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Photo: Daniel Nellis

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Current status and 21st century population trends of breeding seabirds in the U.S. and British Virgin Islands

Paige A. Byerly*[1,2], Susan Zaluski[3], Daniel Nellis[4,5], Judy Pierce[5,6], Paul L. Leberg[2,7]

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Cover Page: Roseate Tern (*Sterna dougallii*) adult on its nest incubating an egg and panting in the heat. Shark Cay, St. Thomas, U.S. Virgin Islands on 5 June 2017. Photographer: Daniel Nellis

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*Corresponding author: [1]Smithsonian's National Zoo and Conservation Biology Institute, Washington, DC 20008, USA; e-mail: pabyerly@gmail.com

[2]Department of Biology, University of Louisiana at Lafayette, Lafayette, LA 70503, USA;

[3]H. Lavity Stoutt Community College, Paraquita Bay, Parham Town VG1110, British Virgin Islands; e-mail: szaluski@hlscc.edu.vg

[4]U.S. Department of Agriculture, St. Thomas, USVI 00802, USA; e-mail: daniel.nellis@usda.gov

[5]Formerly: U.S. Virgin Islands Division of Fish and Wildlife, Nazareth, St. Thomas, USVI 00802, USA

[6]e-mail: vitropicbird@yahoo.com

[7]e-mail: paul.leberg@louisiana.edu

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Abstract

Data from long-term monitoring (LTM) programs can provide important insights into wildlife population trends and aid in the conservation of declining species. There is a lack of such LTM data across taxa in the Caribbean, which can make accurate identification of population dynamics challenging. When rigorous data derived from LTM are not available, comparison of count data derived from single season surveys can still provide valuable insights into population trends, even when data are collected by different methods. In the Virgin Islands, seabird declines have been noted across species groups, but few estimates of temporal trends exist. We compared estimated population sizes from two time points in the early 21st century to more rigorous count data collected in 2016–2018 for seven seabird species. We found widespread declines, with the magnitude of declines greater for resident species (Brown Boobies *Sula leucogaster*, Masked Boobies *Sula dactylatra*, and Brown Pelicans *Pelecanus occidentalis*) than for migratory species (Royal Terns *Thalasseus maximus*, Sandwich Terns *Thalasseus sandvicensis acuflavidus*, and Roseate Terns *Sterna dougallii*). We also found that Red-footed Boobies (*Sula sula*) were extirpated from the region. Our results suggest that immediate management intervention is needed in the Virgin Islands to prevent further seabird declines and potential species extirpations.

Keywords

island conservation, marine environment, population monitoring, seabird, Virgin Islands

Resumen

Estado actual y tendencias poblacionales del siglo XXI de las aves marinas nidificantes en las Islas Vírgenes británicas y estadounidenses • Los datos de los programas de monitoreo a largo plazo (LTM) pueden brindar información importante sobre las tendencias poblacionales de la vida silvestre y ayudar en la conservación de las especies en declive. Existe una falta de este tipo de datos en todos los taxones en el Caribe; lo que puede dificultar la identificación precisa de las dinámicas poblacionales. Cuando datos rigurosos derivados de LTM no están disponibles, la comparación de datos de conteos obtenidos de muestreos de una sola temporada aún puede proporcionar información valiosa sobre las tendencias poblacionales; incluso cuando los datos se recopilan mediante diferentes métodos. En las Islas Vírgenes, se han observado disminuciones en las poblaciones de aves marinas en todos los grupos de especies, pero existen pocas estimaciones de tendencias temporales. Comparamos los tamaños poblacionales estimados de dos puntos temporales: a principios del siglo XXI con datos de conteo más rigurosos recopilados entre 2016 y 2018 para siete especies de aves marinas. Encontramos disminuciones generalizadas, con una magnitud mayor para las especies residentes (*Sula leucogaster*, *Sula dactylatra* y *Pelecanus occidentalis*) que para las migratorias (*Thalasseus maximus*, *Thalasseus sandvicensis acuflavidus* y *Sterna dougallii*). También encontramos que la especie *Sula sula* fue extirpada de la región. Nuestros resultados sugieren que se necesita una intervención de manejo inmediata en las Islas Vírgenes para evitar una mayor disminución de las poblaciones de aves marinas y la posible extirpación de especies.

