

Annotated Checklist of Terrestrial Mammals of the Virginia Barrier Islands and the Adjacent Delmarva Peninsula Mainland

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Abstract - The Virginia barrier islands lie along the seaward margin of the southern Delmarva Peninsula in the mid-Atlantic region of the United States, and collectively they comprise an internationally recognized biosphere reserve. Despite this recognition, no comprehensive checklist of mammals exists for the islands or the adjacent Delmarva Peninsula mainland. Herein we report on the species composition of terrestrial mammals of this region based on (1) a search of museum collections, (2) a compilation of literature sources and personal communications, and (3) our own extensive fieldwork (1975–2020). We documented 6 orders, 12 families, and 25 species of native terrestrial mammals. The islands are depauperate in comparison with the mainland, with several native species missing from the islands. We also documented 3 orders, 3 families, and 4 species of non-native mammals that are currently established on the islands. In addition, we herein present a historical overview of livestock species that were introduced to the islands, but (with 1 exception) no longer occur there. European settlement of the mainland and the islands began in the early 1600s; however, permanent human structures have been absent from most of the islands for the past 60+ years, leaving them undeveloped and in a natural state. These islands are undergoing rapid geological and ecological change under the pressure of accelerated sea-level rise associated with climate change. This checklist provides a foundation for future biogeographic studies of mammals in this region and serves as a baseline against which to measure future ecological and distributional changes.

Introduction

The entire coastline of the mid-Atlantic region of the United States is undergoing rapid geological and ecological change under the pressure of accelerated sea-level rise (Boon and Mitchell 2015). Many of the Virginia barrier and marsh islands lying along the seaward margin of the southern Delmarva Peninsula are experiencing unprecedented rates of erosion and migration over sub-decadal time scales (Deaton et al. 2017). Consequent changes in the landscapes of these undeveloped, essentially wild, islands are readily apparent (Wolner et al. 2013, Zinnert et al. 2019).

The first complete checklist of mammals on any of the islands was compiled for Assateague Island by Paradiso and Handley (1965). Dueser et al. (1979)

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subsequently conducted systematic surveys and reported comprehensive lists for 11 of the islands south of Assateague. Since then, numerous studies have contributed to our knowledge of the ecology and genetics of the land mammals that inhabit these islands (Adkins 1980, Cranford and Maly 1990, Dueser and Brown 1980, Dueser and Porter 1986, Dueser and Terwilliger 1987, Dueser et al. 2013, Forsys and Dueser 1993, Forsys and Moncrief 1994, Kirkland and Fleming 1990, Krim et al. 1990, Loxterman et al. 1998, Moncrief and Dueser 2001, Moncrief et al. 2017, Porter and Dueser 1982, Porter et al. 2015, Scott and Dueser 1992). However, with the exception of Paradiso and Handley (1965) and Dueser et al. (1979), there have been no attempts to summarize the entire mammalian species composition for this group of islands.

Annotated checklists provide fundamental information for conservation and management efforts as well as for other analyses, such as those that consider questions related to patterns and drivers of species occurrence (e.g., Svenning et al. 2011, Turvey and Fritz 2011). For this study, we sought to provide (1) a comprehensive list of species of terrestrial mammals for the Virginia barrier islands and the adjacent Delmarva Peninsula mainland; (2) a comprehensive list of islands on which each species is a resident; and (3) details of the multiple lines of evidence we used to compile these lists. Based on 45 years of fieldwork on the islands (1975–2020), this checklist provides a baseline against which to assess the response of the terrestrial mammal fauna to the panoply of ecological changes occurring on the islands.

Study Area

The Delmarva Peninsula includes the state of Delaware, the Eastern Shore of Maryland (Caroline, Cecil, Dorchester, Kent, Queen Annes, Somerset, Talbot, Wicomico, and Worcester counties), and the Eastern Shore of Virginia (Accomack and Northampton counties). This peninsula has clear-cut geographical boundaries, a rich archeological history, a long written record of naturalist observations, and extensive remaining potential habitat for mammalian species (Hogue and Hayes 2015).

The Virginia barrier islands extend ~150 km along the seaward margin of the Peninsula, centered at approximately 37°30'N and 75°40'W in Accomack and Northampton counties, VA (Fig. 1). This land was inhabited by the Accomac and Occohannock people at the time of European settlement (Rountree and Davidson 1997). This 1000-km² landscape is a dynamic, highly fragmented mosaic of open bays, salt marshes, marsh islands, back barriers, and barrier islands that formed during a period of Holocene era sea-level rise ~5000 years ago (Hayden et al. 1991, Newman and Munsart 1968). We have identified 25 barrier and marsh islands for sampling during the time we have been working on the islands (Fig. 1). The islands lie 0.4–12.1 km offshore and vary from 1 to 10 m in elevation and from 14 to 9344 ha in area. Vegetation composition includes emergent sandbars, low-lying marsh, grassland with extensive overwash zones, shrub thickets, and mature forests on elevated islands (McCaffrey and Dueser 1990). The soils are typically poorly drained, loamy soils in the marshes and deep sands on the uplands (Cobb and Smith 1989, Peacock and Edmonds 1994).

The islands are separated by estuarine marshes and bays that connect to the Atlantic Ocean through deep inlets, which are drowned drainage basins (Krantz et al. 2016, Oertel et al. 1989). Moncrief et al. (2017) provided a brief overview of the recent Holocene geologic history of this watery landscape.

