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An Overview of Amphibian and Reptile Assemblages on Virginia's Eastern Shore, with Comments on Conservation

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INTRODUCTION

The history of published information on the herpetofauna of the Virginia portion of the Eastern Shore is checkered. Early documents suggest that the indigenous people, the Accomacks, used reptiles as food and ornamentation (Hariot, 1588; Smith, 1612). Some of the freshwater turtles and all of the sea turtles were probably eaten by the Accomacks and early European colonists (Hariot, 1588; Beatty & Malloy, 1940). Modern scientific interest in the herpetology of this region did not begin until the collection of specimens for the Smithsonian Institution in the late 19th century (Conant et al., 1990). The first amphibian known to science from Virginia's Eastern Shore was a Southern Leopard Frog (*Rana sphenocephala*) from Cape Charles collected on 18 September 1890 by Barton Bean. Captain G. D. Hitchins collected the first reptile (Ribbon Snake, *Thamnophis sauritus*) from this location in May 1897. Several species of amphibians and reptiles were collected from Smith Island, Northampton County, in 1894, 1897, and 1899 (Smithsonian Institution records). Only recently has the history of herpetological exploration in this area included more than distribution records.

The first scientific paper documenting the occurrence of amphibians and reptiles on the Eastern Shore of Virginia was by Dunn (1918). He listed five species of amphibians and 14 species of reptiles from this area based on a survey of museum collections. Additional species and locations were provided by Fowler (1925), Reed (1957), and Tobey (1985). Distributional records and notes on natural history were provided by Schwab (1989), Eckerlin (1995), Hobson & Stevenson (1995), Gray & Wright (1996), Wright & Gray (1996), Roble & Chazal (2000), and Roble et al. (2000). Brannon et al. (2001) provided recent distributional records for several of the islands. Aspects of the natural history of selected species are discussed by Scott (1986) and Hranitz (1993). A summary of the natural history of the amphibians and reptiles from the barrier islands is in Conant et al. (1990). Highton (1977) and Wynn (1986) evaluated genetic variation in the Eastern Red-backed Salamander (*Plethodon cinereus*). Dunson (1970, 1980, 1986) studied of the physiology of estuarine snakes and turtles in the Chincoteague area. Mitchell (1994) summarized available information on reptiles from throughout the Eastern Shore and the rest of Virginia, and Mitchell & Reay (1999) provided species distribution maps. The natural history of the herpetofauna of Assateague and Chincoteague islands of Virginia and Maryland was described by Mitchell & Anderson (1994). A brief history of herpetofaunal checklists for the area, along with keys to amphibians and reptiles was included in Mitchell (1999). This mini-review demonstrates that information on the amphibians and reptiles of Virginia's Eastern Shore has been growing steadily.

Currently, the herpetofauna of the Eastern Shore of Virginia is known to include 14 species of frogs, five salamanders, 12 turtles (including sea turtles), four lizards, and 12 snakes. The composition of the fauna favors reptiles (28) over amphibians (19). This diversity compares to a total of 134 species recorded for Virginia (Mitchell, 1994; Mitchell & Reay, 1999). All of the 47 species known to occur on the Eastern Shore are also found on Virginia's mainland but represent only 71% of the 66 species that occur in the Maryland portion of Delmarva (Table 1). Number of species of both amphibians and reptiles declines from the northern end of Delmarva to the southern end of the

Table 1. Distribution of amphibians and reptiles in the two Virginia Eastern Shore counties (Accomack, Northampton) compared to the Maryland portion of the Delmarva Peninsula and the Virginia Coastal Plain. Sources of distribution records are Harris (1975), Mitchell (1994), Mitchell & Reay (1999), Scott Smith (Maryland DNR, pers. comm.), Roble et al. (2000), and Anonymous (2001).

Species	Accomack	Northampton	Maryland	VA Coastal Plain
Frogs				
Acris crepitans	x	x	x	x
Bufo americanus	x		x	x
Bufo fowleri	x	x	x	x
Hyla chrysoscelis	x	x	x	x
Hyla cinerea	x	x	x	x
Hyla gratiosa			x	x
Pseudacris crucifer	x	x	x	x
Pseudacris f. kalmi	x	x	x	x*
Scaphiopus holbrookii	x	x	x	x
Rana catesbeiana	x		x	x
Rana clamitans	x	x	x	x
Rana palustris	x		x	x
Rana sphenocephala	x	x	x	x
Rana sylvatica	x		x	x
Rana virgatipes			x	x
Gastrophryne carolinensis	x	x	x	x
Total frogs	14	10	16	15
Salamanders				
Ambystoma maculatum			x	x
Ambystoma opacum	x	x	x	x
Ambystoma tigrinum			x	x
Desmognathus fuscus			x	x
Eurycea bislineata	?		x	x
Hemidactylium scutatum	x	x	x	x
Plethodon cinereus	x	x	x	x
Pseudotriton montanus			x	x
Pseudotriton ruber			x	x
Notophthalmus viridescens	x	x	x	x
Total salamanders	4**	4	10	10
Total amphibians	18	14	26	25
Turtles				
Apalone spinifera			x	
Caretta caretta	x	x	x	x
Chelonia mydas		x	x	x
Lepidochelys kempii	x	x	x	x
Dermochelys coriacea	x	x	x	x
Chelydra serpentina	x	x	x	x
Chrysemys picta	x	x	x	x
Clemmys guttata	x	x	x	x
Clemmys insculpta			x	x
Clemmys muhlenbergii			x	

Table 1. (continued).

