U.S. Virgin Islands' Resiliency and Changing Environmental Conditions

Cooperative Report: Funded by the U.S. Geological Survey and U.S. Fish and Wildlife Service

Prepared by: Hailey Shanovich[1], Samuel Wilhelm[3], Kristen Graas[3], Amanda Chandler[3], Paul Armsworth[3], Louise Vaughn[2]

[1] United States Geological Survey, Southeast Climate Adaptation Science Center

[2]United States Fish and Wildlife Service, Southeast Conservation Adaptation Strategy

[3]University of Tennessee – Knoxville, Department of Ecology & Evolutionary Biology

Prepared for the U.S. Virgin Islands Division of Fish and Wildlife

Published 2025

Suggested Citation

Shanovich, H. N., Wilhelm, S., Chandler, A., Graas, K., Armsworth, P., Vaughn, L. 2025. Climate Resiliency in the United States Virgin Islands. Southeast Climate Adaptation Science Center. (36 pages)

Acknowledgements

This work was supported by the U.S. Geological Survey (USGS) Southeast Climate Adaptation Science Center (CASC) and included technical graduate student contributors from the University of Tennessee – Knoxville who have been included as authors on this report. We thank the US Virgin Islands Division of Fish and Wildlife for their engagement. We thank Drs. Adam Terando (USGS Southeast CASC), Sam Droege (USGS Bee Lab), Paul Armsworth (University of Tennessee – Knoxville) and William 'Bill' Gould (USDA Caribbean Climate Hub) for their reviews of parts of or the entirety of this report. Lastly, we thank Dr. Catherine M. Hulshof De La Peña (Virginia Commonwealth University) for sharing her full dataset on projected range changes of butterfly species from Puerto Rico.

Table of Contents

Foreword

Series Overview

The following report is part of a multi-part series synthesizing the potential hazards of changing environmental conditions on southeastern states' and territories' ecoregions and vulnerability of wildlife. This work was conceived as part of an interagency effort to facilitate the inclusion of adaptation considerations into 2025 revisions of state wildlife action plans (SWAPs) motivated by the Association of Fish and Wildlife Agencies' voluntary guidance for states to incorporate adaptation into SWAPs and formal encouragement from the U.S. Fish and Wildlife Service (USFWS) in 2012 (AFWA, 2022). To best provide capacity for each agency, the reports are tailored to the needs of each state or territory agency within the Southeast region undergoing said revisions to their plans. This work was developed as a collaboration between the U.S. Geological Survey (USGS) Southeast Climate Adaptation Science Center (SE CASC) and the USFWS Southeast Conservation Adaptation Strategy with input from the Southeastern Association of Fish and Wildlife Agencies' Wildlife Diversity Technical Committee.

Process

To effectively synthesize the potential hazards of changing environmental conditions on the U.S. Caribbean territories and vulnerability of their wildlife, the SE CASC developed a process comprised of the following steps: 1) summarize available data and state of the science for changing environmental conditions in the U.S. Caribbean; 2) determine impacts to the landscape and wildlife of each U.S. Caribbean territory; 3) summarize available vulnerability assessments and niche models (i.e., species distribution models) for each territory's revised species of greatest conservation need (SGCN) list; and 4) conduct a literature review of impacts from changing environmental conditions to a specific taxonomic group or habitat of each agency's choosing. Existing data collections of both historical climatology and future projections were summarized for each territory (Bowden et al., 2018; Runkle et al., 2022; NOAA, 2025). Information pertaining to sea-level rise was taken from the National Oceanic and Atmospheric Administration (NOAA) via their Sea-level Rise Technical Reports and Sea-level Rise Viewer Tool (Sweet et al., 2022). Additionally, existing data collations were used to summarize vulnerability assessments and niche models conducted for each territory's SGCN (Armsworth et al., 2025a, 2025b). For each habitat or taxonomic group identified by a territory wildlife agency, we reviewed and synthesized available scientific literature. We searched for relevant literature related to these habitats and species that either explicitly mentioned or indirectly discussed impacts of changing environmental conditions.

Executive Summary

The U.S. Caribbean, including Puerto Rico and the U.S. Virgin Islands (USVI), faces distinct environmental challenges due to its island geography, reliance on natural resources, and heightened vulnerability to climate-related hazards such as drought, sea-level rise, and extreme weather events. These factors, compounded by limited data availability—especially for the USVI—create significant barriers to effective planning and adaptation. Despite some progress in downscaled climate modeling, data gaps persist, particularly for localized projections of extreme events. As climate change accelerates, the region is expected to experience more frequent and intense heatwaves, wildfires, and flooding, threatening ecosystems, wildlife, and human well-being. Understanding species distributions and habitat changes is critical for conservation, yet capacity limitations and insufficient data continue to hinder comprehensive responses.

The USVI are increasingly vulnerable to the compounding impacts of changing environmental conditions including rising temperatures, more intense tropical cyclones, prolonged droughts, sea-level rise, and extreme precipitation events. Since 1950, air temperatures have risen nearly 2°F, with projections indicating further increases of 2 to 2.5°F by 2060, particularly in southern St. Croix and higher elevations of St. Thomas and St. John. These warming trends, along with rising sea surface temperatures, may have contributed to ocean acidification and repeated coral bleaching events, potentially threatening marine biodiversity and reef ecosystems. Simultaneously, annual rainfall is projected to decline by 6–12%, intensifying drought conditions, potentially reducing water availability, and stressing agriculture and freshwater habitats like ghuts. At the same time, extreme rainfall and compound flood events are expected to increase, particularly in low-lying coastal zones. The USVI also faces heightened risks from stronger tropical cyclones, with projections showing a 15% increase in storm rainfall rates and more frequent Category 4 and 5 hurricanes. Past storms, such as Irma and Maria in 2017, caused catastrophic damage to infrastructure and ecosystems. Sea levels in the USVI are rising faster than the global average, increasing the likelihood of flooding, erosion, and saltwater intrusion. These overlapping threats could be alleviated some by the use of nature-based solutions—such as conserving coral reefs, mangroves, and seagrass beds—which could provide protection by buffering wave energy, stabilizing sediment, and enhancing ecosystem and community resilience.

Insects in the USVI remain understudied despite their ecological importance and vulnerability to environmental change. While conservation efforts in the territory have focused on vertebrates and marine species, terrestrial invertebrates—particularly insects—have received limited attention due to a lack of surveys and data. Recent efforts, such as native bee surveys, have begun to fill these gaps, revealing distinct species from the continental U.S. and a reliance on native scrub habitats. Insects on tropical islands like the USVI are often endemic and at greater risk from threats such as hurricanes, rising temperatures, drought, and sea-level rise. Extreme weather events may cause immediate and long-term disruptions to insect populations and their habitats, while warming temperatures and drought may alter plant-insect interactions and reduce food availability. Aquatic insects may be especially vulnerable due to limited freshwater resources, and coastal insects face additional risks from saltwater intrusion and habitat loss driven by sea-level rise. Without long-term monitoring and targeted conservation, many insect species in the USVI may face increasing threats, underscoring a possible need for expanded research, habitat protection, and inclusion in wildlife action planning.

Changing Environmental Conditions in the U.S. Caribbean: Existing Data

Compared to the majority of the U.S., the U.S. Caribbean continues to face unique challenges related to changing weather patterns and ecological conditions including geographic constraints, reliance on imports, critical dependence on local natural resources (e.g., freshwater, fisheries), and differential vulnerabilities to drought, sea level rise, and natural disasters. These distinct compounding factors present unique challenges that differ from the rest of the Southeast U.S. region. Many changing environmental conditions affecting the Caribbean landscape—like sea-level rise, changing weather patterns, and habitat loss—may impact many sectors of society and are intertwined with the economic and social well-being of the people in the region. Given the importance to wildlife of small land parcels, unique habitats, competing conservation and development pressures, and changing coastal and climatic conditions, understanding the distribution of species and habitats and the current and expected changes may be used for effectively planning and managing wildlife conservation.

The U.S. Virgin Islands (USVI) has often been excluded from weather data collection efforts due to administrative structures (Méndez-Lazaro et al., 2023). Data for the U.S. Caribbean are missing for other metrics, such as locally relevant downscaled projections for extreme events (e.g., heatwaves, hurricanes, marine heatwaves, dust storms) (Méndez-Lazaro et al., 2023). Even in cases where downscaled data are available for the U.S. Caribbean region, they are not at a fine-enough resolution to distinguish among the small islands that comprise the USVI (Méndez-Lazaro et al., 2023). USGS generated dynamical downscaling of future projections for select general circulation models that were included in the Coupled Model Intercomparison Project (CMIP5) for the US Caribbean and associated results have been included throughout this section (Bowden et al. 2018). These structures, combined with the lack of data, have resulted in capacity challenges that continue to create gaps in a wide range of sectors (e.g., health, natural resources, education, agriculture, food security, imports, and housing). Based on these trends, it is possible that the habitats, ecosystems, and conditions of the USVI will be altered as faster rates of change also increase the challenge of adaptation for natural systems and wildlife (Gould et al., 2018; Méndez-Lazaro et al., 2023). Assessments indicate that current trends will continue such as increasing frequency, intensity, and duration of heatwaves, increasing wildfire risk, and rising sea levels (Gould et al., 2018; Méndez-Lazaro et al., 2023).

Impacts to the US Virgin Islands from changing environmental conditions

Like the rest of the Southeast, USVI is predicted to experience a number of impacts from a changing world like more extreme heat, extreme precipitation events, drought, sea-level rise, and tropical cyclones—although the magnitude of predicted changes varies by model, scenario, and timeframe under consideration (Méndez-Lazaro et al., 2023). The USVI is unique in that the islands that comprise the territory are characterized by a larger coastline area relative to the total inland area, which means that much of the coastal infrastructure, economy, and population are vulnerable to sea level rise, more frequent and more intense precipitation events, and flooding.

Warmer air and ocean temperatures

Temperatures in the USVI have risen almost 2°F since 1950 (Runkle et al., 2022). The number of very hot days (i.e., the number of days with high temperatures exceeding 95°F) does not exhibit a statistically significant trend, but extremely warm nights have generally been above average since 2000, with the highest number occurring since 2015 (Runkle et al., 2022). However, trends in average temperature anomalies for the Caribbean show a steady increase in temperature anomalies since 1990 (NOAA, 2025;

Figure 1). Average temperature anomaly calculations are produced by subtracting the long-term mean land and ocean temperatures from a daily temperature value: a positive anomaly means that the daily temperature is warmer than the long-term average for that day; a negative anomaly means it is cooler than the average. Caribbean Islands average temperature anomalies have been positive since 1990, meaning that since 1990 land and ocean daily temperatures have been warmer than the long-term average (Figure 1).

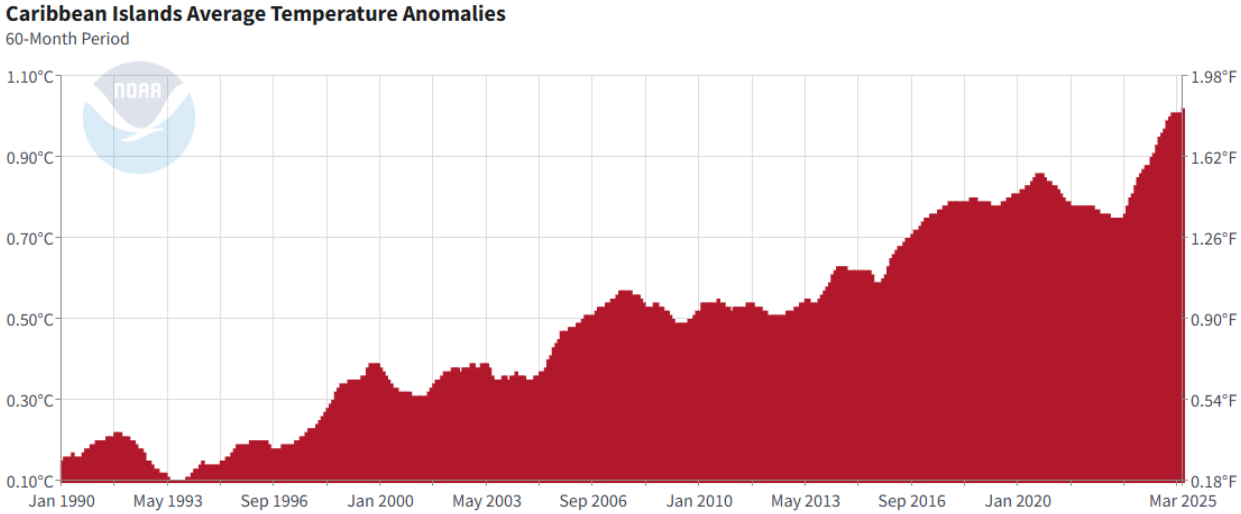

Figure 1. *Temperature anomalies for the Caribbean Islands from January 1990 to March 2025 with respect to the 1910-2000 average in both degrees Celsius and Fahrenheit. Data source: NOAA Climate at a Glance Global Time Series (NOAA, 2025).*

By 2060, model simulations under a higher scenario show that average temperature changes for the USVI are projected to increase between 2 to 2.5°F, with the largest change for maximum temperatures for the southern side of St. Croix and for some of the higher elevations within St. Thomas and St. John (Bowden et al., 2020; Figure 2). Changes in minimum temperatures are projected to be even more drastic than maximum temperatures with (Bowden et al., 2020; Figure 3). Under this same scenario, at least 50 days of unprecedented maximum and minimum temperatures in each future year are projected per year relative to the historical period (1981-2010), with some exceptional years exceeding 200 days (Bowden et al., 2020).

