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Islands at bay: rising seas, eroding islands, and waterbird habitat loss in Chesapeake Bay (USA)

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Abstract Like many resources in the Chesapeake Bay region of the U.S., many waterbird nesting populations have suffered over the past three to four decades. In this study, historic information for the entire Bay and recent results from the Tangier Sound region were evaluated to illustrate patterns of island erosion and habitat loss for 19 breeding species of waterbirds. Aerial imagery and field data collected in the nesting season were the primary sources of data. From 1993/1994 to 2007/2008, a group of 15 islands in Tangier Sound, Virginia were reduced by 21% in area, as most of their small dunes and associated vegetation and forest cover were lost to increased washovers. Concurrently, nesting American black ducks (*Anas rubripes)* declined by 66% , wading birds (herons-egrets) by 51%, gulls by 72%, common terns *(Sterna hirundo)* by 96% and black skimmers (*Rynchops niger*) by about 70% in this complex. The declines noted at the larger Bay-wide scale suggest that this study area maybe symptomatic of a systemic limitation of nesting habitat for these species. The island losses noted in the Chesapeake have also been noted in other Atlantic U. S. coastal states. Stabilization and/or restoration of at least some of the rapidly eroding islands at key coastal areas are critical to help sustain waterbird communities.

Keywords American black ducks · Chesapeake Bay · Common terns · Islands · Wading birds · Waterbirds

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The Chesapeake Bay is the largest estuary in the United States and at one time was considered one of the most productive estuaries in the world (Ernst 2003; Ray and McCormick-Ray 2004; Schubel 1986). Rising sea levels since the end of the Pleistocene, and especially in the past century, have converted a drowned Susquehanna River system with a complex landscape into a simpler one with the loss of many of its islands (Cronin 2005; Leatherman et al. 1995; Wray 1992; Table 1). The growing concern over climate change effects, coupled with development of Geographic Information Systems (GIS) technology and fine-resolution imagery in recent years, has resulted in greater attention being paid to shoreline changes in the Bay and along the Atlantic Coast in general (Boesch et al. 2000; U.S. Climate Change Science Program, USCCSP 2009). This 2009 report highlighted the vulnerability of the mid-Atlantic region to relative sea-level rise (U.S. Climate Change Science Program 2009). In spite of the size of the

Table 1 Historic losses of large island in Chesapeake Bay (modified from Leatherman et al. 1995). Land masses are given in hectares

Island name	Historic area (date)	Recent area (date)	Percent loss	Comments
Smith	4,597 (1849)	3,260 (1987)	29	Submerging
Bloodsworth[a]	2,368 (1849)	1,905 (1988)	19	Submerging
Hoopers[a]	1,637 (1949)	1,257 (1994)	23	Submerging
Poplar[b]	460 (1880–90)	<1 (1998)	99	Abandoned 1930; being restored since 1998
Sharps	371 (1660)	0 (1962)	100	Hotel and island gone by 1962
Barren	292 (1664)	104 (1990)	64	Abandoned in 1916
St. Clements	167 (1624)	17 (2007)[c]	90	Abandoned in 1920s
Holland	90 (1668)	32 (2007)[c]	64	Abandoned in 1922

[a] Recent areas estimated from Digital Orthophoto Quarter Quadrangle measurements (DFB)

[b] Historic data based on U.S. Army Corps of Engineers estimate for Poplar Island only (Erwin et al. 2007); the figure (1,400 acres) from Leatherman et al. (1995) included the entire complex, including Jefferson and Coaches Islands

[c] D. Brinker, unpubl., digital orthoimage measurements; at St. Clements Island, erosion control using riprap began in the early 1980s, so there has been no change in area in the past two decades, comparing figures of Leatherman et al. (1995) with 2007 measurements (D. Brinker, unpubl.)

report (784 pages), there was no individual section devoted to the loss of islands in the Bay or region. While these federal reports on climate change evaluate loss of salt and brackish marshes in terms of hectares lost (or at risk), little attention is paid to the pattern of loss, i.e., the fragmentation and losses within an archipelago of marsh islands and their associated avifauna. Similarly, a recent review of the impacts of climate change on coastal systems virtually ignored the trophic connections between estuarine resources and vertebrate consumers such as waterbirds, marine mammals, and marine turtles (Harley et al. 2006). Not only does omitting part of the food web distort models that purport to represent ecosystem processes, but key trust resources (e.g., federal endangered species) of state and federal management agencies are relegated to lowest priority. Most of the conservation areas set aside within the Chesapeake system over the last century were created to protect migratory waterbird habitat within the national wildlife refuge system.

