Virginia Journal of Science
Volume 41, Number 4A
Spring 1990

Herpetofauna of the Virginia Barrier Islands

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ABSTRACT

Twenty-nine species of amphibians and reptiles have been recorded from the Virginia Barrier Islands, compared with 46 species from mainland Eastern Shore. Assateague, Chincoteague, Parramore, Hog, and Smith Islands have the highest species diversity, apparently because of a greater variety of vegetative habitats and presence of freshwater. Knowledge of the herpetology of these islands is still in the exploration stage; several islands have yet to be surveyed. A brief history of herpetological exploration and observations on the known biology of each species are presented. Particular attention is paid to the species' insular ecology. Forty-two percent of the mainland amphibian fauna is represented on the islands, compared to 78% of the reptilian fauna. Examination of models of island formation suggests that it may not be necessary to invoke dispersal over saltwater to explain the origin of the island herpetofaunas. The linear relationship of species number to island area is positive and significant, whereas the relationship of species number to isolation from the mainland is nonsignificant. Elimination of Assateague Island from the analysis, because of the presence of man-altered habitats, renders the species-area relationship nonsignificant.

Key words: amphibians, reptiles, insular ecology, biogeography

INTRODUCTION

The amphibian and reptile fauna of the Virginia barrier islands is a subset of species derived from the Delmarva herpetofaunal assemblage. We present a brief history of herpetofaunal exploration, an annotated checklist, and a discussion of

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the biogeography of this fauna. Basic research is still needed on both the mainland Eastern Shore and the barrier islands, however, before the checklists can be considered complete. Little ecological research has been done on the amphibians and reptiles of the barrier islands. This decreases our ability to evaluate the origins of biogeographical patterns. Thus, the chief purpose of this paper is to provide a basis for future herpetological research in the region.

HERPETOFAUNAL EXPLORATION

C. W. Richmond obtained *Bufo woodhousii, Coluber constrictor, Elaphe obsoleta*, and *Nerodia sipedon* on Smith Island on 16 May 1894, the earliest collection date known. In the summer of 1899, Perry Schufelt collected *Sceloporus undulatus* and *Scincella lateralis* from Smith Island, Paul Bartsh took an *Opheodrys aestivus* on Smith Island in June 1897, and E. A. Mearns obtained a series of *Bufo woodhousii fowleri* from Smith Island in May 1910. On 4-7 May 1912, H. W. Fowler visited Assateague, Chincoteague, and Wallops Islands, and published the first notes on their herpetofauna (Fowler, 1925). In the same journal, M. K. Brady (1925) reported on ten species he found on Hog Island during June 1925. A single page of notes found in the "unknown" file in the Division of Amphibians and Reptiles, National Museum of Natural History, dated "17-20 June" (no year), was apparently authored by Brady. These notes indicate he also visited Cobb and Pig Islands (Pig Island was then a grass-covered low dune connected to Cobb Island in shallow water; it no longer exists). A single specimen of *Opheodrys aestivus* was collected by C. C. Sperry on Cobb Island on 26 June 1924 for the U.S. Biological Survey.

Conant first visited the islands 28-29 April 1947, when he obtained several species on Parramore and Hog Islands and made extensive collections on the adjacent mainland. His interest in the Virginia barrier islands stemmed from his intensive fieldwork on the herpetofauna of the Delmarva Peninsula, on which he briefly reported in 1945. His collections made between 1936 and 1948 and in 1957 and 1975 helped to provide much of the basis for our understanding of the composition of the herpetofauna of this region. The first general published list of amphibians and reptiles of the Virginia barrier islands was provided by Conant in 1981.

Over a period of several years (1950-1973) single specimens of a variety of species were donated to the U.S. National Musuem of Natural History by people who visited Assateague and Chincoteague Islands. Lee (1972, 1973) summarized his observations on the herpetofauna of Assateague Island made during 1968-1972. A U.S. Fish and Wildlife Service team headed by R. B. Bury explored Parramore and Smith Islands during four weekend periods in November 1974, October 1975, and April and June 1976.

Recent herpetological research stems from three sources. Scott (1986) reported on sexual dimorphism, variation, and seasonal activity in a population of hognose snakes (*Heterodon platirhinos*) on Assateague Island. Dunson (1970, 1985, 1986) compared salinity tolerances and studied growth and physiology of five freshwater turtles and one estuarine turtle. Mitchell and Pague visited seven islands (Assateague, Chincoteague, Wallops, Parramore, Hog, Cobb, and Smith) during 22-30 May 1986. They also visited Cobb and Hog Islands on 11-12 June 1987. Their objectives were to obtain voucher specimens for species and islands lacking them,

and to gain some insight into the biogeography of the herpetofauna of this nearshore archipelago. They also began a mark-recapture study of the snakes of Cobb Island during this time. Pague visited five islands on 20-22 September 1988. Barry Truitt, current manager of the Virginia Coast Reserve, provided additional records for Myrtle Island in 1985 and 1986.

SPECIES ACCOUNTS

The mainland Eastern Shore of Virginia harbors 46 species of amphibians and reptiles (Mitchell and Pague, in press). Eight species of amphibians and 21 species of reptiles have been recorded from the Virginia barrier islands (Table 1). Of these, ten species have been found only on Assateague, Chincoteague, and Wallops Islands (7 amphibians and 3 reptiles). The following notes are included to summarize what we know about the distribution and ecology of each species on the islands, and to indicate where further research is needed. Comments about freshwater were derived from the literature, G.J. Hennessey and B. Truitt (pers. comm.), and our own observations. Explanation of museum designations are in Acknowledgments. USNMFH and CMFS indicate specimens with USNM or CM field tag numbers. TNC records refer to notes housed in the Virginia Coast Reserve at Brownsville and VIMS records are those housed in the Virginia Institute of Marine Science in Gloucester Point, Virginia. Common names follow Collins *et al.* (1982)

Plethodon cinereus (Green)

The redback salamander is the only salamander found on the Virginia barrier islands. J.C. Bridwell obtained two specimens on Chincoteague on 22 September 1938 (USNM). Conant collected five individuals under rotting pine logs on Chincoteague Island on 11 April 1941 (CM) within 30 m of where a small attenuated marine estuary extended into the island. This species has also been found on barrier islands in Georgia and South Carolina (Gibbons and Coker, 1978).