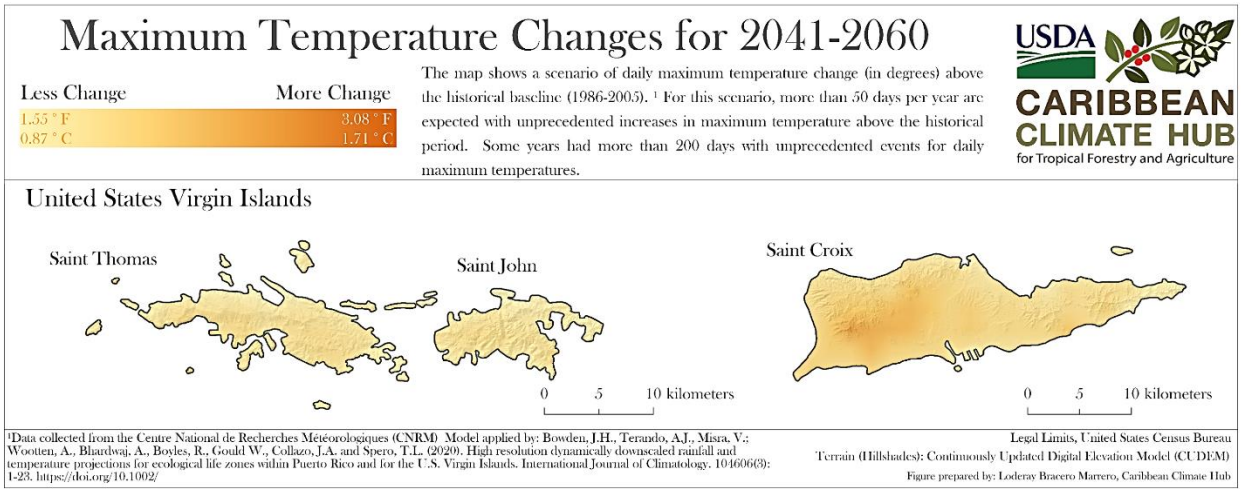

Figure 2. *Projected future changes of maximum temperatures under a high emission scenario (RCP 8.5) above the historical baseline (1981-2010). Figure produced by the USDA Caribbean Climate Hub from downscaled data by Bowden et al. (2020).*

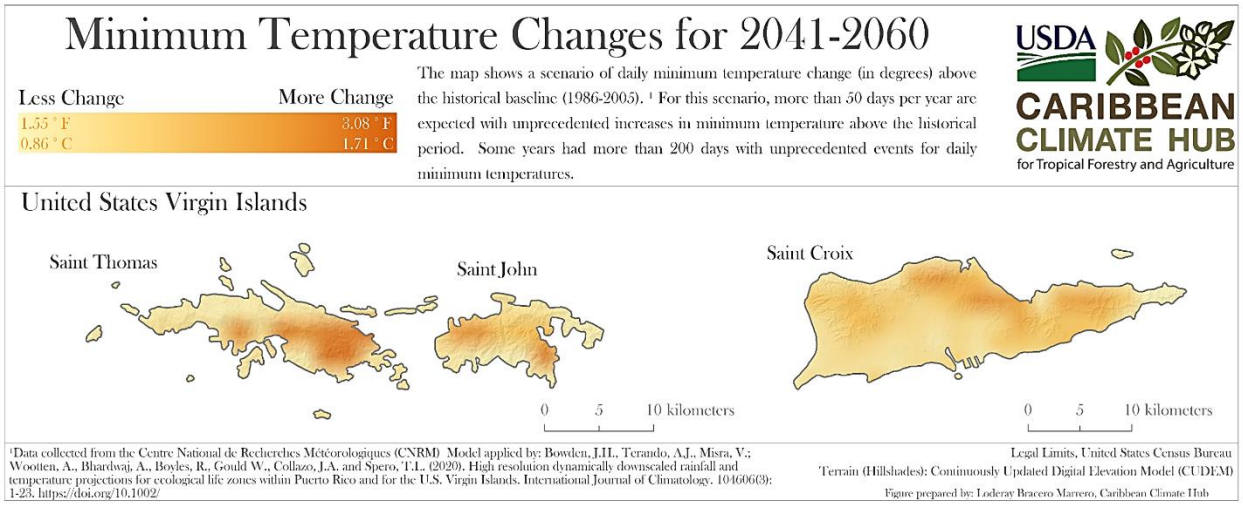

Figure 3. *Projected future changes of minimum temperatures under a high emission scenario (RCP 8.5) above the historical baseline (1981-2010) Figure produced by the USDA Caribbean Climate Hub from downscaled data by Bowden et al. (2020).*

Oceans provide crucial ecosystem services and are home to a large array of marine wildlife and commercial fishery species in the USVI that are in the Territory's Marine Resources and Fisheries Strategic and Comprehensive Conservation Plan (USVI-DPNR, 2005). Sea surface temperatures of the surrounding ocean area, which provide an essential regulator on air temperatures in the USVI, have risen by almost 2°F since the start of the 20th century (Figure 4). Elevated sea surface temperatures (SST) also influence the health of coral reef ecosystems and the marine life that depends on them. Additionally, monitoring SSTs allows scientists to monitor hurricane "wake" cooling, observe major shifts in coastal upwelling, and many other applications. Increased SST also means oceans are becoming more acidic which has direct impacts to the life they support (Méndez-Lazaro et al., 2023). NOAAs Coral Reef Watch routinely tracks SST anomalies to assess heat stress that causes coral bleaching (https://coralreefwatch.noaa.gov/). Warming ocean temperatures cause mass coral bleaching events and disease outbreaks that are becoming more frequent (Blondeau et al., 2020). In 2005, the USVI suffered a major coral bleaching event, followed by a disease outbreak that cost the islands nearly half of its corals in an extensive die off; major bleaching then occurred again in 2010 and 2019 (Blondeau et al., 2020).

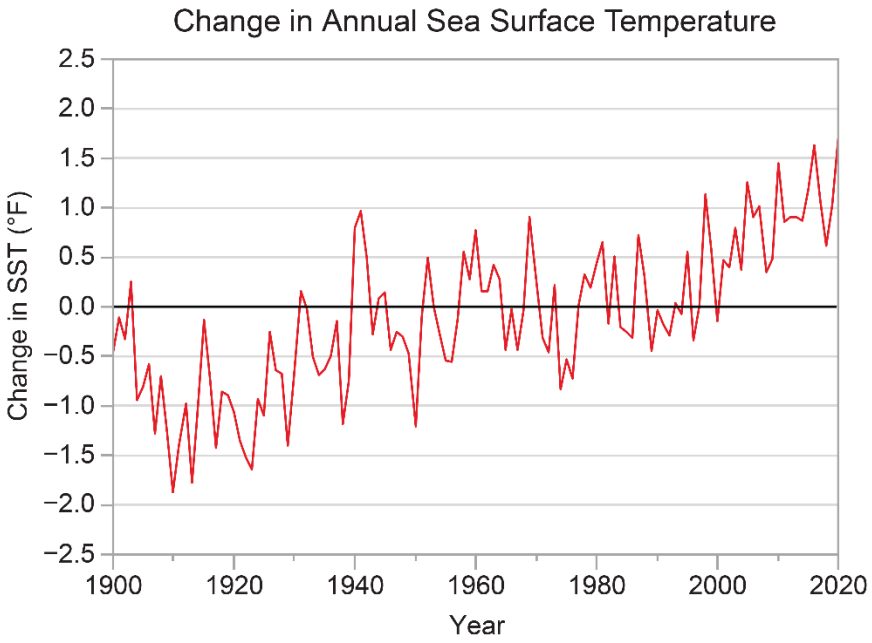

Figure 4. *Observed changes for 1900–2020 (compared to the 1951–1980 average) in annual average sea surface temperature (SST) for the region surrounding the U.S. Virgin Islands (62°W–68°W, 17°N–19°N). SSTs have increased steadily since the mid-1900s. Sources: CISESS and NOAA NCEI. Data: NOAA ERSST v5. Figure reproduced from Runkle et al., 2022.*

Less precipitation and more intense droughts

Annual rainfall in the USVI is less than 60 inches across all the islands and much of the rainfall in the wet season (May through October) derives from tropical cyclones (hurricanes and tropical storms) and easterly waves, which move from east to west (Runkle et al., 2022). High sea surface temperatures can also trigger local thunderstorm activity. In the dry season (November through April), rainfall is caused by cold fronts moving from west to east. A decrease in annual average precipitation in the USVI is projected over this century (Figure 5). Models project a significant reduction in annual average rainfall by end-century with reductions between 6-12% for the USVI (Bowden et al., 2020; Runkle et al., 2022; Méndez-Lazaro et al., 2023; Figure 5). Precipitation changes are unlikely to be uniform across the islands and projections show larger reductions in rainfall for the southern sides of the USVI (Bowden et al., 2020; Figure 5). The consequence of reductions in annual average rainfall is a large increase in the number of consecutive dry days, especially for the wet season under a higher scenario (i.e., SSP5-8.5) (Méndez-Lazaro et al., 2023).This means that the USVI may face an increased risk of drought, potentially affecting water supplies, agriculture, the economy, and wildlife (Runkle et al., 2022; Méndez-Lazaro et al., 2023).

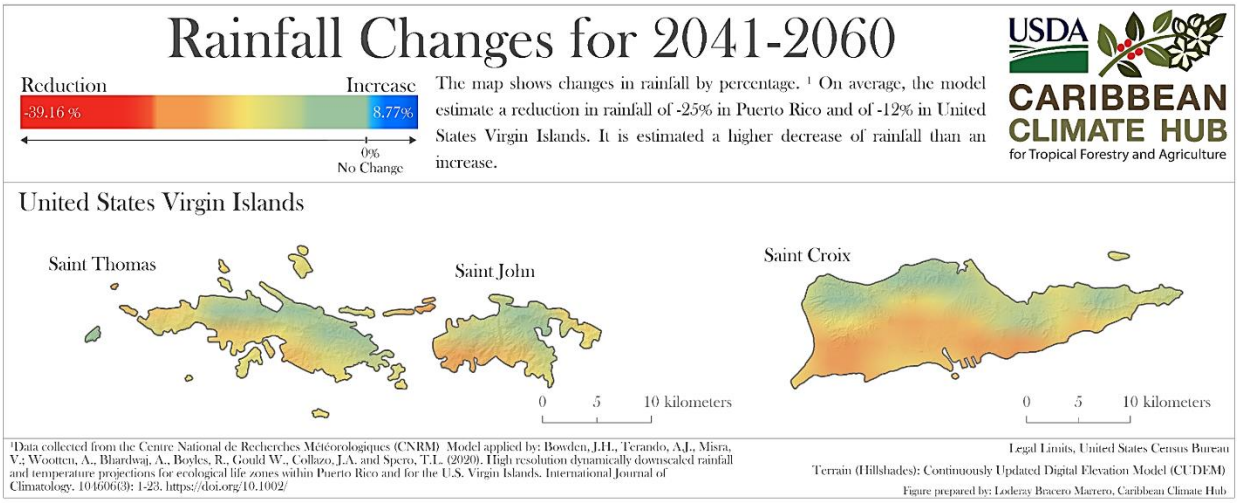

Figure 5. *Map of projected of rainfall changes by percentage for the United States Virgin Islands under a high scenario above the historical baseline (1981-2010). Figure produced by the USDA Caribbean Climate Hub from downscaled data by Bowden et al. (2020).*

Drought is a complex phenomenon that is a challenge to define and quantify but broadly results when there is a mismatch between moisture supply and demand. Drought can last for weeks or even decades in some cases and can develop slowly over months or come on rapidly. Meteorological drought happens when there is a severe or ongoing lack of precipitation. Hydrological drought results from deficits in surface runoff and subsurface moisture supply. Any increases in temperature can cause more rapid loss of soil moisture during consecutive dry days, increasing the intensity of naturally occurring droughts in the future for USVI (Runkel et al., 2022). Additionally, higher temperatures projected throughout the year in USVI (Figures 2 & 3) are expected to increase the rate of soil moisture loss (i.e., evapotranspiration) during dry spells, which could lead to more intense droughts (Runkle et al., 2022).

Seasonal droughts (i.e., droughts of 3 months or longer) occur annually in the USVI and are typically experienced as the “dry season”. The U.S. Drought Monitor has included the USVI since 2019 and publishes biweekly drought severity ratings for the islands: Caribbean | U.S. Drought Monitor. Additionally, the Caribbean Regional Climate Centre has developed the CariCOF Drought Outlook as an early warning tool that identifies ongoing ad emerging drought conditions out to several months and provides practical information on how to address them for seasonal and yearly planning. The frequency of severe seasonal droughts, however, has increased since about 2005 (Figure 6). While future projections of rainfall and drought for the U.S. Caribbean are variable, under higher scenarios, a phenomenon called “subtropical drying” is observed (Bowden et al., 2020). This means that there may be an increasing risk of aridity within the Caribbean islands in the future (Bowden et al., 2020).

Watercourses, commonly called ghuts, are some of the most diverse habitats in the USVI, containing distinct forest types, as well as vital freshwater habitat for wildlife (Gardner, 2008). Ghuts also play a critical role in hydrology of the islands by defining the drainage pattern over even small areas and serve as a crucial water source for agriculture in the Territory (Gardner, 2008). However, aside from spring-fed natural pools, most ghuts are ephemeral, carrying water only during the wet season, and flows vary dramatically with rainfall levels (Nemeth & Platenberg, 2007). The increasing risks of aridity and increasing frequency of droughts in the USVI may influence the health of ghuts that affect marine ecosystems important for unique biological communities (Nemeth & Platenberg, 2007; Figure 6).