In this report, data are presented on island erosion and habitat changes at scales ranging from individual islands to the whole Bay. Objectives are: (1) to relate changes in a selected subset of islands in Virginia to the changes in populations of a suite of breeding waterbirds, many of which are included on state and federal lists of species of concern (e.g., the Atlantic Coast Joint Venture, Black Duck Joint Venture Management Board 2008; Kushlan et al. 2002; North American Waterbird Conservation Plan,) and (2) to suggest more effective management to conserve small islands and their avian inhabitants.

Study area and methods

While data for the entire Chesapeake Bay are of interest, the focus of this study is the Tangier Sound region of Virginia (Fig. 1). This region has received recent scrutiny because of its historical waterbird nesting activity over the past 20 years (G. Costanzo, unpubl. data). The data presented here are particularly valuable in that a recent time-analysis of island change in the Commonwealth of Virginia (DDM, unpublished data) could be directly coupled with thorough nesting inventories of ground-nesting waterbirds for the same periods. Information from other regions of the Bay is also mentioned for comparative purposes but the data are more sparse in other areas.

Island characteristics

Island areas were obtained from recent publications (Erwin et al. 2007; Leatherman et al. 1995; Wray 1992) for the some of the larger islands (>75 ha) in the Bay. Areal estimates of selected islands from the Leatherman et al. (1995) report were recently updated with 2007 imagery for some Maryland islands (DFB). Maryland aerial images (digital ortho-corrected) were acquired from the Maryland Department of Natural Resources during 2007 for estimating the area of smaller islands. All images were referenced to the NAD 83 coordinate system. The 2007 areas of smaller islands were estimated using ArcView software ver. 3.2.

To estimate the total number of islands potentially usable by nesting waterbirds in the Bay, digital orthophoto quarter quad (DOQQ) images were used in both Maryland and Virginia. The criteria included: (1) a true island at least 0.1 ha in area that is not inundated on daily high tides; (2) island has no permanent human habitation; and (3) is not connected or within close proximity (<2 km) to a mainland marsh that may support mammalian predators. The DOQQ images for Virginia used to estimate the number of islands in the Virginia portion of the Bay were from the early 1990s imagery (C. Gist, University of Virginia GeoSpatial Center)