Species	Accomack	Northampton	Maryland	VA Coastal Plain
Turtles (continued)				
Graptemys geographica			x	
Malaclemys terrapin	x	x	x	x
Pseudemys rubriventris	x	x	x	x
Terrapene carolina	x	x	x	x
Kinosternon subrubrum	x	x	x	x
Sternotherus odoratus	x		x	x
Total turtles	11	11	16	13
Lizards				
Sceloporus undulatus	x	x	x	x
Eumeces fasciatus	x	x	x	x
Eumeces laticeps	x	x	x	x
Scincella lateralis	x	x	x	x
Total lizards	4	4	4	4
Snakes				
Agkistrodon contortrix	x	x	x	x
Carphophis amoenus	x	x	x	x
Cemophora coccinea			x	x
Coluber constrictor	x	x	x	x
Diadophis punctatus	x	x	x	x
Elaphe guttata			x	x
Elaphe obsoleta	x	x	x	x
Heterodon platirhinos	x	x	x	x
Lampropeltis getula	x	x	x	x
Lampropeltis triangulum			x	x
Nerodia erythrogaster			x	x
Nerodia sipedon	x	x	x	x
Opheodrys aestivus	x	x	x	x
Pituophis melanoleucus			x	
Regina septemvittata			x	x
Storeria dekayi	x	x	x	x
Storeria occipitomaculata			x	x
Thamnophis sauritus	x	x	x	x
Thamnophis sirtalis	x	x	x	x
Virginia valeriae			x	x
Total snakes	12	12	20	19
Total reptiles	27	27	40	36
Total species	45	41	66	61

* *P. f. feriarum* in the Coastal Plain
** not including the questionable record

peninsula and may be related to historical distribution patterns, historical patterns of habitat availability, and modern habitat alteration by humans.

Despite the recreational and conservation interest in Virginia's Eastern Shore, no information exists on population sizes of amphibians and reptiles, the structure and dynamics of populations and communities, or how these aspects vary geographically. There are few data on life history characteristics of most species on Virginia's Eastern Shore. Information of this nature is needed to make realistic recommendations for the long-term conservation of this fauna.

This review provides a contextual framework for future work on the natural history and conservation of the Eastern Shore herpetofauna. I include an overview of the structure of amphibian and reptile assemblages based on my experience with their occurrence in selected habitat types and then comment on aspects of the conservation of the Eastern Shore herpetofauna. My review is intended to make naturalists, conservation biologists, regulators, and land managers aware of the gaps in our knowledge of these two groups of vertebrates in this portion of the Commonwealth and to suggest some things that can be done to enhance their conservation in this area.

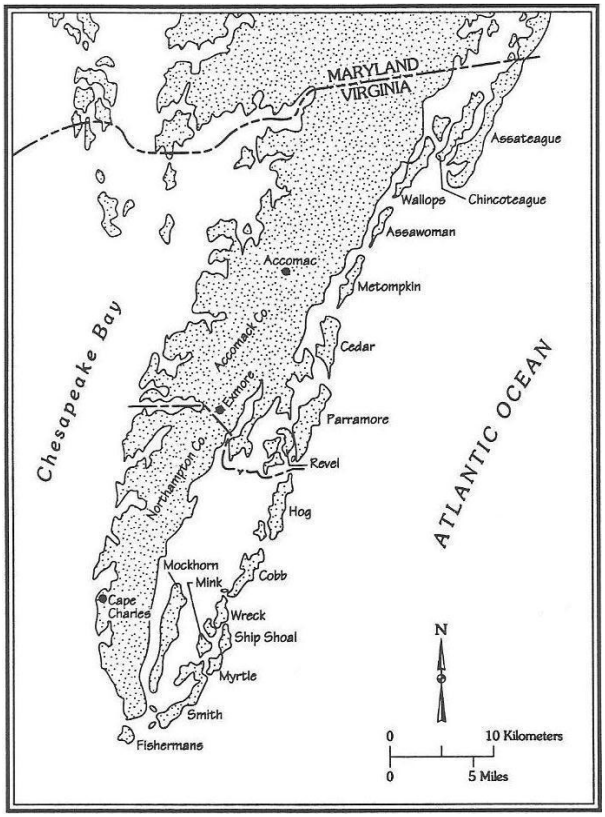

Fig. 1. The Eastern Shore of Virginia.

AMPHIBIAN AND REPTILE ASSEMBLAGES

The Eastern Shore of Virginia includes two counties, Accomack and Northampton, at the lower end of the Delmarva Peninsula (Fig. 1). The mainland portion of this region supports a diversity of upland, freshwater wetland, and estuarine habitats. The 14 barrier islands that lie along the eastern margin contain maritime forest, shrub, and beach/dune habitats, along with the estuarine systems on the western margins. Plants and plant associations of the barrier islands have been described by McCaffrey & Dueser (1990a, b). Other aspects of the ecology and natural history of the area were described and evaluated in a series of papers in the Virginia Journal of Science (Dueser, 1990).

I grouped the possible combinations of habitats inhabited by amphibians and reptiles on the Eastern Shore into nine categories: (1) freshwater ponds and lakes (impoundments), (2) hardwood to mixed hardwood-pine woodlands, (3) pine woods, (4) vernal pools, (5) springs and streams, (6) tidal creeks, (7) estuaries, (8) barrier islands, and (9) agricultural and urban areas. These include the habitat types in which herpetologists and naturalists have observed and collected amphibians and reptiles in this area. The species I include in each habitat type (Table 2) are based primarily on personal observations on the Eastern Shore, supplemented with knowledge of these animals from elsewhere in eastern Virginia. Only one habitat, the estuary, contains an assemblage of species exclusive of other habitats. Most of the amphibians and reptiles in this region have physiological tolerance limits and life histories that enable them to occupy a variety of habitats. Several also survive in agricultural and urban areas.

I provide an overview of the structure of each herpetofaunal assemblage in each of the nine habitats by examining the ecological roles of selected species. These descriptions are oversimplified because of movements of many of these vertebrates among habitat types. However, they allow us to recognize assemblages of species in definable habitats of this region. These descriptions provide a baseline against which future evaluations of species-habitat associations can be compared. Common and scientific names follow Crother (2000).