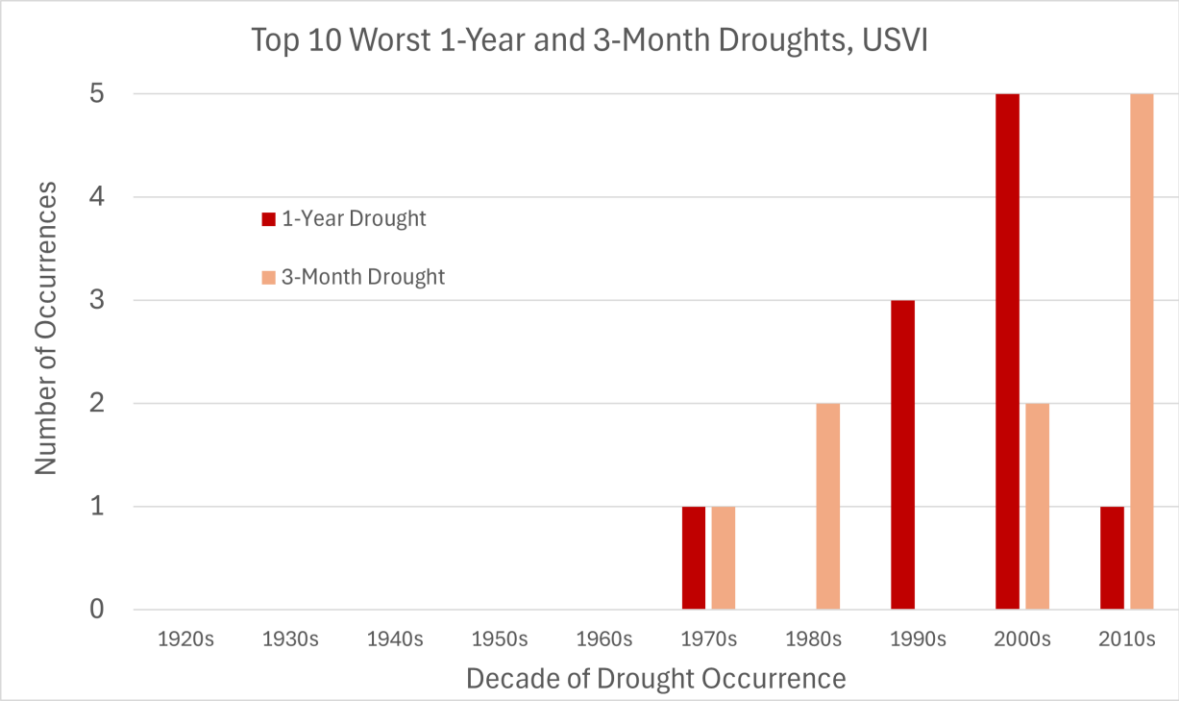

Figure 6. *Occurrence of the 10 most severe seasonal (3-month) and long-term (12-month) droughts in the USVI by decade based on /-3 and SPI-12 calculated at seven long-term weather stations on St. Thomas, St. John, and St. Croix. Reproduced from U.S. Virgin Islands 2024 Hazard Mitigation &Resilience Plan for the USVI (https://resilientvi.org/drought-in-usvi).*

Extreme Precipitation, Compounded Flooding and Tropical Storms

Future changes in total precipitation are uncertain, but extreme precipitation events are projected to increase, with associated increases in the intensity and frequency of flooding (Wong et al., 2014; Runkle et al., 2022). Extreme rainfall that occurs while ocean water inundates (e.g., because of high tides or storm surges) and affects low-lying areas in the coastal plain creates compound flooding events (Hoffman, 2023). Many of the coastal zones and shorelines in the USVI are projected to have a medium to high hazard index for compounded flooding events (Figure 7). Onshore vegetation greatly helps reduce the risk of compounded flood hazard impacts as can be seen in Figure 8, where dark blue represents areas with higher compounded flood hazard and lower vegetation values. Areas that are at greater risk of compounded flood hazard impacts but also have less onshore vegetation to help mitigate flooding extent or longevity are potentially at increased risk (Fleming et al., 2024). In areas with critical built infrastructure, coastal communities and species of greatest conservation need (SGCN), efforts might be made to restore or increase vegetation to improve flood-attenuating properties (Fleming et al., 2024).

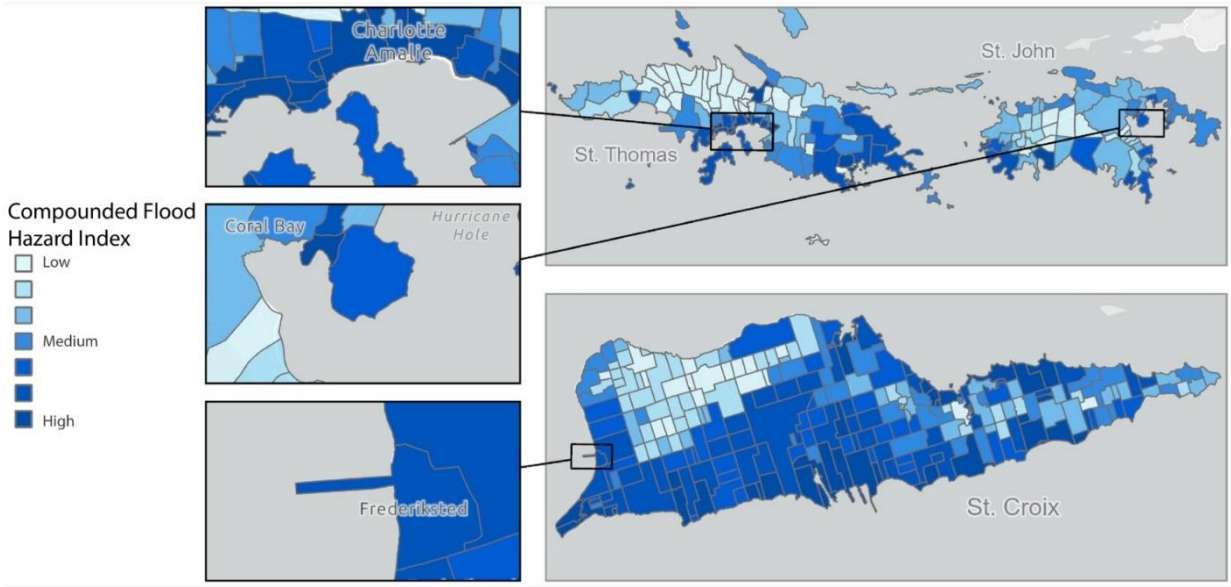

***Figure 7**. Compounded flooding scenario for the USVI, emphasizing areas more or less likely to encounter coastal and stormwater flooding through increased flood hazard potential. These data combine modeled storm surge from a Category 5 hurricane, stormwater flooding potential from precipitation events, and 2ft of sea-level rise to estimate simultaneous flooding form different causes. Figure reproduced from Fleming et al. (2024).*

***Figure 8**. Compounded flood hazard index in relation to vegetation for the USVI. These data combines modeled compounded flooding and inverted vegetation index for the islands so that dark blue estates have higher compounded flood hazard and lower vegetation values. Figure reproduced from Fleming et al. (2024).*

Within the Atlantic basin, the tropical cyclone rain rate is projected to increase by about 15% and the average storm wind intensity around 3% for a global average temperature increase of 3.6°F (2°C) above present-day levels (Méndez-Lazaro et al., 2023). In particular, the number of intense tropical cyclones

(Categories 4 and 5) are projected to increase (Méndez-Lazaro et al., 2023). Tropical cyclone events (hurricanes and tropical storms) are an important concern for the islands due to their position in the Caribbean hurricane belt, where these events occur near the islands on average every one to two years (Runkle et al., 2022). The tropical cyclones that affected the USVI since 2000 include Tropical Storm Jeanne in 2004, Hurricane Irene (Category 1) in 2011, and Hurricanes Irma (Category 5) and Maria (Category 4) in 2017 (Runkle et al., 2022). In September 2017, Hurricane Maria caused winds that locally reached Category 5 intensity, combined with extremely heavy rainfall and the destructive power of wave action and storm surge, led to extensive damage to buildings and infrastructure (Runkle et al., 2022). Severe flooding and mudslides affected much of the USVI, and most residents lost power for months in what is still the most severe power outage in American history. Maria is the third costliest hurricane in US history, with an estimated $90 billion in total damage across the islands (Runkle et al., 2022).

There has been some research on the impacts of hurricanes and tropical storms on the coral reef communities of the USVI. Coral communities, as well as reef sponge and fish communities, and their recovery were studied after Hurricanes Irma and Maria in September 2017 (Rogers, 2019; Gochfeld et al., 2020; Langwiser et al., 2024). Heavy damage to coral reefs occurred throughout the islands, but damage on St. John was particularly severe in a unique mangrove/coral ecosystem, within Virgin Islands Coral Reef National Monument, where many red mangrove trees were completely uprooted, and the prop roots of others were stripped of their corals and sponges (Blondeau et al., 2020; Rogers, 2019). Although many corals were overturned or buried, colonies of most species survived, but recovery will depend on red mangrove propagules becoming re-established to support rich marine life again (Rogers, 2019). Coral reef fish communities showed no disturbance impact from the hurricanes at St. Thomas and St. John but did show significant disturbance impact at St. Croix (Langwiser et al., 2024). The proportion of reef fish species with significant density changes were similar at St. Croix, suggesting that overall disturbance impacts are nuanced across reef fish species (Langwiser et al., 2024). In St. Thomas, percent cover of sponges declined by 24.9% post-hurricanes and sponge density declined slightly (Gochfeld et al., 2020). Overall sponge volume did not vary over time, but sponge diversity increased post-hurricanes (Gochfeld et al., 2020). At all sites sampled, recruitment and/or regrowth of sponges were observed within ten weeks post-hurricanes, indicating potential resilience in Caribbean sponge communities, but whether or not they will return to pre-hurricane conditions is uncertain (Gochfeld et al., 2020).

Sea-level rise

Sea level in the USVI has increased by 9.6 cm (3.8 in) on St. Thomas since 1975, and 11.6 cm (4.6 in) on St. Croix since 1977, which translates to an average rate of 2.63 mm/yr (0.1 in/yr) on St. Croix, and 2.1 mm/yr (0.08 in/yr) on St. Thomas (USVI-DPNR, 2023). Other estimates from satellite imagery and gauges estimate that sea level has risen by 8 cm (3.1 in) between 2000 and 2020, representing a rate of 4 mm/yr (0.15 in/yr), which is in line with, but slightly above, observed global sea level rise values of 3.6 mm (0.14 in/yr) between 2006 and 2015 (Jacobs et al., 2016; USVI-DPNR, 2023), which is also faster than the NOAA estimate above that was computed over a longer time scale. This difference in rate is likely a sign that sea-level rise is accelerating (USVI-DPNR, 2023). Modeling indicates that in the event the Greenland ice sheet and West Antarctic ice sheet melt over the next 100 years the Caribbean will experience rises in sea surface levels up to 25% above global averages (Simpson et al., 2009). Even

partial melting of the ice sheets could result in greater rises in Caribbean Sea surface levels than in most other areas of the Earth (Simpson et al., 2009).

Portions of the USVI are highly vulnerable to sea level rise (Jacobs et al., 2016). Coastal and low-lying areas are highly likely to experience a myriad of changes due to sea-level rise like flooding, erosion, and submergence (Wong et. al., 2014; Figure 9). Due to the magnitude of sea-level rise projected throughout the 21st century and beyond—coupled with subsidence—coastal systems and low-lying areas may increasingly experience adverse impacts such as submergence, flooding, and erosion (Wong et. al., 2014). As sea levels continue to rise, some coastal ecosystems may be submerged and converted to open water, and saltwater intrusion may allow salt-tolerant coastal ecosystems to move inland at the expense of upslope and upriver ecosystems (Wong et. al., 2014). Soils are invaluable on the islands, supporting many plant species of greatest conservation need and agriculture. Sea-level rise and flooding from tropical storms may intensify and speed up erosion. Figure 9 shows that most of the soils on the islands exhibit a moderate erodibility factor, and in other words, are at increased risk to erosion from flooding.

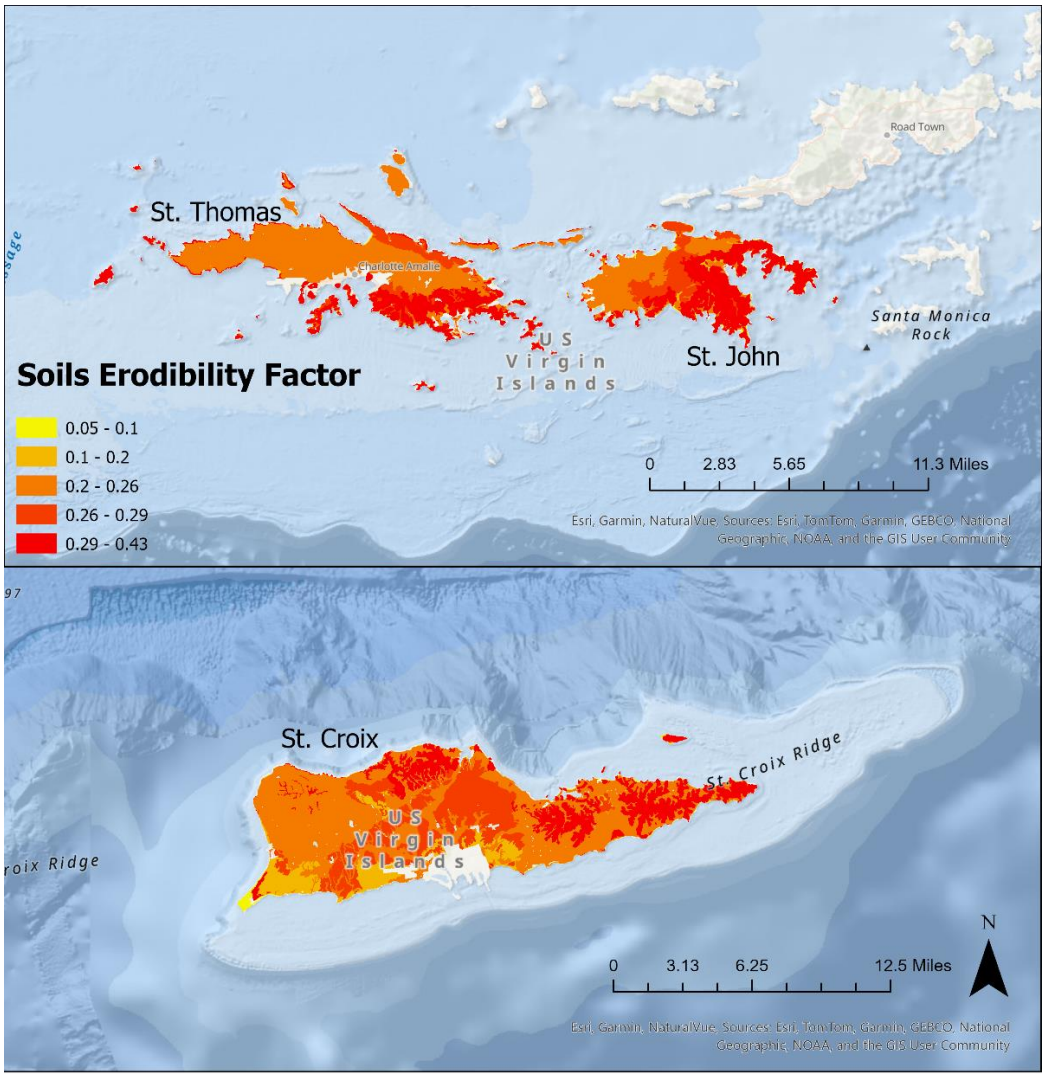

Figure 9. *Map of current soil erodibility in a given year for the US Virgin Islands. Soil erodibility factors are calculated using soil texture, organic matter, permeability and structure. The soil erodibility factor scale goes from*

0 to 1 and is represented as a fraction. Derived from the USDA Natural Resources Conservation Service SSURGO dataset. USA SSURGO - Erodibility Factor - Overview

The NOAA 2022 Sea Level Rise Technical Report, *Global and Regional Sea Level Rise Scenarios for the United States,* provides the most recent projections available to all U.S. coastal areas out to the year 2150 (Sweet et al., 2022). The following tables show the projected amount of sea-level rise (SLR) by decade within the USVI under various SLR scenarios and the projected extent of flooding in acres and percent area for the USVI with SLR (Tables 1 & 2; Sweet et al., 2022). These tables can be compared together to see what the extent of flooding may be by a certain decade in the USVI. For example, under an intermediate-low SLR scenario, about 1 ft of SLR is projected for the USVI (Table 1), which could result in 154,229 acres (61.5%) of coastal land flooding (Table 2). Figure 10 also provides a territory-wide map of areas likely to experience flooding at high tide based on each foot of SLR above current levels.