Bufo woodhousii fowleri Hinckley

Fowler's toads have been reported from five islands (Table 1; ANSP, GMU, USNM), all of which have, or have had, freshwater or weak brackish water. It is currently the only amphibian known from a Virginia barrier island other than Assateague, Chincoteague, or Wallops. The presence of viable populations presumably depends on freshwater for development of eggs and larvae. Brady (1925) and Scott (1986) found breeding adults and larvae in freshwater ponds, whereas Lee (1972) reported a breeding congregation in a slightly brackish pool. Adults can tolerate dry terrestrial environments and at least temporary exposure to saltwater; Engles (1952) noted that this toad entered saltwater when pursued. Brady (1925) reported that toads on Hog Island preyed upon the land amphipod *Orchestia gryllus*.

Bufo woodhousii was recorded as being abundant by Brady (1925), Lee (1972), and Scott (1986). Neither Conant, during the 1940's, nor the U.S. Fish and Wildlife Service team in the mid-1970's found this species on Hog, Parramore, or Smith Islands where it had been observed previously. Mitchell and Pague have since (1986) seen these toads on Smith Island and B. Truitt (pers. comm.) reports them common there. Toad populations may be adversely affected by coastal storms that add salt to freshwater ponds and pools. The freshwater ponds seen by Brady (1925)

Table 1. Amphibians and reptiles of the Virginia barrier islands. Records represented by voucher specimens are indicated with an "X", unvouchered observations and literature records with an "O", and a questionable record is indicated with a "?". Assateague (AS), Chincoteague (CH), Wallops (WA), Parramore (PA), Revel (RE), Hog (HO), Cobb (CO), Wreck (WR), Myrtle (MY), Smith (SM), Fisherman (FI).

Species	Barrier Island										
	AS	CH	WA	PA	RE	HO	CO	WR	MY	SM	FI
Salamanders											
Plethodon cinereus		X									
Anurans											
Bufo woodhousii	X	X	X			X				X	
Hyla cinerea	O	X									
Pseudacris triseriata	O										
Rana catesbeiana	X										
Rana clamitans	X										
Rana palustris			X								
Rana utricularia	X	X	O								
Turtles											
Caretta caretta	O			O		O	O	O		O	O
Chelonia mydas	O			O		O					
Chelydra serpentina	O	O	O	X		O				X	
Chrysemys picta	O	O									
Clemmys guttata	O	O				X				X	
Dermochelys coriacea	O			O				O		O	
Kinosternon subrubrum	X	O	O	X		X				X	
Lepidochelys kempi						O					O
Malaclemys terrapin	X	X	O	X	O	X	O		O	X	X
Pseudemys rubriventris	O										
Terrapene carolina	O									X	O
Lizards											
Sceloporus undulatus	O									X	
Scincella lateralis										X	X
Snakes											
Coluber constrictor	X	O	X			O				X	
Diadophis punctatus		X									
Elaphe obsoleta	X		O			O	O			O	
Heterodon platirhinos	X	X	O			O					
Lampropeltis getula										X	
Nerodia sipedon	X	O	O	X		O				X	
Opheodrys aestivus	X		O	X	O	X	X	X	X	X	X
Storeria dekayi				X		X	X				
Virginia valeriae							?				

on Hog Island have been long since displaced seaward by island erosion and movement (Conant, pers. obs.; B. Truitt, pers. comm.).

Hyla cinerea (Schneider)

The green treefrog is apparently common on Assateague Island (Lee, 1972). Mitchell and Pague collected this species on Chincoteague Island on 29 May 1986 (USNM). Populations of green treefrogs are known to occur in brackish marshes

(Neill, 1958). Gibbons and Coker (1978) listed this frog from nearly every island they tabulated along the coast of the southeastern United States.

Pseudacris triseriata kalmi Harper

The New Jersey chorus frog was reported from Assateague Island by Lee (1973), who heard large choruses at the southern end of the island in the early part of that year. Gibbons and Coker (1978) listed no member of the *triseriata* complex of *Pseudacris* from any barrier island.

Rana catesbeiana Shaw

Bullfrog tadpoles were collected in a shallow, drying impoundment by CAP and JCM on Assateague Island on 29 May 1986 (USNMFH). This species was recently documented from Bodie Island, North Carolina (Braswell, 1988). It has not been reported from other barrier islands studied (Gibbons and Coker, 1978; Gibbons and Harrison, 1981).

Rana clamitans melanota (Rafinesque)

Five green frogs were collected on Assateague Island on 20 October 1984 by C.H. Ernst and S. W. Gotte (GMU). This species (*R. clamitans*) has not been recorded from any other barrier island along the Atlantic seaboard (Gibbons and Coker, 1978). It is common on the mainland Eastern Shore.

Rana palustris Le Conte

A single pickerel frog was collected on Wallops Island on 20 October 1984 by C.H. Ernst and S.W. Gotte (GMU). Pickerel frogs have not been recorded from any other coastal island (Gibbons and Coker, 1978). The closest known locality is in Worcester County, Maryland (Harris, 1975).

Rana utricularia Cope

Lee (1972) found adult southern leopard frogs behind the primary dunes at the southern end of Assateague Island. Voucher specimens are known for Assateague (USNM) and Chincoteague (ANSP, CM, UMMZ, USNM) Islands, and W.A. Dunson observed it on Wallops Island. This frog is frequently found in brackish marshes (Neill, 1958), and has been recorded on many of the southeastern coastal islands (Gibbons and Coker, 1978).