Freshwater Lakes and Ponds

The freshwater lake and pond assemblage is comprised of several freshwater turtles, one or two snakes, one salamander, and several frogs. Turtles include all of the freshwater basking species and species that occur primarily on the pond bottom. All of these species become active at about the same time of year, April, although they may occasionally be seen in winter months. They use much of the same habitat but eat different prey. Basking turtles include *Chrysemys picta* and *Pseudemys rubriventris*, the former an omnivore and the latter an herbivore. Three species of bottom-walkers occur on the Eastern Shore: *Chelydra serpentina*, *Kinosternon subrubrum*, and *Sternotherus odoratus*. The latter is an omnivore that is apparently rare south of northern Accomack County (Mitchell, 1994), and may interact little with the other species in most lakes and ponds. *Chelydra* is a large predator and eats a wide variety of animal prey, carrion, and plants. The omnivorous *K. subrubrum* rarely occurs in deep lakes, although it may be found in shallow edges. Mud turtles spend long periods of time in terrestrial habitats, including overwintering in shallow burrows (Ernst et al., 1994).

Frogs partition their habitats in freshwater lakes and ponds by breeding at different times of the year and occupying different microhabitats (Wright, 1914; Wright & Wright, 1949; Mitchell, 2000b). Phenological relationships are unknown for Virginia's Eastern Shore but they likely approximate those described by Lee (1973) for Delaware and the Eastern Shore of Maryland. In late winter, *Pseudacris crucifer* males call from shallow water in the upper end of ponds, as do those of *Rana palustris*. Most calling activity is completed by early May. *Rana sphenocephala* usually starts calling in March in shallow water but may continue into fall months. Summer breeders include *Hyla chrysoscelis*, a shallow water species, *Rana catesbeiana* which breeds around lake margins, and *Rana clamitans* which occur in the shallows of lake and pond margins. Both of the ranids occur in natural vernal pools, but only the latter reproduces in these ephemeral wetlands. *Hyla cinerea* and *Acris crepitans* call for extended periods in summer from vegetation around pond margins, the latter from grasses along the edge and the former from shrubs and trees. *Nerodia sipedon* preys on frogs and their tadpoles, and *Thamnophis sirtalis* occasionally enters shallow water in grassy areas to prey on these animals. *Notophthalmus viridescens* occurs in many of the lakes and ponds in the area.

Hardwoods to Mixed Hardwood-pine Woodlands

Areas of mixed hardwoods and hardwood-pine habitats on the Eastern Shore contain a terrestrial fauna with subterranean and arboreal elements. Several species of small, secretive snakes live in and under the leaf litter. These are *Carphophis amoenus*, *Diadophis punctatus*, and *Storeria dekayi*. *Carphophis* preys on worms, *Diadophis* preys mostly on Ground Skinks (*Scincella lateralis*) and Red-backed Salamanders (*Plethodon cinereus*), and *Storeria* eats slugs. Black Ratsnakes (*Elaphe obsoleta*) are the largest snakes on the Eastern Shore, and in my experience in the 1980s, the species most commonly killed on roads. Copperheads (*Agkistrodon contortrix*) are entirely terrestrial but are not commonly encountered on the Eastern Shore. Eastern Box Turtles (*Terrapene carolina*) are common, terrestrial omnivores in this region and play important roles in dispersal of the seeds of some plants (Braun & Brooks, 1987). In open areas, such as at the edges of forest patches, the lizards *Sceloporus undulatus* and *Eumeces laticeps* occupy the drier sites and *Eumeces fasciatus* the more mesic sites. Four-toed Salamanders (*Hemidactylium scutatum*) occur in microhabitats that are moist much of the year, especially if sphagnum is present.

Pine Woods

Fewer amphibians and reptiles survive in pine forests because these areas are usually too dry. The most commonly encountered species is *Sceloporus undulatus*, although *Eumeces laticeps* may occur in some locations. Fowler's Toads (*Bufo fowleri*) and Spadefoot Toads (*Scaphiopus holbrookii*) are fossorial but may be abundant. Snakes, such as *Coluber constrictor* and *Elaphe obsoleta*, occur in pine forests in low numbers. *Plethodon cinereus* occurs on the forest floor where there is adequate moisture.

Vernal Pools

Ephemeral bodies of water located in and adjacent to hardwood stands and pine woodlands support a variety of species that are adapted to such dynamic habitats. Vernal pools may be small to large in size and usually shallow enough to dry out in most years. They also include the Delmarva bays that formerly were important features on the Eastern Shore landscape (Pettry et al., 1979). Several species of frogs use these wetlands extensively for reproduction, including *Acris crepitans*, *Bufo americanus*, *Pseudacris crucifer*,

Pseudacris feriarum kalmi (New Jersey Chorus Frog), *Hyla chrysoscelis*, *Rana clamitans*, *R. palustris*, *R. sphenocephala*, *R. sylvatica*, and *Scaphiopus holbrookii*. Persistence of surface water through most summer months allows for annual population recruitment, although in drought years production of metamorphs may not occur. *Clemmys guttata*, *Nerodia sipedon*, and *Thamnophis sirtalis* are occasional inhabitants of vernal pools; the two snakes being important predators of anurans. Marbled Salamanders (*Ambystoma opacum*) lay eggs under debris in dry vernal pools in the fall; once fall and winter rains fill the pools the larvae overwinter and the females move to the subterranean retreats.