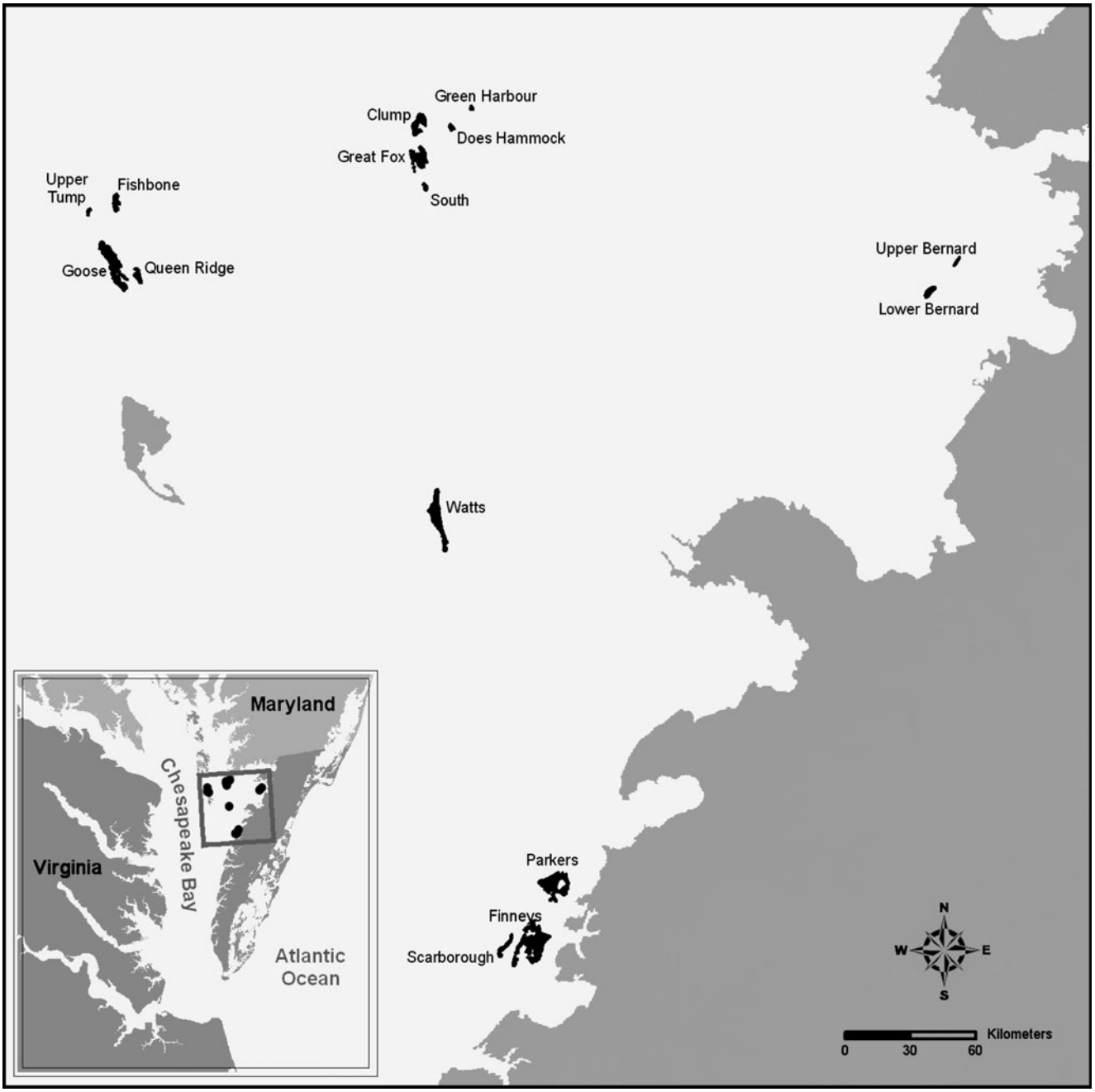

Fig. 1 Tangier Sound area, in southeastern Chesapeake Bay, Virginia. The islands shown have been the subject of island area change (1994 to 2007) and breeding waterbird studies from 1993 to 2008

and from 1988 to 1995 for Maryland (DFB, Maryland Department of Natural Resources data files).

For the Tangier Sound study area in Virginia, 1994 aerial photography was compared with 2007 photography. Land-water boundaries were digitized in ArcMap utilizing a scale of approximately 1:2000. Tide levels were estimated for each aerial photograph; it was determined that tide had little influence on our core land area calculations for the 1994–2007 comparisons as marsh boundaries were clearly delineated. Area change was then determined for 15 islands in the Tangier Sound area (Fig. 1). In addition, two islands in Maryland just north of Tangier Island (Shanks and Cheeseman) were evaluated for island loss rates using measurements from 1968 USGS topographic maps. These islands were important waterbird nesting sites since the 1970s (J. Weske, unpublished data), and marked the earliest colony sites of the eastern brown pelican (*Pelecanus occidentalis)* in the Bay (Brinker et al. 2007) The time frame spanned from 1968 topographic maps to the 1990–93 period.

Habitat characteristics and changes could not be accurately quantified at every island, given the low resolution of the 1994 imagery (5 m compared to 1-m resolution for the 2007 Virginia imagery) and lack of any ground habitat measurements from that period. Some important characteristics to nesting waterbirds include elevation change, as well as changes in the cover of forest (mostly mixed pine-deciduous trees), dune grass (*Ammophila breviligulata*), marsh grasses, and sand-shell substrate. Where possible, we evaluated some of the coarse level changes at some of the larger islands using the 1994 and 2007 imagery from GoogleEarth, then determining changes in polygon area using ARC GIS. In addition, some gross habitat changes were documented in our field notebooks over the past 15 years at all islands. For the Great Fox Islands, interviews with their field staff provided valuable information on major habitat changes occurring there since the mid 1990s.

Waterbird populations

The estimated breeding populations of waterbirds were extracted from both published sources (Brinker et al. 2007; Williams et al. 2007) and from recent statewide surveys and banding efforts conducted in Maryland and Virginia. These data are maintained and managed by the Maryland Department of Natural Resources' Natural Heritage Program in Maryland and by the Center for Conservation Biology, College of William and Mary in Virginia. For the colonially nesting species, the wading birds (herons and allies), gulls, and terns (including the Black Skimmer, *Rynchops niger*), we used the 1993 data (the most reliable of the earlier surveys) to compare with 2003 data for the Bay-wide population trends (Brinker et al. 2007); the Tangier Sound island population survey dates were 1993 compared with 2008 survey data; these dates corresponded most closely to those dates for which the island GIS data were used. For waterfowl breeding (emphasizing American black ducks) within the Tangier study area, a different protocol is followed with different timing (GC, unpublished report), so the best early data (1994) were used to compare with the most recent (2007) data. These also closely match the dates for the aerial photographic-GIS data comparison.