Caretta caretta (Linnaeus)

Loggerhead sea turtles are commonly seen in the estuarine channels, and stranded individuals have been observed on the beaches of Assateague (VIMS), Parramore (TNC), Hog (VIMS), Cobb (VIMS), Wallops (TNC), Wreck (TNC), Smith (TNC, VIMS), and Fisherman (VIMS) Islands. Lee (1972) reported a nesting female on Assateague Island in 1972. A headstart program (relocation and captive incubation of nests) started by the U.S. Fish and Wildlife Service in 1969 on Assateague Island (Lee, 1972) was apparently unsuccessful. One female was observed nesting on the north end of Parramore Island on 18 June 1979 (B. Truitt, pers. comm.). Brady (1925) noted that large numbers were caught on hook and line and in nets around Hog Island. Lutcavage and Musick (1985) reported aggregations of loggerheads on the Atlantic side of the barrier islands. We assume that turtles seen in the estuary are utilizing the area for feeding. They prey primarily on horseshoe crabs (Keinath *et al.*, 1987).

Chelonia mydas mydas (Linnaeus)

Brady (1925) found a stranded Atlantic green turtle on Hog Island and VIMS has a record for Parramore Island. Schwartz (1960) recorded a female in Chin-

Table 2. Diversity and biomass of turtles in two unnamed mainland tidal creeks near Chincoteague (see Dunson, 1986) and a freshwater impoundment on Assateague Island, Virginia. Values are biomass in kg; number of individuals in parentheses. All data are from W. A. Dunson (pers. comm.)

Species	Creek A	Creek C	Assateague
C. serpentina	22.46 (8)	85.74 (36)	102.60 (24)
K. subrubrum	0.14 (1)	1.28 (12)	--- *
C. guttata	0.44 (3)	1.30 (10)	---
M. terrapin	9.75(11)	0.76(1)	---

* Occurred commonly but not quantified; several *Chrysemys picta* also caught.

coteague Bay at White Rock, Worcester County, Maryland. Green turtles are carnivorous as juveniles and feed almost exclusively on submerged sea grass as adults (Musick, 1979).

Chelydra serpentina serpentina (Linnaeus)

The common snapping turtle has been found on six islands: Assateague (Lee, 1972; Dunson, 1986), Chincoteague (Fowler, 1925), Wallops (W.A. Dunson, pers. comm.), Parramore (AMNH), Hog (Brady, 1925), and Smith (USNM). It is known from only four other Atlantic barrier islands (Gibbons and Coker, 1978). All observations were of turtles in freshwater ponds or pools. W.A. Dunson (pers. comm.) found that a population of this species in a freshwater impoundment on Assateague Island was comprised of 7 immatures, 6 females, and 11 males. Total biomass for this population was higher than that found for either of two mainland tidal creeks (Table 2). *Chelydra serpentina* commonly utilizes tidal habitats on the Eastern Shore of Virginia (Dunson, 1986). We conclude from his work that adults could easily colonize barrier islands.

Chrysemys picta picta (Schneider)

Lee (1972) found the eastern painted turtle to be moderately common in freshwater impoundments on Assateague Island and Fowler (1925) reported it from Chincoteague. It is abundant in freshwater habitats on mainland Eastern Shore but is unrecorded from other coastal islands. It was most likely introduced on Assateague, and a Chincoteague resident claims to have done so (W.A. Dunson, pers. comm.).

Clemmys guttata (Schneider)

Spotted turtles have been found on Hog and Smith Islands (USNM) and observed on Assateague (Lee, 1972) and Chincoteague (Fowler, 1925). The U.S. Fish and Wildlife Service team found six individuals on 23 October 1975 in small freshwater pools in the mixed pine-hardwood forest on Smith Island. Average carapace length of five specimens from the islands (96.9 mm, 92.3- 100.7) was nonsignificantly smaller than that of eight specimens from mainland Eastern Shore (106.9 mm, 84.5-120.0) ($t = -1.84$, $P = 0.094$). Spotted turtle biomass was nearly equal to that of mud turtles in two mainland tidal creeks (Table 2).

W.A. Dunson (pers. comm.) found spotted turtles in tidal water of no more than 6% normal seastrength at high tide in a mainland creek. Growth in adults occurred in water up to 36.2% seastrength (Dunson, 1986), however, within the range of

values he reported for *C. serpentina*. Adults are therefore likely to be able to tolerate seawater for limited periods of time, although they are less likely than snapping turtles and mud turtles to disperse from the mainland to the islands.

Dermochelys coriacea (Linnaeus)

The leatherback sea turtle is the rarest of the sea turtles recorded from the barrier islands. It is normally seen only several miles offshore and in the mouth of Chesapeake Bay (B. Truitt, pers. comm.). One was reported stranded on Parramore Island on 21 June 1938 by F.M. Uhler (photo available in Conant's files). G.J. Hennessey (pers. comm.) reported that George Reiger saw an enormous leatherback seven miles east of Wachapreague Inlet on 26 July 1980. VIMS has records for Assateague, Wreck, and Smith Islands. Leatherbacks are pelagic and feed primarily on jellyfish (Musick, 1979).

Kinosternon subrubrum subrubrum (Lacépède)

Eastern mud turtles have been observed on Chincoteague and Wallops Islands (Fowler, 1925; W.A. Dunson, pers. comm.) and collected from Assateague (USNM), Parramore (CM), Hog (USNM), and Smith (USNM) Islands. Brady (1925) found them to be abundant in freshwater ponds on Hog Island but the reduction of freshwater habitat on this island has probably reduced the mud turtle population. Carapace lengths of 14 adult museum specimens from the islands (males: 69.5-90.0 mm, $\overline{X}$ = 81.0 ± 7.2, n = 7; females: 73.3-100.0 mm, $\overline{X}$ = 80.4 ± 9.1, n = 7) average smaller than that of a sample we obtained from a pond above a mainland tidal creek near Oyster (males: 82.2-107.7 mm, $\overline{X}$ = 96.8 ± 6.9, n = 11; females: 82.1-89.7 mm, $\overline{X}$ = 85.6 ± 2.6, n = 6). The difference between males is significant ($t = -4.64$, $P < 0.001$). Mean body mass of mud turtles in a tidal creek population near Chincoteague (106.7 g, Table 2) was substantially lower than mean body mass of adult turtles from the freshwater pond population near Oyster (149.3 g).