As measured from the National Oceanic and Atmospheric Administration (NOAA) Coastal-Change Analysis Program (C-CAP) land-cover data layers for the lower Delmarva Peninsula (Virginia and Maryland) for the year 2001 (<https://coast.noaa.gov/digitalcoast/data/ccapregional.html>), the average distance between nearest-neighbor islands was 808 m (SE = 162.7) and between adjacent islands that are separated by deep, swift-running inlets was 518 m (SE = 83.5). The average distance from the mainland was 5835 m (SE = 745.5; min-max: 351–12,868 m). Given the rates of erosion and accretion in this dynamic environment, the distances

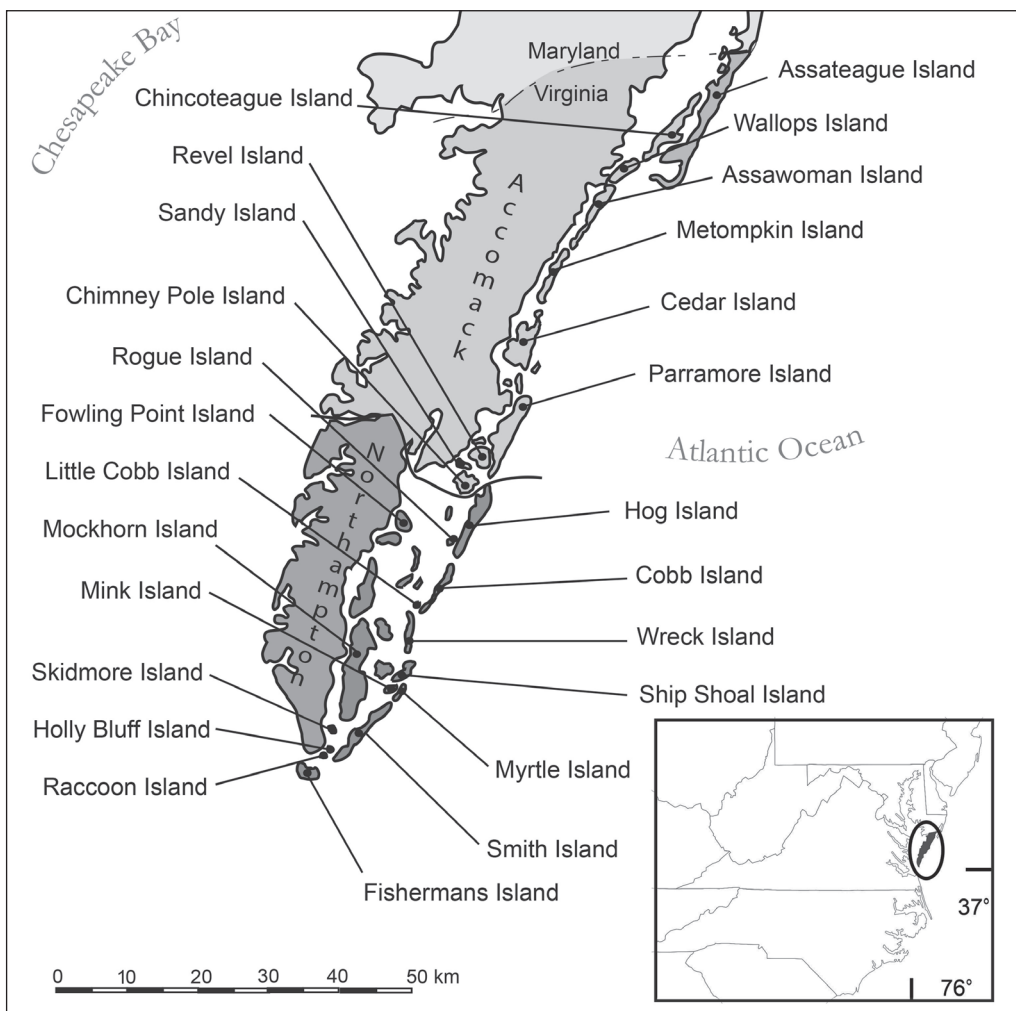


Figure 1. Location of the barrier and marsh islands of the Virginia barrier island complex. Assateague, Chincoteague, and Wallops islands support permanent human residences and facilities, but the other islands lack human structures and exist in an essentially wild state.

between nearest-neighbor islands might be subject to changes on the order of 10s to 100s of meters in any given year.

The 3 northernmost islands (Assateague, Chincoteague and Wallops) have permanent human residences and facilities. Some of the other islands have been occupied sporadically since at least the 1600s, but have been without permanent structures since a series of severe coastal storms in the early 1930s (Badger and Kellam 1989, Barnes and Truitt 1997, Graham 1976a). From the mid-17th into the mid-20th centuries, many of the islands were used to pasture horses, cattle, sheep, and swine (Barnes and Truitt 1997, Graham 1976b). The islands now exist in a natural state, with the evidence of human presence largely absent. Except for a few small, scattered private in-holdings, the islands are held in public ownership by the US Fish and Wildlife Service, or the Commonwealth of Virginia, or are privately owned by The Nature Conservancy (TNC). TNC holdings comprise the Volgenau Virginia Coast Reserve (VCCR), recognized as a National Science Foundation (NSF) Long-Term Ecological Research (LTER) site (Hayden et al. 1991), a Man and the Biosphere Reserve, and a Western Hemisphere International Shorebird Reserve Network site (Badger 1978, 1991, 1997).

The study islands represent a variety of physiographies and vegetation structures: marsh (Chimney Pole, Fowling Point, Mink, Raccoon), grassland (Assawoman, Little Cobb, Metompkin, Myrtle, Sandy, Ship Shoal), shrubland (Cedar, Cobb, Hog, Holly Bluff, Mockhorn, Rogue, Wreck), and forested (Assateague, Chincoteague, Fishermans, Parramore, Revel, Skidmore, Smith, Wallops) islands. Cedar and Hog islands formerly supported forest, but no longer do. Given the effects of area and elevation, habitat complexity on these islands is cumulative, so that forested islands also have areas of shrubland, grassland, and marsh; shrubland islands have grassland and marsh; and grassland islands have marsh (Dueser and Brown 1980). Assateague, Chincoteague, Fishermans, and Wallops islands are connected to the Peninsula mainland by highway bridges, but all the others in this study are accessible only by crossing open tidal waters. Given the relative absence of the usual sources of anthropogenic threat on barrier islands (e.g., development pressure, livestock grazing, and wandering pets; Hice and Schmidly 2002), the Virginia islands provide an ideal natural laboratory for assessing the impacts and implications of natural processes on the structure and function of an intact coastal ecosystem.