Springs and Streams

The headwaters of most Eastern Shore tidal creeks are comprised of freshwater seeps, springs, and streams. Except where humans have altered the landscape, these habitats are shaded under hardwood forest canopies. Riparian zones exist along some of the tributaries. These habitats are the only Eastern Shore locations for *Eurycea bislineata* (only one observation of this salamander is known to me, an escapee in a small stream near Locustville; JCM, pers. obs.). This salamander spends much of the year in moist areas in and along adjacent streams. Eastern Mud Salamander (*Pseudotriton montanus*) occurs in Wicomico and Worcester counties, Maryland (Harris, 1975), and may yet be found in Virginia. Stream habitats in this area support two frogs (*Rana palustris* and *Rana clamitans*), one snake (*Nerodia sipedon*), and a turtle (*Kinosternon subrubrum*). Pockets of this habitat and assemblage have persisted in the predominately agricultural landscape (JCM, pers. obs.).

Tidal Creeks

The most dynamic habitat on the Eastern Shore containing amphibians and reptiles is tidal creeks. Considerable stress on the physiological systems of amphibians and reptiles in this community occurs from changes in salinity ranging from freshwater to 50% seawater. Dunson (1970, 1986; Dunson & Mazzotti, 1989) studied the physiology of turtles living in tidal creeks to determine how they cope with the periodic physical changes. He discovered that some species are able to tolerate more saltwater than others and that these differences influence where they occur in the creek. Dunson (1986) illustrated the distributions of three species of predominately freshwater turtles in a small creek relative to salinity and tidal influence, and relative to the distribution of the estuarine turtle *Malaclemys terrapin*. All three species occurred in the portion of the creek that contains freshwater during low tides. A similar analysis of the distributions of turtles in a much larger creek (Table 3) illustrates, by comparison, how environmental factors and physiological tolerances of turtles on the Eastern Shore affect chelonian community composition. Northern Watersnakes (*Nerodia sipedon*) occur in tidal creeks but has no enhanced tolerance to salt water (Dunson, 1980). Little is known about its population ecology in these systems in Delmarva. Salt marshes are also likely to support populations of *Lampropeltis getula*, as Eastern Kingsnakes occur on Smith Island and are certainly able to migrate across sea water (Conant et al., 1990).

Table 3. Distribution of freshwater turtles in Little Mosquito Creek, Accomack County, in relation to changing salinities due to tidal flow. Salinities are means of surface and bottom values. Abbreviations: Cs = *Chelydra serpentina*, Cp = *Chrysemys picta*, Cg = *Clemmys guttata*, Ks = *Kinosternon subrubrum*, Mt = *Malaclemys terrapin*, So = *Sternotherus odoratus*. Data provided by W. A. Dunson.

Distance from mouth (km)	% sea water at low tide	% sea water at high tide	Species
0		86	Mt
1.00		86	Mt
2.00		86	Mt
3.00		83	Mt
3.50	11	80	Mt
4.00	9	71	
4.25	0	57	
4.50	0	51	
4.75	0	51	Ks
5.00	0	49	Cs, Ks
5.25	0	43	Cs, Ks, So
5.50	0	29	Cs, Ks, So, Cp
5.75	0	14	Cs, Ks, So, Cp
6.00	0	6	Cs, Ks, So, Cp, Cg
6.20	0	0	Cs, So, Cp

Estuaries

Estuarine habitats support only one permanent reptile resident, *Malaclemys terrapin*. This turtle preys on mud snails and other mollusks, and terrapin eggs are energy sources for a variety of avian and mammalian predators. The precise role of this species in energy dynamics of the estuary is yet to be determined. The four species of sea turtles are all transients, occurring only in summer months. *Caretta caretta* is the only species of sea turtles regularly seen in the deeper channels (B. Truitt, pers. comm.).

Barrier Islands

The composition of the herpetofaunal assemblages of the barrier islands varies among islands. Conant et al. (1990) reviewed the biogeography of the amphibians and reptiles on the barrier islands of Virginia. The Assateague - Chincoteague - Wallops cluster contains the highest number of species (20, Mitchell & Anderson, 1994). Smith Island at the southern end of the near-shore archipelago has the second highest number (15). The composition of herpetofaunal assemblages on each of the islands derives from historical events affecting their occurrence and the availability of appropriate habitat, especially fresh water. Construction of freshwater ponds and dikes on the southern end of Assateague Island provided suitable habitat for several aquatic turtles and at least two ranid frogs. Islands with grasslands and myrtle thickets contain *Opheodrys aestivus*. On Hog, Cobb, and Parramore Islands, *Storeria dekayi* is sympatric with *O. aestivus*, and in some cases both species occur under the same cover objects (see Plate 69 in Mitchell, 1994). *Coluber constrictor* occurs on the larger islands (e.g., Smith and Hog) in the same habitat. The serpentine predator of these snakes, *Lampropeltis getula*, occurs only on Smith Island. The only two lizards on the barrier islands, *Scincella lateralis* and *Sceloporus undulatus*, occur sympatrically on Smith and Fisherman islands. The former occurs in grassland areas and Fence Lizards occur in pinewoods. Ground Skinks also occur on other islands (Brannon et al., 2001).

On those islands with fresh water (e.g., Assateague, Hog, Parramore, and Smith) *Chelydra serpentina*, *Clemmys guttata*, and *Kinosternon subrubrum* are locally abundant. Few amphibians occur on the barrier islands. Several species of frogs and one salamander occur in the Assateague - Chincoteague -Wallops cluster (Conant et al., 1990; Mitchell & Anderson, 1994). The toad, *Bufo fowleri*, occurs in sandy areas on Hog, Parramore, and Smith Islands, in addition to the northern cluster. Its occurrence is limited by fresh water. Its primary predator, *Heterodon platirhinos*, has been found in sandy areas on several islands (Assateague, Chincoteague, Wallops, and, at least formerly, Hog).

Barrier islands pose special problems to researchers seeking to delineate assemblages of amphibians and reptiles occurring on them because of historical changes and the dynamic nature of these landmasses. Observations of recent investigators suggest that several changes in community composition have occurred on some islands within the last half century (Conant et al., 1990).