W.A. Dunson (pers. comm.) found *K. subrubrum* in mainland tidal creeks that experienced salinities of 6-51% normal seastrength at high tide. Growth in hatchling mud turtles from tidal creeks occurred up to a salinity of 45% seastrength (Dunson, 1986), higher than the values he observed for *C. serpentina*. The occurrence of this species on the barrier islands probably depends on the availability of fresh to brackish water. Conant found mud turtles in freshwater, but much more frequently in brackish water habitats on the Delmarva peninsula.

Lepidochelys kempi (Garman)

The Atlantic ridley sea turtle is rarely seen among the barrier islands (B. Truitt, pers. comm.). G.J. Hennessey found and carefully examined a small ridley (straight-line carapace length 35.6 cm) found dead at the south end of Hog Island on 14 September 1980. He also observed a slightly larger turtle that appeared to be a ridley on 25 June 1980 "inside a temporal inlet in mid-Metomkin Island in very shallow water." VIMS has a record for Fisherman Island. Some individuals may use the barrier island estuary as a feeding ground; they specialize on blue crabs (Lutcavage and Musick, 1985). This estuary is apparently not as important to immature ridleys as the Chesapeake Bay (Lutcavage and Musick, 1985; Keinath, *et al.*, 1987).

Malaclemys terrapin terrapin (Schoepff)

The northern diamondback terrapin occurs on all of the Virginia barrier islands. Vouchered records exist for Assateague (CM), Chincoteague (UMMZ), Parramore (CM, GMU, USNM), Hog (GMU, MSB, USNM), Smith (GMU, MCZ, USNM), and Fisherman (VCU) Islands, and unvouchered records exist for Revel (B. Truitt, pers. comm.), Cobb (TNC records), Wreck (TNC records), and Myrtle (B. Truitt, pers. comm.) Islands. It is the only truly estuarine representative of the herpetofauna and is the most commonly seen reptile on and around the islands, especially in late-spring and summer. Neill (1958) found no records of this species in freshwater. It is abundant in the marshes between the mainland and the islands. Other authors (*e.g.*, Brady, 1925; Lee, 1972) noted the abundance of this species on the barrier islands and in the estuary. This turtle was hunted extensively between 1880 and 1930 for the restaurant trade, but the market declined in the 1930's (Conant, 1955; Ernst and Barbour, 1972). A recent upsurge in the restaurant trade was documented by Garber (1988), who noted that some turtles were caught in Virginia, probably near the town of Chincoteague (B. Truitt, pers. comm.). The harvest rates are unknown and we do not know what the impact on natural populations will be.

Females lay an average of 11.2 eggs per clutch from 30 May and to about 25 July in open sandy areas away from vegetation above the high tide line. Females may lay more than one clutch per season. Maximum carapace length of females recorded for the islands is 205 mm and for males is 143 mm, indicating strong sexual dimorphism. Dunson (1970, 1985) and Robinson and Dunson (1976) studied growth and physiology of hatchlings in relation to salinity tolerances. Diamondback terrapins specialize on molluscan prey.

Pseudemys rubriventris rubriventris (Le Conte)

Lee (1972) observed the redbelly turtle in man-made freshwater impoundments on Assateague Island. Although it is abundant on mainland Eastern Shore (JCM and CAP, unpublished), it is scarce on Assateague (W.A. Dunson, pers. comm.) and has not been reported from any other island. We have found adult specimens of this species in the Chesapeake Bay encrusted with barnacles (JCM and CAP, unpublished), suggesting some tolerance of salt water.

Terrapene carolina carolina (Linnaeus)

Lee (1973) reported seeing an eastern box turtle on Assateague Island. The U.S. Fish and Wildlife Service team found five adults in pine hardwoods on Smith Island (USNM) on 23 October 1975 and Mitchell and Pague found one adult female under grass cover on Smith Island on 23 May 1986. G.J. Hennessey received information about a shell found on Fisherman Island in 1976, but since US Route 13 crosses this island, the possibility of an intentional release cannot be ruled out. Box turtles can withstand difficult weather conditions by withdrawing into their shells and resting in ground forms and under grass clumps. Fresh water is apparently necessary for populations in Virginia (JCM and CAP, pers. obs.); it is not known how much metabolic water is obtained from the fruits, berries, and animal prey they eat. Latham (1916) found box turtles in salt water on Long Island. Box turtles are known to occur on only one other barrier island, Kiawah Island, South Carolina (Gibbons and Harrison, 1981). They may have been brought to Smith Island by former human inhabitants.

Sceloporus undulatus hyacinthinus (Green)

Lee (1972) reported that two adult northern fence lizards were observed in a loblolly pine stand on the southern end of Assateague Island. Two adult females were collected by Percy Schufeldt in the summer of 1899 from Smith Island (USNM). The ecology of this species on the islands in unknown. This species also occurs on Cumberland Island, Georgia (Gibbons and Coker, 1978).

Scincella lateralis (Say)

The ground skink has been confirmed from Smith (MSB, USNM) and Fisherman (VCU) Islands. This skink has been reported from barrier islands in North Carolina and South Carolina (Gibbons and Coker, 1978). Conant collected two and observed four others on Smith Island on 20 October 1948; they were under boards and the bark of a decaying log. Mitchell and Pague found one in a supratidal grassy area of Smith Island on 28 May 1986. Neill (1958) noted that this skink avoids areas that are damp from salt spray. Little is known of its ecology on the barrier islands. We suspect that juveniles of *C. constrictor* may prey upon these skinks.