Materials and Methods

We compiled collection information for specimens in the Mammal Collection of the Virginia Museum of Natural History (VMNH), and we searched 312 electronic museum databases using the VertNet portal on 16 August 2020. In addition to VMNH, the following institutions report specimens from Accomack and/or Northampton counties, VA: American Museum of Natural History (AMNH); California Academy of Sciences (CAS); Cornell University Museum of Vertebrates (CUMV); The Field Museum of Natural History (FMNH); University of Kansas, Natural History Museum and Biodiversity Research Center (KU); Louisiana State University, Museum of Natural Science (LSUMZ); University of California,

Berkeley, Museum of Vertebrate Zoology (MVZ); North Carolina Museum of Natural Sciences (NCSM); University of Michigan Museum of Zoology (UMMZ); United States National Museum of Natural History (USNM); and University of Washington, Thomas Burke Memorial Washington State Museum (UWBM). In addition, between 1975 and 2020, we conducted live-trapping surveys (more than 45,000 trap nights) and systematic track surveys (more than 400 observer days) on the islands and the adjacent mainland in Accomack and Northampton counties, VA (Dueser et al. 2018, Porter and Dueser 2021). The sandy substrate and generally patchy vegetation make the islands ideal for detecting identifiable tracks and scat, and the low diversity of species reduced the potential for misidentifications. We also compiled and synthesized information from publications and from unpublished reports by colleagues, including capture reports from >100,000 trap nights by USDA Wildlife Services between 2001 and 2018.

We consider a native species to be “resident” on an island based on its persistent occurrence over multiple surveys, which we interpret to be indicative of a self-sustaining population. Furthermore, in most cases we also had evidence of reproduction and recruitment for species we consider to be resident. Based on these same criteria, we consider a non-native species to be “established” on an island. We consider species that we found to be undetectable in multiple recent sampling events or that we detected only infrequently to be “absent” from an island or perhaps only transient; only further sampling can clarify the status of these cases.

Results

All species in Table 1 occur on the Virginia barrier islands and/or the adjacent mainland of the southern Delmarva Peninsula in Accomack and Northampton counties, VA. For each of these, we provide details of their occurrence. Scientific names follow Pagels and Moncrief (2015), and common, or vernacular, names follow Wilson and Reeder (2005).

ORDER DIDELPHIMORPHIA (pouched mammals)

Family Didelphidae (opossums)

Didelphis virginiana Kerr (Virginia Opossum). Specimens from the mainland: Accomack County (USNM). Specimens from Assateague Island (USNM). We have capture records from Assawoman, Metompkin, and Wallops islands, 1 report from Hog Island (Bailey 1946), and capture records from Northampton County. We consider Virginia Opossums to be resident on Assateague and Wallops islands.

ORDER SORICOMORPHA (insectivores)

Family Soricidae (shrews)

Sorex cinereus Kerr (Cinereus Shrew). Specimens from the mainland: Accomack County (MVZ, USNM). Before Moncrief and Dueser (1998) reported the first record of the Cinereus Shrew from Accomack County, there was no evidence of its presence on Virginia’s Eastern Shore. We found no specimens from the islands and have no capture records.

Blarina brevicauda (Say) (Northern Short-tailed Shrew). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (AMNH, USNM, VMNH). In addition, we have capture records from Raccoon Island (Dueser et al. 1979) and Wallops Island (Baker et al. 2015). We consider Northern Short-tailed Shrews to be resident on Wallops Island.

Table 1. Terrestrial mammals of the southern Delmarva Peninsula and Virginia barrier islands, including species that have been introduced (I), those that have colonized the region since European contact (C), and those that have been successfully reintroduced (R) in recent times. For each species, we indicate (1) presence (+) or absence (-) on the mainland of Accomack and/or Northampton counties, VA, in 2020 (Main.); (2) the number of islands on which we believe it to be resident or established as of 2020 (Res.); and (3) the number of islands on which it has been reported but is not resident or established as of 2020 (Rep.).

Order/species	Common name	Main.	Res.	Rep.
Didelphimorphia				
<i>Didelphis virginiana</i>	Virginia Opossum	+	2	3
Soricimorpha				
<i>Sorex cinereus</i>	Cinereus Shrew	+	0	0
<i>Blarina brevicauda</i>	Northern Short-tailed Shrew	+	1	1
<i>Cryptotis parva</i>	North American Least Shrew	+	4	1
<i>Scalopus aquaticus</i>	Eastern Mole	+	0	1
<i>Condylura cristata</i>	Star-nosed Mole	+	0	0
Lagomorpha				
<i>Lepus californicus</i> (I)	Black-tailed Jackrabbit	-	1	3
<i>Sylvilagus floridanus</i>	Eastern Cottontail	+	6	5
Rodentia				
<i>Sciurus carolinensis</i>	Eastern Gray Squirrel	+	3	2
<i>Sciurus niger</i> (R)	Eastern Fox Squirrel	-	1	0
<i>Glaucomys volans</i>	Southern Flying Squirrel	+	0	0
<i>Oryzomys palustris</i>	Marsh Oryzomys	+	25	0
<i>Peromyscus leucopus</i>	White-footed Deermouse	+	4	3
<i>Microtus pennsylvanicus</i>	Meadow Vole	+	8	8
<i>Microtus pinetorum</i>	Woodland Vole	+	1	0
<i>Ondatra zibethicus</i>	Common Muskrat	+	13	0
<i>Zapus hudsonius</i>	Meadow Jumping Mouse	+	1	0
<i>Mus musculus</i> (I)	House Mouse	+	11	2
<i>Rattus norvegicus</i> (I)	Brown Rat	+	6	6
Carnivora				
<i>Canis latrans</i> (C)	Coyote	+	0	5
<i>Vulpes vulpes</i> (C)	Red Fox	+	4	6
<i>Urocyon cinereoargenteus</i>	Gray Fox	+	1	0
<i>Procyon lotor</i>	Raccoon	+	10	15
<i>Mustela frenata</i>	Long-tailed Weasel	+	0	1
<i>Neovison vison</i>	American Mink	+	2	10
<i>Lontra canadensis</i>	North American River Otter	+	16	0
<i>Mephitis mephitis</i>	Striped Skunk	+	0	0
Artiodactyla				
<i>Cervus nippon</i> (I)	Sika	-	1	0
<i>Odocoileus virginianus</i> (R)	White-tailed Deer	+	7	13

Cryptotis parva (Say) (North American Least Shrew). Specimens from the mainland: Accomack County (MVZ) and Northampton County (AMNH, VMNH). Specimens from the following islands: Assateague (NCSM, USNM, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fowling Point (VMNH), and Wallops (USNM). We have capture records from Cedar Island. We consider North American Least Shrews to be resident on Assateague, Chincoteague, Fowling Point, and Wallops islands.