Table 1. *Projected sea level rise by decade within United States Virgin Islands. Values are based on area weighted averages of decadal projections for 1-degree grid cells that overlap this area based on NOAA's 2022 Sea Level Rise Report. 2060 corresponds to the Southeast Conservation Adaptation Strategy goal: a 10% or greater improvement in the health, function, and connectivity of Southeastern ecosystems by 2060.*

SLR Scenario	2020 (ft)	2030 (ft)	2040 (ft)	2050 (ft)	2060 (ft)	2070 (ft)	2080 (ft)	2090 (ft)	2100 (ft)
Low	0.23	0.36	0.49	0.62	0.75	0.85	0.95	1.1	1.2
Intermediate-low	0.26	0.39	0.56	0.75	0.95	1.2	1.4	1.6	1.8
Intermediate	0.26	0.43	0.62	0.89	1.2	1.5	2	2.6	3.4
Intermediate-high	0.26	0.46	0.72	1.1	1.6	2.3	3.2	4	5
High	0.26	0.46	0.82	1.3	2	3	4.2	5.4	6.8

Table 2. *Extent of flooding for coastal regions by projected average highest daily tide due to sea level rise within United States Virgin Islands. Values from the NOAA sea-level rise inundation data.*

Feet of sea-level rise	Acres	Percent of Area
0 feet	153,619	61.2%
1 foot	154,229	61.5%
2 feet	154,647	61.6%
3 feet	155,365	61.9%
4 feet	156,105	62.2%
5 feet	156,690	62.4%
6 feet	157,419	62.7%
7 feet	157,967	63.0%
8 feet	158,452	63.2%
9 feet	158,880	63.3%
10 feet	159,299	63.5%
Not projected to be inundated by up to 10 feet	*80,501*	*32.1%*
Sea-level rise data unavailable	*11,111*	*4.4%*
Total area	**250,911**	**100%**

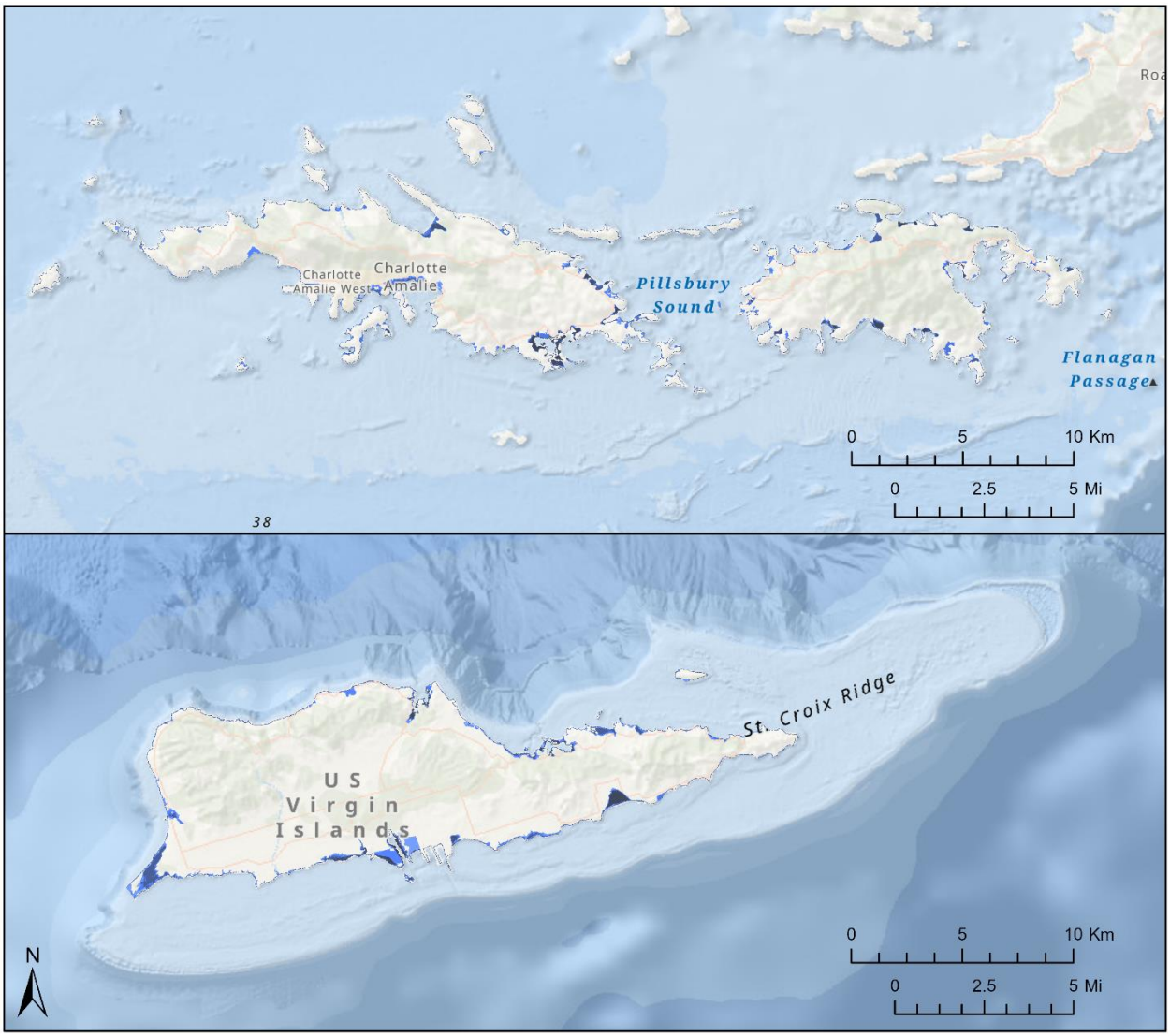

Figure 10. *NOAA's sea-level rise (SLR) inundation models represent areas likely to experience flooding at high tide based on each foot of SLR above current levels. Darker blue areas will experience flooding first, and at greater depth, compared to lighter blue areas. These models are not linked to a future timeframe; see the projections in tables 10 and 11. NOAA calculates the inundation footprint at "mean higher high water", or the average highest daily tide. The area covered in each SLR scenario includes areas projected to be inundated at lower levels. For example, the area inundated by 4 ft of SLR also includes areas inundated by 3 ft, 2 ft, 1 ft, and 0 ft of SLR (where 0 ft represents current levels).*

Coral reefs, mangroves, and sea grass meadows are all considered essential components of ecosystem-based adaptation for coastal resilience to sea-level rise and compounded flooding in the USVI (Guannel et al., 2016; Keyzer et al., 2020). Coral reefs protect coastlines from storms and erosion by breaking and reducing wave energy (Blondeau et al., 2020). Sea grass beds stabilize sediment through root systems

and assist in reducing wave motion and mangroves root systems provide stability from coastline erosion, storm surges, currents, and wave action (James et al., 2023). Additionally, sea grass beds provide a unique chemical habitat formation that helps mitigate the impacts of ocean acidification (James et al., 2023). By conserving land-sea ecosystem interfaces (i.e., boundaries between mangroves, seagrasses and reefs), resilience can be built efficiently within and between these habitats that share synergistic benefits (Keyzer et al., 2020; Carlson et al., 2021). At least four types of conservation efficiencies can be achieved by protecting these coastal ecosystems: 1) increased resistance to disturbance through inter-ecosystem feedbacks, 2) protection of high wildlife biodiversity within small geographic areas, 3) habitat portfolio effects giving rise to climate refugia, and 4) synergistic ecosystem services (Carlson et al., 2021). By conserving land-sea ecosystem interfaces (i.e., boundaries between mangroves, seagrasses and reefs), resilience may be built efficiently within and between these habitats that share synergistic benefits (Keyzer et al., 2020; Carlson et al., 2021).

Adaptation strategies

Identifying adaptation strategies to address impacts and vulnerability can be a step towards resiliency. Adaptation and mitigation comes in various forms, and multiple frameworks have been built to support planning for and implementing adaptation. Most climate adaptation frameworks generally include:

1. Recognizing limitations to adaptation, such as the degree of natural resource management, availability of funding, or staffing capacity; and
2. Deciding which type(s) of adaptation approach(es) meet specific conservation goals.

Some vulnerability assessments and adaptation strategies specifically for landscape level ocean and wildlife resilience in the US Virgin Islands include, but not limited to:

- Community Vulnerability Assessment to Flood Hazard in the U.S. Virgin Islands - NCCOS - National Centers for Coastal Ocean Science
- NCCOS U.S. Virgin Islands Coral Reef Prioritization Digital Atlas
- US Virgin Islands Coral Reef Restoration Plan and Coral Reef Management Priorities: Management Plans & Guidelines - Virgin Islands Department of Planning and Natural Resources
- USDA US Forest Service - The U.S. Virgin Islands Gap Analysis Project
- Climate Change Adaptation Planning Assessment and Implementation: Final Vulnerability and Risk Assessment Report by McKayle et al. (2019)

Responses of U.S. Virgin Islands' Species' to Changing Conditions

Identification of SGCN and regional SGCN (RSGCN) that are vulnerable to changing environmental conditions may be important to developing adaptive management strategies. A species may be considered vulnerable if it is both sensitive to changing environmental conditions and also exposed to the impacts of that change (Williams et al., 2008). Two common tools that have been used to determine a species' vulnerability to changing environmental conditions include 1) assessments like NatureServe's CCVI tool (Lyons et al., 2024), and 2) environmental niche modeling-based vulnerability estimates produced by the academic research community. The CCVI tool is a worksheet-based tool where users apply readily available information about a species' natural history, distribution, landscape circumstances, and expert opinions to predict whether it will likely suffer a range contraction and/or population reduction due to changing environmental conditions (e.g., temperature, precipitation) that

then produces a vulnerability score. By design, this score is distinct from NatureServe's global and national conservation status ranking system that considers other threats. For example, a species could score as not particularly vulnerable in terms of its Global or State rank (G-or S-rank), which is based on other factors, but could still rate as vulnerable to climate change. To date, several Southeastern Association of Fish and Wildlife Agencies (SEAFWA) states have used the CCVI tool to conduct assessments of their SGCN in order to inform previous SWAPs, management priorities, and research and conservation planning, and these previous assessments can serve as references for what has been done before and to shape planning and conservation efforts (Armsworth et al., 2025a). Ecological niche models (also called species distribution models) start by identifying shared environmental conditions (i.e., the species' niche) at sites where a species is known to have occurred and then predict where similar conditions may be found on the landscape in the future. Some models also consider the ability of a species to disperse to reach any new areas that may become suitable. The resulting predictions from these models allow researchers to create spatially explicit estimates of whether suitable environmental conditions for a species are likely to remain stable, become more widespread in the landscape (i.e. increase), or become more geographically rare in the future (i.e. decrease).

Niche model results may be used in tandem with CCVI estimates to enhance the understanding of a given species' vulnerability, because assessments and niche models have complementary strengths that may help land managers make informed conservation decisions. Niche models offer spatially explicit predictions (i.e., changes in suitable habitat) about the direct exposure of a species to changing environmental conditions but are only available for a limited set of species, in part because the models require extensive data on a species before they can be applied. Assessments use an expert judgment-based approach that allows integration of different types of information about species and what might make them vulnerable (e.g., their natural history). Therefore, outputs from both of these tools may be used to paint a full picture of a given species 'vulnerability while keeping in mind the geographic (e.g., region or habitat that was evaluated) and biological contexts (e.g., estimated dispersal distance) used.

Summary of available vulnerability assessments for US Virgin Islands SGCN

Thirty-one USVI SGCN have been assessed previously using vulnerability assessments from either the NatureServe CCVI tool (Armsworth et al., 2025a) or NOAA Fisheries (Burton et al., 2023). Figure 11 shows the results from these 31 assessments of USVI SGCN to date, indicating whether they have been found to be extremely, highly or moderately vulnerable to changing environmental conditions, presumed stable or have population increases likely. So far, USVI birds are the only group of species with estimates of increases likely in a part of their range (Figure 11) compared to fish and mammals; those two species include the great egret (*Ardea alba*) and the snowy egret (*Egretta thula*) and were assessed by the Appalachian Landscape Conservation Cooperative (Sneddon & Galbraith, 2015). Florida and Louisiana have evaluated many of the other USVI bird SGCN for the species status in their respective states and estimated them to have varying levels of vulnerability (Dubois et al., 2011; Holcomb et al., 2015; Figure 11). All the fish and marine mammals assessed to date for USVI SGCN have been done by NOAA Fisheries for the South Atlantic and so are highly accurate and relevant for their ranges in the USVI (Burton et al., 2023; Figure 11). Though more assessments are needed for other species and more taxa, especially those that are not as well studied (e.g., invertebrates), these current estimates show that fish have the largest relative proportion of USVI's SGCN vulnerable to changing environmental conditions. In other words, all of the assessed fish SGCN in USVI are vulnerable to changing environmental conditions (Figure 11).

