6	
180	Arthropod	2	6	
180	Plant	11.4	2	
180	Other	3.6	5	
181	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	4.9	6	
181	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
181	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
181	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	85.6	8	
181	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
181	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
181	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
181	Crustacea, larger Astacidae.	0	6	
181	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	2.2	6	
181	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0	5	
181	Adult Gryllidae.	0	6	
181	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
181	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
181	Plant material.	3.4	2	
181	Detritus and unidentifiable carrion.	3.8	5	
182	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	9.4	6	
182	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
182	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	1.4	8	

182	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	19.3	8	
182	Small bivalves, includes Sphaeriidae, small Corbiculidae.	3.9	8	
182	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
182	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0.7	6	
182	Crustacea, larger Astacidae.	21.6	6	
182	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
182	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	1.2	5	
182	Adult Gryllidae.	0	6	
182	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
182	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
182	Plant material.	1.9	2	
182	Detritus and unidentifiable carrion.	40.7	5	
183	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	38.5	6	
183	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	6.9	8	
183	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
183	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	14.7	8	
183	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.6	8	
183	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
183	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
183	Crustacea, larger Astacidae.	3	6	
183	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0.8	6	
183	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0.4	5	
183	Adult Gryllidae.	1.1	6	
183	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
183	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0.5	7	
183	Plant material.	0	2	
183	Detritus and unidentifiable carrion.	33.5	5	

184	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	74.9	6	
184	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
184	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
184	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	8.7	8	
184	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
184	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
184	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
184	Crustacea, larger Astacidae.	2.3	6	
184	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
184	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	2.8	5	
184	Adult Gryllidae.	8.5	6	
184	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
184	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
184	Plant material.	0	2	
184	Detritus and unidentifiable carrion.	3	5	
185	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	0.2	6	
185	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
185	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
185	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	87.7	8	
185	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
185	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
185	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
185	Crustacea, larger Astacidae.	0.2	6	
185	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
185	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0	5	
185	Adult Gryllidae.	0	6	

185	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0.6	6	
185	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
185	Plant material.	0.4	2	
185	Detritus and unidentifiable carrion.	10.8	5	
186	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	26.7	6	
186	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	1.9	8	
186	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
186	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	64.2	8	
186	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
186	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
186	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	2.5	6	
186	Crustacea, larger Astacidae.	0	6	
186	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0.6	6	
186	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0	5	
186	Adult Gryllidae.	0	6	
186	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
186	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
186	Plant material.	0	2	
186	Detritus and unidentifiable carrion.	3.8	5	
187	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	0.3	6	
187	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
187	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
187	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
187	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
187	Larger bivalves, includes Unionidae, large Corbiculidae.	1	8	
187	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	

187	Crustacea, larger Astacidae.	23.6	6	
187	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0.7	6	
187	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0	5	
187	Adult Gryllidae.	0	6	
187	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0.9	6	
187	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	2.1	7	
187	Plant material.	0.9	2	
187	Detritus and unidentifiable carrion.	70.6	5	
188	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	4.3	6	
188	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
188	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
188	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
188	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.4	8	
188	Larger bivalves, includes Unionidae, large Corbiculidae.	3.8	8	
188	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	5.4	6	
188	Crustacea, larger Astacidae.	19.9	6	
188	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
188	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	1.1	5	
188	Adult Gryllidae.	0	6	
188	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
188	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
188	Plant material.	12.8	2	
188	Detritus and unidentifiable carrion.	42.4	5	
189	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	13	6	
189	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
189	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	

189	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
189	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0	8	
189	Larger bivalves, includes Unionidae, large Corbiculidae.	1.4	8	
189	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
189	Crustacea, larger Astacidae.	22	6	
189	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
189	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0	5	
189	Adult Gryllidae.	0	6	
189	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0.5	6	
189	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
189	Plant material.	37.1	2	
189	Detritus and unidentifiable carrion.	26	5	
190	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	26.5	6	
190	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
190	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
190	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
190	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.3	8	
190	Larger bivalves, includes Unionidae, large Corbiculidae.	0.9	8	
190	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	21.3	6	
190	Crustacea, larger Astacidae.	28.8	6	
190	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
190	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	1	5	
190	Adult Gryllidae.	0	6	
190	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
190	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
190	Plant material.	5.3	2	
190	Detritus and unidentifiable carrion.	15.9	5	

191	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	20	6	
191	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0.1	8	
191	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0.1	8	
191	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
191	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.2	8	
191	Larger bivalves, includes Unionidae, large Corbiculidae.	.	8	
191	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	2.6	6	
191	Crustacea, larger Astacidae.	8.5	6	
191	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
191	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	2.6	5	
191	Adult Gryllidae.	0	6	
191	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	1.2	6	
191	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0.1	7	
191	Plant material.	26.9	2	
191	Detritus and unidentifiable carrion.	37.8	5	
192	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	71.5	6	
192	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0.2	8	
192	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0.2	8	
192	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
192	Small bivalves, includes Sphaeriidae, small Corbiculidae.	2.6	8	
192	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
192	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0.7	6	
192	Crustacea, larger Astacidae.	0	6	
192	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
192	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	3.7	5	
192	Adult Gryllidae.	0	6	

192	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
192	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	1.2	7	
192	Plant material.	13.9	2	
192	Detritus and unidentifiable carrion.	6.3	5	
193	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	75.2	6	
193	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
193	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
193	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
193	Small bivalves, includes Sphaeriidae, small Corbiculidae.	3.5	8	
193	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
193	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0.9	6	
193	Crustacea, larger Astacidae.	1.2	6	
193	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0	6	
193	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	0.6	5	
193	Adult Gryllidae.	0	6	
193	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
193	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
193	Plant material.	4	2	
193	Detritus and unidentifiable carrion.	14.7	5	
194	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	90.4	6	
194	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0	8	
194	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	0	8	
194	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
194	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.5	8	
194	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
194	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	6.3	6	

194	Crustacea, larger Astacidae.	0	6	
194	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0.5	6	
194	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	1.4	5	
194	Adult Gryllidae.	0	6	
194	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
194	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0	7	
194	Plant material.	0	2	
194	Detritus and unidentifiable carrion.	1	5	
195	Gastropods, volume less than 2.5 cc per individual. Includes Hydrobiidae, some Viviparidae, some Planorbidae.	2.1	6	
195	Gastropods, volume greater than 2.5 cc per individual. Includes Ampullariidae, some Viviparidae, some Planorbidae.	0.1	8	
195	Gastropods, Pleuroceridae (Goniobasis), volume less than .08 cc per individual.	20.7	8	
195	Gastropods, Pleuroceridae (Goniobasis), volume greater than .08 cc per individual.	0	8	
195	Small bivalves, includes Sphaeriidae, small Corbiculidae.	0.1	8	
195	Larger bivalves, includes Unionidae, large Corbiculidae.	0	8	
195	Crustacea, includes Palaemonetidae, Talitridae, small Astacidae.	0	6	
195	Crustacea, larger Astacidae.	75.1	6	
195	Large insect larvae, includes Scarabidae, Agrionidae, Lygaeidae, etc.	0.5	6	
195	Small insect larvae, includes Pyrallidae, Coenagrionidae, etc.	1	5	
195	Adult Gryllidae.	0	6	
195	Adult Coleoptera, includes Hydrophyllidae, Scarabidae, Gyrinidae, etc.	0	6	
195	Vertebrata, includes Centrarchidae, Catastomidae, Poeciliidae.	0.1	7	
195	Plant material.	0.1	2	
195	Detritus and unidentifiable carrion.	0.3	5	
196	Filamentous Algae	3	4	
196	Vascular Plants	4	2	
196	Snails	46	8	
196	Bivalves	1	8	
196	Crustaceans	7	6	
196	Insects	30	6	
196	Arachnids	1	5	
196	Vertebrates (fishes)	3	7	
197	Zebra and Quagga Mussels	54	8	

197	Snails	24	8	
197	Fingernail clams	0.4	8	
197	Crayfish	0.4	6	
197	Trichopterans	5	6	
197	Dipterans	0.1	6	
197	Unidentified Insects	3	6	
197	Fish	0.1	7	
197	Plant Leaves	10	2	
197	Plant stems	3	1	
197	Filamentous Algae	0.06	4	
197	Stalked Algae	0.4	3	
197	Seeds	0.3	3	
198	Zebra and Quagga Mussels	47	8	
198	Snails	26	8	
198	Fingernail clams	1	8	
198	Crayfish	0	6	
198	Trichopterans	5	6	
198	Dipterans	0.07	6	
198	Unidentified Insects	8	6	
198	Fish	0.2	7	
198	Plant Leaves	4	2	
198	Plant stems	0.4	1	
198	Filamentous Algae	0	4	
198	Stalked Algae	0.4	3	
198	Seeds	8	3	
199	Corbicula	58.3	8	
199	Snails	3.3	8	
199	Seeds	27.6	3	
199	Insect Parts	4.8	6	
199	Plant Parts	1.9	2	
199	Algae	1	4	
200	Angiosperms	8.2	2	
200	Chlorophyta	6.2	4	
200	Chara	3.9	4	
200	Anisoptera	16.2	6	
200	Physa	11.4	8	
200	Trichoptera	10.2	6	
200	Diptera	9.4	6	
200	Coleoptera	9	6	
200	Ephemeroptera	6.5	5	
200	Fish	4.5	7	
200	Hemiptera	4.3	6	
200	Rana pipiens	2.8	7	
200	Zygoptera	2.2	6	
200	Megaloptera	1.4	6	
200	Procambarus	0.6	6	
200	Ostracods	0.6	5	
201	Fruits and seeds	6.9	4	
201	Aquatic plants	5.6	2	