Family Talpidae (moles)

Scalopus aquaticus (L.) (Eastern Mole). Specimens from the mainland: Accomack County (MVZ) and Northampton County (UMMZ, USNM). Bailey (1946) reported this species from Cobb Island. We question this report, and we consider Eastern Moles to be absent from the Virginia barrier islands.

Condylura cristata (L.) (Star-nosed Mole). Specimens from the mainland: Accomack County (USNM). We have capture records of the Star-nosed Mole from the Northampton County mainland.

ORDER LAGOMORPHA (hare-shaped mammals)

Family Leporidae (hares and rabbits)

Lepus californicus Gray (Black-tailed Jackrabbit). Specimens from the mainland: none. Specimens from Cobb (VMNH) and Little Cobb (USNM) islands. We have reliable reports (R. Boettcher, Virginia Department of Wildlife Resources, Machipongo, VA, pers. comm.) of this species on Hog Island, and Clapp et al. (1976) reported observations on Rogue Island. This species is not native to Virginia (Pagels and Moncrief 2015). We agree with the conclusion of Clapp et al. (1976) that Black-tailed Jackrabbits are established only on Cobb Island, where a shipping error led to the accidental introduction of mail-order jackrabbits from Kansas in the 1960s, rather than the mail-order cottontails that had been planned (H. Bowen, Willis Wharf, VA, pers. comm.).

Sylvilagus floridanus (J.A. Allen) (Eastern Cottontail). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (USNM). Specimens from the following islands: Assateague (USNM), Chincoteague (USNM), Fishermans (USNM), Hog (MVZ, USNM, VMNH), and Smith (USNM). Hanlon et al. (1989) reported 3 sightings on Parramore Island, and E. Berge (Virginia Tech, Blacksburg, VA, pers. comm.) reported 67 camera-trap photos of Eastern Cottontails on Parramore Island. Baker et al. (2015) observed this species on Wallops Island. We have track records from Assawoman, Revel, and Ship Shoal islands. Mayne et al. (1981) reported observing tracks of this species on Cedar Island. The status of the Eastern Cottontail on Fishermans Island is uncertain. Blem and Pagels (1973) reported Eastern Cottontail skulls in pellets regurgitated by *Tyto alba* (Scopoli) (Barn Owl) on Fishermans Island in 1971 and 1972. B. Truitt (The Nature Conservancy, Nassawadox, VA, pers. comm.) observed the Eastern Cottontail on Fishermans Island in 1988. Fies (1991), however, reported that this species is probably absent from Fishermans and Smith islands. Furthermore,

despite extensive fieldwork during the past 21 years, P. Denmon (US Fish and Wildlife Service, Cape Charles, VA, pers. comm.) has no recent reports of Eastern Cottontails from Fishermans Island. We consider Eastern Cottontails to be resident on Assateague, Chincoteague, Hog, Parramore, Revel, and Wallops islands.

ORDER RODENTIA (gnawing mammals)

Family Sciuridae (squirrels)

Sciurus carolinensis Gmelin (Eastern Gray Squirrel). Specimens from the mainland: Northampton County (LSUMZ, USNM, VMNH). Specimens from Chincoteague Island (VMNH). We have capture records from Assateague Island. Dueser et al. (1979) reported single sightings of this species on Parramore and Smith islands. B. Truitt (pers. comm.) reported a dead Eastern Gray Squirrel in the mouth of a *Vulpes vulpes* (L.) (Red Fox) on Parramore Island in 1977. Hanlon et al. (1989) later reported Eastern Gray Squirrels on Parramore Island. Baker et al. (2015) observed this species on Wallops Island in summer 2015, and one of us (R.D. Dueser) observed an Eastern Gray Squirrel on Smith Island in October 2015. Based on 150+ observer days of field work since 1990, we now consider the Eastern Gray Squirrel to be absent from Parramore Island, but resident on Chincoteague, Smith, and Wallops islands.

Sciurus niger L. (Eastern Fox Squirrel). Specimens from the mainland: none. Specimens from Assateague Island (VMNH). We have capture records from the mainland in Northampton County. This species was on the Federal Endangered Species List (as *S. n. cinereus* L.[Delmarva Fox Squirrel]). It was considered extirpated from Virginia at the time of listing in 1967. Later, it was reintroduced to Chincoteague National Wildlife Refuge (NWR) on Assateague Island in Accomack County (1968–1971) and to Brownsville Farm, near Nassawadox, in Northampton County (1982–1983). The Chincoteague NWR introduction was successful, while the Brownsville introduction failed (Terwilliger 2000). We consider the Eastern Fox Squirrel to be resident on Assateague Island, but, despite occasional uncorroborated reports in Northampton County, not on the mainland.

Glaucomys volans (L.) (Southern Flying Squirrel). We are not aware of any specimens from Accomack and Northampton counties, VA. We have capture records of the Southern Flying Squirrel on the Accomack County mainland, but we are not aware of any reports of captures or observations on the islands or in Northampton County.

Family Cricetidae (cricetids)

Oryzomys palustris (Harlan) (Marsh Oryzomys). Specimens from the mainland: Accomack County (MVZ, NCSM, USNM, VMNH) and Northampton County (AMNH, FMNH, UMMZ, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (MVZ, VMNH), Chimney Pole (VMNH), Chincoteague (CUMV, NCSM, USNM), Cobb (USNM, VMNH), Fishermans (VMNH), Fowling Point (VMNH), Hog (USNM, VMNH), Holly Bluff (VMNH), Little Cobb (VMNH), Metompkin (VMNH), Mink (VMNH), Mockhorn (VMNH),

Myrtle (VMNH), Parramore (USNM, VMNH), Raccoon (VMNH), Revel (VMNH), Rogue (VMNH), Sandy (VMNH), Ship Shoal (VMNH), Skidmore (USNM), Smith (USNM, VMNH), Wallops (USNM, VMNH), and Wreck (USNM, VMNH). In addition, we have capture records from Assawoman Island. We consider the Marsh *Oryzomys* to be resident on all these islands.