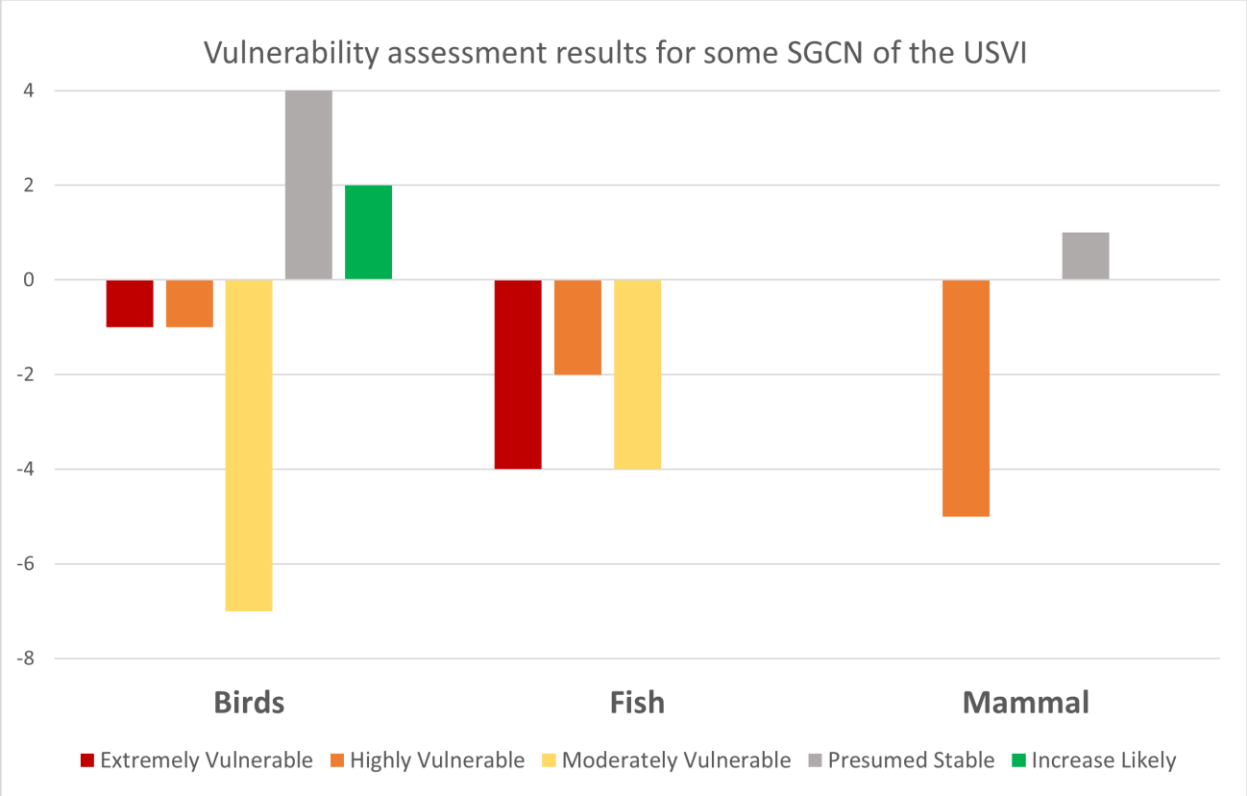

Figure 11. *SGCN of the United States Virgin Islands estimated to be vulnerable, stable, or may increase in population based on available CCVI estimates from SEAFWA states (i.e., in their 2015 SWAPs) and other sources compiled by Armsworth et al. (2025a).*

Summary of available ecological niche models for US Virgin Islands SGCN

Similarly, 31 USVI SGCN have been modeled for their species distribution shifts under future changing environmental conditions with the vast majority of these having been done for bird taxa (Armsworth et al., 2025b). However, it is important to note that these models have been done for North America and/or specific parts of these species ranges and do not specifically include the Caribbean geography. Figure 12 summarizes the combined results for these ecological niche models. Based on these niche model estimates to date, SGCN in all assessed taxa may experience decreases in their suitable landscape within the USVI (Figure 12). The four bird SGCN that are estimated to experience large decreases in suitable habitat include the white-cheeked pintail (*Anas bahamensis)*, the scaly-naped pigeon (*Patagioenas squamosa*), the white-tailed tropicbird (*Phaethon lepturus*), and the roseate tern (*Sterna dougallii*) (Armsworth et al., 2025b). However, over half of the assessed bird SGCN were estimated to remain stable or experience increases in their suitable range (Armsworth et al., 2025). Range predictions need to be done for migratory bird, fish and mammals that include the geographic extent of the Caribbean in order to fully understand their trends in the Caribbean.

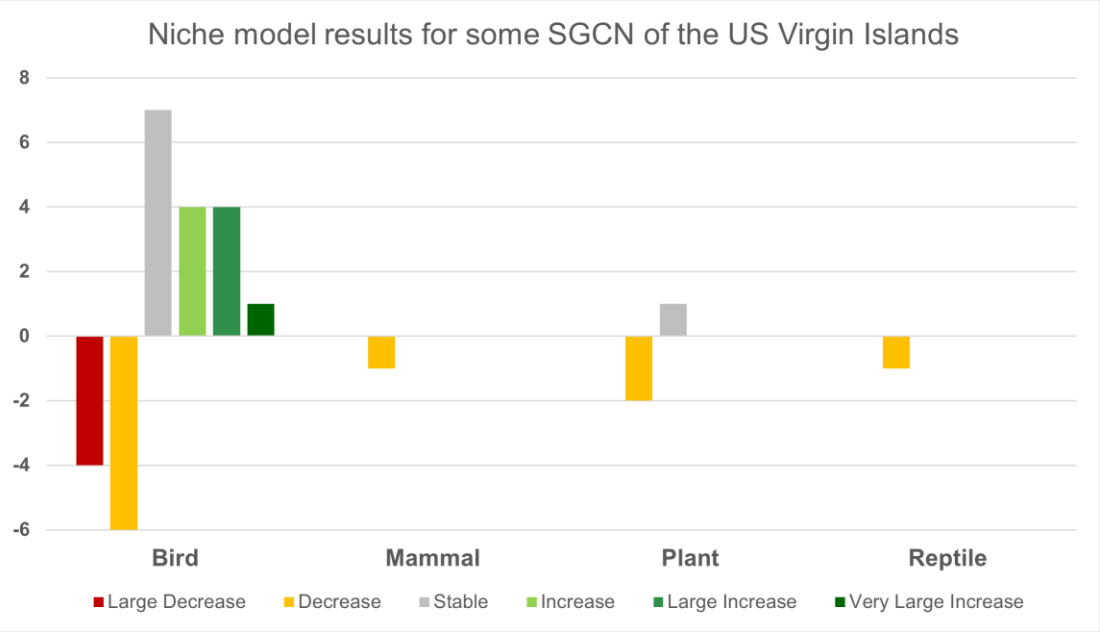

***Figure 12**. SGCN of the United States Virgin Islands estimated to be vulnerable, stable, or may increase in population based on available niche model estimates for eastern North America ranges from the literature compiled by Armsworth et al. (2025b).*

Comparing CCVI and available ecological niche models results

Comparing the results of the ecological niche models to the assessments for USVI SGCN reveal similar trends for taxa that were evaluated using both methods. For example, we can see that all USVIs evaluated taxa will experience some level of vulnerability (i.e., moderately, highly, extremely vulnerable) and some decreases (i.e., decrease or large decrease) (Figures 11 & 12). Birds have the greatest number of SGCN with predicted stable or increasing populations across both approaches, partially due to how many more bird SGCN have been evaluated compared to other taxa (Figures 11 & 12). But looking beyond birds, results from both methods suggest that manatees (*Trichechus manatus*) are projected to experience decreases in their suitable habitat and be moderately vulnerable (Figures 11 & 12). Niche model estimates are not yet available for many fish and invertebrate species, which the scientific literature suggests may be some of the most vulnerable to changing environmental conditions in the Southeast region (Halpern and Kappel, 2012; Poff et al., 2012). However, the available assessments for some aquatic and marine taxa suggest that fish and marine mammals have high numbers of USVI SGCN predicted to be extremely and highly vulnerable to changing environmental conditions (Figure 11).

A closer look – insects in the USVI, threats, and needs

Ongoing conservation programs are being administered for several different taxonomic groups on the USVI, including seabirds, waterbirds, sea turtles, bats, amphibians, fish and coral (Byerly et al., 2023; USVI-DPNR, 2018; Gulick et al., 2022; Rothenberger et al., 2008). These taxa occupy a variety of different habitats on the islands, and monitored species cover an array of taxonomic diversity and niches. However, terrestrial invertebrates included in the USVI 2018 Wildlife Action Plan (WAP) were limited to four crab species that were found to be either Low Risk (LR) or Data Deficient-At Risk (DDR) (USVI-DPNR, 2018). Insects, the most abundant group of organisms on Earth, were previously not able to be included

in WAPs due to a lack of surveys and data (USVI-DPNR, 2018). Insects are important in terrestrial food webs and provide crucial ecosystem services. For example, some insect groups pollinate wild plants and crops, including bees, butterflies, moths, wasps, flies, and beetles.

Despite large gaps in knowledge about the insect fauna of Caribbean islands, it seems that the islands have high insect abundance, and rich taxonomic and functional biodiversity. For example, in Puerto Rico, one survey of over 38,000 insect specimens from forest fragments near the University of Puerto Rico - Mayagüez documented 30 families of beetles alone (Martínez et al., 2009). However, a recent review of Puerto Rican Lepidoptera (moths and butterflies) found that basic taxonomic and ecological knowledge was lacking, despite such information being foundational to the conservation of these groups (Terry et al., 2023). More surveys, monitoring programs and ecological studies could be used to determine the status of individual insect species in the USVI.

In general, insects on tropical islands are more likely to be endemic and at risk, though this pattern may not hold true for more speciose groups such as beetles (Kaiser-Bunbury et al., 2010). Although some work has been done cataloguing insect species on the USVI (Beatty, 1944; Gibbs, 2018; Lu et al., 2014, 2018; Muchmore et al., 1987), the size and scope of extant fauna remains largely unknown, and there have been no long-term monitoring programs attempted for any insect taxa. The comprehensive bee fauna of Saint Croix, Saint John and Saint Thomas, for example, was just surveyed by Dr. Sam Droege (USGS Native Bee Lab) in 2024 and 2025, and so, able to be included in this WAP revision (Droege, unpublished data). While a complete checklist is forthcoming, some of the native bee species recorded for the islands are pictured in Figure 13. Bees of the USVI may require the native scrub habitat, such as that found on St. Thomas, and are only rarely found in urbanized areas where much of the flowering plants are ornamentals (Sam Droege, pers. comm.). The native bee biodiversity on the USVI may be quite low compared with continental North America, as was the density of occurrence of these species (Droege pers. comm.). Monitoring and further researching bees of the USVI can help determine their rarity and conservation status (Figure 13).

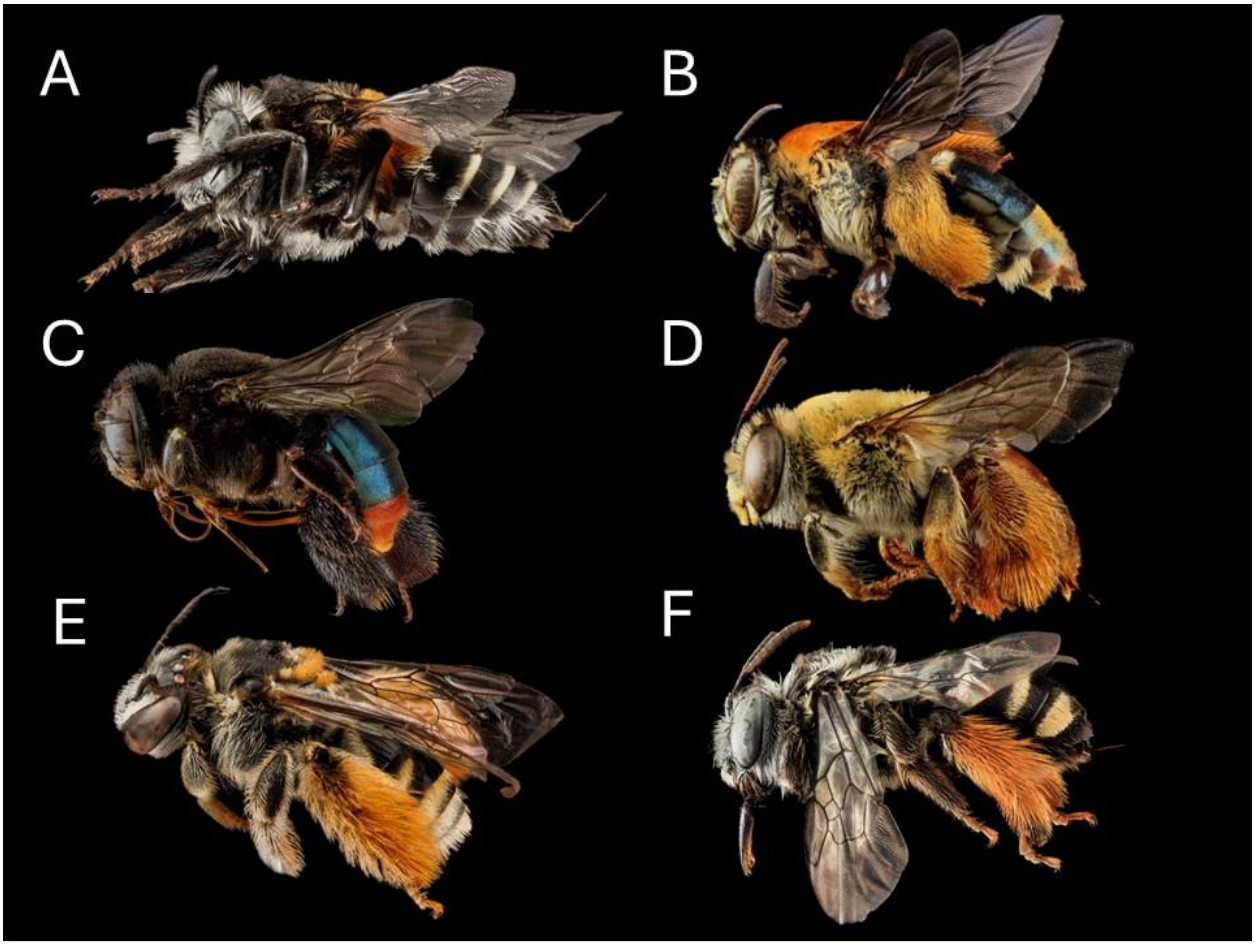

Figure 13. *Some of the native bee species of the US Virgin Islands: A) Anthophora tricolor, female; B) Centris decolorate, female; C) Centris haemorrhoidalis, female; D) Centris lanipes, female; E) Exomalopsis similis, female; F) Melissodes trifasciatus, female. All photos by the USGS Native Bee Lab and are in the public domain.*