201	Bivalvia	6.9	8	
201	Gastropoda	6.9	8	
201	Crustacea	4.2	6	
201	Insecta	4.2	6	
201	Fish	23.6	7	
201	Tadpoles	20.8	5	
201	Frogs	6.9	7	
201	Pelusios sp.	1.4	8	
201	Meat	12.5	7	
202	Fruits and seeds	8.3	4	
202	Aquatic plants	4.2	2	
202	Gastropoda	6.9	8	
202	Crustacea	15.3	6	
202	Insecta	15.3	6	
202	Fish	45.8	7	
202	Bird	1.4	7	
202	Mammals (Rodentia)	2.8	7	
203	Gastropoda	3.3	8	
203	Crustacea	3.3	6	
203	Fish	36.7	7	
203	Anurans (adults)	16.7	7	
203	Anuran tadpoles	33.3	5	
203	Indeterminant vertebrate	6.7	7	
204	Fruits	3.6	4	
204	Seeds	2.6	4	
204	Aquatic plants	5.2	2	
204	Annelida	2.6	5	
204	Gastropoda	3.6	8	
204	Bivalvia	0.6	8	
204	Arachnida	1.9	5	
204	Insecta	4.2	6	
204	Crustacea	13.3	6	
204	Fish	37	7	
204	Anurans (adults)	2.6	7	
204	Anuran eggs	6.5	5	
204	Anuran tadpoles	15.9	5	
204	Indeterminant Vertebrate	0.3	7	
205	Fruits	3.8	4	
205	Seeds	1.9	4	
205	Aquatic plants	4.2	2	
205	Annelida	5.7	5	
205	Gastropoda	1.9	8	
205	Arachnida	1.4	5	
205	Insecta	0.5	6	
205	Crustacea	12.7	6	
205	Fish	37.3	7	
205	Anurans (adults)	6.6	7	
205	Anuran eggs	8	5	
205	Anuran tadpoles	15.6	5	

205	Indeterminant Vertebrate	0.5	7	
206	Fruits	8.3	4	
206	Seeds	8.3	4	
206	Aquatic plant	12.5	2	
206	Annelida	8.3	5	
206	Crustacea	12.5	6	
206	Fish	25	7	
206	Anuran eggs	8.3	5	
206	Anuran tadpoles	16.7	5	
207	Earthworm, Metaphire spp.	9.69	7	
207	Apple snail, Pila globosa	7.58	8	
207	Freshwater mussel, Lamellidens sp.	10.67	8	
207	Freshwater snails, Bellamaya spp.	20.51	8	
207	Garden snail, Asiatica fulico	8.15	8	
207	Aquatic insects, Belostoma sp.	4.92	6	
207	Carapace of prawn	5.06	6	
207	Legs of crab	6.88	6	
207	Mastacembalus puncalus	2.81	7	
207	Fish bone	5.48	7	
207	Fish muscles	5.9	7	
207	Bones of frog	1.4	7	
207	Chicken viscera	3.37	7	
207	Animal fragments	7.58	7	
208	Plant material excl. seeds	35.9	2	
208	Seeds	24.3	3	
208	Beetles	11.5	6	
208	Weevils	2.5	6	
208	Japanese Beetles	0	6	
208	Millipedes	10.3	6	
208	Caddisfly Larvae	5.1	6	
208	Ants	3.9	6	
208	Flies	2.6	6	
208	Snails	2.6	8	
208	Unknown Arthropods	1.3	6	
209	Plant material excl. seeds	36.1	2	
209	Seeds	27.8	3	
209	Beetles	15.3	6	
209	Weevils	0	6	
209	Japanese Beetles	8.3	6	
209	Millipedes	1.4	6	
209	Caddisfly Larvae	4.1	6	
209	Ants	4.1	6	
209	Flies	0	6	
209	Snails	0	8	
209	Unknown Arthropods	2.8	6	
210	Murdannia keisak (leaves)	7.3	2	
210	Polygonum sp. (seeds)	3.6	1	
210	Plant roots and shoots	7.4	1	
210	Unidentifiable leaves and stems	1.2	2	

210	Gastropoda	1.8	8	
210	Ephemeridae larvae	0.9	5	
210	Coleoptera	0.6	6	
210	Diptera larvae and pupae	69.8	5	
210	Lepidoptera larvae	0.6	5	
210	Plecoptera larvae	0.3	6	
210	Odonata larvae	0.3	6	
210	Unidentifiable terrestrial insects	1.2	6	
210	Amphipoda	0.1	6	
210	Oligochaeta	4.9	7	
211	Filamentous Algae	0.1	4	
211	Gramineae	0.4	1	
211	Murdannia keisak (leaves)	80.7	2	
211	Polygonum sp. (seeds)	0.5	1	
211	Eclipta prostrata (leaves and fruits)	8.2	2	
211	Lemna aequinoctialis	0.1	4	
211	Ageratum conyzoides (leaves)	0.2	2	
211	Plant roots and shoots	0.3	1	
211	Unidentifiable leaves and stems	0.4	2	
211	Gastropoda	0.4	8	
211	Coleoptera	0.2	6	
211	Diptera larvae and pupae	7.9	5	
211	Odonata larvae	0.1	6	
211	Unidentifiable terrestrial insects	1	6	
211	Amphipoda	0.1	6	
211	Pisces	0.1	7	
212	Grasses	0.2	1	
212	Murdannia keisak (leaves)	22.5	2	
212	Polygonum sp. (seeds)	1.5	1	
212	Eclipta prostrata (leaves and fruits)	9.8	2	
212	Plant roots and shoots	5.5	1	
212	Gastropoda	9.2	8	
212	Ephemeridae larvae	0.4	5	
212	Coleoptera	0.1	6	
212	Diptera larvae and pupae	28.7	5	
212	Lepidoptera larvae	1.2	5	
212	Plecoptera larvae	0.2	6	
212	Odonata larvae	0.1	6	
212	Unidentifiable terrestrial insects	3	6	
212	Amphipoda	0.1	6	
212	Oligochaeta	13.6	7	
212	Hirundinea	2.8	7	
212	Pisces	1.1	7	
213	Filamentous Algae	0.1	4	
213	Grasses	3.9	1	
213	Murdannia keisak (leaves)	74.4	2	
213	Polygonum sp. (seeds)	0.4	1	
213	Eclipta prostrata (leaves and fruits)	0.8	2	
213	Lemna aequinoctialis	6.8	4	

213	Ageratum conyzoides (leaves)	1	2	
213	Plant roots and shoots	0.3	1	
213	Gastropoda	4.7	8	
213	Coleoptera	0.1	6	
213	Diptera larvae and pupae	3.5	5	
213	Lepidoptera larvae	0.3	5	
213	Plecoptera larvae	2.1	6	
213	Odonata larvae	0.1	6	
213	Unidentifiable terrestrial insects	0.3	6	
213	Decapoda	0.1	6	
213	Amphipoda	0.1	6	
213	Oligochaeta	1	7	
213	Hirundinea	0.1	7	
213	Pisces	0.3	7	
214	Grass	47	1	
214	Ficus	15	2	
214	Dayflower	8	2	
214	Alligator weed	4	2	
214	Other Plants	12	2	
214	Native snails	5	8	
214	Fish	1	7	
214	Shrimp	5	6	
214	Bird	2	7	
215	Native snails	29	8	
215	Fish	28	7	
215	Shrimp	9	6	
215	Crab	4	6	
215	Apple Snail	2	8	
215	Insects	2	6	
215	Shells	2	8	
215	Other animals	3	7	
215	Grass	15	1	
215	Water hyacinth	2	2	
215	Other plants	4	2	
216	Snails and slugs	52.5	8	
216	Mushrooms	10	2	
216	Caterpillars	10	7	
216	Carabids	4	6	
216	Centipedes	3.5	6	
217	Cambarus sp.	75	6	
217	Hyla versicolor versicolor	25	7	
218	Undetermined Plants	34.2	2	
218	Determined Plants (seeds)	17.4	1	
218	Undetermined animal	2.3	6	
218	Insecta	19.6	6	
218	Gastropoda	10.6	8	
218	Isopoda	3.5	6	
218	Diplopoda	2.5	6	
218	Mammalia	1.6	7	