Agricultural and Urban Areas

Several species of amphibians and reptiles are often encountered in agricultural and urban areas, habitats not as well defined as those above. In summer, ditches and periodically wet fields contain populations of *Bufo fowleri*, *Scaphiopus holbrookii*, and *Gastrophryne carolinensis*. The most common snakes are *Elaphe obsoleta* and *Coluber constrictor*. *Terrapene carolina* is often found in ecotonal areas between patches of woods and agricultural fields. Hedgerows and ecotones support *Agkistrodon contortrix*. All of these species may be found occasionally in urbanized areas of the Eastern Shore where there are habitat patches that provide shelter and prey.

CONSERVATION OF HERPETOFAUNAL DIVERSITY

Current distributions of the amphibians and reptiles on Virginia's Eastern Shore reflect numerous historical changes in the landscape. Some species were undoubtedly more widespread before European agricultural techniques destroyed much of the original forest and pocosin-like wetlands. Conversely, some species probably expanded their populations due to the number of freshwater lakes and ponds created by humans (e.g., *C. picta*) and increased abundance of grassland and old field habitats (e.g., *C. constrictor*). Species occupying these habitats are less likely to decline in the future than those in habitats threatened by expanding agricultural and urban activities. There are, however, numerous threats to the amphibians and reptiles on Virginia's Eastern Shore, and there are opportunities to enhance their conservation.

Harvesting vertebrates for human trade and consumption has undoubtedly resulted in elimination and reduction of many populations on the Eastern Shore. Bird populations declined precipitously in the late 1800s and early 1900s in the face of over-hunting, egg collecting, and killing of certain species for feathers (Ehrlich et al., 1988; Barnes & Truitt, 1998). Historical overexploitation has probably affected bird and mammal populations more than it has affected the herpetofauna. Until recently, the primary human use of amphibians and reptiles was for personal consumption. Sea turtles were taken on occasion by fishermen until they were protected by the U.S. Endangered Species Act. Other species eaten historically and perhaps currently were Bullfrogs, Diamondback Terrapins, Snapping Turtles, and Red-bellied Cooters. Two other forms of human use may result in overexploitation of amphibians and reptiles. These include harvesting for commercial trade (Diamondback Terrapin, Snapping Turtle) and removal of individuals for the pet trade. Information is lacking on the extent of poaching for the pet trade but if statistics from other regions in the United States (Franke & Telecky, 2001) are applicable, then the number of animals removed from the Eastern Shore may not be sustainable. Diamondback Terrapins have been harvested for commercial trade since the late 1800s (Carr, 1952; Ernst et al., 1994). The terrapin fishery peaked in 1944 in Maryland, for example, with a take of over 204,120 kg, but dropped off drastically due to the near extirpation of turtles and decline in the fad for turtle soup (Roosenburg, 1990). One operation based in Chincoteague apparently continued to supply scientific researchers with specimens at least through the 1980s (e.g., Cowan, 1990). Large scale mortality of Diamondback Terrapins in commercial and recreational crab pots and fyke nets set for fish across coves (Roosenburg et al., 1997; M. Whilden, Maryland DNR, pers. comm.) has certainly caused population declines of this species. A modern review of such problems is clearly warranted.

Other sources of population decline on Virginia's Eastern Shore are killing of amphibians and reptiles on roads by vehicular traffic on roads, indiscriminate killing of snakes, introduced species, and pollution of wetlands and streams by agricultural pesticides and herbicides. Mortality on roads has become a prime source of population decline in many areas (Wilkins & Schmidly, 1980; Fahrig et al., 1995; Wood & Herlands, 1997; Mitchell, 2000a). The killing of snakes out of fear and ignorance may be ingrained in humans (Wilson, 1996), and it has undoubtedly been practiced since human occupation of the Eastern Shore. Rattlesnakes (*Crotalus horridus*) may have occurred on the Delmarva Peninsula historically but there are no known extant populations (Mitchell, 1994). An introduced species that contributes to the decline of native species is the domestic cat (*Felis catus*). Domestic free-ranging and feral cats are well known to kill and in some cases eat native amphibians and reptiles (Mitchell & Beck, 1993). A wide range of amphibian and reptile malformations, sickness, and mortality is caused by pesticides and herbicides (Sparling et al., 2000, and chapters therein). Virginia's Eastern Shore has long been used for intensive agriculture that has most certainly caused harmful levels of chemicals in the soil and aquatic systems in this region. Nitrogen pollution, for example, from fertilizations, livestock, precipitation, and effluents from industrial and human wastes has been shown to cause developmental abnormalities and death in amphibians (Rouse et al., 1999). Although data on these topics pertaining directly to Virginia's Eastern Shore are lacking, such sources of mortality and population decline undoubtedly exist here. Observations of such impacts and declines should be documented in publications.

The first broad-scale effort to protect the Eastern Shore's biodiversity from further decline was the formation of the Virginia Coast Reserve (VCR) by The Nature Conservancy (Hennessey, 1976). Today, the VCR manages 45,000 acres (18,212 ha) of mainland and barrier island habitat. Likewise, the establishment of several national wildlife refuges (Chincoteague, Fisherman Island, Wallops Island, and Eastern Shore of Virginia), state Natural Area preserves and parks (Wreck Island, Savage Neck Dunes, Kiptopeke State Park, and Parker's Marsh Natural Area), and several state wildlife management areas (e.g., Mockhorn Island, Saxis Marsh) help to ensure the future of some of the amphibians and reptiles living in these areas. Another development aiding conservation of the Eastern Shore herpetofauna is the growing awareness of local communities that Neotropical migrant birds constitute a resource to be protected (Terbourgh, 1989; Carter et al., 2000). Ecotourism is a growing industry in this area and is exemplified by the fall birding festival held annually in October. Protection of habitat for birds will also benefit amphibians and reptiles.