Field nest surveys in Tangier Sound were performed consistently over the time period of the study, with waterfowl surveys beginning in April each period, and colonially nesting species in mid-to-late May. For the colonially nesting species, a fixed-wing aerial survey was first performed to determine island use by nesting gulls, terns, skimmers and wading birds. This was followed by ground visitation by two or more field personnel within 10 days of the aerial survey where total nest counts were made at each of the islands once during the peak nesting period, June 1 to 20, in the survey years (see Watts and Byrd 2006 for protocol). For waterfowl, the nesting searches were conducted from April through June using ground searches and rope dragging to flush nesting birds. Islands were visited every 2–3 weeks during the nesting period.

Results

Bay-wide island changes

In Maryland, many of the larger islands identified earlier as having suffered high erosion (Leatherman et al. 1995) continue to lose significant land area (Table 1). Sharps Island was totally submerged by 1962, and the larger Poplar Island would have disappeared by 2000 if the U.S. Army Corps of Engineers and Maryland Port Administration had not intervened with a major restoration project (Erwin et al. 2007). Poplar's erosion may have been one of the highest in Maryland. In 1990, Leatherman et al. (1995) estimated it to be 50 ha in area, but by 1996, it was reduced to less than 1 ha (RME, pers. observ.). Although these large islands may provide nesting sites for some of the larger wading birds (tree-nesters), they are not often used by the ground-nesting species, due in large part to the presence of mammals (Erwin et al. 2003).

Of the small to moderate size islands, the 2007 Maryland DOQQ map data revealed that an estimated 200 islands were potentially suitable for either breeding colonial waterbirds or waterfowl in that portion of the Bay. From early (1977) waterbird surveys in the Bay, a total of 17 small islands that had been used at least 1 year for nesting had disappeared between 1977, the period of the first comprehensive surveys of colonial waterbirds in Chesapeake Bay (Erwin and Korschgen 1979) and 2007 (DFB, pers. observations). A similar loss assessment has not been done for the same time period in Virginia, however, the Virginia DOQQs from the early 1990s show that only about 60 islands existed at that time that might be considered suitable habitat for breeding waterbirds using the criteria described above.

Island changes — Tangier Sound

In Virginia, the Tangier Sound study area also exhibited extensive erosion, with an overall 21% loss of island area in only 13 years among the 15 islands (Table 2). In addition, the two important bird nesting islands just north of Tangier Sound in Maryland, Shanks and Cheeseman, were formerly estimated at 12.9 ha and 11.6 ha (1968 map), respectively, but disappeared by the early 1990s. The Tangier Island subset did not show any clear relationship between original island size and loss rates (Spearman r=0.201, P=0.47, n=15), contrary to expectations.

Table 2 Recent losses of island area (and percent decline) and breeding populations of waterbird guilds at selected islands in the Tangier Sound region of Virginia, 1993–1994 to 2007–2008. Areas are in hectares, and estimates of waterbird numbers are nesting pairs

Island	Area		Waders		Terns		Gulls		Ducks	
	1994	2007	1993	2008	1993	2008	1993	2008	1994	2007
Watts	36.3	25.4 (35)	1,172	392			0	92	12	5
Goose	30.2	25.1 (17)					0	2	17	5
Finneys	34.8	29.8(14)							8	4
Parkers	25.8	22.3 (14)							11	4
Great Fox	17.3	12.8 (26)			900	0	0	25	2	1
Clump	11.0	9.8 (11)			0	818	0	3	16	4
Does Hammock	0.9	0.9 (0)			0	512	0	2	2	1
Green Harbor	0.63	0.58 (8)							2	1
South	2.0	1.0 (50)							5	0
Fishbone	4.0	3.4 (17)					0	13	2	1
Queen Ridge	3.2	2.9 (9)							2	1
Upper Tump	1.8	1.6(11)			70	233	0	11		
Upper Bernard	0.79	0.33 (59)			550	0	2	4	19	0
Lower Bernard	4.7	2.4 (49)	0	199			670	36	5	12
Scarborough	2.8	2.3 (18)	25	0					15	4
TOTAL Per cent decline	175	138 (−21)	1,207	591 (−51)	1,520	1,563 (+3)[a]	672	188 (−72)	118	43 (−64)