218	Decapoda	1.5	6	
218	Reptilia	1.3	7	
218	Aves	1.3	7	
218	Annelida	1	7	
218	Amphibia	0.4	7	
218	Arachnida	0.3	4	
218	Chilopoda	0.2	6	
218	Pisces	0.2	7	
219	47 mm Anisoptera nymphs	2.9	6	
219	23-27 mm Anisoptera nymphs	18.1	6	
219	15-18 mm Anisoptera nymphs	24.8	5	
219	Adult dragonflies	1	6	
219	Zygoptera nymphs	1	6	
219	Zygoptera adults	0	6	
219	Belostomatidae	11.4	6	
219	Corixidae	1	6	
219	Gerridae	0	5	
219	Nepidae (Ranatra)	1	7	
219	Notonectidae	10.5	6	
219	unid. Hemiptera	3.8	6	
219	Chrysomelidae	0	6	
219	Dyticidae adults	1.9	6	
219	Dyticidae larvae	4.8	5	
219	Haliplidae	1	6	
219	unid. Coleoptera	1.9	6	
219	DIPTERA (Chironomidae)	1.9	5	
219	ARACHNIDA (Spiders)	1	5	
219	DECAPODA	1	6	
219	Cambaridae (Procambarus)	6.7	6	
219	VERTEBRATA unid. anura	1.9	7	
219	PLANT MATERIAL (Panicum sp.)	2.9	1	
220	47 mm Anisoptera nymphs	4.5	6	
220	23-27 mm Anisoptera nymphs	18.2	6	
220	15-18 mm Anisoptera nymphs	15.9	5	
220	Adult dragonflies	0	6	
220	Zygoptera nymphs	18.2	6	
220	Zygoptera adults	4.5	6	
220	Belostomatidae	0	6	
220	Corixidae	2.3	6	
220	Gerridae	2.3	5	
220	Nepidae (Ranatra)	2.3	7	
220	Notonectidae	4.5	6	
220	unid. Hemiptera	0	6	
220	Chrysomelidae	4.5	6	
220	Dyticidae adults	0	6	
220	Dyticidae larvae	0	5	
220	Haliplidae	0	6	
220	unid. Coleoptera	0	6	
220	DIPTERA (Chironomidae)	2.3	5	

220	ARACHNIDA (Spiders)	0	5	
220	DECAPODA	18.2	6	
220	Cambaridae (Procambarus)	0	6	
220	VERTEBRATA unid. anura	0	7	
220	PLANT MATERIAL (Panicum sp.)	2.3	1	
221	47 mm Anisoptera nymphs	0	6	
221	23-27 mm Anisoptera nymphs	5.3	6	
221	15-18 mm Anisoptera nymphs	15.8	5	
221	Adult dragonflies	10.5	6	
221	Zygoptera nymphs	0	6	
221	Zygoptera adults	0	6	
221	Belostomatidae	0	6	
221	Corixidae	0	6	
221	Gerridae	5.3	5	
221	Nepidae (Ranatra)	5.3	7	
221	Notonectidae	0	6	
221	unid. Hemiptera	0	6	
221	Chrysomelidae	0	6	
221	Dyticidae adults	5.3	6	
221	Dyticidae larvae	0	5	
221	Haliplidae	5.3	6	
221	unid. Coleoptera	5.3	6	
221	DIPTERA (Chironomidae)	5.3	5	
221	ARACHNIDA (Spiders)	21.1	5	
221	DECAPODA	5.3	6	
221	Cambaridae (Procambarus)	0	6	
221	VERTEBRATA unid. anura	0	7	
221	PLANT MATERIAL (Panicum sp.)	10.5	1	
222	Lithobates spp. (tadpoles)	0.5	5	
222	Araneae (spiders)	0	5	
222	Procambarus acutus	19.6	6	
222	Dystiscidae	2.5	6	
222	Hydrophhilidae	0.5	6	
222	Unknown Coleoptera	1	6	
222	Ephemeroptera	0.5	5	
222	Belostomatidae	6.4	6	
222	Corixidae	0.5	6	
222	Gerridae	0.5	6	
222	Naucoridae	0.5	6	
222	Nepidae	2	6	
222	Unknown Hemiptera	1	6	
222	Hymenoptera	8.3	5	
222	Lepidoptera	0	5	
222	Anisoptera	0	6	
222	Unknown Odonata	1	6	
222	Unknown insects	2	6	
222	Roots	8.8	1	
222	Seeds	9.3	2	
222	Vegetative matter	16.7	2	

222	Juncus effusus	4.4	1	
222	Ricciocarpus natans	5.9	2	
222	Typha latifolia	5.4	1	
222	Zizaniopsis miliacea	2.9	1	
223	Lithobates spp. (tadpoles)	8.7	5	
223	Araneae (spiders)	2.2	5	
223	Procambarus acutus	17.4	6	
223	Dystiscidae	0	6	
223	Hydrophhilidae	0	6	
223	Unknown Coleoptera	4.3	6	
223	Ephemeroptera	0	5	
223	Belostomatidae	4.3	6	
223	Corixidae	6.5	6	
223	Gerridae	0	6	
223	Naucoridae	0	6	
223	Nepidae	0	6	
223	Unknown Hemiptera	0	6	
223	Hymenoptera	0	5	
223	Lepidoptera	0	5	
223	Anisoptera	0	6	
223	Unknown Odonata	0	6	
223	Unknown insects	6.5	6	
223	Roots	6.5	1	
223	Seeds	13	2	
223	Vegetative matter	21.7	2	
223	Juncus effusus	0	1	
223	Ricciocarpus natans	2.2	2	
223	Typha latifolia	4.3	1	
223	Zizaniopsis miliacea	2.2	1	
224	Lithobates spp. (tadpoles)	0	5	
224	Araneae (spiders)	0	5	
224	Procambarus acutus	14.5	6	
224	Dystiscidae	5.5	6	
224	Hydrophhilidae	3.6	6	
224	Unknown Coleoptera	3.6	6	
224	Ephemeroptera	0	5	
224	Belostomatidae	12.7	6	
224	Corixidae	1.8	6	
224	Gerridae	3.6	6	
224	Naucoridae	1.8	6	
224	Nepidae	5.5	6	
224	Unknown Hemiptera	1.8	6	
224	Hymenoptera	1.8	5	
224	Lepidoptera	0	5	
224	Anisoptera	1.8	6	
224	Unknown Odonata	1.8	6	
224	Unknown insects	1.8	6	
224	Roots	12.7	1	
224	Seeds	7.3	2	

224	Vegetative matter	14.5	2	
224	Juncus effusus	0	1	
224	Ricciocarpus natans	0	2	
224	Typha latifolia	1.8	1	
224	Zizaniopsis miliacea	1.8	1	
225	Libinia sp.	68.3	8	
225	Persephona mediterranea	9.7	8	
225	Hepatus epheliticus	1.4	8	
225	Hexapanopeus angustifrons	0.6	8	
225	Menippe mercenaria	0	8	
225	Callnectes sapidus	0.4	8	
225	Portunus gibbesii	0	8	
225	Calappa sp.	0.1	8	
225	Farfantepenaeus sp.	0	8	
225	Balanus sp.	0.9	8	
225	Limulus polyphemus	0.3	8	
225	Hippocampus	0	7	
225	Molgula occidentalis	0	5	
225	Styela plicata	0.2	5	
225	Nassarius sp.	0.1	8	
225	Cerithium sp.	0.1	8	
225	Costoanachis sparsa	0.1	8	
225	Crepidula fornicata	0.1	8	
225	Busycon egg case	0.1	8	
225	Crassostrea virginica	0.2	8	
225	Modiolus sp.	0.1	8	
225	Tagelus sp.	0	8	
225	Halodule wrightii	0.1	1	
225	Thalassia testudinum	0.1	1	
225	Syringodium filiforme	0.1	1	
225	Acanthophora spicifera	0.1	2	
225	Unidentified red algae	0.1	2	
225	Unidentified green algae	0.1	2	
225	Unidentified invertebrate	0	8	
226	Libinia sp.	73	8	
226	Persephona mediterranea	5.9	8	
226	Hepatus epheliticus	0.1	8	
226	Hexapanopeus angustifrons	0	8	
226	Menippe mercenaria	0.4	8	
226	Callnectes sapidus	0	8	
226	Portunus gibbesii	0.1	8	
226	Calappa sp.	0	8	
226	Farfantepenaeus sp.	0.1	8	
226	Balanus sp.	0.6	8	
226	Limulus polyphemus	0.1	8	
226	Hippocampus	0.1	7	
226	Molgula occidentalis	0.1	5	
226	Styela plicata	0	5	
226	Nassarius sp.	0	8	

226	Cerithium sp.	0	8	
226	Costoanachis sparsa	0	8	
226	Crepidula fornicata	0	8	
226	Busycon egg case	0	8	
226	Crassostrea virginica	0.2	8	
226	Modiolus sp.	0	8	
226	Tagelus sp.	0.1	8	
226	Halodule wrightii	0.1	1	
226	Thalassia testudinum	0.1	1	
226	Syringodium filiforme	0.1	1	
226	Acanthophora spicifera	0.1	2	
226	Unidentified red algae	0.1	2	
226	Unidentified green algae	0	2	
226	Unidentified invertebrate	0.1	8	
227	Horseshoe crab Limulus polyphemus	0.4	8	
227	Blue crab Callinectes sapidus	16.1	8	
227	Unidentified portunid Callinectes sp.	4.4	8	
227	Rock crab Cancer irroratus	3.2	8	
227	Spider crab Libinia spp.	12.9	8	
227	Lady crab Ovalipes ocellatus	0.8	8	
227	Hermit crab Pagurus spp.	3.6	8	
227	Purse crab Persephona mediterranea	9.7	8	
227	Mantis shrimp Squilla empusa	0.4	7	
227	Bony fish	2	7	
227	Eastern American oyster Crassostrea virginica	0.4	8	
227	Blue mussel Mytilus edulis	6.9	8	
227	Unidentified bivalve	0.8	8	
227	Cerith sp. Bittium sp.	5.6	8	
227	Wentletrap Epitonium sp.	0.4	8	
227	Eastern mud snail Ilysanassa obsoleta	0.8	8	
227	Three-line mud snail Ilyanassa trivittatus	6.5	8	
227	Unidentified mud snail Ilyanassa or Nassarius sp.	2.4	8	
227	Mottled dog whelk Nassarius vibex	20.6	8	
227	Atlantic moon snail Neverita duplicata	0.8	8	
227	Unidetified gastropod	1.2	8	