My major concerns for the protection of amphibian and reptile biodiversity on Virginia's Eastern Shore are the future of hardwood and mixed hardwood-pine woodlands, the remaining ephemeral wetlands (including remnant Delmarva Bays), and freshwater springs and streams, and the large scale chemical

pollution that may be affecting amphibian populations. Clearly, a first step is identification of the remaining hardwood tracts and remnant isolated wetlands. The conservation of springs and streams requires special search efforts on the ground. The first step in protecting amphibians and reptiles in these habitats is to locate and accurately map all locations of these sensitive habitats. These should then be ranked according to a scheme that integrates natural condition (e.g., species richness and diversity) with threats, including chemical intrusion and surrounding land use. Buffer zones and other means of protection of these integral habitats can then be designed and implemented. Effective conservation of amphibians and reptiles cannot be realized without focusing on habitats and the landscape in which they are embedded. Documentation of malformed and sick amphibians would reveal whether such problems are occurring here as they do elsewhere in the face of chemical pollution.

Lands that are managed for conservation objectives need not necessarily be built entirely from pristine habitats, none of which now exist on the Eastern Shore, except for possibly some estuarine marshes. Any effort on behalf of the conservation of the biodiversity of amphibians and reptiles on the Eastern Shore must take into consideration the concept of reclaimed farmland. Although habitat loss from agricultural practices has been dramatic, it is possible to include farmland in restoration efforts for conservation. A parcel of land, a portion of which contains hardwood forest, isolated wetlands, springs and streams, and the agricultural areas, will grow into a viable natural habitat complex, if allowed to do so. This, of course, assumes that the parcel and adjacent lands contain most of the biodiversity of the area. Several such large areas on the lower Delmarva Peninsula, in conjunction with farmland containing corridors of habitat, may be sufficient to maintain amphibian and reptile diversity on Virginia's Eastern Shore for the long term.

The design of conservation lands has been debated in the scientific literature (Shafer, 1990; Fahrig & Merriam, 1994; Meffe & Carroll, 1997), but the final size and configuration of any conservation area is more likely to be determined by what is available than by biological data. This is exemplified in the current habitat mosaic remaining on much of the Eastern Shore (Fig. 2, also see Fig. 4 in Pettry et al., 1979). Much of this area is affected by agricultural operations, small towns, and roads. The natural habitat remaining is limited to patches such as small woodlots and scattered aquatic habitats.

Inventories of the remaining natural habitats on the Eastern Shore are critical to ensure that the appropriate sites are identified and targeted for protection. If the habitats are too small to contain the minimum population size and home range requirements of the more mobile species, then ways of effectively enlarging the habitat should be sought. One such way is to allow movement, and thus genetic exchange, between relatively small habitat islands via habitat corridors (Noss & Harris, 1986; Meffe & Carroll, 1997).

I recommend that broad-scale public education be a key ingredient in any conservation effort on the Eastern Shore. Human needs should be factored into a holistic conservation framework, one that preserves cultural and natural heritage into an integrated framework. This approach is being used effectively elsewhere in the world (e.g., Costa Rica: Allen, 1988; Janzen, 1988). The Eastern Shore of Virginia would be an appropriate place to develop such a strategy in the United States. The ingredients are already in place.

There are many opportunities for research on the amphibians and reptiles on Virginia's Eastern Shore, as well as discovery of much new knowledge about these animals in the habitats within this coastal environment. The natural history of most species is poorly known and even casual observations should be accumulated and published. Studies of the conservation biology of rare and currently common species would yield many new insights that would enhance future management efforts.

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Fig. 2. Aerial view of a portion of the Eastern Shore of Virginia near Cheriton, Northampton County. U.S. Route 13 bisects the photograph on the left. The view shows the habitat mosaic typical of the Eastern Shore and illustrates habitat islands and corridors. Note the remnant Delmarva Bay in the agricultural field in the lower right-hand portion of the photo. Photograph taken 1 December 1972; used with permission of the Virginia Department of Transportation.

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LITERATURE CITED

Allen, W. H. 1988. Biocultural restoration of a tropical forest. BioScience 38: 156-161.

Anonymous. 2001. Herps of Savage Neck Dunes Natural Area Preserve: addendum. Catesbeiana 21: 36.

Barnes, B. M., & B. R. Truitt. 1997. Seashore Chronicles: Three Centuries of the Virginia Barrier Islands. University Press of Virginia, Charlottesville, VA. 249 pp.

Beatty, R. C., & W. J. Mulloy. 1940. William Byrd's Natural History of Virginia or the Newly Discovered Eden. Edited and Translated [from W. Vogel, "Eine kurtze Beschreibung von Virginia," in S. Jenner, Neugefundes Eden, Berne, 1737]. The Dietz Press, Richmond, VA. 95 pp. (English) + 109 pp. (German).

Brady, M. K. 1925. Notes on the herpetology of Hog Island. Copeia (137): 110-111.

Brannon, M. P., N. D. Moncrief, & R. D. Dueser. 2001. New records of reptiles from the Virginia barrier islands. Banisteria 18: 42-43.

Braun, J., & G. R. Brooks, Jr. 1987. Box turtles (*Terrapene carolina*) as potential agents for seed dispersal. American Midland Naturalist 117: 312-318.

Carr, A. 1952. Handbook of Turtles of the United States and Canada. Cornell University Press, Ithaca, NY. 542 pp.

Carter, M. F., W. C. Hunter, D. N. Pashley, & K. V. Rosenburg. 2000. Setting conservation priorities in the United States: The Partners in Flight Approach. The Auk 117: 541-548.

Conant, R. 1945. An annotated check list of the amphibians and reptiles of the Del-Mar-Va peninsula. Society for Natural History, Delaware. 8 pp.