Coluber constrictor constrictor Linnaeus

The northern black racer has been recorded from Assateague (AMNH, USNM), Chincoteague (W.A. Dunson, pers. comm.), Wallops (CMFH), Hog (Brady, 1925; TNC records), and Smith (USNM) Islands. It has been found on all the Atlantic barrier islands listed by Gibbons and Coker (1978). Brady (1925) noted they were seen in the tops of myrtle trees and those that were pursued on the ground sought protection in the myrtles. Both Brady (1925, Hog) and Lee (1972, Assateague) reported them to be uncommon. Mitchell and Pague, however, found this snake to be the most abundant terrestrial reptile on Smith Island on 28 May 1986. The catholic nature of this snake's diet and its ability to inhabit xeric habitats (JCM and CAP, unpublished) allow it to flourish on barrier islands.

Diadophis punctatus edwardsii (Merrem)

A single northern ringneck snake was collected by J.C. Bridwell at Chincoteague on 26 September 1938 (USNM). This is the only record for any barrier island along the Atlantic Seaboard (see Gibbons and Coker, 1978).

Elaphe obsoleta obsoleta (Say)

The black rat snake has been collected from Assateague (USNM) and Wallops (JCM photo) Islands and has been observed on Hog, Cobb, and Smith Islands (TNC records). This species has been reported for all but one Atlantic barrier island previously studied (Gibbons and Coker, 1978). It is an uncommon species on the islands but abundant on mainland Eastern Shore (RC, JCM and CAP, pers. obs.). On 23 June 1978, B. Truitt and B. Williams observed an adult individual that appeared to have washed up on the beach of Cobb Island. The snake was alive but appeared emaciated. We are unaware of a population on Cobb Island. Black rat snakes prey primarily on small rodents and birds (Uhler *et al.*, 1939; JCM and CAP, unpublished). The occurrence of these snakes on some of the barrier islands may be limited by the availability of prey populations.

Heterodon platirhinos Latreille

The eastern hognose snake has been verified from Assateague (USNM) and Chincoteague (USNM) Islands and observed on Wallops (Fowler, 1925) and Hog (Brady, 1925) Islands. Brady (1925) noted they were abundant on Hog Island, but extensive recent field work revealed none (R. Dueser, RC, JCM, and CAP, pers.

obs.). Minimum population density was estimated to be 4.8 snakes/ha on the southern end of Assateague Island (Scott, 1986). The presence of this species may depend on the occurrence of its primary prey, Fowler's toads. The decline of the hognose snake population may have followed that of the toad population on Hog Island (see comments under *Bufo woodhousii fowleri* account). This species has been reported from only one other barrier island outside the Virginia system (Gibbons and Coker, 1978).

Lampropeltis getula getula (Linnaeus)

The eastern kingsnake (see nomenclatural note in Frost and Collins, 1988) is known only from Smith Island (USNM); it is found on most of the barrier islands in North Carolina and South Carolina (Gibbons and Coker, 1978). This species was the second most abundant snake on Smith Island on 28 May 1986. All known specimens were found under boards in the grass habitat between the primary and secondary dunes. Kingsnakes are predators of rodents, other reptiles, and the eggs of some turtles (Knight and Loraine, 1986). We suspect its primary prey on the island are small rodents, *Coluber constrictor*, and possibly *Opheodrys aestivus*.

Nerodia sipedon sipedon (Linnaeus)

The northern water snake has been collected on Assateague (USNM), and Parramore (AMNH), and Smith (USNM) Islands. It has been observed on Chincoteague (W.A. Dunson, JCM, CAP), Wallops (Fowler, 1925) and Hog (Brady, 1925) Islands. Brady (1925) noted it was common around freshwater ponds and in salt marshes on Hog Island. Lee (1972) reported that it occurred in brackish and salt marshes but was uncommon on Assateague Island. Gibbons and Coker (1978) reported that this species or its southern ecological equivalent, *N. fasciata*, occurred on every barrier island studied.

Available specimens are phenotypically similar to mainland water snakes. The dorsal pattern consists of dorsal blotches that occur as bands on the anterior third of the body but break up and occur as alternating dorsal and lateral blotches on the posterior two-thirds. One specimen from Smith Island (USNM 22633, collected in 1894) lacks the alternating pattern; a strong crossbanded pattern is present. The only consistent difference from mainland Eastern Shore snakes is that there is more dark pigmentation on both the dorsum and venter. The posterior half of the venter of one specimen from Assateague Island (USNM 165917) is nearly black. Some insular populations of *Nerodia sipedon* have been found to consist of banded, patternless, and intermediate individuals (Camin and Ehrlich, 1958; Conant and Clay, 1963). A tidal marsh population in the Potomac River has been reported to be unbanded (Bulmer, 1985). Conant has found that dark pigmentation of the venter is of common occurrence among many populations from or near brackish habitats of coastal areas of both New Jersey and mainland Delmarva. Farther south, on the Outer Banks and along shores of the associated Sounds of North Carolina, melanism, both dorsally and ventrally, is commonplace (Conant and Lazell, 1973).

Little ecological information is available for barrier island water snakes. A note accompanying the 1899 Smith Island collection said the water snakes were "found in pools of brackish water preying on small fish". One (USNM 22633) also contained a *B. woodhousii fowleri* swallowed headfirst.

Opheodrys aestivus conanti Grobman

The barrier island green snake has been vouchered from eight of the Virginia barrier islands (Table 2, AMNH, CM, USNM, VCU) and observed on Wallops Island (Fowler, 1925); also Revel (Table 1). It probably occurs on all islands with grassland/shrub habitat. This species (*O. aestivus*) was reported from all of the Atlantic barrier islands studied by Gibbons and Coker (1978). Grobman (1984) examined specimens from the Virginia islands and available specimens from the Delmarva Peninsula, mostly Maryland, and concluded that the barrier island populations were sufficiently different from mainland populations to warrant subspecific recognition. This taxonomic distinction was based on the fewer number of ventral and subcaudal scales than in populations from the mainland. Our data confirm the difference; however, we recognize that specimens from mainland Eastern Shore of Virginia are needed before we can ascertain whether the differences are restricted to the islands or represent clinal variation along the peninsula.

Brady (1925) reported this snake to be common on Hog Island and neighboring islands where grassland communities existed. Lee (1972) reported only one green snake from Assateague Island. We found these snakes to be abundant under debris in the wrack zone (Cobb and Hog Islands) and in the pine-myrtle association on Parramore Island in 1947 and 1986. This species is sometimes found syntopic with *Storeria dekayi*. Mitchell and Pague are currently investigating other aspects of its ecology on Cobb Island.