Appendix C

Appendix Table C-1: Bibliography of Published Turtle Diet Data (incomplete)

Species	Source	Listed As	Used	Comments
Actinemys marmorata	Bury, R. B. (1986). Feeding ecology of the turtle, Clemmys marmorata. Journal of Herpetology, 20(4), 515–521.	*Clemmys marmorata*		
Agrionemys horsfieldi	Lagarde, F., Bonnet, X., Corbin, J., Henen, B., Nagy, K., Mardonov, B., & Naulleau, G. (2003). Foraging Behaviour and Diet of an Ectothermic Herbivore : Testudo horsfieldi. Ecography, 26(2), 236–242.	*Testudo horsfieldi*	y	
Amyda cartilaginea	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	*Trionyx cartilagineus*		
Apalone mutica	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.6		y	
Apalone mutica	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276	*Trionyx muticus*	y	
Apalone spinifera	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	*Amyda spinifera*	y	
Apalone spinifera	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.7		y	
Apalone spinifera	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276	*Trionyx spiniferus*	y	
Astrochelys radiata	Rasoma, R. V. J., Raselimanana, A. P., Ratovonamana, Y. R. ., & Ganzhorn, J. U. (2013). Habitat use and diet of Astrochelys radiata in the subarid zone of southern Madagascar. Chelonian Conservation and Biology, 12(1), 56–69.			
Batagur baska	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111		y	
Batagur borneoensis	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University.	*Callagur borneoensis*	y	

	Retrieved from https://thekeep.eiu.edu/theses/3111			
Caretta caretta	Di Beneditto, A. P. M., Fulgencio De Moura, J., & Siciliano, S. (2015). Feeding habits of the sea turtles Caretta caretta and Lepidochelys olivacea in south-eastern Brazil. Marine Biodiversity Records, 8(August 2019). https://doi.org/10.1017/S1755267215001001			
Caretta caretta	Plotkin, P. T., Wicksten, M. K., & Amos, A. F. (1993). Feeding ecology of the loggerhead sea turtle Caretta caretta in the Northwestern Gulf of Mexico. Marine Biology, 115(1), 1–5. https://doi.org/10.1007/BF00349379			
Caretta caretta	Tomas, J., Aznar, F. J., & Raga, J. A. (2001). Feeding ecology of the loggerhead turtle Caretta caretta in the western Mediterranean. Journal of Zoology, 255(4), 525–532. https://doi.org/10.1017/s0952836901001613			
Carettochelys insculpta	Georges, A., & Kennett, R. (1989). Dry-season Distribution and Ecology of Carettochelys insculpta (Chelonia : Carettochelydidae) in Kakadu National Park, Northern Australia. Australia Wildlife Research, 16, 323–335. http://doi.org/10.1071/WR9890323		y	
Chelodina burrungandjii	FitzSimmons, N. N., Featherston, P., & Tucker, A. D. (2015). Comparative dietary ecology of turtles (Chelodina burrungandjii and Emydura victoriae) across the Kimberley Plateau, Western Australia, prior to the arrival of cane toads. Marine and Freshwater Research. Retrieved from http://dx.doi.org/10.1071/MF15199			
Chelodina rugosa	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.		y	
Chelonia mydas	Amorocho, D. F., & Reina, R. D. (2007). Feeding ecology of the East Pacific green sea turtle Chelonia mydas agassizii at Gorgona National Park, Colombia. Endangered Species Research, 3, 43–51. https://doi.org/10.3354/esr003043			
Chelonia mydas	Carrión-Cortez, J. A., Zárate, P., & Seminoff, J. A. (2010). Feeding ecology of the green sea turtle (Chelonia mydas) in the Galapagos Islands. Journal of the Marine Biological Association of the United Kingdom, 90(5), 1005–1013. https://doi.org/10.1017/S0025315410000226			
Chelonia mydas	Mendonça, M. T. (1983). Movements and feeding ecology of immature Green Turtles (Chelonia mydas) in a Florida lagoon. Copeia, 1983(4), 1013–1023. https://doi.org/10.2307/1445104			
Chelonoidis carbonaria	Moskovits, D. K., & Bjorndal, K. A. (1990). Diet and Food Preferences of the Tortoises Geochelone carbonaria and G . denticulata in Northwestern Brazil. Herpetologica, 46(2), 207–218.	*Geochelone carbonaria*	y	Seems like percent of FO?
Chelonoidis carbonaria	Ghilardi Jr., R., & Alho, C. J. R. (1990). Produtividade sazonal da floresta e atavidade	*Geochelone carbonaria*		

	de forrafeamento animal em habitat terra firme da Amazonia. Acta Amazonica, 20, 61–76.			
Chelonoidis carbonaria	Jerozolimski 2009			
Chelonoidis carbonaria	Wang, E., Donatti, C. I., Ferreira, V. L., Raizer, J., & Himmelstein, J. (2011). Food Habits and Notes on the Biology of Chelonoidis carbonaria (Spix 1824) (Testudinidae, Chelonia) in the Southern Pantanal, Brazil. South American Journal of Herpetology, 6(1), 11–19. https://doi.org/10.2994/057.006.0102			
Chelonoidis denticulatus	Guzmán, A., & Stevenson, P. R. (2008). Seed dispersal, habitat selection and movement patterns in the Amazonian tortoise, Geochelone denticulata. Amphibia Reptilia, 29(4), 463–472. https://doi.org/10.1163/156853808786230442	*Geochelone denticulata*	y	
Chelonoidis denticulatus	Moskovits, D. K., & Bjorndal, K. A. (1990). Diet and Food Preferences of the Tortoises Geochelone carbonaria and G . denticulata in Northwestern Brazil. Herpetologica, 46(2), 207–218.	*Geochelone denticulata*	y	Seems like percent of FO?
Chelonoidis denticulatus	Ghilardi Jr., R., & Alho, C. J. R. (1990). Produtividade sazonal da floresta e atavidade de forrafeamento animal em habitat terra firme da Amazonia. Acta Amazonica, 20, 61–76.	*Geochelone denticulata*		
Chelus fimbriatus	Teran, A. F., Vogt, R. C., & Gomez, M. de F. S. (1995). Food Habits of an Assemblage of Five Species of Turtles in the Rio Guapore , Rondonia , Brazil. Journal of Herpetology, 29(4), 536–547.			
Chelydra serpentina	Alexander, M. M. (1943). Food Habits of the Snapping Turtle in Connecticut. The Journal of Wildlife Management, 7(3), 278–282. Retrieved from http://www.jstor.org/stable/3795533		y	
Chelydra serpentina	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist		y	
Chelydra serpentina	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276			
Chelydra serpentina osceola	Punzo, F. (1975). Studies on the feeding behavior , diet , nesting habits and temperature telationships of Chelydra serpentina osceola (Chelonia : Chelydridae). Journal of Herpetology, 9(2), 207–210. Retrieved from http://www.jstor.org/stable/1563038		y	
Chelydra serpentina serpentina	Bush, F. M. (1959). Foods of Some Kentucky Herptiles. Herpetologica, 15(2), 73–77.		y	
Chersina angulata	Joshua, Q. I., Hofmeyr, M. D., & Henen, B. T. (2010). Seasonal and Site Variation in Angulate Tortoise Diet and Activity. Journal of Herpetology, 44(1), 124–134. https://doi.org/10.1670/08-306R1.1			

Chrysemys picta	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	y	
Chrysemys picta	Cooley, C. R., Floyd, A. O., Dolinger, A., & Tucker, P. B. (2003). Demography and diet of the painted turtle (Chrysemys picta) at high-elevation sites in southwestern Colorado. Southwestern Naturalist, 48(1), 47–53. https://doi.org/10.1894/0038-4909(2003)048<0047:DADOTP>2.0.CO;2		
Chrysemys picta	Knight, A. W., & Gibbons, J. W. (1968). Food of the Painted Turtle, Chrysemys picta, in a Polluted River. American Midland Naturalist, 80(2), 558. https://doi.org/10.2307/2423551		
Chrysemys picta	Lindeman, P. V. (1996). Comparative life history of painted turtles (Chrysemys picta) in two habitats in the inland Pacific Northwest. Copeia. https://doi.org/10.2307/1446947		
Chrysemys picta	Padgett, D. J., Carboni, J. J., & Schepis, D. J. (2010). The dietary composition of chrysemys picta picta (Eastern Painted Turtles) with special reference to the seeds of aquatic macrophytes. Northeastern Naturalist, 17(2), 305–312. https://doi.org/10.1656/045.017.0212		
Chrysemys picta bellii	Fritsch, E. G. (1941). Food habits of the Western Painted Turtle Chrysemys marginata bellii Gray. Proceedings of the Iowa Academy of Science, 47, 361–369.		
Chrysemys picta bellii	Macculloch, R. D., & Secoy, D. M. (1983). Demography, growth, and food of western painted turtles Chrysemys picta bellii (Gray), from southern Saskatchewan. Canadian Journal of Zoology, 61(7), 1499–1509. https://doi.org/10.1139/z83-202		
Chrysemys picta marginata	Rowe, J.W. and Parsons, W., 2000. Diet of the midland painted turtle (Chrysemys picta marginata) on Beaver Island, Michigan. Herpetological Review, 31(1), p.16.		
Cuora amboinensis	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	y	
Cyclemys dentata	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	y	
Deirochelys reticularia	Demuth, J. P., & Buhlmann, K. A. (1997). Diet of the turtle Deirochelys reticularia on the Savannah River Site, South Carolina. Journal of Herpetology, 31(3), 450–453. https://doi.org/10.2307/1565680	y	converted to percentage of all occurrences
Deirochelys reticularia	McKnight, D. T., Jones, A. C., & Ligon, D. B. (2015). The omnivorous diet of the western chicken turtle (Deirochelys reticularia miaria). Copeia, 103(2), 322–328. https://doi.org/10.1643/CH-14-072	y	converted to percentage of all occurrences