Table 3 provides a list of Lepidoptera (moths and butterflies) known to occur in the USVI and a summary of current NatureServe conservation status rank information globally, nationally for the continental United States, and for the nearest state of Florida. While many of the butterfly species included here have a NatureServe ranking of G5 (i.e., globally secure), some are considered threatened to a specific region or state. The table also provides a vulnerability index of the range percent change values from Puerto Rico populations of taxa that co-occur on the USVI (data from Hulshof et al. ,2024). This value represents the projected changes in range size for the year 2061-2080, where negative values indicate a range loss, and positive values indicate a range gain (Hulshof et al., 2024; Table 3). Native bee species (Hymenoptera), along with two species of Lepidoptera, are listed in the footnotes as they lack NatureServe assessments.

Table 3. *Pollinating Lepidoptera (butterflies and moths) species of the US Virgin Islands. Current NatureServe Global and National conservation status ranks for the continental United States are included as well as NatureServe State conservation status rank for Florida (Acronyms for conservation status rank categories can be found on NatureServe Explorer). Migratory indicates whether a species is a migratory butterfly or moth. Range Percent Change represents the projected change in the species range by 2061, where negative values indicate a range loss, calculated from data from Hulshof et al. (2024) using Puerto Rico populations of these species*

Taxon Family	Scientific Name	Common Name	Global Rank	National Rank	Florida Rank	Migratory	Range Percent Change
Butterflies							
Hesperiidae	*Burnsius oileus*	Tropical Checkered-Skipper	G5	N5	S5	No	NA
	Choranthus vitellius	V-Mark Skipper	NA	NA	NA	NA	-26%
	Cymaenes tripunctus	Three-spotted Skipper	G5	NU	SU	No	0%
	Epargyreus zestos	Zestos Skipper	GU	NX	SX	No	NA
	Ephyriades arcas	Caribbean Duskywing	NA	NA	NA	NA	166%
	Erinnyis ello	Florida Duskywing	G5	N4	SNR	Yes	NA
	Nyctelius nyctelius	Violet-banded skipper	NA	NA	NA	NA	0%
	Polites otho	Southern Broken-Dash	G5	N5	S5	No	0.1%
	Polygonus histrio	Hammock Skipper	G3	NNR	SU	No	NA
	Urbanus dorantes	Dorantes Longtail	G5	N4	S4	No	0%
	Wallengrenia otho drury	Drury's broken-dash	NA	NA	NA	NA	27%
Lycaenidae	*Hemiargus hanno*	Hanno Blue	NA	NA	NA	NA	132%
	Leptotes cassius	Cassius Blue	G5	N5	S4	No	202%
	Strymon columella	Columella scrub-hairstreak	G5	N3N4	S4	No	NA
Nymphalidae	*Danaus plexippus*	Monarch butterfly	G4	N2B, N2N3	S4	Yes	-35%
	Junonia neildi	West Indian Mangrove Buckeye	G5	NNR	S4	No	NA
	Junonia zonalis	Northern Tropical Buckeye	G5	NNR	S2	No	NA
Pieridae	*Ascia monuste**	Great Southern White	G5	N5	SNR	No	-17%
	Eurema elathea	Banded Yellow	NA	NA	NA	NA	34%
	Glutophrissa drusilla	Florida White	G5	N2N3	S2	No	161%
	Pyrisitia lisa	Little Yellow	G5	N5	S5	No	0%
Riodinidae	*Anaea troglodyta*	Florida Leafwing	G4	N1	SNR	No	36%
	Anartia jatrophae	White Peacock	G5	N4	S5	No	-9%
Moths							
Erebidae	*Composia credula*	a tiger moth	NA	NA	NA	NA	NA
	Empyreuma pugione	Spotted Oleander Moth	GNR	NNA	SNA	NA	NA
	Horama panthalon	Texas Wasp Moth	G5	NA	NA	No	

	Utetheisa ornatrix	Ornate Bella Moth	G5	NNR	SNR	No	NA
Sphingidae	*Agrius cingulata*	Pink-spotted Hawkmoth	G5	N5	SNR	Yes	NA
	Erinnyis ello	Ello Sphinx	G5	N4	SNR	No	NA
	Eumorpha vitis	Vine Sphinx	G5	N4	SNR	No	NA
	Manduca rustica	Rustic Sphinx	G5	N5	SNR	No	NA
	Pseudosphinx tetrio	Tetrio Sphinx	G5	NNR	SNR	No	NA

Table 3 Footnotes

*subspecies *(phileta subspecies)*

Other native species included in the USVI insect list but are data deficient in all categories include the bees: *Coelioxys abdominalis*, *Megachile holosericea*, *Megachile luctifera*, *Lasioglossum dispersum*, *Lasioglossum enatum*, *Lasioglossum rufopanticis*, *Anthophora tricolor*, *Centris decolorata*, *Centris haemorrhoidalis*, *Centris lanipes*, *Centris smithii*, *Exomalopsis bahamica*, *Exomalopsis pubescens*, *Exomalopsis pulchella*, *Exomalopsis similis*, *Melissodes trifasciatus*, *Mesoplia* sp., *Megachile* St. Croix sp., *Lasioglossum* St. Croix sp., *Augochlora* sp., and the moths: *Hypercompe icasia and Glutophrissa punctifera.*

Though information on the status of Lepidoptera in the USVI is limited, we know of at least 24 species that have been assessed for extinction risk via NatureServe conservation status ranks (Table 3). Several of these butterfly species that have had their conservation status ranks assessed globally and nationally have been found to be Secure or Apparently Secure including: Tropical checkered-skipper (*Burnsius oileus),* Florida dusky-wing (*Erinnyis ello*), southern broken-dash (*Polites otho*), Dorantes longtail (*Urbanus Dorantes*), Cassius blue (*Leptotes cassius*), little yellow (*Pyrisitia lisa*), and the white peacock (*Anartia jatrophae*) (Table 3). Of those assessed, the hammock skipper (*Polygonus histrio*) is of highest global concern with a ranking of Vulnerable (Table 3). The hammock skipper's occurrence is limited to the Caribbean and Florida and was recently reconfirmed as a distinct species in a DNA barcoding study of Greater Antillean butterflies (Núñez et al., 2023; Figure 14). While ranked as Secure globally, the Florida leafwing (*Anaea troglodyta*), whose occurrence is only known from populations in southern Florida and the Caribbean, is in urgent need of conservation in the United States, being ranked as Critically Imperiled nationally (Table 3; Figure 14). However, both of the hammock skipper and Florida leafwing have yet to be assessed for a NatureServe state ranking in Florida, or the USVI, making our knowledge of their risk incomplete (Figure 14). The Florida white (*Glutophrissa drusilla*) has been assessed as Vulnerable/Imperiled nationally and Imperiled in Florida (Table 3; Figure 14). Using data from Puerto Rico, though, the Florida leafwing and Florida white are projected to experience increases in their ranges of 36% and 161%, respectively (Hulshof et al., 2024; Table 3). Without surveys and monitoring in the USVI, it is unknown what these species' statuses are on the islands and if they differ from the global, national or Florida ranks, or from Puerto Rico data.

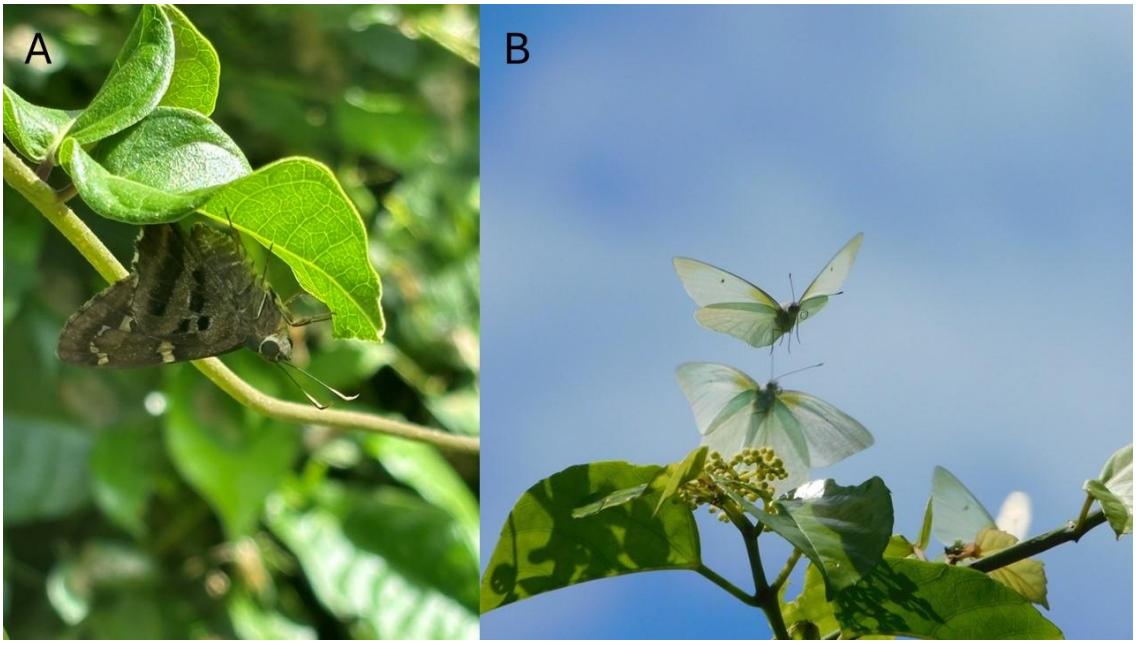

Figure 14. *Photos of A) the hammock skipper (Polygonus histrio) by Sean Kelly and B) the Florida white (Glutophrissa drusilla) by Amy Highstrom in the US Virgin Islands via iNaturslist.*

Monarch butterflies in the Caribbean are generally non-migratory and have year-round breeding populations (Zhan et al., 2014). Puerto Rico is home to what some consider a subspecies of monarch, the Puerto Rican Monarch (*Danaus plexippus* subsp. *portoricensis*), that does show evidence for genetic differentiation from migratory populations in North America (Echevarría Ramos and Hulshof, 2019, Hemstrom et al., 200; Terry et al. ,2023). Monarchs have been considered for inclusion under the Endangered Species Act (ESA), though debate about whether monarch subspecies should be considered separate or included within the larger taxonomic grouping of the species has prevented their listing (Hemstrom et al., 2022, Terry et al., 2023). Data from Puerto Rico indicates the Monarch butterfly population there may experience a 36% decrease in its suitable range by 2061 (Hulshof et al., 2024).

Threats to insects in the US Virgin Islands

The USVI faces an array of challenges due to weather and extreme events. Threats from extreme weather events were identified in the most recent WAP (USVI-DPNR 2018) as being among the most ecologically impactful to the USVI (Gould et al., 2020; USVI- DPNR, 2018). Island biomes face increased vulnerability to extreme weather events, increasing air and ocean temperatures, and sea-level rise (Chalazas, 2024; Gerlach, 2008, USVI- DPNR, 2018; Wood et al., 2017). To that end, USVI insects may face similar extreme weather-related threats in comparison to insects on other islands.

Hurricanes

The intensity and frequency of extreme weather events have and may continue to increase in the USVI (Kropf et al., 2025). Hurricane and tropical storm impacts are experienced often in the USVI and can cause both immediate and long-term landscape changes to islands and their invertebrate communities (Jones, 2014; Uriarte et al., 2023). In general, islands such as the USVI face greater risks from extreme weather events due to their reduced migration options for species between suitable habitat patches

(Wood et al., 2017). Hurricanes facilitate a complex cascade of changes in forest microclimates resulting from large amounts of biomass being relocated from the canopy to the forest floor (Bloch & Willig, 2006). Hurricane disturbances have historically played an important role in mediating the successional trajectories of sub-tropical forests, like those at the Luquillo Experimental Forest in Puerto Rico, but an increase in their frequency or intensity could upset the population dynamics of even those species which are most well-adapted to extreme disturbance (López-Marrero et al., 2019; Willig & Presley, 2022).

Studies from Puerto Rico and other Caribbean Islands have shown that different types of insects vary in their response to hurricanes across taxonomic and functional groups (Aparicio-Jiménez et al., 2014). In the immediate wake of Hurricane Maria in Puerto Rico, butterfly populations were most sensitive to seasonal, temperature-mediated fluxes; butterfly abundances did not vary across two forests which differed widely in their canopy openness, humidity levels, and other forest structural properties (Aparicio-Jiménez et al., 2014). On the other hand, walking stick bug (Phasmatidae) populations exhibited an immediate drop post-disturbance, but populations recovered in accordance with the availability of their host plants (Schowalter et al., 2021). However, population densities of the walking stick bug *Lamponius portoricensis* were found to be in slow decline due to a combination of warming temperatures and increased frequencies of extreme drought events and hurricanes (Willig & Presley, 2022). Alternatively, some island insects may be well-adapted to disturbance events like hurricanes and may even benefit from disturbance. The abundance of common ant species increased by 400% post Hurricane Maria at lower elevations in Puerto Rico (O'Meara & Yee, 2024). A long-term study of arthropod abundances in the forest canopies near the Luquillo Experimental Forest demonstrated that total insect abundance increased following Hurricane Hugo in 1989 and Hurricane Maria in 2017 (Schowalter et al., 2021).