Storeria dekayi dekayi (Holbrook)

Populations of northern brown snakes are known from Parramore (AMNH, CM, USNM), Hog (CM), and Cobb (USNMFS) Islands. Conant found this snake to be abundant on Parramore and Hog Islands in 1947. During 1948 he also encountered it on Parramore Island, but none was seen on Hog Island, which was visited two weeks after that island had been virtually completely covered by an exceptionally high tide, and salt water was standing almost everywhere. This species also occurs at Cape Hatteras, North Carolina (Gibbons and Coker, 1978). Island populations are phenotypically similar to populations on the Virginia mainland, in both pattern and scutellation (JCM and CAP, unpublished). We have found them under debris in the wrack zone and in a pine-cedar-myrtle association. Several specimens have what appeared to be earthworm remains in their stomachs. Other aspects of its ecology are being studied on Cobb Island.

Virginia valeriae valeriae Baird and Girard

Fowler (1925) reported the eastern earth snake from Hog Island, based on a specimen supposedly in the Academy of Natural Sciences of Philadelphia. The ANSP has no record of it, however (J.E. Cadle, pers. comm.). Dunn (1918) listed this species from Northampton County, apparently based on this specimen. Mitchell and Pague found none during a visit to Hog Island on 30 May 1986; neither did Conant during his visits to that island in 1947, 1948, and 1975. No localities are confirmed for the mainland Eastern Shore of Virginia (the three in Tobey, 1985 are erroneous), although they are recorded for the Eastern Shore of Maryland (Harris, 1975). This species should be listed as unverified from the Virginia barrier islands.

Table 3. Composition of the herpetofauna of the Eastern Shore and barrier islands of Virginia. The ninth island snake is the unverified *Virginia valeriae* from Hog Island.

Group	Mainland	Islands	Percent
Frogs	14	7	50.0
Salamanders	5	1	20.0
All amphibians	19	8	42.1
Turtles	12	11	91.7
Turtles, minus sea turtles	8	7	87.5
Lizards	3	2	66.7
Snakes	12	8 (9)	66.7
All reptiles	27	21	77.8
All reptiles, minus sea turtles	23	17	73.9

DISCUSSION

The composition of the herpetofauna of the Virginia barrier islands heavily favors reptiles (Table 3). Of the amphibian fauna occurring on mainland Eastern Shore, only 42.1% is also found on the barrier islands, compared with 77.8% of the reptiles. The single species of salamander and all but one of the frogs are found only on the Assateague-Wallops cluster at the northern end of the island chain. Their absence on Smith Island is puzzling because that island encompasses most of the vegetative community types found on the northern cluster. The paucity of amphibians on the islands is undoubtedly related to the permeability of amphibian skin to water. Although numerous populations of amphibians, notably anurans, have been reported from brackish water habitats (Neill, 1958), survival in highly saline environments is low. Terrestrial island habitats are also xeric and few amphibians can tolerate such desiccating conditions. Most reptiles, on the other hand, are able to withstand short-term immersion in sea water because of the relative impermeability of the scale-covered epidermis (Lillywhite and Maderson, 1982). Their colonizing ability and persistence on barrier islands are reflected in the higher representation of the mainland Eastern Shore reptile fauna (73.9%, excluding sea turtles).

Several aspects of the herpetofauna on the Virginia barrier islands offer comparisons with the fauna on the coastal islands from North Carolina to Florida studied by Gibbons and Coker (1978). The frogs *Hyla cinerea* and *Rana utricularia*, both frequently found in brackish marshes in Virginia (JCM and CAP, pers. obs.), are found on most of the southeastern islands but are restricted to Assateague and Chincoteague Islands in Virginia. The mud turtle, *Kinosternon subrubrum*, occurs on nearly all of the Atlantic barrier islands, whereas the box turtle, *Terrapene carolina*, has been confirmed for only three Atlantic barrier islands (Gibbons and Harrison, 1981; Braswell, 1988; this study). The snapping turtle, *Chelydra serpentina*, absent from several of the apparently suitable southeastern islands, is found on all Virginia islands which have freshwater. The five-lined skink, *Eumeces fasciatus*, is absent from all of the Atlantic barrier islands despite its abundance on the mainland. The single species of small ground snake, *Storeria dekayi*, found on

several of the Virginia islands is known from only one other southeastern barrier island (Braswell, 1988). It is puzzling why the hognose snake, *Heterodon platirhinos*, has such a spotty occurrence on islands compared with its ubiquitous prey species, toads of the genus *Bufo*. Two snakes that are found on several of the southeastern islands (Gibbons and Coker, 1978; Gibbons and Harrison, 1981; Braswell, 1988) are notably absent from the Virginia islands, specifically *Thamnophis sauritus* and *Thamnophis sirtalis*. Speculations about the causes of such differences would be pointless without a full knowledge of the historical biogeography of all these island populations, man's influence, and the physiology and life history of each species. Such information should be obtained where possible.

Models of the formation of the Virginia barrier islands (Rice *et al.*, 1976 and references therein) offer insights into the origin of the herpetofauna on these islands. Three models have been used to describe island formation: (1) production of long shore sand bars away from the shore line, the deBeaumont-Johnson model; (2) successive elongation of a coastal sand spit, the Gilbert-Fisher model; and (3) the formation of coastal dune ridges that were subsequently isolated by rising sea level, the Hoyt-Godfrey model. Islands arising by the deBeaumont-Johnson model would have to be colonized completely by dispersal over salt water. Islands arising by processes described by the other two models have had mainland connections. The amphibian and reptile populations on these islands could originally have been parts of mainland populations that later became fragmented when the islands were separated by rising sea level. An example of the Gilbert- Fisher model is Currituck Spit, comprising Back Bay National Wildlife Refuge and False Cape State Park. This area harbors a large herpetofauna that is similar in many respects to the adjacent mainland fauna (Pague and Mitchell, 1982). Assateague Island may have been a spit connected to the mainland; its herpetofauna is the most diverse of any of the islands. An example of the Hoyt-Godfrey model is the Cape Henry area of Virginia Beach. This dune ridge system, now isolated from the mainland, contains a large herpetofaunal assemblage similar to the adjacent mainland (CAP and JCM, unpublished). The primary conclusion from these observations is that it may not be necessary to invoke dispersal over seawater to explain the origins of all the barrier island herpetofaunas.