Conant, R., & J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. Third edition, Houghton Mifflin Co., Boston, MA. 450 pp.

Conant, R., J. C. Mitchell, & C. A. Pague. 1990. Herpetofauna of the Virginia barrier islands. Virginia Journal of Science 41: 364-380.

Cowan, F. B. 1990. Does the lachrymal salt gland of *Malaclemys terrapin* have a significant role in osmoregulation? Canadian Journal of Zoology 68: 1520-1524.

Crother, B. I. (Committee Chair). 2000. Standard English and common names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. Society for the Study of Amphibians and Reptiles, Herpetological Circular 29: 1-82.

Dueser, R. D. 1990. Biota of the Virginia Barrier Islands: symposium introduction. Virginia Journal of Science 41: 257-258.

Dunn, E. R. 1918. A preliminary list of the reptiles and amphibians of Virginia. Copeia (53): 16-27.

Dunson, W. A. 1970. Some aspects of electrolyte and water balance in three estuarine reptiles, the diamondback terrapin, American and "salt water" crocodiles. Comparative Biochemistry and Physiology 32: 161-174.

Dunson, W. A. 1980. The relation of sodium and water balance to survival in sea water of estuarine and freshwater races of the snakes *Nerodia fasciata*, *N. sipedon*, and *N. valida*. Copeia 1980: 268-280.

Dunson, W. A. 1986. Estuarine populations of the snapping turtle (*Chelydra*) as a model for the evolution of marine adaptations in reptiles. Copeia 1986: 741-756.

Dunson, W. A., and F. J. Mazzotti. 1989. Salinity as a limiting factor in the distribution of reptiles in the Florida Bay: a theory for the estuarine origin of marine snakes and turtles. Bulletin of Marine Science 44: 229-244.

Eckerlin, R. P. 1995. Field notes: *Carphophis amoenus*. Catesbeiana 15: 47-48.

Ehrlich, P. R., D. S. Dobkin, & D. Wheye. 1988. The Birders Handbook. Simon and Schuster, New York, NY. 705 pp.

Ernst, C. H., J. E. Lovich, & R. W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, DC. 578 pp.

Fahrig, L., & G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8: 50-59.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, & J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73: 177-182.

Fowler, H. W. 1925. Records of amphibians for Delaware, Maryland and Virginia, III. Virginia. Copeia (146): 65-67.

Franke, J., & T. M. Telecky. 2001. Reptiles as pets, an examination of the trade of live reptiles in the United States. The Humane Society of the United States, Washington, D.C. 146 pp.

Garber, S. D. 1988. Diamondback terrapin exploitation. Plastron Papers 17(6). 5 pp.

Gray, W. P., & R. A. S. Wright. 1996. Field notes: *Heterodon platyrhinos*. Catesbeiana 16: 11-12.

Hariot, T. 1588. A Briefe and True Report of the New Found Land of Virginia. Theodore de Bay, Frankfurt, Germany (reprinted in March of America Facsimile Series, No. 15, Univ. Microfilms, Inc., Ann Arbor, MI, 1966).

Harris, H. S., Jr. 1975. Distributional survey (Amphibia/Reptilia): Maryland and the District of Columbia. Bulletin of the Maryland Herpetological Society 11: 73-167.

Hennessey, G. R. (ed.). 1976. Virginia Coast Reserve, ecosystem description, land use history and climate and soils. Volume 1. The Nature Conservancy, Arlington, VA. 568 pp.

Highton, R. 1977. Comparison of microgeographic variation in morphological and electrophoretic traits. Pp. 397-436 *in* M. K. Hecht, W. C. Steere, & B. Wallace (eds.), Evolutionary Biology, Vol. 10, Plenum Publication Corporation, New York, NY.

Hobson, C. S., & D. J. Stevenson. 1995. Field notes: *Thamnophis sirtalis sirtalis*. Catesbeiana 15: 23.

Hranitz, J. M., T. S. Klinger, F. C. Hill, R. G. Sagar, T. Mecken, & J. Carr. 1993. Morphometric variation between *Bufo woodhousii fowleri* Hinckley (Anura: Bufonidae) on Assateague Island and the adjacent mainland. Brimleyana 19: 65-75.

Janzen, D. H. 1988. Tropical dry forests, the most endangered major tropical ecosystem. Pp. 130-137 *in* E. O. Wilson (ed.), Biodiversity. National Academy Press, Washington, D.C.

Keinath, J. A., J. A. Musick, & R. A. Byles. 1987. Aspects of the biology of Virginia's sea turtles: 1979-1986. Virginia Journal of Science 38: 329-336.

Lee, D. S. 1973. Seasonal breeding distributions for selected Maryland and Delaware amphibians. Bulletin of the Maryland Herpetological Society 9: 101-104.

Lutcavage, M., & J. A. Musick. 1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985: 449-456.

McCaffrey, C. A, & R. D. Dueser. 1990a. Preliminary vascular flora of the Virginia barrier islands. Virginia Journal of Science 41: 259-281.

McCaffrey, C. A, & R. D. Dueser. 1990b. Plant associations on the Virginia barrier islands. Virginia Journal of Science 41: 282-299.

Margules, C. R., A. O. Nicholls, & R. L. Pressey. 1988. Selecting networks of reserves to maximize biological diversity. Biological Conservation 43: 63-76.

Martof, B. S., W. M. Palmer, J. R. Bailey, & J. R. Harrison, III. 1980. Amphibians and Reptiles of the Carolinas and Virginia. University of North Carolina Press, Chapel Hill, NC. 264 pp.

Meffe, G. K., & C. R. Carroll. 1997. Principles of Conservation Biology. 2nd Edition, Sinauer Associates Inc. Publishers, Sunderland, MA. 729 pp.