Peromyscus leucopus (Rafinesque) (White-footed Deermouse). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH) and Northampton County (AMNH, USNM, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (VMNH), Chincoteague (NCSM, USNM), Fishermans (VMNH), Hog (MVZ, USNM, VMNH), and Wallops (USNM). In addition, we have capture records from Fowling Point Island. We consider the White-footed Deermouse to be resident on Assateague, Chincoteague, Fishermans, and Wallops islands.

Microtus pennsylvanicus (Ord) (Meadow Vole). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH); Northampton County (AMNH, FMNH, NCSM, UMMZ, USNM, VMNH). Specimens from the following islands: Assateague (NCSM, USNM, VMNH), Cedar (MVZ, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fowling Point (VMNH), Hog (VMNH), Metompkin (VMNH), Mockhorn (VMNH), Myrtle (VMNH), Parramore (USNM, VMNH), Revel (VMNH), Ship Shoal (VMNH), Smith (USNM, VMNH), and Wallops (USNM, VMNH). In addition, we have capture records from Holly Bluff Island. Blem and Pagels (1973) reported Meadow Voles in Barn Owl pellets collected on Fishermans Island. It is possible that the owl(s) captured the voles on the nearby Northampton County mainland, because we have never captured Meadow Voles on Fishermans Island during numerous trapping sessions from 1989 to 2015, and neither has R. Rose (Old Dominion University, Norfolk, VA, pers. comm.), who has also conducted extensive live-trapping surveys of small mammals on Fishermans Island and the Northampton County mainland. Mayne et al. (1981) reported captures of the Meadow Vole from Assawoman Island. We consider it to be resident on Assateague, Chincoteague, Fowling Point, Holly Bluff, Mockhorn, Parramore, Smith, and Wallops islands.

Microtus pinetorum (Le Conte) (Woodland Vole). Specimens from the mainland: Accomack County (KU, MVZ, USNM, VMNH); Northampton County (AMNH, UMMZ, USNM, VMNH). In addition, Baker et al. (2015) captured Woodland Voles on Wallops Island, and we consider this species to be resident on that island.

Ondatra zibethicus (L.) (Common Muskrat). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (VMNH). Specimens from the following islands: Assateague (USNM), Chincoteague (CUMV, USNM), and Metompkin (VMNH). We observed tracks on Cedar, Cobb, Hog, Myrtle, Parramore, Revel, Ship Shoal, Smith, and Wreck islands. We also observed multiple lodges on Hog Island (Porter 2018). Mayne et al. (1981) reported tracks of this species from Assawoman Island. We consider Muskrats to be resident on all these islands.

Family Dipodidae (jumping mice)

Zapus hudsonius (Zimmermann) (Meadow Jumping Mouse). Specimens from the mainland: Accomack County (USNM, VMNH). Specimens from the following island: Assateague (USNM, VMNH). We consider the Meadow Jumping Mouse to be resident on Assateague Island.

Family Muridae (murids)

Mus musculus L. (House Mouse). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH) and Northampton County (CAS, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (MVZ, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fishermans (VMNH), Fowling Point (VMNH), Hog (MVZ, USNM, VMNH), Metompkin (VMNH), Myrtle (VMNH), Parramore (USNM), Raccoon (VMNH), Revel (VMNH), Smith (USNM, VMNH), and Wallops (USNM). This species is not native to Virginia (Pagels and Moncrief 2015). We consider the House Mouse to be established on Assateague, Cedar, Chincoteague, Fishermans, Fowling Point, Hog, Metompkin, Parramore, Raccoon, Smith, and Wallops islands.

Rattus norvegicus (Berkenhout) (Brown Rat). Specimens from the mainland: none. Specimens from the following islands: Assateague (USNM), Cobb (VMNH), Hog (VMNH), Metompkin (VMNH), Parramore (USNM), and Revel (VMNH). In addition, we have capture records from Cedar, Chimney Pole, and Sandy islands. Blem and Pagels (1973) reported Brown Rat skulls from Barn Owl pellets collected on Fishermans Island, but we have no capture records to confirm the current presence of this species on the island despite extensive live trapping. It is possible that the rats were captured on the nearby Northampton County mainland. We observed tracks on Little Cobb Island. This species is not native to Virginia (Pagels and Moncrief 2015). We consider Brown Rats to be established on Assateague, Chincoteague, Hog, Metompkin, Parramore, and Revel islands.

ORDER CARNIVORA (flesh-eating mammals)

Family Canidae (dogs, foxes, and allies)

Canis latrans Say (Coyote). We found no specimens from Accomack and Northampton counties. We have capture records from Assateague, Fishermans, and Parramore islands. We have camera-trap records from the Northampton County mainland. We have observed Coyote tracks on Metompkin and Sandy islands. We do not believe Coyotes are resident on any of the Virginia barrier islands. Hogue and Hayes (2015) argued that the Coyote was not found on the Peninsula at the time of European arrival, but rather arrived through natural range expansion following the extirpation of *Canis lupus* L. (Wolf). We consider the Coyote to be a native resident of Accomack and Northampton counties as a result of natural range expansion, but we do not consider it to be resident on any of the islands.

Vulpes vulpes (L.) (Red Fox). Specimens from the mainland: Northampton County (VMNH). Specimens from the following islands: Assateague (USNM), Chincoteague (USNM), Hog (USNM), Metompkin (VMNH), and Parramore

(VMNH). In addition, we have capture records from Assawoman, Cedar, and Wallops islands. We have observed tracks on Cobb and Revel islands. Notably, one of us (R.D. Dueser) watched a Red Fox swim from Parramore Island to Revel Island on 5 November 2002. We have reliable reports from January 2018 of a Red Fox crossing the ice from Wildcat Marsh on Chincoteague Island over to Assateague Island (D. Leonard, Chincoteague, VA, pers. comm.) and of a Red Fox leaving the mainland from a small neck called “Webb’s Island” in Northampton County, heading east out onto a vast expanse of icy marsh (M. Killmon, The Nature Conservancy, Nassawadox, VA, pers. comm.). We consider the Red Fox to be resident on Assateague, Chincoteague, Parramore, and Wallops islands.