Palabras clave

aves marinas, conservación de islas, Islas Vírgenes, medio ambiente marino, monitoreo de poblaciones

Résumé

Situation et tendances démographiques des oiseaux marins nicheurs au XXIe siècle dans les Îles Vierges américaines et britanniques • Les données issues de programmes de suivi à long terme peuvent (LTM) fournir des informations importantes sur les tendances des populations d'animaux sauvages et contribuer à la conservation des espèces en déclin. Ce type de données manque pour les taxons des Caraïbes, ce qui peut rendre difficile la caractérisation précise de la dynamique des populations. Des données issues de dénombrements réalisés au cours d'une seule saison peuvent cependant fournir des indications précieuses sur les tendances des populations, même lorsqu'elles sont recueillies par des méthodes différentes. Sur les Îles Vierges, le déclin des oiseaux marins a été constaté dans tous les groupes d'espèces, mais il existe peu d'estimations des tendances au cours du temps. Pour sept espèces d'oiseaux marins, nous avons comparé la taille des populations estimée à partir de deux points temporels au début du XXIe siècle à des données de comptage recueillies de manière plus rigoureuse en 2016–2018. Nous avons mis en évidence un déclin généralisé dont l'ampleur est plus importante pour les espèces présentes toute l'année (Fou brun *Sula leucogaster*, Fou masqué *Sula dactylatra*, et Pélican brun *Pelecanus occidentalis*) que pour les espèces migratrices (Sterne royale *Thalasseus maximus*, Sterne caugek *Thalasseus sandvicensis acuflavidus*, et Sterne de Dougall *Sterna dougallii*). Nous avons également constaté que le Fou à pieds rouges (*Sula sula*) avait disparu de la région. Nos résultats suggèrent qu'une intervention de gestion immédiate est nécessaire sur les Îles Vierges pour empêcher de nouveaux déclins des oiseaux marins et la disparition potentielle de ces espèces.

Mots clés

conservation des îles, environnement marin, Îles Vierges, oiseaux marins, suivi de population

Seabirds are one of the most imperiled avian groups, with over 43% of species declining due to anthropogenic causes such as human disturbance, predation by invasive species, and changes to prey bases (Dias *et al.* 2019). Accurate quantification of population trends is a necessary first step in conservation planning to prevent further declines. Long-term monitoring (LTM) data, or data collected via standardized survey methods across long temporal periods, can be used to demonstrate such trends (Paleczny *et al.* 2015). However, despite their imperiled status, only 19% of seabird populations are actively monitored (Paleczny *et al.* 2015). This is in part because regular yearly surveys of seabird colonies are not possible in many regions, particularly in the tropics. In the tropics, island seabird colony sites can be difficult to access due to both financial and logistical constraints, limiting the collection of LTM data.

Standardized, rigorous monitoring programs are crucial to ensure that surveys are reproducible and assessments of population trends are valid. Important factors to consider in designing seabird surveys and collecting data include observer skill level, survey type, count phenology, and nest concealment (Haynes-Sutton *et al.* 2018), as well as the spatial extent of surveys. When colonies are situated among small, widespread islands and cays, surveys are complicated by the logistic capabilities of working across a broad spatial scale. However, for species that may periodically move colony sites, it can be unclear if count numbers represent actual declines or undercounting when potential nesting sites in a region are not surveyed (Pierce 2009, Haynes-Sutton *et al.* 2018). Timing of surveys is also critical. While seabirds in northern latitudes breed within a short window, many seabird species in the tropics breed year-round or have staggered breeding seasons through the year, making timing of counts an important component of accurately assessing population sizes (Haynes-Sutton *et al.* 2018). Tropical seabirds are also more prone to skip breeding when conditions are poor (Monticelli *et al.* 2008, Waugh *et al.* 2015), meaning that counts must be conducted over multiple years to accurately assess trends. All of these factors represent potential sources of error in count datasets that can bias results and invalidate comparisons between time periods, which can render the data unusable for seabird conservation planning.

Data deficiencies are especially a problem in the Caribbean, where limited capacity, vast number of breeding islands, and large numbers of independently operating nations make it difficult to evaluate seabird abundances and population trends across the region (McGowan *et al.* 2006, Bradley 2009). In the Caribbean, avian monitoring is often conducted through community science efforts. Citizen science programs such as the Caribbean Waterbird Census (CWC; birdscaribbean.org/our-work/caribbean-waterbird-census-program) have been highly effective for land- and shorebird monitoring in the Caribbean, leading to the creation of LTM datasets. Such monitoring programs are not likely to be successful for all avian taxa, however. Seabirds nest on offshore islands that are difficult to access and often closed to the public, making monitoring typically only feasible for local agencies, NGOs, and researchers with specialized training. Accordingly, much available seabird knowledge in the Caribbean is based on historical records, anecdotal evidence, or "snapshot" single-year surveys (McGowan *et al.* 2006, Zaluski *et al.* 2018). Given the dearth of regular monitoring data across much of the region, any count data over large temporal periods can provide valuable information, but such data are often not used or compared because of inconsistencies in collection methods. However, even when methods of data collection are not consistent, comparison of temporal count data can be used to demonstrate overall population trends, even when the absolute differences between time periods should not be quantified.