Dermatemys mawei	Moll, D. (1989). Food and feeding behavior of the turtle, Dermatemys mawei, in Belize. Journal of Herpetology, 23(4), 445–447.	y
Elseya albagula	Armstrong, G., & Booth, D. T. (2005). Dietary ecology of the Australian freshwater turtle (Elseya sp.: Chelonia: Chelidae) in the Burnett River, Queensland. Australian Wildlife Research, 32, 349–353. Retrieved from papers3://publication/uuid/272ED325-2F11-404B-816D-74F90860E969	y
Elseya dentata	Kennett, R., & Tory, O. (1996). Diet of Two Freshwater Turtles , Chelodina rugosa and Elseya dentata (Testudines : Chelidae) from the Wet-Dry Tropics of Northern Australia. Copeia, 1996(2), 409–419.	y
Emydoidea blandingii	Kofron, C. P., & Schreiber, A. A. (1985). Ecology of Two Endangered Aquatic Turtles in Missouri: Kinosternon flavescens and Emydoidea blandingii. Journal of Herpetology, 19(1), 27–40.	y
Emydoidea blandingii	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	y
Emydoidea blandingii	Rowe, J. W. (1992). Dietary Habits of the Blanding's Turtle (Emydoidea blandingi) in Northeastern Illinois. Journal of Herpetology, 26(1), 111–114.	y
Emydura krefftii	Georges, A. (1982). Diet of the Australian freshwater turtle Emydura krefftii (Chelonia: Chelidae) in an unproductive lentic environment. Copeia, 1982(2), 331–336.	
Emydura krefftii	Trembath, D. F. (2005). The comparative ecology of Krefft's River Turtle Emydura krefftii in Tropical North Queensland, MSc Thesis	
Emydura victoriae	FitzSimmons, N. N., Featherston, P., & Tucker, A. D. (2015). Comparative dietary ecology of turtles (Chelodina burrungandjii and Emydura victoriae) across the Kimberley Plateau, Western Australia, prior to the arrival of cane toads. Marine and Freshwater Research. Retrieved from http://dx.doi.org/10.1071/MF15199	
Emys orbicularis	Ottonello, Dario; Salvidio, Sebastiano; Rosecchi, E. (2005). Feeding habits of the European pond terrapin Emys orbicularis in Camargue (Rhône delta, Southern France). Amphibia-Reptilia, 26(4), 562–565. http://doi.org/10.1163/156853805774806241	y
Emys orbicularis	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	y
Emys trinacris	Ottonello, D., D'Angelo, S., Oneto, F., Malavasi, S., & Zuffi, M. A. L. (2016). Feeding ecology of the Sicilian pond turtle Emys trinacris (Testudines, Emydidae)	

	influenced by seasons and invasive aliens species. Ecological Research, 32(1), 71–80. https://doi.org/10.1007/s11284-016-1416-1		
Glyptemys muhlenbergii	Melendez, N. A., Zarate, B., Fingerut, J., & McRobert, S. P. (2017). Diet of Bog Turtles (Glyptemys muhlenbergii) from Northern and Southern New Jersey, USA. Herpetological Conservation and Biology, 12, 272–278.	y	converted to percentage of all occurrences
Gopherus agassizii	Hansen, R. M., Johnson, M. K., & Van Devender, R. T. (1976). Foods of the Desert Tortoise , Gopherus agassizii , in Arizona and Utah. Herpetologica, 32(3), 247–251.l 1976	y	
Gopherus agassizii	Jennings, W. B., & Berry, K. H. (2015). Desert tortoises (Gopherus agassizii) are selective herbivores that track the flowering phenology of their preferred food plants. PloS One, 10(1), e0116716. https://doi.org/10.1371/journal.pone.0116716	y	
Gopherus agassizii	Snider, J. R. (1993). Foraging ecology and sheltersite characteristics of Sonoran Desert tortoises. In Proceedings of the Desert Tortoise Council Symposium (Vol. 1992, pp. 82-84).	y	
Gopherus agassizii	Oftedal, O. T.. (2002). Desert Tortoise - Selective spring foraging by juvenile desert tortoises in the Mojave desert. Chelonian Research and Biology.		juveniles only
Gopherus berlandieri	Scalise, J. L. (2011). Food habits and selective foraging by the Texas Tortoise (Gopherus berlandieri). Texas State University-San MArcos.	y	
Gopherus polyphemus	Carlson, J. E., Menges, E. S., & Marks, P. L. (2003). Seed dispersal by Gopherus polyphemus at Archbold Biological Station, Florida. Florida Scientist, 2003(2), 147–154.	y	FO with scats and feeding observations, used this to calculate percent of all observations
Gopherus polyphemus	Birkhead, R. D., Guyer, C., Hermann, S. M., & Michener, W. K. (2005). Patterns of Folivory and Seed Ingestion by Gopher Tortoises (Gopherus polyphemus) in a Southeastern Pine Savanna. The American Midland Naturalist, 154(1), 143–151. https://doi.org/10.1674/0003-0031(2005)154[0143:POFASI]2.0.CO;2		
Gopherus polyphemus	Figueroa, A., Lange, J., & Whitfield, S. M. (2021). Seed Consumption by Gopher Tortoises (Gopherus polyphemus) in the Globally Imperiled Pine Rockland Ecosystem of Southern Florida, USA. Chelonian Conservation and Biology.		
Gopherus polyphemus	MacDonald, L. A., & Mushinsky, H. R. (1988). Foraging Ecology of the Gopher Tortoise, Gopherus polyphemus, in a Sandhill Habitat. Herpetologica, 44(3), 345–353.		FO in scats and foraging observations, percentable FO for some food items
Gopherus polyphemus	Mushinsky, H. R., Stilson, T. A., & McCoy, E. D. (2003). Diet and Dietary Preference of the Juvenile Gopher Tortoise (Gopherus Polyphemus). Herpetologica, 59(4), 475–483.		positive or negative selection per plant (like % FO)

Graptemys flavimaculata	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.10		y
Graptemys geographica	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist		y
Graptemys geographica	Richards-Dimitrie, T., Gresens, S. E., Smith, S. A., & Seigel, R. A. (2013). Diet of Northern Map Turtles (Graptemys geographica): Sexual Differences and Potential Impacts of an Altered River System. Copeia, 3(3), 477–484. http://doi.org/10.1643/CE-12-043		y
Graptemys geographica	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.		y
Graptemys gibbonsi	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.9		y
Graptemys nigrinoda	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.5		y
Graptemys nigrinoda	Lindeman, P. V. (2016). Diets of syntopic black-knobbed sawbacks (Graptemys nigrinoda) and Alabama map turtles (Graptemys pulchra) in the Alabama River. American Midland Naturalist, 175(2), 194–205. https://doi.org/10.1674/0003-0031-175.2.194		
Graptemys oculifera	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.12		y
Graptemys ouachitensis	East, M. B., & Ligon, D. B. (2013). Comparison of diet among reintroduced and wild juvenile alligator snapping turtles (Macrochelys temminckii) and adult female ouachita map turtles (Graptemys ouachitensis). Southwestern Naturalist, 58(4), 450–458. https://doi.org/10.1894/0038-4909-58.4.450		n/a
Graptemys ouachitensis	Moll, D. (1976). Food and Feeding Strategies of the Ouachita Map Turtle (Graptemys pseudogeographica ouachitensis). American	*Graptemys pseudogeographica ouachitensis*	y

	Midland Naturalist, 96(2), 478. https://doi.org/10.2307/2424089	
Graptemys ouachitensis	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276	y
Graptemys ouachitensis	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.	y
Graptemys pearlensis	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.11	y
Graptemys pseudogeographica	Vogt, R. C. (1981). Food partitioning in three sympatric species of Map Turtle, genus Graptemys (Testudinata, Emydidae). American Midland Naturalist, 105(1), 102–111.	y
Graptemys pulchra	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.4	y
Graptemys pulchra	Lindeman, P. V. (2016). Diets of syntopic black-knobbed sawbacks (Graptemys nigrinoda) and Alabama map turtles (Graptemys pulchra) in the Alabama River. American Midland Naturalist, 175(2), 194–205. https://doi.org/10.1674/0003-0031-175.2.194	
Graptemys versa	Lindeman, P. V. (2006). Diet of the Texas Map Turtle (Graptemys versa): Relationship to Sexually Dimorphic Trophic Morphology and Changes Over Five Decades as Influenced by an Invasive Mollusk. Chelonian Conservation and Biology, 5(1), 25. https://doi.org/10.2744/1071-8443(2006)5[25:DOTTMT]2.0.CO;2	y
Hydromedusa maximiliani	Novelli, I. A., Gomides, S. C., Brugiolo, S. S. S., & de Sousa, B. M. (2013). Alimentary habits of Hydromedusa maximiliani (Mikan, 1820) (Testudines, Chelidae) and its relation to prey availability in the environment. Herpetology Notes, 6(1), 503–511.	
Hydromedusa tectifera	Alcalde, L., Derocco, N. N., & Rosset, S. D. (2010). Feeding in Syntopy: Diet of Hydromedusa tectifera and Phrynops hilarii (Chelidae). Chelonian Conservation and Biology, 9(1), 33–44. http://doi.org/10.2744/CCB-0794.1	
Indotestudo elongata	Ihlow, F., Geissler, P., Sovath, S., Handschuh, M., & Böhme, W. (2012). Observations on the feeding ecology of Indotestudo elongate (Blyth, 1853) in the wild in Cambodia and Vietnam. Herpetology Notes, 5(January), 5–7.	
Indotestudo travancorica	Veerappan, D., & Vasudevan, K. (2012). Feeding ecology of the Travancore tortoise	