Hogue and Hayes (2015) believed that the Red Fox is not a native species on the Delmarva Peninsula, because it was not present prior to European colonization. Red Foxes in the eastern United States were long thought to be solely of European origin, introduced to the American colonies for sport hunting (Churcher 1959, Kamlar and Ballard 2002). However, recent genetic studies indicate that the history of Red Foxes on the Delmarva Peninsula is complicated. Kasprowicz et al. (2016) and Kuo et al. (2019) presented genetic evidence that native populations of North American Red Foxes underwent natural range expansion, moving southward from New England around the same time that European Red Foxes from Britain were introduced to the Delmarva Peninsula. The expanding wave of native Red Fox populations eventually reached the Delmarva Peninsula, and the native animals interbred with British foxes, producing admixed native/non-native populations on the Delmarva Peninsula (Kasprowicz et al. 2016, Kuo et al. 2019). Complicating the situation further, Kasprowicz et al. (2016) also found evidence of subsequent interbreeding between captive-bred animals (escapees from fur farms in the 1900s) and the admixed populations of wild Red Foxes on the Delmarva Peninsula. Given the prevalence of the native genotype in the region as a result of natural range expansion, even with some degree of admixture with non-native genotypes, we consider the Red Fox to be a native species on the Delmarva Peninsula.

Urocyon cinereoargenteus (Schreber) (Gray Fox). Specimens from the mainland: Accomack County (VMNH). We have capture records from the Northampton County mainland and from Wallops Island (B. Scharle, USDA-Wildlife Services, Wallops Island, VA, pers. comm.). We consider the Gray Fox to be resident on Wallops Island.

Family Procyonidae (raccoons)

Procyon lotor (L.) (Raccoon). Specimens from the mainland: Accomack County (USNM) and Northampton County (NCSM, VMNH). Specimens from the following islands: Assateague (USNM), Cedar (VMNH), Cobb (VMNH), Fishermans (VMNH), Hog (VMNH), Metompkin (VMNH), Myrtle (VMNH), Parramore (USNM, VMNH), Revel (VMNH), Smith (USNM, VMNH), and Wallops (USNM). In addition, we have capture records from Mink, Mockhorn, Rogue, and Skidmore islands. We also have observed tracks on Chimney Pole, Fowling Point, Holly Bluff, Little Cobb, Raccoon, Sandy, Ship Shoal, and Wreck islands. An article in the

Peninsula Enterprise (Neighborhood Notes: Chincoteague 1912:3) reported that “Our sportsmen (on Chincoteague Island) have had lots of fun this week, killing coons, weighing from 14 to 16 lbs., and as many as five and six a day. In the memory of the oldest inhabitants, a coon was never seen on the island before. A number of them also were found on Assateague.” A subsequent article in the *Peninsula Enterprise* (Neighborhood Notes: Wachapreague 1914:4) reported that “Tobias Jeems, Esq., the successful coon-hunter, paid Parramore's Beach L. S. Station (on Parramore Island) a visit in the great storm last Saturday and spent two days there with the boys rejuvenating, so he told us, and added that when he again visits the island and departs therefrom, we may expect him to return with a full bag of raccoons. And to cap the climax, it is said, he does the trick oftentimes without the aid of canines, running them down or pursuing them to their habitats where they fall an easy prey to his capacious reach and herculean clutch.” Truitt and Peterson (1999) reported observing tracks on Assawoman Island. We consider the Raccoon to be resident on Assateague, Chincoteague, Fishermans, Hog, Mockhorn, Parramore, Revel, Skidmore, Smith, and Wallops islands.

Family Mustelidae (weasels and allies)

Mustela frenata Lichtenstein (Long-tailed Weasel). Specimens from the mainland: Accomack County (USNM). We are not aware of any specimens from the islands; we have no capture records, and we are not aware of any reports of captures in Northampton County or on any of the islands. In addition, we have seen a taxidermied Long-tailed Weasel in the Northampton County Courthouse that is labeled as follows “Found dead on the side of the road near Locustville in Accomack Co. on September 18, 2003. Found and taxidermied by famous naturalist (and very experienced fur trapper) George W. Reiger who lives in Locustville.”

Arquilla (2007) reported “Long-tailed Weasel, *Mustela frenata*” on Cobb Island in his Table 8. However, on page 48 he says “South Cobb Island supported a large gull colony, and Least Weasel [*Mustela nivalis* L.] tracks were also observed.” We question this report of *Mustela* on Cobb Island on the basis of the meager evidence and the fact that extensive surveys on the island over the past 45 years have produced no other report of any weasel. Cobb is one of the most remote islands and perhaps the least likely to support a terrestrial mammal found nowhere else in this barrier system.

Neovison vison (Schreber) (American Mink). Specimens from the mainland: none. Specimens from Smith Island (USNM). Hogue and Hayes (2015) report that a road-killed animal was observed by a trapper in Accomack County. We have track records from Cedar, Cobb, Fishermans, Hog, Little Cobb, Metompkin, Mink, Myrtle, Parramore, Ship Shoal, and Wreck islands. We consider the American Mink to be resident on Parramore and Smith islands.

Lontra canadensis (Schreber) (North American River Otter). Specimens from the mainland: Accomack County (VMNH). Specimens from Assateague Island (UWBM). We observed animals on the Northampton County mainland and in creeks behind Parramore and Hog islands, and we observed tracks on Cedar, Chimney Pole, Cobb, Fishermans, Holly Bluff, Metompkin, Mockhorn, Myrtle,

Raccoon, Ship Shoal, Smith, and Wreck islands. Truitt and Peterson (1999) reported observing tracks of this species on Assawoman Island. We consider the North American River Otter to be a likely resident on all of these islands.

Family Mephitidae (skunks)

Mephitis mephitis (Schreber) (Striped Skunk). We are not aware of any specimens from Accomack and Northampton counties. We have no capture records of this species, and we are not aware of any reports of captures in Accomack or Northampton counties. We have a reliable report (R. Boettcher, pers. comm.) of observations of Striped Skunks on the mainland in both Accomack and Northampton counties, and we consider this species to be resident in both counties.

ORDER ARTIODACTYLA (even-toed hoofed mammals)

Family Cervidae (deer)

Cervus nippon Temminck (Sika). Specimens from the mainland: none. Specimens from Assateague Island (AMNH, NCSM, USNM). This species is not native to Virginia (Pagels and Moncrief 2015). The Sika is established on Assateague Island in Accomack County (Flyger 1960).