[a] Only Forster's Terns increased; Common Terns and Black Skimmers declined from 750 pairs to 70 pairs from 1994 to 2008

Habitat changes within this Tangier Sound complex were apparent over the past 15 years (Table 3). Along with perimeter erosion, large areas of uplands (primarily pines and mixed hardwoods) were lost on the largest island, Watts. The wading bird colony declined, with some of the birds presumably moving to the shrubs on Lower Bernard Island (Tables 2 and 3). However, even islands with patches of *Iva* shrubs seem to be losing much of this habitat as well. Especially at the larger islands of Watts, Clump and Goose, the dune ridges that supported dune grass were largely destroyed, along with much of the understory greenbrier (*Smilax* spp.) and poison ivy (*Toxicodendron radicans*). These habitats are especially important for nesting ducks and gulls. For American black ducks (*Anas rubripes*), not only are the dune grasses important but to a lesser extent, forests provide nest cover as well. The losses of small dunes and expansion of sand-shell overwash on some islands (e.g. Clump) indicate that elevation has been reduced on this complex as overwash events have increased. Nonetheless, the expanded sand areas attracted a large number of terns (four species) and black skimmers which probably moved from the eroding South Island (A. Wickline, pers. commun., Table 3). The resulting marsh grasses and rushes (*Spartina alterniflora* and *Juncus roemerianus*) that are more halophytic and tolerant of inundation than upland grasses have expanded on the larger islands in the areas where dunes have been flattened. These areas are far less attractive to ground-nesting ducks, gulls, and terns-skimmers; the exception is the Forster's tern which usually nests in wrack (mostly dead *Zostera marina* mats) within *Spartina* marshes. This species is considered a marsh specialist and never nests in dry upland habitats (McNicholl et al. 2001). With more overwash sand and shell, nesting habitat may increase at least in the short term for common terns, black skimmers, and American oystercatchers (e.g. see the Clump Island change, Table 2). However, their ability to raise a brood to fledging becomes problematic with more frequent overwashes in recent years.

Bay-wide waterbird changes

The overall Chesapeake Bay populations of many species of waterbirds of concern have shown significant declines since the early 1990s (Tables 4 and 5), and earlier (Erwin and Korschgen 1979). For the gull and tern group, the declines are especially dramatic for common terns (*Sterna hirundo*), royal terns (*S. maxima*), gull-billed terns (*Gelochelidon nilotica*), and black skimmers (Table 4). Of the three breeding species of gulls, the great black-backed gull (*Larus marinus*) is the only species that appears to be increasing in the Bay (Table 4). For wading birds (herons, egrets, ibises), the largest declines have occurred among cattle egrets (*Bubulcus ibis*), snowy egrets (*Egretta thula*), and tricolored herons *(Egretta tricolor*) (Table 5). White

Table 3 Changes in habitat of Tangier Sound islands, 1994 to 2007. Where coarse habitat changes could be detected from the 1994 low-resolution aerial photography to the more recent 2007 +high-resolution imagery, areas are provided from ARC GIS analyses