If the herpetofaunas of the Virginia barrier islands were of mainland origin, then the probability is high that coastal processes and island dynamics have decreased the original number of species. The many changes on Hog Island are excellent examples of marine transgressions. The number of species remaining as a result of these processes may be a function of either distance from the mainland or island area, or both (MacArthur and Wilson, 1967). Our preliminary analysis indicates the linear relationship of species number (excluding sea turtles) to distance from the mainland for the Virginia barrier island group is negative and non-significant ($P = 0.572$). However, the linear relationship of species number to island area is positive and significant ($r^2 = 0.529$, $P = 0.017$). If we eliminate Assateague Island from the analysis because of the presence of man-made freshwater impoundments, the species-area correlation becomes non-significant ($P = 0.121$). Smith Island, despite its relatively small size, contains the second largest number of species in the Virginia barrier island group. This is probably because of the diversity of habitats on the island. Dueser and Brown (1980) found that rodent

diversity on the Virginia barrier islands was influenced most significantly by vegetation height and number of woody plant associations. Herpetofaunal species diversity may be explained by the number of habitat types on each island and the occurrence of freshwater. Gibbons and Coker (1978) found that the numbers of amphibians and reptiles (analyzed separately) for nine Atlantic coast barrier islands were significantly correlated with woodland area.

The impact of human habitation of the Virginia barrier islands on the amphibian and reptile fauna is undoubtedly significant but impossible to assess without information on historical occurrences. Nevertheless, it is probable that logging, livestock grazing, and farming (Graham, 1976) and controlled burning and creation of freshwater impoundments, as on Assateague Island (W.A. Dunson, pers. comm.), decreased the amount of forested land. These impacts increased types of habitat favorable to some species and decreased it for others. An increase in grassland and shrub habitats would be favorable to *Coluber constrictor, Opheodrys aestivus*, and *Storeria dekayi*. The increase in freshwater has undoubtedly favored an increase in anuran and turtle species diversity on Assateague Island. Forest-dwelling species, like *Elaphe obsoleta* and *Terrapene carolina*, would be negatively affected by loss of habitat. Humans certainly killed snakes on the islands just as they do virtually everywhere.

We concur with Gibbons and Harrison (1981) in that the most severe impact on terrestrial amphibians and reptiles stems from the removal of organic litter and ground cover in forests. These authors also point out the importance of shallow water sites to anuran breeding and larval development and that alteration of these sites for mosquito control would be detrimental. The loss of these features or any major vegetative community type would negatively affect herpetofaunal species diversity on the Virginia barrier islands.

Mitchell and Pague (in press) discuss the loss of habitat to agriculture and logging on mainland Eastern Shore, and some ways in which management efforts can conserve the herpetofauna. Loss of habitat will continue to have negative impacts on source populations from which the islands may be colonized. The predicted urban sprawl will certainly continue this process.

Our current knowledge of herpetofaunal species diversity on the Virginia barrier islands is limited to that obtained from numerous short-term visits to the islands. The potential increase in species numbers gleaned from the use of time-intensive methods (*e.g.*, drift fences with pitfall traps), so well illustrated by Braswell (1988), justifies future field efforts.

ACKNOWLEDGMENTS

Transportation to the islands was made possible through the kindness of the U.S. Coast Guard and Gerard J. (Rod) Hennessey and Barry Truitt, of the Virginia Coast Reserve. All extended every courtesy to us, supplied us with an abundance of information, and both Hennessey and Truitt kept us informed of observations and discoveries they made when we were not present in the area, and they either sent or saved specimens for us which they found. Both were excellent boat captains and enthusiastically responded to our studies. We are greatly indebted to them, and thank them also for their companionship. James D. Lazell, Frederick A. Ulmer, Jr., and the late James D. Anderson, as well as several students and others, assisted

Conant on the islands, and the late Isabelle H. Conant obtained many photographs in 1948, notably of the destruction wreaked by storms on Hog Island.

Mitchell and Pague are especially indebted to Sarah Bellmund, Kurt Buhlmann, Ellen Censky, Joshua Mitchell, Morgan Truitt, and Ted Turner for their help in the field. William A. Dunson escorted them through parts of Assateague, Chincoteague, and Wallops Islands, provided specimens, and gave them considerable insight into the biogeography of the herpetofauna of that area. We are all grateful to him for providing considerable unpublished data on the turtles of the Chincoteague-Assateague area and for his thoughtful review of our paper. John Keinath kindly supplied us with VIMS records. Karen Terwilliger pin-pointed several study sites on the mainland. The Virginia Coast Reserve graciously issued research permits. The Nongame Wildlife and Endangered Species Program of the Virginia Department of Game and Inland Fisheries provided financial support.

We are grateful to the curators of the following museum and university collections for providing records and allowing us to examine specimens in their care: American Museum of Natural History (AMNH), Carnegie Museum of Natural History (CM), George Mason University (GMU), University of Michigan, Museum of Zoology (UMMZ), Museum of Southwestern Biology, University of New Mexico (MSB), National Museum of Natural History (USNM), Virginia Commonwealth University (VCU).

LITERATURE CITED

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

Braswell, A. L. 1988. A survey of the amphibians and reptiles of Nags Head Woods Ecological Preserve. ASB Bull. 35:199-217.

Bulmer, W. 1985. Report on an unbanded population of *Nerodia sipedon* from Virginia. Va. J. Sci. 36:106 (abstract).