Here, we present compiled breeding records of priority colonial seabird species from the Virgin Islands (VI). Located approximately 97 kilometers east of Puerto Rico, the VI comprise an archipelago of more than 60 islands, rocks, and cays divided into two separate political territories: U.S. (USVI) and British (BVI). The USVI and BVI are approximately 1 km apart (Fig. 1), making it likely that seabird populations are shared between the two territories but are governed separately, making coordination of management activities challenging. Available evidence has also shown widespread seabird extirpation and declines in the VI, particularly in the BVI (McGowan *et al.* 2006, Pierce 2009, Schreiber and Pierce 2009, Zaluski *et al.* 2018, Soanes *et al.*

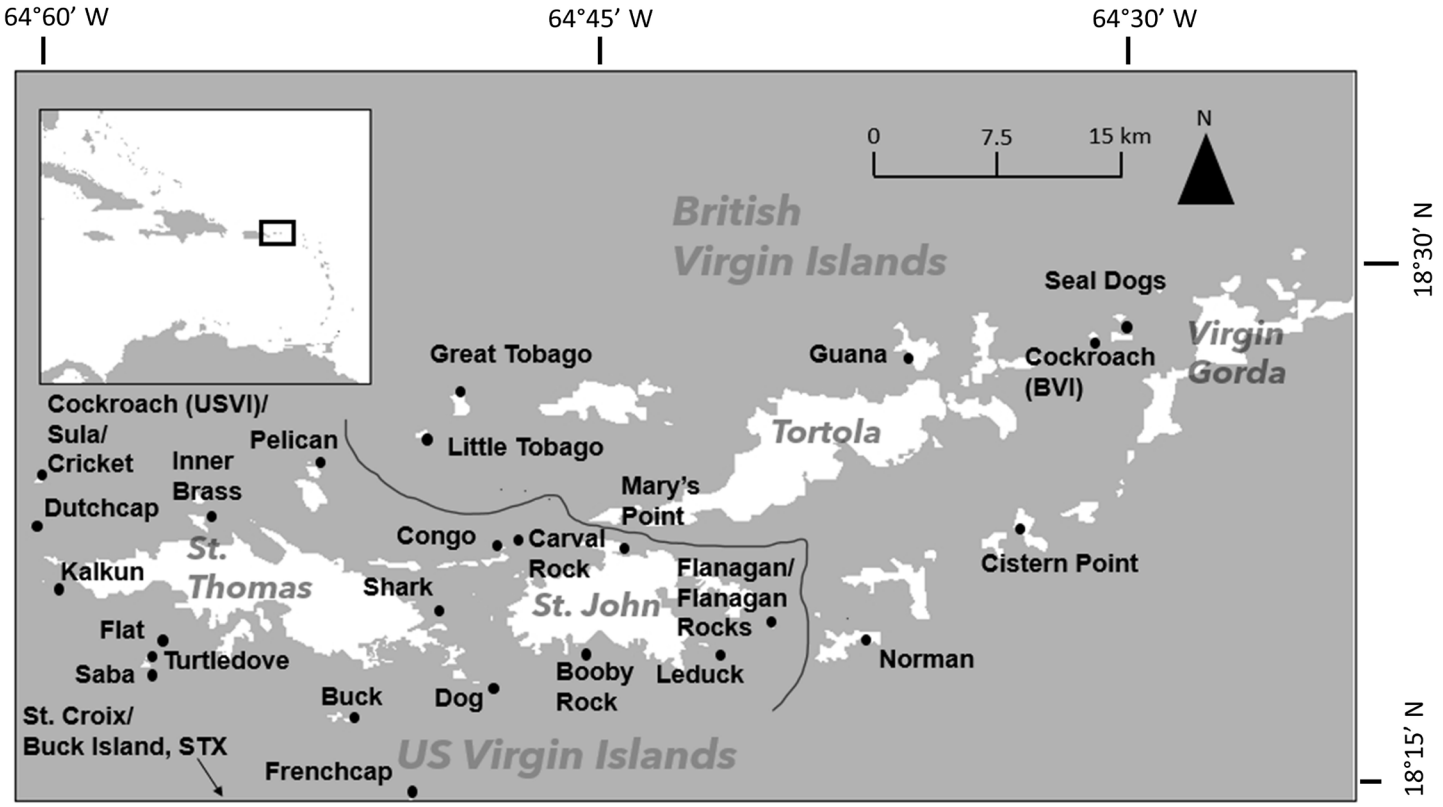

Fig. 1. Extent of study region in the U.S. and British Virgin Islands with locations of important seabird nesting islands.