Temperature rise

Warming trends may have both direct and indirect impacts on insect taxa. Direct impacts of rising temperatures include changes to insect physiology, voltinism, and other life-history traits. However, the negative impacts of heat-related risks may be exacerbated for island fauna due to the patterns of endemism among communities and the lack of available refugia (Dueñas et al. 2021). Although many insect species are expected to expand their ranges to higher latitudes or altitudes, for many island species, migration is unlikely to be a viable option due to limited land area and surrounding oceans (Cornelissen, 2011; Parmesan et al., 1999; Dueñas et al., 2021).Rising temperatures may also impact insects indirectly, mediated through impacts to insect habitats and including their plant hosts (Bale et al., 2002; Macinnis-Ng et al., 2021; Fontúrbel et al., 2021). Heat impacts on host plants pose a particular threat, given the coevolved relationships between many insects and their plant hosts (Fontúrbel et al., 2021; Kaiser-Bunbury et al., 2010). For example, drought can decrease production of flowers and fruits and increase plant mortality, potentially upsetting ecological mutualisms (e.g., pollination) or eliminating food sources for insect larvae.

A recent study looked at 62 of the estimated 100 species of butterflies in Puerto Rico using natural history collections to construct past and predict future distributions, including potential species overlap as different species adapt (Hulshof et al., 2023). Future projections were then used to see if temperature was causing these changes and if it was influential on select traits (i.e., wing color). Results showed that butterfly species richness and functional biodiversity were projected to decrease (Hulshof et al., 2023).

Predicted range changes for these butterfly species across entire islands were found to be driven primarily by annual temperature variation, with both smaller-winged and lighter colored taxa being more likely to shift their distributions to higher elevations (Hulshof et al., 2023). Fifteen of these species also occur in the USVI and their projected range changes are included in Table 3.

Aquatic insects are particularly vulnerable to impacts to water resources and more frequent drought. For example, a 42-year monitoring study demonstrated massive declines in insect abundance, and disrupted phenology and trophic structure in the headwaters of freshwater streams associated with rising ambient water temperature (Baranov et al. 2020). Caribbean islands are known to have high levels of endemism (>60%) in their aquatic entomofauna (Cineas & Dolédec, 2022). Flint (1978) demonstrated that, within the Greater Antilles, 80% of the Trichoptera they surveyed occurred on just a single island. Caribbean islands vary widely in their freshwater resources, and these are likely prone to fluctuations, mediated not only by changing environmental conditions but also the increasing demand for freshwater among people living on the islands (Scalley, 2012). Although the USVI has relatively few freshwater rivers and streams, these may warrant scrutiny when investigating the status of insect diversity.

Sea level rise

Sea level rise (SLR) is expected to encroach on terrestrial habitats, especially those on or immediately adjacent to the coast like mangroves or salt marshes (Rippel et al. 2021). Encroachment by seawater of insular terrestrial and freshwater systems increases their salinity levels, which may have pronounced negative impacts on insect populations. On the Corsican island of Cavallo, 60% of wetland beetle fauna were driven locally extinct by changes in salinity levels from SLR (Poher et al., 2017). SLR may also indirectly hurt insects by driving declines of their host plants (Rippel et al., 2021). As coastal habitats become increasingly saline, plant communities may shift in favor of salt-tolerant species (He & Silliman, 2019); biotic reshuffling of this type could be particularly problematic for insects that specialize on particular plant hosts for part(s) of their life cycle. Given the rapidity of SLR, biotic communities occurring along coasts and low-lying areas may be among the most vulnerable to the immediate effects of changing environmental conditions.

Interactions with habitat loss and development

Weather and extreme events may impact ecosystems synergistically with other types of disturbance. Habitat loss fragmentation and loss from development activities are primary concerns. For example, the USVI has a long history of deforestation, starting with the conversion to sugar cane plantations in the 1700s. Nearly all habitat types are disrupted to some extent and only 3% of USVI land today exists as mature forest and secondary forests (USVI-WAP, 2018). St. Thomas is highly developed to support half of the total USVI population, while St. Croix is about twice the size of St. Thomas and is primarily devoted to agriculture. Over half of St. John is inclusively within the Virgin Islands National Park boundaries, though more developed areas outside of these boundaries continue to encroach on the protected area (USVI-WAP, 2018). Without a comparative examination of the insect communities across these different habitat types it is difficult to know exactly what the impacts of land use change have been to these taxa.

Future conservation efforts for USVI insects

Conservation efforts for insects on the USVI could likely benefit from increased study of population demographics and life histories. Baseline data are lacking for the vast majority of insect biodiversity on the islands. Without having any evidence of population trends it is difficult to establish which species are most at-risk or could benefit from specific conservation practices. This is a critical knowledge gap, given that studies from Puerto Rico have revealed insects to vary in their responses to disturbances, and that a "one-size-fits-all" approach may not achieve conservation goals (Aparicio-Jiménez et al., 2014). More effort to sample across habitat types in order to characterize the compositions of insect communities could be valuable.

Bees are one such taxa on the USVI. Several native species have been documented across the islands, and recent survey efforts have captured species that may be new to science as well as the absence of species known from historical collections (Sam Droege pers. comm.; Beatty et al., 1944; Gibbs, 2018). Although the total species list is short, it comprises relatively high taxonomic diversity (3 families and 9 genera) for the islands land mass. Functional trait diversity is also well represented in the bees of the USVI, representing both cavity-nesting (*Megachile* genus) and ground-nesting (*Anthophora*, *Centris*, *Exomalopsis*, *Melissodes* genera) bees, floral oil-collecting (*Centris* genus) bees, brood parasitic (*Coelioxys*, *Mesoplia* genra) bees, and eusocial bees (*Lasioglossum* genus). Thus, conservation needs will likely vary among the extant bee fauna and need to be tailored towards their specific ecologies.

Conservation statuses of certain insect species may vary across their different global populations. Some Caribbean Lepidoptera may experience extreme changes in habitat quality throughout their migratory ranges (Flockhart et al., 2015). For example, despite having a global status rank of G4 - "Apparently Secure" on NatureServe, the Florida Leafwing populations in the US are critically imperiled (Table 3). There is also a recognized endemic subspecies (*Anaea troglodyta* subsp. *floridalis*) that has been listed on the Endangered Species Act (ESA) since 2014 (Florida Leafwing Butterfly | U.S. Fish & Wildlife Service). This subspecies was recently stated to only be found in southern Florida pine scrublands (Heffernan et al. 2023), though at least at one point in time was also known from the lower Florida Keys (Duarte & Mielke, 2003). Similar instances and situations may be the case in the USVI as well, and thus, the statuses of insect populations living in the Caribbean could be assessed at the relevant scales and independently of global trends.

Protection of natural habitats could help buffer negative effects of change on insect diversity. Protecting areas that include a range of habitat types offers the possibility of protecting insects across many different taxonomic groups. For example, bees of the USVI are rarely found in developed areas and may require the native scrub habitat, so, prioritizing protection of scrub habitat and restoration of other areas could be beneficial for them (Sam Droege, pers. comm). Aside from helping insects, giving priority to the restoration and conservation of natural habitats could benefit many other native animals and plants.

Works Cited

Armsworth, P.R., Barve, N., Jackson, H., Jones, C., Mamantov, M., Richards, C., Roth, S. and Wade, B., 2025a. CCVI Estimates Harvested from the Literature Published between 2011 and 2015 for Parts of the Southeast and Northeast United States: U.S. Geological Survey data release. https://doi.org/10.5066/P16BL9ZY

Armsworth, P.R., Dalliance, E., Durant, J., Insalaco, S., Jantz, S., and Lyon, L., 2025b. Climate Vulnerability Estimates from Correlative Niche Models for Southeastern U.S. Species: A Tool to Support State Wildlife Action Plan Revisions(2025): U.S. Geological Survey data release, https://doi.org/10.5066/P14QMCJL.

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., ... & Whittaker, J. B. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global change biology, 8(1), 1-16.

Baranov, V., Jourdan, J., Pilotto, F., Wagner, R., & Haase, P. 2020. Complex and nonlinear climate-driven changes in freshwater insect communities over 42 years. Conservation Biology, 34(5), 1241-1251.

Beatty, H. A. (1944). The insects of St. Croix, VI. *I.* Journal of Agriculture of the University of Puerto Rico, *28*(3-4), 114-172.

Bloch, C. P., & Willig, M. R. 2006. Context-dependence of long-term responses of terrestrial gastropod populations to large-scale disturbance. Journal of Tropical Ecology, 22(2), 111-122.

Blondeau, J., Brandt, M., Donovan, C., Eakin, M., Edwards, K., Edwards, K., Edwards, P. ,Enochs, I. C., Feeley, M., Fleming, C., Formel, N., Geiger, E., Gorstein, M., Grove, J., Groves, S., Henderson, L., Hibbert, M., Holloway, N., Johnson, M., Kelley, T., Kelsey, H., Koss, J., Manzello, D., Miller, N., Pott, C., Smith, T., Towle, E., Viehman, S. 2020. Coral reef condition: A status report for the U.S. Virgin Islands. United States, National Oceanic and Atmospheric Administration - Coral Reef Conservation Program. https://doi.org/10.25923/53gr-cn06

Bowden, J. Wootten, A., Terando, A. and Boyles, R. 2018, Weather Research and Forecasting (WRF): Puerto Rico & US Virgin Islands Dynamical Downscaled Climate Change Projections: U.S Geological Survey data release, https://doi.org/10.5066/F7GB23BW

Bowden, J.H., Terando, A.J., Misra, V., Wootten, A., Bhardwaj, A., Boyles, R., Gould, W., Collazo, J.A. and Spero, T.L., 2020. High-resolution dynamically downscaled rainfall and temperature projections for ecological life zones within Puerto Rico and for the US Virgin Islands. International Journal of Climatology, 41(2), pp.1305-1327.

Burton, Michael L.;Muñoz, Roldan C.;Quinlan, John A.;Nelson, Mark W.;Bacheler, Nathan M.;Runde, Brendan J.;Binion-Rock, Samantha M.;Kellison, G. Todd;Smith, Joseph W.;Laney, R. Wilson;Sedberry, George R.;Morley, James W.;Poland, Steve;Brodie, Russel;Gentry, Lauren;Gore, Karla;Rock, Jason E.;Johnson, Matthew;Reichert, Marcel;Flowers, Jared;Collier, Chip. 2023. A Climate vulnerability assessment for fish and invertebrates in the United States South Atlantic large marine ecosystem. NOAA technical memorandum NMFS-SEFSC; 768. DOI: https://doi.org/10.25923/f90h-1z90

Byerly, P. A., Zaluski, S., Nellis, D., Pierce, J., & Leberg, P. L. 2023. Current status and 21st century population trends of breeding seabirds in the US and British Virgin Islands. *Journal of Caribbean* Ornithology, 36, 126-134.

Carlson, R. R., Evans, L. J., Foo, S. A., Grady, B. W., Li, J., Seeley, M., Xu, Y., Asner, G. P. 2021. Synergistic benefits of conserving land-sea ecosystems. Global Ecology and Conservation 28: e01684. https://doi.org/10.1016/j.gecco.2021.e01684

Cineas, C., & Dolédec, S. 2022. Species richness and composition of Caribbean aquatic entomofauna: role of climate, island area, and distance to mainland. Frontiers of Biogeography, 14(3). https://doi.org/10.21425/F5FBG54479

Duarte, M., & Mielke, H. 2003. Notes on the historic range and natural history *of Anaea troglodyte floridalis* (Nymphalidae). Journal of the Lepidopterists' Society, 57(3), 243-249.

Dubois, N., A. Caldas, J. Boshoven, and A. Delach. 2011. Integrating Climate Change Vulnerability Assessments into Adaptation Planning: A Case Study Using the NatureServe Climate Change Vulnerability Index to Inform Conservation Planning for Species in Florida [Final Report]. Defenders of Wildlife, Washington D.C.

Dueñas, A., Jiménez-Uzcátegui, G., & Bosker, T. 2021. The effects of climate change on wildlife biodiversity of the Galapagos Islands. Climate Change Ecology, 2, 100026.

Echevarría Ramos, M., & Hulshof, C. M. 2019. Using digitized museum collections to understand the effects of habitat on wing coloration in the Puerto Rican monarch. Biotropica, 51(4), 477-483.

Fleming, C. S., Regan, S. D., Freitag, A., Aslam, U., and Burkart, H. 2024. A community vulnerability assessment to flood hazard in the U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS 344. https://doi.org/10.25923/mej9-p181

Flint Jr, O. S. 1978. Probable origins of the West Indian Trichoptera and Odonata faunas. In *Proceedings of the 2nd International Symposium on Trichoptera: University of Reading, England, 25–29 July 1977* (pp. 215-223). Dordrecht: Springer Netherlands.

Flockhart, D. T., Pichancourt, J. B., Norris, D. R., & Martin, T. G. 2015. Unravelling the annual cycle in a migratory animal: breeding-season habitat loss drives population declines of monarch butterflies. Journal of Animal Ecology, 84(1), 155-165.