Island	Habitat changes noted
Watts Island	Mixed pine forest at north end declined from 3.91 to 0.38 ha; forest area at south end declined from 4.67 to 4.20 ha. Low (1–2 m) dunes all along island lost as well as accompanying beach grass (*Ammophila breviligula* and other spp.). Woody ground cover reduced in forest as well. Reduced nesting cover.
Clump Island	A few high sandy areas remain, but two cuts have occurred through the island in recent years (A. Wickline, pers. comm.); middle section of the island had a narrow sand margin (ca. 0.1 ha) on the west side in 1994, which expanded (overwash) to 0.35 ha in 2007; southern end had a small (0.10 ha) sandbar in 1994, which expanded to 0.68 ha in 2007. Former western dune ridge (1–2 m high) now reduced by 60–70%, with loss of beach grasses. Overwash now more frequent.
Great Fox Complex	South Island eroding rapidly, with total loss of sandy areas that formerly (1993) had terns (P. Willey, pers. comm.). Overwashes on spring high tide. Southwest portion of largest island has encroaching overwash sand that is invading marsh area.
Goose	Flattening of all sand dunes on west side of island; loss of both beach grasses and some of the thicker *Spartina alterniflora* growth around dune edges. Island now cut into several portions at high tides. Much less ground cover for nesting.
Finney's	Island was lower than the other larger neighboring islands in 1994, with limited amount of ground cover (most *Juncus* spp. and a few shrubs, *Iva frutescens*). Cover more reduced in 2007, and island now cut into several sections.
Parkers	This had the highest (up to 3 m) dunes in early 1990s, but now all reduced with highest only ca. 1 m. Very little beach grass remaining. Much overwash and sandy deposits where vegetation existed 15 years ago; nesting cover very sparse.
Does Hammock	Little change in vegetation but some erosion with *Spartina* marsh being overwashed with ca. 1 ha of sand (2007). Flooding occurs more often.
Fishbone and Queens Ridge	Both remain very low islands; small berms with woody shrubs in early 1990s now with reduced vegetation, overall smaller habitat area.
Upper Bernard	Much smaller and thinner than in 1994; little to no beach grass left, mostly *Spartina* marsh; total loss of *Iva* and other woody vegetation. Frequent washovers in recent years.
Lower Bernard	Also much smaller. Low (1 m) dune ridges on north and west sides now gone; ducks shifted from nesting in beach grass areas to lower *Spartina* and *Scirpus* spp.marsh areas more prone to flooding. Pond on west side now breached and open to daily tides. Stand of *Iva* shrubs remains but has thinned the past decade, but still supports small wading bird colony.
Scarborough	South end has been cut in 2–3 separate sections; small dunes on west and south sides much reduced; grass area much reduced; North end now much thinner and *Iva* shrubs now much thinner than a decade ago.
Upper Tump	Small island that has little dense vegetation (formerly *Juncus* stands) remaining

ibis (*Eudocimus alba*) have expanded their range north in Virginia and thus, show marked numerical increases. Both black-crowned night herons (*Nycticorzx nycticorax*) and yellow-crowned night herons (*Nyctanassa violacea*) have shown increases (Table 5).

Waterbird changes — Tangier Sound

Within this Bay-wide perspective, changes in populations of waterbirds within the Tangier Sound study area revealed many changes since 1994 (Table 2). The tern group shifted locations among the islands, with a slight increase resulting only from one species; Forster's terns increased substantially from 770 pairs in 1993 to 1340 in 2008. However, simultaneous sharp declines were recorded for common terns (from 400 to 15 pairs) and black skimmers (350 to 55 pairs).

Among waterfowl, the American black duck declined from about 99 nesting pairs in 1994 to only 34 in 2007. Mallards (*A. platyrhynchos*) showed little change (11 to 9), but gadwall *(A. strepera)* declined from 8 pairs to zero by 2007.

Large changes in wading bird populations were recorded at Watts Island, part of a national wildlife refuge, which eroded by one-third from 1994 to 2007 (36 down to 24 ha). The largest decline was shown by cattle egrets, from 375 pairs in 1993 to zero by 2008; this also was reflective of Bay-wide declines (Table 4). Also, snowy egrets dropped from 425 pairs to only 85, tricolored herons from 48 to 10, little blue herons (*E. caerulea*) from 34 to 7 pairs, and glossy ibis (*Plegadis falcinella*) from 209 to 68 pairs over the same time period. Small numbers apparently moved from Watts to the Lower Bernard Island in 2008 (Table 2).

Among the gull species, only the great black-backed gull increased, from 22 pairs in 1993 to 125 pairs in 2008. This again reflects the patterns found in the Bay-wide estimates over the same time period. A large decline of both herring gulls and laughing gulls occurred at Lower Bernard Island

Table 4 Recent changes in the breeding populations of seabirds in the Chesapeake region, 1993 versus 2003 (modified from Brinker et al. 2007). Listed are numbers of breeding pairs estimated (and number of colonies) based on comprehensive surveys performed in both years

Species	1993	2003	Per cent change
Terns (and skimmers):			
Common Tern[a]	8,130 (56)	3,236 (45)	−60
Forster's Tern[b]	3,692 (84)	3,484 (79)	−6
Gull-billed Tern[a]	607 (31)	322 (17)	−47
Least Tern[a]	1,514 (42)	1,476 (38)	−3
Royal Tern	6,586 (4)	3,332 (5)	−49
Black Skimmer[a]	3,359 (29)	1,924 (18)	−43
Total	23,888	13,774	−42
Gulls:			
Great Black-backed Gull	600 (41)	1,770 (61)	+195
Herring Gull	10,931 (58)	7,484 (74)	−32
Laughing Gull	45,389	44,953	−1
Total	56,920	54,207	−5

[a] "High Conservation Priority" according to the Mid-Atlantic/New England/Maritimes (MANEM) Regional Waterbird Plan (http://www.fws.gov/birds/waterbirds/MANEM)

[b] "Moderate" Conservation Concern according to Kushlan et al. 2002 (North American Waterbird Conservation Plan; http://www.waterbirdconservation.org)

from 1993 to 2008, at the same time that wading birds increased there.