2020), but most data collection has focused only on key species of conservation interest. We present updated status information for seven seabird species in the VI with the goal of informing seabird protection and management efforts in the Caribbean.

Methods

Study Area

We counted seabirds around the islands of St. Thomas and St. John in the USVI and the majority of the BVI (Fig. 1), as this area contains the most breeding seabirds in the VI. We omitted St. Croix in the USVI due to an inability to procure count data for the island, despite the recorded presence of nesting Least Terns (*Sternula antillarum*) on the island. We also omitted Anegada in the BVI due to limited resources to travel to the island for seabird surveying, although historically Sandwich Terns (*Thalasseus sandvicensis acuflavidus*), Least Terns, and Laughing Gulls (*Leucophaeus atricilla*) were known to nest on the island (Schreiber and Pierce 2009). Seabirds in the VI nest exclusively on tiny islands and cays, most of which are volcanic in origin and are steep, rugged, and difficult to access. Presence of native and introduced fauna on these islands varies; there are no native terrestrial mammals in the VI, and invasive mammalian presence is highly site-specific. On offshore nesting cays, common invasive mammals include black rats (*Rattus rattus*), domestic goats (*Capra hircus*), and house mice (*Mus musculus*).

Ownership and management of cays and islands is complex for both territories. In the USVI, 29 of the 57 islands with potential nesting seabird presence (which varies annually) are owned and managed by the Department of Planning and Natural Resources (DPNR) and are closed to public access (Pierce 2009, Murry *et al.* 2019). Fourteen of the 57 are privately owned and managed (Murry *et al.* 2019). In the BVI, protection varies widely among the 42 cays that represent potential seabird habitat (McGowan *et al.* 2006). Several of these, including West Dog and the Tobagos, are designated national parks with restricted entry, but the rest are either public land not closed during the seabird breeding season or are private and managed independently. For all protected islands across both territories, however, enforcement of restrictions is minimal, regardless of protected status (McGowan *et al.* 2006; Pierce 2009).

Approximately 17 seabird species historically bred in this region (Schreiber and Pierce 2009). For the purposes of this study, we focused only on colonially breeding seabirds with populations that were surveyed as of 2018 and include data only for species that we feel had rigorous enough count data to detect changes over time. We present here temporal data for Brown Boobies (*Sula leucogaster*), Masked Boobies (*Sula dactylatra*), Red-footed Boobies (*Sula sula*), Brown Pelicans (*Pelecanus occidentalis*), Roseate Terns (*Sterna dougallii*), Royal Terns (*Thalasseus maximus*), and Sandwich Terns. Contemporary surveys have not been conducted for Laughing Gulls, Sooty Terns (*Onychoprion fuscatus*), Bridled Terns (*Onychoprion anaethetus*), Brown Noddies (*Anous stolidus*), or Magnificent Frigatebirds (*Fregata magnificens*). We therefore do not include these species, despite the fact that available evidence indicates that many have declined in the region (Pierce 2009, Schreiber and Pierce 2009, Zaluski *et al.* 2018). We also do not include records for shearwaters (Procellariidae) and tropicbirds (Phaethontidae) as individuals from these groups have low abundance and conceal their nests, and contemporary surveys for these species have been inconsistent

and across a limited spatial scale (McGowan *et al.* 2006).

For our study, we grouped species as residents (Brown Pelicans, Red-footed Boobies, Masked Boobies, and Brown Boobies) and migrants (Sandwich, Royal, and Roseate Terns). These groupings do not necessarily reflect underlying life history traits, but are instead intended to highlight temporal occupancy. Resident species occupy the territories year-round, and therefore may be more vulnerable to seasonal stressors such as increased sea surface temperature and hurricanes, which are more frequent in the late summer and early autumn. By contrast, migratory species are only present in the VI in the spring and early summer (Rogers *et al.* 2008). By migrating, these species avoid poor autumn conditions, but also experience different pressures on wintering grounds that may influence population trends (Shealer *et al.* 2005).

Data Collection

Published historical breeding records for seabirds in the West Indies are scarce. Methods can vary considerably among survey types, and quantifying changes in counts conducted across different time periods can result in inaccurate interpretations of population trends due to discrepancies in survey methods. Because of this, we considered early 21st century population counts to identify the direction of any changes rather than attempting to quantify statistics such as annual percentage growth rate. When data were recorded as a range, we based temporal comparisons on the median estimate from each range. All results for both early 21st century and recent counts are presented as number of breeding pairs. For recent counts, one egg or chick was counted per nest, with nest counts then representing number of breeding pairs.