Fontúrbel, F. E., Nespolo, R. F., Amico, G. C., & Watson, D. M. 202). Climate change can disrupt ecological interactions in mysterious ways: Using ecological generalists to forecast community-wide effects. Climate Change Ecology, 2, 100044. https://doi.org/10.1016/j.ecochg.2021.100044

Gardner, L. 2008. A strategy for management of ghuts in the U.S. Virgin Islands. Water Resources Research Institute, University of the Virgin Islands (Report). https://www.uvi.edu/files/documents/Research_and_Public_Service/WRRI/strategy_management.pdf

Gochfeld, D.J., Olson, J.B., Chaves-Fonnegra, A. *et al.* 2020. Impacts of Hurricanes Irma and Maria on Coral Reef Sponge Communities in St. Thomas, U.S. Virgin Islands. Estuaries and Coasts **43**, 1235–1247. https://doi.org/10.1007/s12237-020-00694-4

Guannel, G., Arkema, K., Ruggiero, P., Verutes, G. 2016. The Power of Three: Coral Reefs, Seagrasses and Mangroves Protect Coastal Regions and Increase Their Resilience. PLoS ONE 11(7): e0158094. https://doi.org/10.1371/journal.pone.0158094

Gould, W.A., E.L. Díaz, (co-leads), N.L. Álvarez-Berríos, F. Aponte-González, W. Archibald, J.H. Bowden, L. Carrubba, W. Crespo, S.J. Fain, G. González, A. Goulbourne, E. Harmsen, E. Holupchinski, A.H. Khalyani, J. Kossin, A.J. Leinberger, V.I. Marrero-Santiago, O. Martínez-Sánchez, K. McGinley, P. Méndez-Lázaro, J. Morell, M.M. Oyola, I.K. Parés-Ramos, R. Pulwarty, W.V. Sweet, A. Terando, and S. Torres-González, 2018: U.S. Caribbean. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 809–871. doi: 10.7930/NCA4.2018.CH20.

Gulick, A. G., Ewen, K. A., Pollock, C. G., & Hillis-Starr, Z. M. 2022. Trends in abundance and reproductive success of the hawksbill turtle nesting population at Buck Island Reef National Monument, St. Croix, US Virgin Islands. Endangered Species Research, 48, 191-198.

Halpern, B. S., & Kappel, C. V. 2012. Extinction risk in a changing ocean. In Hannah, L. ed. Saving a Million Species: Extinction Risk from Climate Change. Washington DC, Island Press. pp. 285-308.

He, Q., & Silliman, B. R. 2019. Climate change, human impacts, and coastal ecosystems in the Anthropocene. Current Biology, 29(19). DOI:10.1016/j.cub.2019.08.042

Heffernan, E., Markee, A., Truglio, M. R., Barkdull, M., Steele Cabrera, S., & Daniels, J. 2023. Population genetic structure of a rare butterfly in a fragmented south Florida ecosystem. Insects, 14(4), 321. https://doi.org/10.3390/insects14040321

Hemstrom, W. B., Freedman, M. G., Zalucki, M. P., Ramírez, S. R., & Miller, M. R. 2022. Population genetics of a recent range expansion and subsequent loss of migration in monarch butterflies. Molecular Ecology, 31(17), 4544-4557. https://doi.org/10.1111/mec.16592

Hulshof, C. M., Ackerman, J. D., Franqui, R. A., Kawahara, A. Y., & Restrepo, C. (2024). Temperature seasonality drives taxonomic and functional homogenization of tropical butterflies. Diversity and Distributions, 30, e13814. https://doi.org/10.1111/ddi.13814

Jacobs, K. R., Fain S. J., Henry, S., Archibald W, Gould WA. 2016. Synthesis of Climate Change Related Knowledge and Information in the United States Virgin Islands: An Institutional Analysis. Report for the U.S. Department of Interior, Office of Insular Affairs. 177 pp. USDA Caribbean Climate Hub, U.S. Forest Service, International Institute of Tropical Forestry.

James, R. K., Keyzer, L. M., van de Velde, S. J., Herman, P. M. J., van Katwijk, M. M., Bouma, T. J. 2023. Climate change mitigation by coral reefs and seagrass beds at risk: How global change compromises coastal ecosystem services. Science of The Total Environment 857(3): 159576. https://doi.org/10.1016/j.scitotenv.2022.159576

Jones, R. D. 2014. Quantifying the impact of hurricanes, mid-latitude cyclones and other weather and climate extreme events on the Mississippi-Alabama Barrier Islands using remotely sensed data. Louisiana State University and Agricultural & Mechanical College (Master's Thesis) https://digitalcommons.lsu.edu/gradschool_theses/3514

Kaiser-Bunbury, C. N., Traveset, A., & Hansen, D. M. 2010. Conservation and restoration of plant–animal mutualisms on oceanic islands. Perspectives in Plant Ecology, Evolution and Systematics, 12(2), 131-143.

Kropf, C. M., Vaterlaus, L., Bresch, D. N., & Pellissier, L. 2025. Tropical cyclone risk for global ecosystems in a changing climate. Nature Climate Change, 1-9.

Kyzer, L. M., Herman, P. M. J., Smits, B. P., Pietrzak, J. D., James, R. K., Candy, A. S., et al. 2020. The potential of coastal ecosystems to mitigate the impact of sea-level rise in shallow tropical bays. Estuarine, Costal and Shelf Science 246: 107050. https://doi.org/10.1016/j.ecss.2020.107050

Langwiser, C., Vaughan, N. R., & Grove, L. J. W. 2024. Quantifying hurricane impacts on United States Virgin Islands reef fishes using a catchability invariant approach to compare uncalibrated survey indices. Bulletin of Marine Science, 100(2): 185-210. https://doi.org/10.5343/bms.2023.0011

López-Marrero, Tania, Tamara Heartsill-Scalley, Carlos F. Rivera-López, Isabel A. Escalera-García, and Mariangelí Echevarría-Ramos. 2019. Broadening Our Understanding of Hurricanes and Forests on the Caribbean Island of Puerto Rico: Where and What Should We Study Now? *Forests* 10(9): 710. https://doi.org/10.3390/f10090710

Lu, W., Valentine, B. D., Perez-Gelabert, D. E., & Gutiérrez, E. 2014. Ecology and diversity of cockroaches (Dictyoptera: Blattaria) from the Virgin Islands.

Lu, W., Brock, P. D., Ivie, M., & O'Reilly Jr, R. G. 2018. Ecology and Diversity of Stick Insects (Insecta: Phasmida) from the Virgin Islands. *Editors: Edward Baker & Judith Marshall [Editor Volumes 1-17: Dr PE Bragg]*, 24.

Macinnis-Ng, C., Mcintosh, A. R., Monks, J. M., Waipara, N., White, R. S., Boudjelas, S., ... & Peltzer, D. A. 2021. Climate-change impacts exacerbate conservation threats in island systems: New Zealand as a case study. *Frontiers in Ecology and the Environment, 19*(4), 216-224.

McKayle, C., Guannel, G., Taylor, M., Stephenson, T. 2019. Climate Change Adaptation Planning Assessment and Implementation: Final Vulnerability and Risk Assessment Report. University of the Virgin Islands and the University of the West Indies, Mona. https://www.doi.gov/sites/doi.gov/files/1.-usvi-climate-vulnerability-and-risk-assessment-report-final.pdf

Méndez-Lazaro, P.A., P. Chardón-Maldonado, L. Carrubba, N. Álvarez-Berríos, M. Barreto, J.H. Bowden, W.I. Crespo-Acevedo, E.L. Diaz, L.S. Gardner, G. Gonzalez, G. Guannel, Z. Guido, E.W. Harmsen, A.J. Leinberger, K. McGinley, P.A. Méndez-Lazaro, A.P. Ortiz, R.S. Pulwarty, L.E. Ragster, I.C. Rivera-Collazo, R. Santiago, C. Santos-Burgoa, and I.M. Vila-Biaggi, 2023: Ch. 23. US Caribbean. In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://repository.library.noaa.gov/view/noaa/61592

[NOAA] National Oceanic and Atmospheric Administration. 2017. Coastal Change Analysis Program (C-CAP) New Orleans Region High Resolution Land Cover Data. Data collected 2017. Charleston, SC: National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. Data accessed at https://coast.noaa.gov/digitalcoast/data/ccaphighres.html

[NOAA] National Oceanic and Atmospheric Administration. 2025. National Centers for Environmental information, Climate at a Glance: Global Time Series, published April 2025, retrieved on April 16, 2025 from https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series

Nemeth, D., and Platenberg, R. 2007. Diversity of freshwater fish and crustaceans of St. Thomas watersheds and its relationship to water quality as affected by residential and commercial development. Report, p. 28. https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/other_crcp_publications/Watershed_USVI/steer_exisiting_studies/diversityStThomasguts.pdf

Núñez, R., Genaro, J. A., Miller, J. Y., Barro-Cañamero, A., Álvarez, Y., Fernández, D. M., ... & Hausmann, A. 2023. DNA barcodes of the Greater Antillean butterflies (Lepidoptera: Papilionoidea) suggest a richer, more isolated fauna and higher endemism. Biological Journal of the Linnean Society, 140(3), 447-458.

O'Meara, S., & Yee, D. A. 2024. Ant communities respond to a large-scale disturbance along an elevational gradient in Puerto Rico, USA. Biotropica, 56(2), e13300.

Poff, N. L., Olden, J. D., & Strayer, D. L. 2012. Climate change and freshwater fauna extinction risk. In Hannah, L. ed. Saving a Million Species: Extinction Risk from Climate Change. Washington DC, Island Press pp. 309-336.

Poher, Y., Ponel, P., Guiter, F., Andrieu-Ponel, V., & Médail, F. 2017. Erosion of insect diversity in response to 7000 years of relative sea-level rise on a small Mediterranean island. Biodiversity and Conservation, 26(7), 1641-1657.

Rippel, T. M., Tomasula, J., Murphy, S. M., & Wimp, G. M. 2021. Global change in marine coastal habitats impacts insect populations and communities. Current opinion in insect science, 47, 1-6.

Rogers, C. S. 2019. Immediate effects of hurricanes on a diverse coral/mangrove ecosystem in the U.S. Virgin Islands and the potential for recovery. Diversity 11(8) 130. https://doi.org/10.3390/d11080130

Rothenberger, P., Blondeau, J., Cox, C., Curtis, S., Fisher, W. S., Garrison, V., ... & Waddell, J. 2008. The state of coral reef ecosystems of the US Virgin Islands. In *The state of coral reef ecosystems of the United States and Pacific Freely Associated States* (Vol. 73, pp. 29-73). Silver Spring, MD: NOAA Center for Coastal Monitoring and Assessment's Biogeography Team.

Runkle, J., K.E. Kunkel, L.E. Stevens, S.M. Champion, D.R. Easterling, A. Terando, L. Sun, B.C. Stewart, G. Landers, and S. Rayne, 2022: Puerto Rico and the U.S. Virgin Islands State Climate Summary 2022. NOAA Technical Report NESDIS 150-PR. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/pr/

Scalley, T. H., Scatena, F. N., Moya, S., & Lugo, A. E. 2012. Long-term dynamics of organic matter and elements exported as coarse particulates from two Caribbean montane watersheds. *Journal of Tropical Ecology, 28*(2), 127-139.

Schowalter, T. D., Pandey, M., Presley, S. J., Willig, M. R., & Zimmerman, J. K. 2021. Arthropods are not declining but are responsive to disturbance in the Luquillo Experimental Forest, Puerto Rico. Proceedings of the National Academy of Sciences, 118(2), e2002556117.

Simpson, M.C., Scott, D., New, M., Sim, R., Smith, D., Harrison, M., Eakin, C.M., Warrick, R., Strong, A.E., Kouwenhoven, P., Harrison, S., Wilson, M.D., Nelson, G.C., Donner, S., Kay, R., Geldhill, D.K., Liu, G., Morgan, J.A., Kleypas, J.A., Mumby, P.J., Palazzo, A., Christensen, T.R.L., Baskett, M.L., Skirving, W.J., Elrick, C., Taylor, M., Magalhaes, M., Bell, J., Burnett, J.B., Rutty, M.K., and Overmas, M., Robertson. 2009. An Overview of Modelling Climate Change Impacts in the Caribbean Region with contribution from the Pacific Islands, United Nations Development Programme (UNDP), Barbados, West Indies.

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak, 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf

Terry, C. N., Alonso-Rodríguez, A. M., Miller, S. E., & Hulshof, C. M. 2023. Lepidoptera research in Puerto Rico: Reconnecting with historical legacies to guide future priorities. Biotropica, 55(6), 1215-1232.

U.S. Fish and Wildlife Service. 2021. Birds of Conservation Concern 2021. United States Department of the Interior, U.S. Fish and Wildlife Service, Migratory Birds, Falls Church, Virginia. http://www.fws.gov/birds/management/ managed-species/birds-of-conservation-concern.php

[USVI-DPNR] U.S. Virgin Islands – Department of Planning and Natural Resources, Division of Fish and Wildlife. 2005. United States Virgin Islands Marine Resources and Fisheries Strategic and Comprehensive Conservation Plan. https://original-ufdc.uflib.ufl.edu/CA01300948/00001

[USVI-DPNR] U.S. Virgin Islands – Department of Planning and Natural Resources, Division of Fish and Wildlife. 2018. United States Virgin Islands Wildlife Action Plan: Volume 1 Management Framework and Volume 2 Habitats & Species. https://dpnr.vi.gov/fish-and-wildlife/wildlife-resources/

[USVI-DPNR] U.S. Virgin Islands – Department of Planning and Natural Resources. 2023. U.S. Virgin Islands Coastal Vulnerability Index (Report). https://dpnr.vi.gov/resources/management-plans/

Uriarte, M., Tang, C., Morton, D. C., Zimmerman, J. K., & Zheng, T. 2023. 20th-Century hurricanes leave long-lasting legacies on tropical forest height and the abundance of a dominant wind-resistant palm. Ecology and Evolution, 13(11), e10776.

Williams, S. E., Shoo, L. P., Isaac, J. L., Hoffmann, A. A., & Langham, G. (2008). Towards an integrated framework for assessing the vulnerability of species to climate change. *PLoS biology*, *6*(12), e325.

Willig, M. R., & Presley, S. J. 2022. Long-term spatiotemporal variation in density of a tropical folivore: responses to a complex disturbance regime. Oecologia, 199(4), 979-994.

Wong, P.P., I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, and A. Sallenger, 2014: Coastal systems and low-lying areas. In: Climate Change 2014: Impacts, Adaptation, and

Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361-409.