Odocoileus virginianus (Zimmermann) (White-tailed Deer). We are not aware of any specimens from Accomack and Northampton counties. We have observed this species on the mainland in both counties and on Assateague, Chincoteague, Cobb, Fishermans, Hog, Holly Bluff, Metompkin, Mockhorn, Parramore, Revel, Rogue, Smith, and Wreck islands. We have also observed tracks on Assawoman, Cedar, Little Cobb, Mink, Myrtle, Ship Shoal, and Skidmore islands. Paradiso and Handley (1965) reported this species from Assateague Island. We consider the White-tailed Deer to be resident on Assateague, Chincoteague, Fishermans, Hog, Mockhorn, Parramore, and Smith islands.

Discussion

The mammalian fauna of the southern Delmarva Peninsula has experienced dramatic changes in species composition through both the extirpation of native species and the introduction of non-natives. Humans have occupied the Peninsula for at least the past 13,000 years (Custer 1989, Rountree and Davison 1997). The prehistoric residents were primarily hunters and gatherers (Custer 1989) who made seasonal use of the Virginia barrier islands for fishing, shellfish gathering, and perhaps hunting. Although the evidence of this early activity has been largely erased by the wind and tides, Lowery (2003) identified >20 archeological sites in Accomack and Northampton counties, confirming the presence of humans on the islands in prehistoric times. These sites contained a variety of stone hunting tools from different eras, but none contained mammalian faunal remains. The prehistoric fauna on the southern part of the Peninsula probably included a host of species no longer found in the region, including at least *Ursus americanus* Pallas (American Black Bear), *Puma concolor* (L.) (Cougar), *Lynx rufus* (Schreber) (Bobcat), Wolf, and, perhaps, *Cervus canadensis* Erxleben (Wapiti) (Hogue and Hayes 2015, Paradiso

1969, Rountree and Davison 1997). We are unaware of any reliable record of these species ever occurring on the barrier islands. There is, however, a generic reference to “wolves” on an island (perhaps Assateague) offshore from what is now Accomack County, during the winter of 1650 (Norwood 1650:27).

Permanent European settlement on the southern Delmarva Peninsula began in 1621, when Thomas Savage was granted a tract of 3642 ha (9000 ac) of land in what would become Northampton County by Esmey Shichans, the chief of the Accomac tribe (McCartney 2021). The colonists and their descendants added another source of wildlife exploitation to the region and also introduced new species to the islands. They extirpated 4 carnivores: the Wolf, American Black Bear, Bobcat, and Cougar (Hogue and Hayes 2015). They unintentionally introduced at least 2 usually commensal rodent species (i.e., House Mouse and Brown Rat) that persist on many of the islands, even in the absence of permanent human structures. As detailed above, Europeans also purposefully introduced an English version of the native Red Fox. White-tailed Deer were introduced to Parramore Island in the 1920s, at a time when the species was almost extirpated from the entire Delmarva Peninsula through overhunting and possibly other factors (Graham 1976b, Paradiso 1969); deer are now observed frequently on many of the islands. The introduction of Black-tailed Jackrabbits to Cobb Island in the 1960s is testimony to the continuing local interest in sport hunting; their successful establishment in this harsh environment reflects their adaptability (Dunn et al. 1982). Despite sporadic captures of *Felis catus* L. (Domestic Cat) on Assateague, Parramore, and Wallops islands, we do not believe any island currently supports a population. The full impact of these introductions, both intentional and accidental, is impossible to gauge after the fact.

The extirpation of the large carnivores on the Peninsula (i.e., the Wolf, American Black Bear, and Cougar) left behind a mammalian mesopredator fauna dominated by Raccoons and Red Foxes (Hogue and Hayes 2015). Although it cannot be confirmed, it appears that these species were neither abundant nor widely distributed on the islands at the turn of the 20th century. Numerous hunt clubs operated on the islands from 1880 to 1940, producing a long history of predator removal (Graham 1976b). Some of the last residents of the village of Broadwater on Hog Island in the 1930s reported very few Red Foxes or Raccoons there (Graham 1976b). Red Foxes were seldom hunted or trapped on Smith Island, even during the early 1900s (Graham 1976b). Nevertheless, predator control was used against Raccoons and Red Foxes on islands where they were viewed as a hindrance to game stocking. For example, a specialist was hired during the 1920s to rid Parramore Island of Red Foxes to facilitate the successful introduction of game birds, but he reported that “only a few dens were ever found”, suggesting that Red Foxes were not abundant on the island at this time (Graham 1976b:51). Hunting, trapping, and poisoning of Raccoons and Red Foxes continued on an occasional basis even after the 1920s. These reports from early in the 20th century and the more recent observations of Raccoon and Red Fox movement between islands (Dueser et al. 2013, reports cited herein) suggest that mammalian carnivores are more abundant and widely

distributed on the islands today than in the past. In 2000, a new round of predator management was initiated in an effort to reverse the decline of beach-nesting and colonial waterbirds on the islands (Erwin et al. 2001). Much of what we know about current mesopredator distribution, abundance, and dispersal in this mainland-island system has been learned in connection with the predator-removal programs instituted by the current managers of the islands (Dueser et al. 2013, Moncrief et al. 2017, Porter et al. 2015). Humans have thus brought about significant changes in the mammalian fauna of the Delmarva Peninsula, including the barrier islands, reducing the number and diversity of native wildlife species, particularly predators, and introducing a number of others.