We conducted surveys in 2016–2018 for all species but Roseate Terns, which we surveyed in 2016–2019. For all species, surveys took place on small cays and islands across the VI. Surveying was coordinated in the USVI by the Division of Fisheries and Wildlife (DFW) and in the BVI by the Jost Van Dykes Preservation Society (JVDPS). For all species, we conducted counts both directly prior to and in the year after the 2017 Hurricanes Irma and Maria, allowing us to assess the immediate effects of these storms on both resident and migratory species. Although the hurricanes occurred after peak nesting for resident species and after migratory species had left the region, we anticipated that the severe weather had potential to cause mass mortality of resident species or to alter nest site habitat, which could have resulted in lower colony attendance in 2018 (Raynor *et al.* 2013).

Resident Seabirds.—For resident seabirds, we compiled historical data as published in Schreiber (2000), Collazo *et al.* (2000), Schreiber and Pierce (2009), and Pierce (2009). These records identified individual breeding sites, allowing us to detect changes in site use, and represented best expert estimates of seabird population abundances in the region at the time of or prior to publication.

We surveyed 4 known nesting locations for Brown Pelicans (Congo, Dutchcap, Inner Brass, Mary's Point). We visited each location 3 times between April and December in 2016, 2 times between March and November in 2017, and 1 time in March of 2018. We surveyed 5 known nesting islands for the 3 booby species (Cockroach [USVI], Dutchcap, Frenchcap, Kalkun, and Sula). We visited each island 4 times between January and April of 2016, and December [of the preceding year] to November of both 2017 and 2018. Surveys were timed to account for the 2 laying peaks in September–October and March–April (Collazo *et al.* 2000). All 4 of these resident species exhibit high degrees of site philopatry, and no other islands have been identified as breeding sites during either historical or contemporary seabird surveys (Pierce 2009). As annual coverage of potential nesting islands in the region for other research purposes is extensive, it is improbable that any colonies went undetected during the time of our study. For pelicans, counts were primarily boat-based, as Brown Pelicans in the VI nest in canopies on steep, forested slopes, making colonies difficult to access. During these boat-based surveys, we only recorded nests with visible chicks present and therefore likely underestimate the total breeding pairs in the territory, as we did not include failed or undetected nests in the surveys. For the booby surveys, we conducted counts on foot, with an observer entering the colony and counting all chicks and eggs. Following the reporting protocol of the DFW, our estimate for the number of breeding pairs of each resident species is the sum of the highest count from each island surveyed. This protocol minimizes the likelihood of double-counting eggs and chicks or re-nesting attempts. Highest counts were used regardless of survey date because colonies have asynchronous breeding periods. We do not present data for resident Brown Pelicans or Brown Boobies in the BVI, despite the fact that breeding populations appear to have declined considerably. We could not conduct full temporal and spatial censuses in this territory due to logistic limitations and complications of island ownership. Both Masked and Red-footed Boobies have been extirpated from the British Virgin Islands, but it is not known if they bred there in significant quantities historically (Schreiber and Pierce 2009).

Migratory Seabirds.—For Sandwich and Royal Terns, we relied on population estimates from Chardine *et al.* (2000), Norton (2000), Schreiber and Pierce (2009), and Pierce (2009) for early 21st century records. As with resident seabirds, survey methods were not well characterized, and estimates represent best expert opinion at the time of publication. We did not compile historical data for Roseate Terns, as nest counts for the period 1993–2014 have already been summarized in Soanes *et al.* (2020).

For recent counts of the three tern species, we conducted 1 peak period survey per year roughly between the last week of May and the first week of June, with the target of surveying at nesting peak but before chicks hatched. Royal and Sandwich Terns typically nest in shared colonies and while they may shift colony sites over time, they are largely philopatric in the VI (Pierce 2009). We therefore focused our effort for these two species on previously identified nesting islands (Dog, Flat, Pelican, and Turtledove). Given our extensive searches for Roseate Tern colonies during the tern breeding season (described below), we are confident that no Royal or Sandwich Tern colonies were overlooked. For recent counts of these species, we approached colonies on foot, flushed all birds, and counted nests. When possible, two observers counted nests and the total was averaged. We differentiated eggs of both species by size and appearance, as Royal Tern eggs are considerably larger (63.0 mm × 44.5 mm) and buffier in hue than Sandwich Tern eggs (50.5 mm × 35.7 mm) and the egg size ranges do not overlap (Shealer *et al.* 2020;

Buckley *et al.* 2021).