Discussion

The rapid losses of the Tangier Island islands, coupled with the more-well-known erosion or losses of larger islands elsewhere in the Chesapeake Bay, appears to be mirrored in the declines of many species of nesting waterbirds at the local and regional levels. The loss of the larger islands in the Chesapeake has received attention from a human history aspect, as 42 of the Bay's larger islands or island complexes have been carefully documented and supplemented with photographs and reproductions of historic nautical charts (Cronin 2005).The significant island loss rate in the Chesapeake Bay appears to have affected islands of all sizes and locations within the estuary. The formerly large, inhabited Poplar Island in Talbot County, Maryland was reduced from about 460 ha in the 1880s to less than 50 ha by 1990 (Leatherman et al. 1995), then rapidly down to only 1–2 by 1998 (Erwin et al. 2007). It is expected that, with a larger perimeter-to-area ratio, smaller islands would be subjected to more rapid loss than larger islands, however, our analysis of the selected Tangier Sound dataset did not reveal this. If the current area loss rate of about 20% in 13 years is representative throughout the Bay, there will be very few remaining islands by 2100 that will be suitable for nesting waterbirds.

Table 5 Recent population changes of wading birds[a] in the Chesapeake region, 1993 versus 2003 (modified from Williams et al. 2007)

Species	1993	2003	Per cent change
Great Egret	3,291	3,601	+9
Snowy Egret[b]	4,633	2,336	−28
Little Blue Heron[b]	658	644	−2
Tricolored Heron[b]	1,452	1,037	−29
Cattle Egret	3,799	657	−83
Black-crowned Night Heron	668	935	+40
Yellow-crowned Night Heron	410	476	+16
White Ibis	3	77	+2,467
Glossy Ibis	2,415	2,052	−15
Total	17,329	11,825	−32

[a] Great Blue Herons are not included here because most of their nesting is along the mainland tributaries of the Bay

[b] Species of "High Concern" along the Atlantic Coast (Kushlan et al. 2002)

The declines of most species of waterbirds of conservation concern at the Tangier Island suite of islands seemed to track the overall recent Bay declines, suggesting that the processes occurring in the Tangier region maybe symptomatic of the Bay system. Not only are islands being reduced in area by erosion but habitat changes are occurring in concert with these reductions. The losses of forest on Watts Island, and losses of dunes and dune grasses on Watts, Goose, and Clump for example reduce the habitat available especially for nesting ducks and gulls (Haramis et al. 2002; Stotts and Davis 1960). The evidence of dune losses and overwash increases suggests more frequent storm and tidal inundation on these islands. That the Forster's tern was the only species to show increases in the Tangier Sound is

instructive; this is the only species that specializes in marsh-nesting, often using the dead wrack material within *Spartina* or *Juncus* marshes (which can float) for its nests. As a result, it is much more tolerant of high water and conversion of forest-shrub uplands to marsh wetlands than are the other species.

Although our data were incomplete on American oystercatcher (*Haematopus palliatus*) nesting, this species may also benefit from eroding islands where vegetation dies or washes away during storms or high tide events and sand-shell habitat expands. At least in the Maryland portion of the Bay, they maybe increasing (Traut et al. 2006; Wilke et al. 2007). In 2007, it appeared that a number of these small Tangier Sound islands supported American oystercatcher pairs (GRC, unpublished data). The sand-shell areas were typically either too small or too low to attract colonies of common terns and black skimmers (except at Clump Island), as their declines suggest.