Mitchell, J. C. 1992. Invertebrate prey of *Bufo woodhousii fowleri* (Anura: Bufonidae) from a Virginia barrier island. Banisteria 1: 13-15.

Mitchell, J. C. 1994. The Reptiles of Virginia. Smithsonian Institution Press, Washington, DC. 352 pp.

Mitchell, J. C. 1999. Checklist and key to the amphibians and reptiles of Virginia's Eastern Shore. Catesbeiana 19: 3-18.

Mitchell, J. C. 2000a. Mass mortality of red-spotted newts (*Notophthalmus viridescens viridescens* Rafinesque) on a central Virginia road. Banisteria 15: 44-46.

Mitchell, J. C. 2000b. Amphibian Monitoring Methods & Field Guide. Conservation Research Center, Smithsonian Institution, Front Royal, VA. 56 pp.

Mitchell, J. C., & J. M. Anderson. 1994. Amphibians and Reptiles of Assateague and Chincoteague Islands. Special Publication Number 2, Virginia Museum of Natural History, Martinsville, VA. 120 pp.

Mitchell, J. C., & R. Conant. 2000. Field notes: *Eumeces laticeps*. Catesbeiana 20: 41.

Mitchell, J. C., & K. K. Reay. 1999. Atlas of Amphibians and Reptiles in Virginia. Special Publication No. 1, Virginia Department of Game and Inland Fisheries, Richmond, VA. 122 pp.

Noss, R. F., & L. D. Harris. 1986. Nodes, networks, and MUM's: Preserving diversity at all scales. Environmental Management 10: 299-300.

Pettry, D. E., J. H. Scott, Jr., & D. J. Bliley. 1979. Distribution and nature of Carolina Bays on the Eastern Shore of Virginia. Virginia Journal of Science 30: 3-9.

Reed, C. F. 1957. Contributions to the herpetology of Virginia, 3. The herpetofauna of Accomac and Northampton counties. Journal of the Washington Academy of Science 47: 89-91.

Roble, S. M., & A. C. Chazal. 2000. Field notes: *Rana catesbeiana*. Catesbeiana 19: 34.

Roble, S. M., A. C. Chazal, & A. K. Foster. 2000. A preliminary survey of amphibians and reptiles of Savage Neck Dunes Natural Area Preserve, Northampton County, Virginia. Catesbeiana 20: 63-74.

Roosenburg, W. M. 1990. The diamondback terrapin: population dynamics, habitat requirements, and opportunities for conservation. Pp. 227-234 *in* New Perspectives in the Chesapeake System: A Research and Management Partnership. Proceedings of a Conference, 4-6 December 1990. Chesapeake Research Consortium Publication No. 137. Baltimore, MD.

Roosenburg, W. M., W. Cresko, M. Modesitte, & M. B. Robbins. 1997. Diamondback terrapin (*Malaclemys terrapin*) mortality in crab pots. Conservation Biology 11: 1166-1177.

Rouse, J. D., C. A. Bishop, & J. Struger. 1999. Nitrogen pollution: an assessment of its threat to amphibian survival. Environmental Health Perspectives 107: 799-803.

Schafer, C. L. 1990. Nature Reserves, Island Theory and Conservation Practice. Smithsonian Institution Press, Washington, DC. 189 pp.

Schwab, D. 1989. Field notes: *Malaclemys terrapin terrapin*. Catesbeiana 9: 34-35.

Scott, D. 1986. Notes on the eastern hognose snake, *Heterodon platyrhinos* Latreille (Squamata: Colubridae), on a Virginia barrier island. Brimleyana 12: 51-55.

Smith, J. 1612. A Map of Virginia, With a Description of the Countrey, the Commodities, People, Government, and Religion. London. (Reprinted in Barbour, P.L. (ed.). 1986. The Complete Works of Captain John Smith (1580-1631). 3 Volumes. University of North Carolina Press, Chapel Hill, NC. 1,544 pp.).

Sparling, D. W., G. Linder, & C. A. Bishop (eds.). 2000. Ecotoxicology of Amphibians and Reptiles. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL. 904 pp.

Terbourgh, J. 1989. Where Have all the Birds Gone? Princeton University Press, Princeton, NJ. 207 pp.

Tobey, F. J. 1985. Virginia's Amphibians and Reptiles: A Distributional Survey. Virginia Herpetological Society, Purcellville, VA. 114 pp.

Wilcove, D. S., C. H. McLellan, & A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pp. 237-256 *In* M. E. Soule' (ed.), Conservation Biology, Sinauer Associates, Inc., Sunderland, MA.

Wilkins, K. T., & D. J. Schmidly. 1980. Highway mortality of vertebrates in southeastern Texas. Texas Journal of Science 32: 343-350.

Wilson, E. O. 1996. In Search of Nature. Island Press, Washington, DC. 214 pp.

Wood, R. C., & R. Herlands. 1997. Turtles and tires: the impact of roadkills on Northern Diamondback Terrapin, *Malaclemys terrapin terrapin*, populations on the Cape May Peninsula, southern New Jersey, USA. Pp. 46-53 *In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference. New York Turtle & Tortoise Society, NY.

Wright, A. H. 1914. North American Anura, Life-histories of the Anura of Ithaca, New York. Carnegie Institute of Washington, Washington, D.C. 98 pp.

Wright, A. H., & A. A. Wright. 1949. Handbook of Frogs and Toads of the United States and Canada. Third Edition. Cornell University Press, Ithaca, NY. 640 pp.

Wright, R. A. S., & W. P. Gray. 1996. Field notes: *Malaclemys terrapin*. Catesbeiana 16: 10-11.

Wynn, A. H. 1986. Linkage disequilibrium and a contact zone in *Plethodon cinereus* on the Del-Mar-Va peninsula. Evolution 40: 44-54.