Roseate Terns occupy both the BVI and USVI and shift colony sites yearly, with typically 4–7 colony sites occupied annually between the two territories. Because of this, we conducted an extensive initial annual survey of all potential nesting islands across both territories to ensure that no colonies were overlooked and omitted from the count. As over 30 nesting islands have been identified, we do not list all islands here, but see Soanes *et al.* (2020) for a full summary of islands and monitoring effort. Roseate Tern colonies in the VI can be highly variable in terms of density, nesting substrate, and degree of nest concealment (Byerly *et al.* 2021). In the USVI, we conducted surveys by entering colonies on foot, thereby flushing adults, and searching for all nests. When possible, two or more observers counted each colony and totals were averaged afterwards to account for biases in observer detection. In the BVI, we conducted colony surveys both by foot and by boat. For both territories, when direct nest counts were not possible (due to hazards of accessing the island), we conducted remote counts by boat by approaching the island as closely as possible without causing birds to flush, moving the boat at idle speed parallel to the shoreline, and counting all visible incubating adults. For boat-based surveys, multiple observers conducted each count, at least two counts were conducted, and totals were then averaged. Because colonies surveyed by boat were smaller and situated on steep, unvegetated cliffs (thus preventing access), and because one Roseate Tern parent always remains at the nest during incubation (Byerly *et al.* 2021), we reasoned that boat counts probably provided a high degree of accuracy, despite the discrepancies in count methods. Although we believe Roseate Terns in both territories represent one contiguous breeding population (Soanes *et al.* 2020), we present results from the USVI and BVI separately to highlight specific differences in occupancy for each territory.

Results

Resident Seabirds

Boobies were present during the most recent surveys on 5 of the 6 historical breeding islands in the USVI (Pierce 2009), excluding only Cricket Cay (Table 1). Brown Pelicans were present on all 4 of their identified historical breeding cays (Table 1). Full survey metadata, including number of inferred individuals per island (based on number of nests), number of eggs, chicks, and juvenile birds recorded, and approximate date surveyed, are included in Supplemental File 1.

Comparison of early 21st century and recent population numbers of resident seabirds in the USVI showed substantial declines, with contemporary Brown Pelican and Brown Booby populations both at less than 60% of the low range of early 21st century estimates (Table 2). Red-footed Boobies were extirpated from the territory sometime in the early 2000s, with last

Table 1. Islands and cays with resident breeding seabird presence during 2016–2018 seabird surveys in the U.S. Virgin Islands.

Island	Latitude	Longitude	Species
Cockroach (USVI)	18°24'15.48" N	65°3'32.4" W	Brown, Masked Booby
Dutchcap	18°22'46.56" N	65°3'41.4" W	Brown Booby, Brown Pelican
Frenchcap	18°16'31.18" N	64°53'15.45" W	Brown, Masked Booby
Kalkun	18°21'2.52" N	65°3'28.08" W	Brown Booby
Sula	18°24'12.6" N	65°3'28.44" W	Brown, Masked Booby
Congo	18°22'3.7" N	64°48'12.74" W	Brown Pelican
Inner Brass	18°23'4.56" N	64°58'28.92" W	Brown Pelican
Mary Point	18°22'21.72" N	64°44'42.36" W	Brown Pelican

Table 2. Population estimates for resident seabirds in the U.S. Virgin Islands (as number of breeding pairs) in the 21st century.

Year	Brown Pelican	Masked Booby	Red-footed Booby	Brown Booby
2000	300–350[a]	105[b]	187–191[b]	670[b]
2009[c]	325–425	45–75	100–150	500–1000
2013[d]	NA	19	NA	242
2016[d]	158	14	0	109
2017[d]	147	17	0	173
2018[d]	105	17	0	160

[a]Population estimate as reported in Collazo *et al.* (2000)
[b]Population estimate as reported in Schreiber (2000)
[c]Population estimate as reported in Pierce (2009)
[d]Sum of the highest nest count on each island per year

Table 3. Islands and cays with migratory seabird colony presence during the 2016-2019 seabird surveys in the U.S. (USVI) and British Virgin Islands (BVI)

Island	Year	Territory	Latitude	Longitude	Species
Shark	2016–2019	USVI	18°20'14.28"N	64°50'40.56" W	Roseate Tern
Flanagan	2019	USVI	18°19'36.23" N	64°39'1.12" W	Roseate Tern
Flat	2016–2019	USVI	18°19' 3.64" N	64°59'20.14" W	Roseate Tern
Turtledove	2016–2019	USVI	18°18'30.74" N	65°0'2.06" W	Sandwich, Royal Tern
Pelican	2017, 2019	USVI	18°19'57.14" N	64°37'32.51"	Roseate Tern
Kalkun	2017	USVI	18°21'2.52" N	65°3'28.08" W	Roseate Tern
Dog	2016–2019	USVI	18°17'42.72" N	64°49'0.48" W	Roseate (2017), Sandwich, Royal Tern
Congo	2017	USVI	18°22'3.7" N	64°48'12.74" W	Roseate Tern
Carval Rock	2016–2019	USVI	18°22'10.92" N	64°47'38.40" W	Roseate Tern
Leduck	2016–2018	USVI	18°18'55.8" N	64°41'12.84" W	Roseate Tern
Booby Rock	2018	USVI	18°18'8.28" N	64°42'35.28" W	Roseate Tern
Saba	2016	USVI	18°18'19.8" N	65°0'0" W	Roseate Tern
Cricket	2016	USVI	18°24'31.32" N	65°2'57.84" W	Roseate Tern
East Seal Dog	2019	BVI	18°30'24.12" N	64°25'56.28" W	Roseate Tern
Cistern Point	2017, 2019	BVI	18°22'50.16" N	64°30'54.36" W	Roseate Tern
Cockroach (BVI)	2018–2019	BVI	18°24'15.48" N	65°3'32.4" W	Roseate Tern
Guana	2017	BVI	18°28'31.08" N	64°34'10.6" W	Roseate Tern