	(Indotestudo travancorica) in the Anamalais, Western Ghats, India. Herpetology Notes, 5(January), 203–209.	
Kinosternon flavescens	Kofron, C. P., & Schreiber, A. A. (1985). Ecology of Two Endangered Aquatic Turtles in Missouri: Kinosternon flavescens and Emydoidea blandingii. Journal of Herpetology, 19(1), 27–40.	y
Kinosternon flavescens	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	y
Kinosternon hirtipes	Platt, S. G., Berezin, A. R., Miller, D. J., & Rainwater, T. R. (2016). A dietary study of the rough-footed mud turtle (Kinosternon hirtipes) in Texas, USA. Herpetological Conservation and Biology, 11(1), 142–149.	
Kinosternon integrum	Macip-Ríos, R., Sustaita-Rodríguez, V. H., Barrios-Quiroz, G., & Casas-Andreu, G. (2010). Alimentary Habits of the Mexican Mud Turtle (Kinosternon integrum) in Tonatico, Estado de México. Chelonian Conservation and Biology, 9(1), 90–97. http://doi.org/10.2744/CCB-0782.1	y
Kinosternon leucostomum	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	y
Kinosternon leucostomum	Vogt, R. C., & Guzman, S. G. (1988). Food Partitioning in a Neotropical Freshwater Turtle Community. Copeia, 1988(1), 37–47. Retrieved from http://www.jstor.org/stable/1445920	
Kinosternon leucostomum postinguinale	Ceballos, C. P., Zapata, D., Alvarado, C., & Rincón, E. (2016). Morphology, Diet, and Population Structure of the Southern White-lipped Mud Turtle Kinosternon leucostomum postinguinale (Testudines: Kinosternidae) in the Nus River Drainage, Colombia. Journal of Herpetology, 50(3), 374–380. https://doi.org/10.1670/15-035	
Kinosternon scorpioides	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	y
Kinosternon sonoriense	Hulse, A. C. (1974). Food Habits and Feeding Behavior in Kinosternon sonoriense (Chelonia : Kinosternidae). Journal of Herpetology, 8(3), 195–199.	y
Kinosternon subrubrum	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	y
Lepidochelys kempii	Schmid, J. R., & Tucker, A. D. (2018). Comparing Diets of Kemp's Ridley Sea Turtles (Lepidochelys kempii) in Mangrove Estuaries of Southwest Florida. Journal of Herpetology, 52(3), 252–258. https://doi.org/10.1670/16-164	y
Lepidochelys kempii	Seney, E. E., & Musick, J. A. (2005). Diet analysis of Kemp's ridley sea turtles (Lepidochelys kempii) in Virginia. Chelonian Conservation and Biology, 4(4), 864–871.	y
Lepidochelys kempii	Burke, V. J., Morreale, S. J., & Standora, E. A. (1994). Diet of the Kemp's ridley sea turtle,	

	Lepidochelys kempii, in New York waters. Fishery Bulletin, 92, 26–32.	
Lepidochelys kempii	Seney, E. E. (2016). Diet of Kemp's Ridley Sea Turtles Incidentally Caught on Recreational Fishing Gear in the Northwestern Gulf of Mexico. Chelonian Conservation and Biology, 15(1), 132–137. https://doi.org/10.2744/CCB-1191.1	
Lepidochelys kempii	Servis, J. A., Lovewell, G., & Tucker, A. D. (2015). Diet Analysis of Subadult Kemp's Ridley (Lepidochelys kempii) Turtles from West- Central Florida. Chelonian Conservation and Biology, 14(2), 173–181.	
Lepidochelys kempii	Shaver, D. J. (1991). Feeding Ecology of Wild and Head-Started Kemp's Ridley Sea Turtles in South Texas Waters. Journal of Herpetology, 25(3), 327–334.	
Lepidochelys olivacea	Behera, S., Tripathy, B., Sivakumar, K., & Choudhury, B. C. (2014). Stomach Contents of Olive Ridley Turtles (Lepidochelys Olivacea) Occurring in Gahirmatha, Odisha Coast of India. Proceedings of the Zoological Society, 68(1), 91–95. https://doi.org/10.1007/s12595-014-0100-0	
Lepidochelys olivacea	Colman, L. P., Sampaio, C. L. S., Weber, M. I., & de Castilhos, J. C. (2014). Diet of Olive Ridley Sea Turtles, Lepidochelys olivacea, in the waters of Sergipe, Brazil. Chelonian Conservation and Biology, 13(2), 266–271.	
Lepidochelys olivacea	Di Beneditto, A. P. M., Fulgencio De Moura, J., & Siciliano, S. (2015). Feeding habits of the sea turtles Caretta caretta and Lepidochelys olivacea in south-eastern Brazil. Marine Biodiversity Records, 8(August 2019). https://doi.org/10.1017/S1755267215001001	
Lissemys punctata	Hossain, M. L., Sarker, S. U., & Sarker, N. J. (2012). Food Habits and Feeding Behaviour of Spotted Flapshell, Lissemys punctata (lacepede, 1788) in Bangladesh. Bangladesh Journal of Zoology, 40(2), 197–205.	y
Macrochelys temminckii	East, M. B., & Ligon, D. B. (2013). Comparison of diet among reintroduced and wild juvenile alligator snapping turtles (Macrochelys temminckii) and adult female ouachita map turtles (Graptemys ouachitensis). Southwestern Naturalist, 58(4), 450–458. https://doi.org/10.1894/0038-4909-58.4.450	n/a
Malaclemys terrapin	Herrel, A., Petrochic, S., & Draud, M. (2017). Sexual dimorphism, bite force and diet in the diamondback terrapin. Journal of Zoology. http://doi.org/10.1111/jzo.12520	y
Mauremys caspica rivulata	Sidis, I., & Gasith, A. (1985). Food habits of the Caspian terrapin (Mauremys caspica rivulata) in unpolluted and polluted habitats in Israel. Journal of Herpetology, 19(1), 108–115. https://doi.org/10.2307/1564426	
Mauremys leprosa	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	y

Mauremys reevesii	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	y	
Mauremys sinensis	Chen, T. H., & Lue, K. Y. (1998). Ecology of the Chinese Stripe-Necked Turtle, Ocadia sinenses (Testudines:Emydidae), in the Keelung River, Northern Taiwan. Copeia, 4, 944–952.	y	
Mauremys sinensis	Wang, J., Shi, H., Hu, S., Ma, K., & Li, C. (2013). Interspecific differences in diet between introduced red-eared sliders and native turtles in China. Asian Herpetological Research, 4(3), 190–196. https://doi.org/10.3724/SP.J.1245.2013.00190	y	
Mauremys sinensis	Chen TH, KY Lue. 1999. Food habits of the Chinese stripenecked turtle, Ocadia sinensis, in the Keelung River, northern Taiwan. J. Herpetol. 33: 463-471.	y	
Mauremys sinensis	Chen, T. H., & Lue, K. Y. (2009). Changes in the population structure and diet of the Chinese stripe-necked turtle (Mauremys sinensis) inhabiting a disturbed river in northern Taiwan. Zoological Studies, 48(1), 95–105.		not natural diet, disturbed locality comparing data to Chen 1998
Orlitia borneensis	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	y	
Pelomedusa subrufa	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	y	converted to percentage of all occurrences
Peltocephalus dumerilianus	De La Ossa, Jaime; Vogt, Richard C; Santos-Junior, L. (2011). ALIMENTACIÓN DE PeltocePhalus dumerilianus (TESTUDINES : PODOCNEMIDIDAE) EN CONDICIONES NATURALES. Actualidades Biológicas, 33(94), 85–92.		
Peltocephalus dumerilianus	Pérez-Emán, J. L., & O, A. P. (1997). Diet of the pelomedusid turtle Peltocephalus dumerilianus in the Venezuelan Amazon. Journal of Herpetology, 31(2), 173–179.		
Pelusios castaneus	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	y	converted to percentage of all occurrences
Pelusios niger	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	y	converted to percentage of all occurrences