The islands also have a long history of livestock husbandry. Early European colonists introduced a host of domesticated species to the region, including *Equus caballus* L. (Horse), *Sus scrofa* L. (Domestic Pig), *Ovis aries* L. (Domestic Sheep), *Capra hircus* L. (Domestic Goat), and *Bos taurus* L. (Domestic Cow). The islands were considered good pasturage for livestock from the mid-1600s through the 20th century (Barnes and Truitt 1997, Graham 1976b). Flocks of Domestic Sheep were formerly pastured on Assateague, Chincoteague, Hog, Fowling Point, and Smith islands, and herds of Domestic Cattle on Assateague, Chincoteague, Hog, Mockhorn, and Smith islands. These animals usually were unattended, and often went feral. George Washington Parke Custis, the step-grandson of George Washington and father-in-law of Robert E. Lee, extolled the virtues of the wool of the “native sheep of Smith’s island” (Barnes and Truitt 1997). Robert E. Lee in 1832 proposed ways to improve the pasture available for Domestic Cattle and Domestic Sheep on Smith Island (Barnes and Truitt 1997). Assateague Island still supports a herd of ~150 feral ponies on Chincoteague NWR (Lowney et al. 2005, USFWS 2015). Domestic Cows and Domestic Goats were reported on Assateague Island as recently as the 1960s (Paradiso and Handley 1965). The last Domestic Sheep were removed from Hog Island in 1978 and the last Domestic Cattle in 1986 (B. Truitt, pers. comm.). The last Domestic Sheep anywhere on the islands were removed from Fowling Point Island in 1994 (J. Kelly IV, Red Bank, VA, pers. comm.). The 300-year era of livestock husbandry has ended on the islands except for the Chincoteague ponies. The ecological consequences of this long history of grazing on the islands will never be known.

We have documented 6 orders, 12 families, and 25 species of native terrestrial mammals on the Virginia barrier islands and the adjacent Delmarva Peninsula mainland. We also documented 3 orders, 3 families, and 4 species of non-native mammals that are established on the Virginia barrier islands. Pagels and Moncrief (2015) provide citations of comprehensive monographs with details of each of these species’ biology. It is noteworthy that Paradiso (1969) reported 5 native species from the northern Delmarva Peninsula that do not occur today in Accomack or Northampton counties: *Sorex hoyi* Baird (American Pygmy Shrew), *Tamias striatus* (L.) (Eastern Chipmunk), *Synaptomys cooperi* Baird (Southern Bog Lemming), *Castor canadensis* Kuhl (American Beaver), and *Marmota monax* (L.) (Woodchuck). We found no specimens of any of these species from Virginia’s Eastern Shore, and we have

reliable reports of only 2: American Beaver and Woodchuck. The American Beaver was extirpated from the entire state by 1911 (Handley and Patton 1947). It was reintroduced to a pond in central Northampton County sometime in the 1970s, but recent reconnaissance in the vicinity revealed no evidence of American Beavers (R. Dodd, Eastville, VA, pers. comm.). For the Woodchuck, we have 1 reliable observation (P. Denmon, pers. comm.) in Northampton County in the 2010s, but no reports or observations since then. Given the typical visibility of both of these species, we doubt that either is currently resident in either Accomack County or Northampton County. In addition, a non-native rodent, *Rattus rattus* (L.) (Roof Rat) occurs elsewhere in Virginia, but Paradiso (1969) did not report it from Maryland's Eastern Shore, our searches of collections databases revealed no specimens, and we have no capture records or reports for this species. Hence we do not consider the Roof Rat to be established on the southern Delmarva Peninsula.

In considering the current geographic distribution of native species in this mainland-island system, 5 patterns emerge. (1) Some species have been extirpated and are unlikely to reappear in Accomack and Northampton counties, without intentional reintroduction efforts. We place the American Beaver, Wolf, American Black Bear, Bobcat, and Cougar in this category. Of these, only American Beavers are currently resident on the northern Delmarva Peninsula (Hogue and Hayes 2015; M. Whitbeck, US Fish and Wildlife Service, Cambridge, MD, pers. comm.). (2) Some species appear to be expanding southward on the Delmarva Peninsula mainland. The Coyote has already made this journey in recent decades (Paradiso 1969) and has become well-established. Infrequent observations of the Striped Skunk and Woodchuck in Accomack and Northampton counties suggest these species may be advancing. The American Pygmy Shrew, Eastern Chipmunk, and Southern Bog Lemming may yet be found on the lower Peninsula. (3) Seven species that are resident on the Delmarva Peninsula mainland of Virginia have no representatives on the islands. It is likely that the sandy habitats on the islands are unfavorable for fossorial species such as the Eastern Mole and Star-nosed Mole and for species that den such as the Striped Skunk. The Cinereus Shrew, the Southern Flying Squirrel, and the Long-tailed Weasel appear to be rare even where they occur on the mainland and may thus be poor candidates for island colonization. (4) Many species have been reported from 1 or more islands where they appear not to be resident, likely indicating either local extinction following an early observation (e.g., Virginia Opossum and White-footed Deermouse on Hog Island; Bailey 1946) or simply occurrence of occasional transient individuals of a particularly mobile species (e.g., Coyote, Red Fox, Raccoon, and White-tailed Deer). (5) The smaller rodent species vary widely in occurrence. The Meadow Jumping Mouse and Woodland Vole each is resident on only 1 island and have never been observed on any other. In contrast, the Marsh *Oryzomys* occurs on every island we have sampled and is apparently resident on all. The White-footed Deermouse and Meadow Vole occur on only a few islands, and they are resident on only a subset of the islands where they have ever been captured. Variability among species in dispersal ability and colonization potential have undoubtedly combined with geography and variability in island physiography to

produce these complex patterns of native mammal distribution (Dueser and Brown 1980, Loxterman et al. 1998, Porter et al. 2015).

This checklist provides a foundation for future studies of mammals, especially native species, on the Virginia barrier islands. Well-documented surveys are fundamental to understanding the distribution of species, which is necessary for conservation of biological diversity and informed management decisions (Balmford and Gaston 1999, Jetz et al. 2012, Roberts et al. 2007). This need is particularly true for barrier island systems (Hice and Schmidly 2002). Our report establishes a baseline against which to measure future faunal changes during this period of changing climate and accelerated rate of sea-level rise. Given current vegetation trends (Huang et al. 2018, Wolner et al. 2013, Zinnert et al. 2019), forest- and wetland-dwelling mammals (e.g., Eastern Gray Squirrel, Eastern Fox Squirrel, White-footed Deermouse, Woodland Vole, Meadow Vole, Least Shrew, and American Mink) may be particularly sensitive to habitat changes on the islands. Changes in the distribution of island populations of mammals are likely to produce correlated changes in the genetic structure of those species (Loxterman et al. 1998, Moncrief et al. 2017). In light of declines in populations of beach-nesting and colonial waterbirds (Brinker et al. 2007, Williams et al. 2007), it will be important to monitor the occurrence and distribution of carnivores, particularly Raccoons and Red Foxes, on the islands (Dueser et al. 2013, Porter et al. 2015).

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