Table 4. Population estimates for migratory seabirds in the U.S. Virgin Islands (as number of breeding pairs) in the 21st century.

Year	Survey Date	Royal Tern	Sandwich Tern
2000	NA	150–200[a]	228–1378[b]
2009[c]	NA	200–780	400–900
2016[d]	31 May–2 June	124	455
2017[d]	26–31 May	116	299
2018[d]	28–30 May	118	342

[a]Estimate as reported in Chardine *et al.* (2000)
[b]Estimate as reported in Norton (2000)
[c]Estimate as reported in Pierce (2009)
[d]Nest count by USVI Division of Fish and Wildlife

Table 5. Results from recent population surveys of Roseate Terns in the U.S. (USVI) and British Virgin Islands (BVI; data presented as number of breeding pairs). Nest counts were conducted by PB and DN with the USVI Division of Fish and Wildlife in the U.S. Virgin Islands and by PB and SZ with the Jost Van Dykes Preservation Society in the British Virgin Islands.

Year	Survey Date	Territory	Breeding Pairs
2016	1–2 June	USVI	1,143
	5 June	BVI	125
		Total	**1,268**
2017	17 May–1 June	USVI	750
	6 June	BVI	126
		Total	**876**
2018	29–30 May	USVI	836
	2 June	BVI	227
		Total	**1,063**
2019	5–6 June	USVI	472
	9 June	BVI	130
		Total	**602**

recorded sightings on Frenchcap in September 1998 (3 chicks; JP unpubl. data) and on Dutchcap in July 1999 (58 adults; JP unpubl. data), although published accounts still record the species as extant as of 2009. Masked Boobies are nearing extirpation (Table 2), with a considerable reduction in population size since their estimated 105 breeding pairs in 2000.

Migratory Seabirds

Sandwich and Royal Terns were present on 2 of 4 identified nesting cays in the USVI, as recorded in Chardine *et al.* (2000) and Norton (2000), with no colonies found on Flat Cay or Pelican Cay (Table 3). We did not find any Sandwich Tern colonies in the BVI (excluding Anegada) over the 4 years of surveys, and Royal Terns have been extirpated from the BVI (Schreiber and Pierce 2009); we therefore present data only for the USVI for these species (Table 4).

Both Royal and Sandwich Terns showed moderate declines; however, the large count ranges presented for the early 21st century period suggest that prior estimates were not precise, making it challenging to identify clear population trends. By contrast,

Roseate Terns show continued evidence for the declines recorded by Soanes *et al.* (2020) in both the USVI and BVI (Table 5), with steeper declines in the BVI since the 1990s (Soanes *et al.* 2020) indicating that VI Roseate Terns are nesting in this territory less than in the past.

Discussion

Altogether, our results indicate declining trends for all seabird populations included in this analysis, with greater losses observed for resident versus migratory species. Populations did not appear immediately impacted by the 2017 hurricanes, as we did not see evidence for dramatic population reductions for any of the six extant focal species in the breeding season following the disasters. This was unexpected given the major impacts to both human habitations and the marine habitat in the VI from the 2017 hurricane season (Rogers 2019). We also did not detect any drastic changes in colony site use for any of the six extant species, implying that declines are the result of dwindling sizes of individual colonies rather than any one major colony site extirpation event. Given that the early 21st century seabird counts presented in this study already represent a substantial reduction from pre-20th century population abundances (McGowan *et al.* 2006, Schreiber and Pierce 2009), the population changes noted here are of great concern.