Phrynops geoffroanus	Souza, F. L., & Abe, A. S. (2000). Feeding ecology , density and biomass of the freshwater turtle , Phrynops geoffroanus , inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology, 252(4), 437–446.	y	
Phrynops geoffroanus	Martins, F. I., De Souza, F. L., & Da Costa, H. T. M. (2010). Feeding habits of Phrynops geoffroanus (Chelidae) in an urban river in Central Brazil. Chelonian Conservation and Biology, 9(2), 294–297. https://doi.org/10.2744/CCB-0809.1		
Phrynops geoffroanus	Teran, A. F., Vogt, R. C., & Gomez, M. de F. S. (1995). Food Habits of an Assemblage of Five Species of Turtles in the Rio Guapore , Rondonia , Brazil. Journal of Herpetology, 29(4), 536–547.		
Phrynops hilarii	Alcalde, L., Derocco, N. N., & Rosset, S. D. (2010). Feeding in Syntopy: Diet of Hydromedusa tectifera and Phrynops hilarii (Chelidae). Chelonian Conservation and Biology, 9(1), 33–44. http://doi.org/10.2744/CCB-0794.1		
Phrynops raniceps	Teran, A. F., Vogt, R. C., & Gomez, M. de F. S. (1995). Food Habits of an Assemblage of Five Species of Turtles in the Rio Guapore , Rondonia , Brazil. Journal of Herpetology, 29(4), 536–547.		
Platemys platycephala	Ghilardi Jr., R., & Alho, C. J. R. (1990). Produtividade sazonal da floresta e atavidade de forrafeamento animal em habitat terra firme da Amazonia. Acta Amazonica, 20, 61–76.		
Platysternon megacephalum	Sung, Y. H., Hau, B. C. H., Karraker, N. E., & Karraker, N. E. (2016). Diet of the endangered big-headed turtle Platysternon megacephalum. PeerJ, 2016(12), 10. https://doi.org/10.7717/peerj.2784	y	converted to percentage of all occurrences
Podocnemis expansa	Teran, A. F., Vogt, R. C., & Gomez, M. de F. S. (1995). Food Habits of an Assemblage of Five Species of Turtles in the Rio Guapore , Rondonia , Brazil. Journal of Herpetology, 29(4), 536–547.		
Podocnemis unifilis	Teran, A. F., Vogt, R. C., & Gomez, M. de F. S. (1995). Food Habits of an Assemblage of Five Species of Turtles in the Rio Guapore , Rondonia , Brazil. Journal of Herpetology, 29(4), 536–547.		
Psammobates oculijer	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife …, 23(3), 63–70. Retrieved from http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1	y	
Pseudemys concinna	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	y	
Pseudemys concinna	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use	y	

	and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.2		
Pseudemys gorzugi	Letter, A. W., Waldon, K. J., Pollock, D. A., & Mali, I. (2019). Dietary Habits of Rio Grande Cooters (Pseudemys gorzugi) from Two Sites within the Black River, Eddy County, New Mexico, USA. Journal of Herpetology, 53(3), 204–208. https://doi.org/10.1670/18-057		
Pseudemys scripta	Hart, D. R. (1983). Dietary and Habitat Shift with Size of Red-Eared Turtles (Pseudemys scripta) in a Southern Louisiana Population. Herpetologica, 39(3), 285–290.		
Pseudemys texana	Fields, J. R., Simpson, T. R., Manning, R. W., & Rose, F. L. (2003). Food Habits and Selective Foraging by the Texas River Cooter (Pseudemys texana) in Spring Lake, Hays County, Texas. Journal of Herpetology, 37(4), 726–729.		
Rhinoclemmys annulata	Moll, D., & Jansen, K. P. (1995). Evidence for a role in seed dispersal by two tropical herbivorous turtles. Biotropica, 27(1), 121–127.		
Siebenrockiella crassicollis	Kimmel, C. E. (1980). A Diet and Reproductive Study for Selected Species of Malaysian Turtles. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/3111	y	
Staurotypus triporcatus	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	y	
Staurotypus triporcatus	Vogt, R. C., & Guzman, S. G. (1988). Food Partitioning in a Neotropical Freshwater Turtle Community. Copeia, 1988(1), 37–47. Retrieved from http://www.jstor.org/stable/1445920		bar graph only
Sternotherus carinatus	Kavanagh, B. T., & Kwiatkowski, M. A. (2016). Sexual dimorphism, movement patterns, and diets of Sternotherus carinatus (Razorback Musk Turtle). Southeastern Naturalist, 15(sp9), 117–133. https://doi.org/10.1656/058.015.0SP914	y	
Sternotherus carinatus	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	y	
Sternotherus carinatus	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.8	y	
Sternotherus depressus	Marion, K. R., Cox, W. A. ., & Ernst, C. H. (1991). Prey of the Flattened Musk Turtle, Sternotherus depressus. Journal of Herpetology, 25(3), 385–387.		
Sternotherus minor	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	y	
Sternotherus minor peltifer	Folkerts, G. W. (1968). Food Habits of the Stripe-Necked Musk Turtle, Sternotherus	y	

	minor peltifer Smith and Glass. Journal of Herpetology, 2(3), 171–173.	
Sternotherus odoratus	Berry, J. F. (1975). The Population Effects of Ecological Sympatry on Musk Turtles in Northern Florida. Copeia, 1975(4), 692–701.	y
Sternotherus odoratus	Lagler, K. F. (1943). Food Habits and Economic Relations of the Turtles of Michigan with Special Reference to Fish Management. The American Midland Naturalist, 29(2), 257–312. Retrieved from The American Midland Naturalist	y
Sternotherus odoratus	Mahmoud, I. Y. (1968). Feeding Behavior in Kinosternid Turtles. Herpetologica, 24(4), 300–305.	y
Sternotherus odoratus	Patterson, J. C., & Lindeman, P. V. (2009). Effects of Zebra and Quagga Mussel (<i>Dreissena spp .<\i>) Invasion on the Feeding Habits of Sternotherus odoratus (Stinkpot) on Presque Isle , Northwestern Pennsylvania. Northeastern Naturalist, 16(3), 365–374.	y
Sternotherus odoratus	Wilhelm, C. E., & Plummer, M. V. (2012). Diet of radiotracked musk turtles, Sternotherus odoratus, in a small urban stream. Herpetological Conservation and Biology, 7(2), 258–264.	y
Sternotherus odoratus	Morrison, M., Butterfield, B. P., Ross, S. G., Collins, C., Walde, A., Gray, J., … Munscher, E. C. (2019). The diet of the Eastern Musk Turtle (Sternotherus odoratus) as it pertains to invasive snail consumption in a freshwater spring habitat in Texas. Herpetology Notes, 12, 1133–1139.	
Sternotherus peltifer	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.1	y
Stigmochelys pardalis	Milton, S. J. (1992). Plants Eaten and Dispersed by Adult Leopard Tortoises Geochelone-Pardalis (Reptilia, Chelonii) in the Southern Karoo. South African Journal Of Zoology, 27(2), 45–49.	y
Stigmochelys pardalis	Rall, M., & Fairall, N. (1993). Diets and food preferences of two South African tortoises Geochelone pardalis and Psammobates oculifer. South African Journal of Wildlife …, 23(3), 63–70. Retrieved from http://reference.sabinet.co.za/sa_epublication_article/wild_v23_n3_a1	y
Terrapene carolina	Klimstra, W. N. D., & Newsome, F. (1960). Some Observations on the Food Coactions of the Common Box Turtle , Terrapene C . Carolina. Ecology, 41(4), 639–647.	y
Terrapene carolina	Figueras, M. P., Green, T. M., & Burke, R. L. (2021). Consumption patterns of a generalist omnivore: Eastern box turtle diets in the long island pine barrens. Diversity, 13(8), 1–12. https://doi.org/10.3390/d13080345	

Terrapene carolina bauri	Platt, S. G., Hall, C., Liu, H., & Borg, C. K. (2009). Wet-season Food Habits and Intersexual Dietary Overlap of Florida Box Turtles (Terrapene carolina bauri) on National Key Deer Wildlife Refuge, Florida. Southeastern Naturalist, 8(2), 335–346. https://doi.org/10.1656/058.008.0212	
Terrapene carolina carolina	Bush, F. M. (1959). Foods of Some Kentucky Herptiles. Herpetologica, 15(2), 73–77.	y
Testudo graeca	Rouag, R., Ferrah, C., Luiselli, L., Tiar, G., Benyacoub, S., Ziane, N., & El Mouden, E. H. (2008). Food choice of an algerian population of the spur-thighed tortoise, Testudo graeca. Journal of the Herpetological Association of Africa, 57(2), 103–113. https://doi.org/10.1080/21564574.2008.9635573	
Testudo graeca graeca	El Mouden, E. H., Slimani, T., Ben Kaddour, K., Lagarde, F., Ouhammou, A., & Bonnet, X. (2006). Testudo graeca graeca feeding ecology in an arid and overgrazed zone in Morocco. Journal of Arid Environments, 64(3), 422–435. https://doi.org/10.1016/j.jaridenv.2005.06.010	
Testudo graeca ibera	Iftime, A., & Iftime, O. (2012). Long term observations on the alimentation of Testudo graeca ibera (Testudines, Testudinidae). Acta Herpetologica, 7(1), 105–110.	
Testudo hermanii	Del Vecchio, S., Burke, R. L., Rugiero, L., Capula, M., & Luiselli, L. (2011). Seasonal Changes in the Diet of Testudo Hermanni Hermanni in Central Italy. Herpetologica, 67(3), 236–249.	
Testudo hermanii	Meek, R. (1986). Nutritional Selection in Hermann's Tortoise, Testudo hermanni, in Montenegro and Croatia. Testudo, 7(2), 88–95. Retrieved from http://www.britishcheloniagroup.org.uk/testudo/v7/v7n2meek	
Trachemys scripta	Dreslik, M. J. (1999). Dietary notes on the red-eared slider (Trachemys scripta) and river cooter (Pseudemys concinna) from southern Illinois. Transactions of the Illinois State Academy of Science, 92(3–4), 233–241.	y
Trachemys scripta	McCoy, C. J., Flores-Villela, O. A., Vogt, R. C., Pappas, M., & Mccoy, J. K. (2020). Ecology of Riverine Turtle Communities in the Southern United States: Food Resource Use and Trophic Niche Dimensions. Chelonian Conservation and Biology, 19(2), 197–208. https://doi.org/10.2744/CCB-1447.3	y
Trachemys scripta	Moll, D. (1990). Population Sizes and Foraging Ecology in a Tropical Freshwater Stream Turtle Community. Journal of Herpetology, 24(1), 48–53.	y
Trachemys scripta	Pierce, L. (1992). Diet Content and Overlap of Six Species of Turtle Among the Wabash River. Eastern Illinois University. Retrieved from https://thekeep.eiu.edu/theses/1276	
Trachemys scripta elegans	Wang, J., Shi, H., Hu, S., Ma, K., & Li, C. (2013). Interspecific differences in diet between introduced red-eared sliders and	y