Camin, J. H., and P. R. Ehrlich. 1958. Natural selection in water snakes (*Natrix sipedon* L.) on islands in Lake Erie. Evolution 12:504-511.

Collins, J. T., R. Conant, J. E. Huheey, J. L. Knight, E. M. Sunquist, and H. M. Smith. 1982. Standard common and current scientific names for North American amphibians and reptiles. Soc. Study Am. Amph. Rept., Herpetol. Circ. 12:1-28.

Conant, R. 1945. An annotated check list of the amphibians and reptiles of the Del-Mar-Va peninsula. Pub. Soc. Nat. Hist. Delaware, pp. 1-8.

_____. 1955. LETTER: Terrapin as food. British J. Herpetol. 1:252-253.

_____. 1981. Herpetofauna (Reptiles and Amphibians) of the Virginia Coast Reserve. Pp. 6-7, *In* The Islands. Official Newsletter of the Virginia Coast Reserve. The Nature Conservancy. MacLeod, B. and G.J. Hennessey (eds.).

_____, and W. M. Clay. 1963. A reassessment of the taxonomic status of the Lake Erie water snake. Herpetologica 19:179-184.

_____, and J. D. Lazell. 1973. The Carolina salt marsh snake: A distinct form of *Natrix sipedon*. Brevoria 400:1-13.

Dueser, R. D., and W. C. Brown. 1980. Ecological correlates of insular rodent diversity. Ecology 61:50-56.

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. Comp. Biochem. Physiol. 32:161-174.

_____. 1985. Effect of water salinity and food salt content on growth and sodium efflux of hatchling diamondback terrapins (*Malaclemys*). Physiol. Zool. 58:736-747.

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

Engles, W. L. 1952. Vertebrate fauna of North Carolina coastal islands II. Shackelford Banks. Am. Midl. Nat. 47:702-742.

Ernst, C. H., and R. E. Barbour. 1972. Turtles of the United States. Univ. Press of Kentucky, Lexington, KY, 347 pp.

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

Frost, D. R., and J. T. Collins. 1988. Nomenclatural notes on reptiles of the United States. Herpetol. Rev. 19:73-74.

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

Gibbons, J. W. and J. W. Coker. 1978. Herpetofaunal colonization patterns of Atlantic coast barrier islands. Am. Midl. Nat. 99:219-233.

Gibbons, J. W., and J. R. Harrison, III. 1981. Reptiles and amphibians of Kiawah and Capers Islands, South Carolina. Brimleyana 5:145-162.

Graham, M. A. 1976. Land use history, A study of man's influence in Virginia's barrier islands. Pp. 1-86, *In* Virginia Coast Reserve. Ecosystem Description. Land use history and climate and soils. Vol. 1, Part A. The Nature Conservancy, Arlington, Virginia. G.J. Hennessey (ed.).

Grobman, A. B. 1984. Scutellation variation in *Opheodrys aestivus*. Bull. Florida St. Mus. 29:153-170.

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

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

Knight, J. L., and R. K. Loraine. 1986. Notes on turtle egg predation by *Lampropeltis getulus* (Linnaeus) (Reptilia: Colubridae) on the Savannah River Plant, South Carolina. Brimleyana 12:1-4.

Latham, R. 1916. Notes on *Cistudo carolina* from Orient, Long Island. Copeia (34):65-67.

Lee, D. S. 1972. List of the amphibians and reptiles of Assateague Island. Bull. Maryland Herpetol. Soc. 8:90-95.

_____. 1973. Additional reptiles and amphibians from Assateague Island. Bull. Maryland Herpetol. Soc. 9:110-111.

Lillywhite, H. B., and R. F. A. Maderson. 1982. Skin structure and permeability. Pp. 397-442, *In* Biology of the Reptilia, Vol. 12, Physiology. Academic Press, New York. C. Gans and F. H. Pough (eds.).

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

MacArthur, R. H., and E. O. Wilson. 1967. The Theory of Island Biogeography. Princeton Univ. Press, Princeton, New Jersey, 203 pp.

Mitchell, J. C., and C. A. Pague. (in press). Conservation of amphibian and reptile biodiversity on Virginia's Eastern Shore. *In* Handbook of the Eastern Shore of Virginia. Univ. Press of Virginia, Charlottesville. W. D. Pilkey (ed.).

Musick, J. A. 1979. The marine turtles of Virginia (Families Cheloniidae and Dermochelyidae) with notes on identification and natural history. Va. Inst. Mar. Sci., Ed. Ser. 24, Gloucester Point, Va.

Neill, W. T. 1958. The occurrence of amphibians and reptiles in saltwater areas, and a bibliography. Bull. Mar. Sci. Gulf & Caribbean 8:1-97.

Pague, C. A., and J. C. Mitchell. 1982. A checklist of amphibians and reptiles of Back Bay National Wildlife Refuge and False Cape State Park, Virginia Beach, Virginia. Catesbeiana 2(2):13-15.

Rice, T. E., A. W. Niedoroda, and A. P. Pratt. 1976. The coastal processes and geology of the Virginia barrier islands. Pp. 1-382, *In* Virginia Coast Reserve Study. Ecosystem Description. The Coastal Processes and Geology: Virginia Barrier Islands. Vol. 1, Part B. The Nature Conservancy, Arlington, Virginia. G. J. Hennessey (ed.).

Robinson, G. G., and W. A. Dunson. 1976. Water and sodium balance in the estuarine diamondback terrapin (*Malaclemys*). J. Comp. Physiol. 105:129-152.

Schwartz, F. J. 1960. The barnacle, *Platylepas hexastylos*, encrusting a green turtle, *Chelonia mydas mydas*, from Chincoteague Bay, Maryland. Chesapeake Sci. 1:116-117.

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

Tobey, F. J. 1985. Virginia's amphibians and reptiles, a distributional survey. Privately printed, Virginia Herpetol. Soc., Purcellville, Va. 114 pp.

Uhler, F. M., C. Cottam, and T. E. Clarke. 1939. Food of snakes of the George Washington National Forest. Trans. 4th North American Wildl. Conf., pp. 605-622.