Seabird declines in the VI have been attributed to multiple sources, including predation by invasive species (U.S. Fish and Wildlife Service 2010, Pierce 2009, Byerly *et al.* 2021). Rats are present on many offshore islands and may be important contributors to tern declines in the VI, in particular, as rat predation has been found to cause total nest failure in smaller colonies of Roseate Terns (Byerly *et al.* 2021). However, predation by invasive species cannot fully explain declines across such a diverse array of species and colony types, especially as pelican and booby colonies are less likely to be impacted by rat predation (Anderson *et al.* 1989, Jones *et al.* 2008). Other potential predators such as reptiles and raptors are not known to affect resident seabirds, although rare instances of nest predation by both these predator types have been observed in Roseate Tern colonies (Byerly *et al.* 2021).

Human activities have also been cited as potential major causes of population declines in the VI (Schreiber and Pierce 2009, U.S. Fish and Wildlife Service 2010, Zaluski *et al.* 2018), with disturbance severity varying by territory. Despite limited enforcement of island protections, many of the islands in the USVI are difficult to access, making them relatively inaccessible to human visitors. In our 5 years of modern surveys, we did not find any evidence for human visitation on nesting islands apart from an abandoned camp site found on Dog Island in 2018. Additionally, we did not detect human presence in any of the six Roseate Tern colonies monitored during a 2-yr nest survival study using 24-hr remote cameras (Byerly *et al.* 2021). By contrast, the BVI have less protection and greater tourist use of nesting islands (McGowan *et al.* 2006, Schreiber and Pierce 2009). Many seabird islands in the BVI have coves and beaches that facilitate easier access for visitors, and human activity is commonly seen on these islands during the breeding season (PAB pers. obs.). Greater disturbance may account for the steeper declines and extirpations of some species seen in the BVI. In addition to disturbance, harvest of seabird eggs, particularly of Roseate Terns, was historically common in the territories and was considered a major threat to colony survival (Pierce 2009). This activity appears to have declined culturally, with no anecdotal or direct evidence that any egg harvest occurred during the years of our study, making it unlikely that egg harvest continues to be a threat for seabirds in the VI (Byerly *et al.* 2021).

In addition to the factors mentioned, marine habitat degradation appears to be a major potential cause of decline for breeding seabirds in the VI and greater Caribbean. In the Caribbean, mean annual sea surface temperatures have increased by 1°C since 1982 (Taylor *et al.* 2012), leading to periodic mass die-offs of marine fauna (Rogers *et al.* 2008). Additionally, overexploitation and extensive coastal development have led to extensive habitat degradation and population declines across Caribbean marine taxa (Rogers *et al.* 2008, Paddack *et al.* 2009). While a general declining trend has been observed for many marine organisms in the VI (Garrison *et al.* 1998, Rogers *et al.* 2008, Friedlander and Beets 2008, Stallings 2009), long-term monitoring has been conducted only at a few reference sites, and has mostly focused on corals and coral-associated fishes (Friedlander and Beets 2008, Pittman *et al.* 2014). Seabird population trends in the VI therefore potentially represent an important and unique indication of the declining quality of the marine habitat in the region.

The paucity of data from the region makes it challenging to assess the relative effects of potential threats on seabird populations in the VI, and future research should address this need. Forage fish abundance and growth rates represent a key research need for seabird conservation in the tropics (Beets and LaPlace 1986, Friedlander and Beets 1997). Future research should focus on measuring the availability, distribution, size classes, and energy density of forage fish near important seabird breeding islands in the Caribbean to determine if prey availability is a contributing factor to regional seabird population declines. Foraging ranges and distributions are also needed for species such as Brown Boobies and Sooty Terns that forage away from the colony site in more open ocean habitat. We also recommend increased invasive species management on important seabird nesting islands, with a particular focus on rat removal. Where rat removal is not possible, hazing of prospecting terns from islands with known rat presence would be beneficial for nest survival. Further conservation actions in the BVI should evaluate the effect of visitors on nesting seabirds and the potential for closing important nesting islands during the breeding season.

In addition to these research needs, future seabird conservation efforts in the VI should focus on improving LTM survey designs to facilitate standardization of data collection. This can include incorporating errors in detection rate to account for observer bias and differences in survey types, standardizing survey timing, as well as taking standardized measurements such as spatial extents and locations of colonies (Haynes-Sutton *et al.* 2018). We also recommend that researchers in the VI supplement survey methods by improving data recording, including providing error rates for census estimates and recording exact dates of survey times for resident species, rather than reporting surveys as having been conducted within a seasonal range. Better survey designs will facilitate quantification of population

trends, which will lead to better understanding of population processes and changes in statuses. Overall, our results suggest that management and conservation efforts are needed to prevent further seabird extirpations and declines in the VI, particularly for Masked Boobies, Brown Boobies, and Brown Pelicans. As part of these efforts, a rigorous, standardized survey of seabirds is needed to better establish current baselines and facilitate analysis of future population trends, particularly in the BVI.

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