The loss of small estuarine islands utilized by waterbirds is not limited to just one region of Chesapeake Bay as losses have been noted in Eastern Bay, Kent County, Maryland (e.g., loss of Parsons Island and the near disappearance of Bodkin Island since 1980, DFB and RME, pers. observ.) and in the Guinea Marsh area in the York River mouth, Virginia (loss of 7 of 23 islands from 1994 to 2007; J. Tu, University of Virginia, unpublished data). This pattern seems to be found elsewhere along the Atlantic Coast as well. In the Pamlico Sound region of North Carolina, a number of small dredged material islands have been used by colonial waterbirds for decades (Erwin et al. 2003; Parnell and Shields 1990), however many have eroded rapidly in the past two decades (Parnell and Shields 1990; D.H. Allen, North Carolina Wildlife Resources Commission, pers. comm.). Thus, the colony site options for many species have become more limiting (Erwin et al. 2003). Further north on the ocean coast of Maryland, the situation is similar with former (1970s) tern nesting colonies on two dredged material islands in Sinepuxent Bay now gone, or small estuarine marsh islands in Chincoteague Bay greatly reduced in size (Brinker et al. 2007). Two marsh islands in the Coards Marshes group that had nesting Forster's terns and herring gulls in the 1970s are now gone (RME, pers. observ.). In New York, Jamaica Bay, an important urbanized area for many waterbirds, has experienced losses among a number of islands from a variety of factors. Hartig et al. (2002) reported about a 12% loss of sampled marshes on these islands from 1959 to 1998. In Barnegat Bay, New Jersey, losses of seven small marsh islands, with accompanying nesting common terns and/or black skimmers, have been noted over the past 30 years (J. Burger, Rutgers University, pers. comm.).

What alternatives do nesting waterbirds have when former small islands disappear or become uninhabitable? One case study at Poplar Island near Maryland's eastern shore is illustrative. Shortly after the ca. 500-ha dredged material island was created (starting in 1999), large numbers of common terns colonized the site, with rapid growth likely reflecting relocations of the terns from within the Bay and possibly elsewhere (Erwin et al. 2007). While larger islands may occasionally provide suitable habitat, they usually are inhabited by mammalian predators such as foxes (*Vulpes vulpes*), raccoons *(Procyon lotor*), Norway rats (*Rattus norvegicus*) and other species (Erwin and Beck 2007; Erwin et al. 2003, 2007; Haramis et al. 2002). As a result, seemingly attractive sites may prove to be a "sink" for some species such as common and least terns (Erwin et al. 2007). No doubt other factors could be contributing to population changes of waterbird. The increasing number of great black-backed gulls in the Bay could increase predation on young (Brinker et al. 2007). In addition, changes in fish populations (Watts et al. 2006) and conditions on the wintering grounds may be impacting a number of waterbird species; however, nesting habitat modification is one of the more tractable management tactics that could enhance populations.

Future directions

The declining quality of the Chesapeake Bay in general (Ernst 2003; Ray and McCormick-Ray 2004) and loss of many potential nesting islands for waterbirds places additional bottlenecks on populations that are already under stress from many sources (Erwin and Beck 2007; Ray and McCormick-Ray 2004; Terborgh 1989). The need to stem the loss of small islands is obvious, however, the resources required to stabilize the shorelines of selected islands would be substantial. At present, the Bay islands being 'restored,' stabilized, or augmented are those large sites identified by the U.S. Army Corps of Engineers as dredged material disposal sites such as Maryland's Poplar Island, Hart-Miller Island, and Virginia's Craney Island (Elizabeth River). The dredged material consists of fine sediments from the navigation channels within the Bay system; they are removed during maintenance operations and are disposed of either in 'upland cells' (up to 8 m above mean high water) or become the substrate for wetland cells (Poplar and Hart-Miller islands). Two of the newer sites identified for disposal in Maryland are Barren Island and James Island. Although wildlife and fisheries resource use has been incorporated into the planning for these latter two sites, their large size and proximity to the mainland may result in mammalian colonization over time.

Although it would be costly, a state-federal cost share approach might be taken to stabilize at least 5–6 small (from 2 to 5 ha) islands along both the eastern and western

margins in both the Maryland and Virginia portions of Chesapeake Bay in areas known to have had significant waterbird nesting populations (e.g., Tangier Sound). Stabilizing these islands should also facilitate the reestablishment of submerged aquatic vegetation (SAV) and oyster (*Crassostrea virginica*) reefs, also key targets of the Chesapeake Bay restoration effort. Use of geotextile tubes has been shown to be relatively cost-effective in stabilizing small marsh restoration projects, at least over the short term (R. M. Erwin, pers. observ.).

Finally, additional research is needed to address other limiting factors of waterbirds in many coastal areas, not just in the Chesapeake. Very little is known about how many species of waterbirds may respond to fishery harvest regulations or shifting fisheries communities (Viverette et al. 2007) or how many 'new age' contaminants maybe affecting waterbirds (Rattner and McGowan 2007). In any case, population trajectories of waterbirds as top consumers may provide a useful bioindicator of the overall status and condition of coastal estuaries (Erwin and Custer 2000; Kushlan 1993).

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