	native turtles in China. Asian Herpetological Research, 4(3), 190–196. https://doi.org/10.3724/SP.J.1245.2013.00190		
Trachemys scripta elegans	Lee, H.-J., & Park, D. (2010). Distribution, habitat characteristics, and diet of freshwater turtles in the surrounding area of the Seomjin River and Nam River in southern Korea. Journal of Ecology and Field Biology, 33(3), 237–244. http://doi.org/10.5141/JEFB.2010.33.3.237	y	
Trachemys scripta elegans	Pérez-santigosa, N., Florencio, M., Hidalgo-vila, J., & Díaz-paniagua, C. (2011). Does the exotic invader turtle, Trachemys scripta elegans, compete for food with coexisting native turtles? Natividad. Amphibia-Reptilia, 32(2), 167–175.	y	
Trionyx triunguis	Akani, G. C., Capizzi, D., & Luiselli, L. (2001). Diet of the softshell turtle, Trionyx triunguis, in an Afrotropical forested region. Chelonian Conservation and Biology, 4(1), 200-201.	y	converted to percentage of all occurrences
Trionyx triunguis	Luiselli, L., Akani, G. C., Politano, E., Odegbune, E., & Bello, O. (2004). Dietary shifts of sympatric freshwater turtles in pristine and oil-polluted habitats of the Niger delta, southern Nigeria. Herpetological Journal, 14(2), 57–64.	y	converted to percentage of all occurrences

Appendix D

Appendix Table D-1: Scaling of adductor chamber and head dimensions

Dim	Group	Intercept	Slope	Lower Limit	Upper Limit	P	r^2	F	Growth Type
AH	Female M. terrapin	2.537	0.423	-0.279	1.126	0.182	0.324	2.4	N
	Male M. terrapin	0.587	1.091	0.562	1.620	0.005	0.891	32.8	P
	Female T. scripta	0.962	0.892	0.298	1.486	0.012	0.749	14.9	N
	Male T. scripta	1.387	0.750	0.230	1.270	0.035	0.997	335.4	N
AW	Female *M. terrapin*	2.613	0.511	-0.192	1.214	0.121	0.411	3.5	N
	Male *M. terrapin*	2.398	0.610	0.310	0.910	**0.005**	0.888	31.8	N
	Female *T. scripta*	2.454	0.539	0.334	0.744	**0.001**	0.901	45.6	N
	Male *T. scripta*	2.446	0.579	-0.462	1.619	0.090	0.980	49.9	N
PL	Female *M. terrapin*	3.069	0.228	-0.579	1.035	0.501	0.095	0.5	N
	Male *M. terrapin*	0.507	0.960	0.280	1.641	**0.017**	0.793	15.4	I
	Female *T. scripta*	0.783	0.886	0.537	1.235	**0.001**	0.895	42.6	N
	Male *T. scripta*	1.795	0.568	0.444	0.691	**0.011**	1.000	3416.0	N
PW	Female *M. terrapin*	2.387	0.529	-0.534	1.592	0.257	0.247	1.6	N
	Male *M. terrapin*	1.416	0.887	0.755	1.018	**0.000**	0.989	351.7	N
	Female *T. scripta*	1.563	0.795	-0.100	1.689	0.071	0.510	5.2	N
	Male *T. scripta*	2.074	0.595	-0.662	1.852	0.105	0.973	36.2	N
HW	Female *M. terrapin*	3.937	-0.019	-0.351	0.313	0.889	0.004	0.0	N
	Male *M. terrapin*	3.855	-0.110	-8.528	8.308	0.973	0.000	0.0	N
	Female *T. scripta*	0.387	0.941	0.623	1.259	**0.001**	0.921	57.9	I
	Male *T. scripta*	1.371	0.667	-0.006	1.341	0.050	0.994	158.6	N
HL	Female *M. terrapin*	4.114	-0.062	-0.422	0.297	0.674	0.038	0.2	N
	Male *M. terrapin*	6.988	-0.842	-4.262	2.579	0.532	0.105	0.5	N
	Female *T. scripta*	-0.016	0.937	0.756	1.118	**0.000**	0.973	176.6	N
	Male *T. scripta*	0.773	0.734	0.482	0.985	**0.017**	0.999	1373.0	N

HH	Female *M. terrapin*	4.141	-0.089	-0.460	0.283	0.567	0.070	0.4	N
	Male *M. terrapin*	5.579	-0.616	-4.147	2.915	0.654	0.055	0.2	N
	Female *T. scripta*	0.479	0.992	0.662	1.321	**0.001**	0.923	59.9	I
	Male *T. scripta*	1.249	0.760	-1.049	2.569	0.118	0.966	28.5	N

Appendix E

Appendix Table E-1: Calculated forces as specific tension values from 20-60 N/cm^{-2}

Species	Specimen	Jaw Length (mm)	Mechanical Advantage (IL/OL) at Trituration Basin	MAME PCSA	PCSA Scaled to 30 mm Jaw Length	Specific Tension P_o (N/cm^{-2})	Theoretical Muscle Force (n)	Theoretical Bilateral Static Bite Force (N)	Scaled Theoretical Muscle Force (N)	Scaled Theoretical Bilateral Static Bite Force (N)
***Trachemys scripta* Female**	OUVC 10881	26	0.49	0.6217	0.7173	20.00	12.43	12.15	14.35	14.02
						25.00	15.54	15.19	17.93	17.53
						30.00	18.65	18.23	21.52	21.04
						35.00	21.76	21.27	25.11	24.54
						40.00	24.87	24.31	28.69	28.05
						45.00	27.97	27.35	32.28	31.55
						50.00	31.08	30.39	35.86	35.06
						55.00	34.19	33.42	39.45	38.57
						60.00	37.30	36.46	43.04	42.07
***Trachemys scripta* Male**	OUVC 10873	28.3	0.52	0.6503	0.6893	20.00	13.01	13.53	13.79	14.34
						25.00	16.26	16.91	17.23	17.92
						30.00	19.51	20.29	20.68	21.51
						35.00	22.76	23.67	24.13	25.09
						40.00	26.01	27.05	27.57	28.68
						45.00	29.26	30.43	31.02	32.26
						50.00	32.51	33.81	34.47	35.84
						55.00	35.76	37.19	37.91	39.43
						60.00	39.02	40.58	41.36	43.01
***Malaclemys terrapin* Female**	OUVC 10866	32.7	0.52	2.4414	2.2398	20.00	48.83	51.13	44.80	46.90
						25.00	61.03	63.91	56.00	58.63
						30.00	73.24	76.69	67.19	70.36
						35.00	85.45	89.47	78.39	82.08

						40.00	97.66	102.25	89.59	93.81
						45.00	109.86	115.03	100.79	105.53
						50.00	122.07	127.81	111.99	117.26
						55.00	134.28	140.60	123.19	128.99
						60.00	146.48	153.38	134.39	140.71
***Malaclemys terrapin* Male**	USNM 574916	18.71	0.49	0.4129	0.6620	20.00	8.26	8.09	13.24	12.98
						25.00	10.32	10.12	16.55	16.22
						30.00	12.39	12.14	19.86	19.46
						35.00	14.45	14.16	23.17	22.71
						40.00	16.52	16.18	26.48	25.95
						45.00	18.58	18.21	29.79	29.19
						50.00	20.64	20.23	33.10	32.44
						55.00	22.71	22.25	36.41	35.68
						60.00	24.77	24.28	39.72	38.93
***Chelydra serpentina* Male**	OUVC 10867	40.96	0.45	4.9760	3.6446	20.00	99.52	90.06	72.89	65.96
						25.00	124.40	112.57	91.11	82.45
						30.00	149.28	135.09	109.34	98.94
						35.00	174.16	157.60	127.56	115.43
						40.00	199.04	180.12	145.78	131.92
						45.00	223.92	202.63	164.00	148.41
						50.00	248.80	225.14	182.23	164.90
						55.00	273.68	247.66	200.45	181.39
						60.00	298.56	270.17	218.67	197.88