

A Brief Ecological Characterization of the Cooper's Island and Castle Harbour Islands Conservation Area



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and Natural Resources

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Executive Summary

The Castle Harbour Islands are a biodiversity hotspot within the Bermuda eco-region, and this site represents the most important centre of endemism remaining on modern Bermuda.

The Castle Harbour Islands are located in St. George's Parish at the East End of Bermuda. The site consists of twenty islands, rocky islets and rocks as well as the peninsula, formed by land reclamation, which incorporates the former Cooper's Island. The islands and rocks are surrounded by a variety of shallow marine habitats, including coral reefs, seagrass beds, sand flats and boiler reefs.

The Castle Harbour Islands contain extensive and near pristine examples of rocky shore habitat and sandy beaches. The islands represent a significant breeding area for the Caribbean White-tailed Tropicbird (*Phaethon lepturus catesbyi*), and the only breeding site of the endemic, globally endangered Bermuda Petrel (*Pterodroma cahow*). The site hosts significant populations of migrant seabirds, shorebirds and songbirds at various times of the year, and provides an important foraging site for globally threatened Green Turtles (*Chelonia mydas*) and Hawksbill Turtles (*Eretmochelys imbricata*). The restored pre-colonial forest of the Nonsuch Island living museum represents an endemic-dominated plant and animal community that is unique in the world.

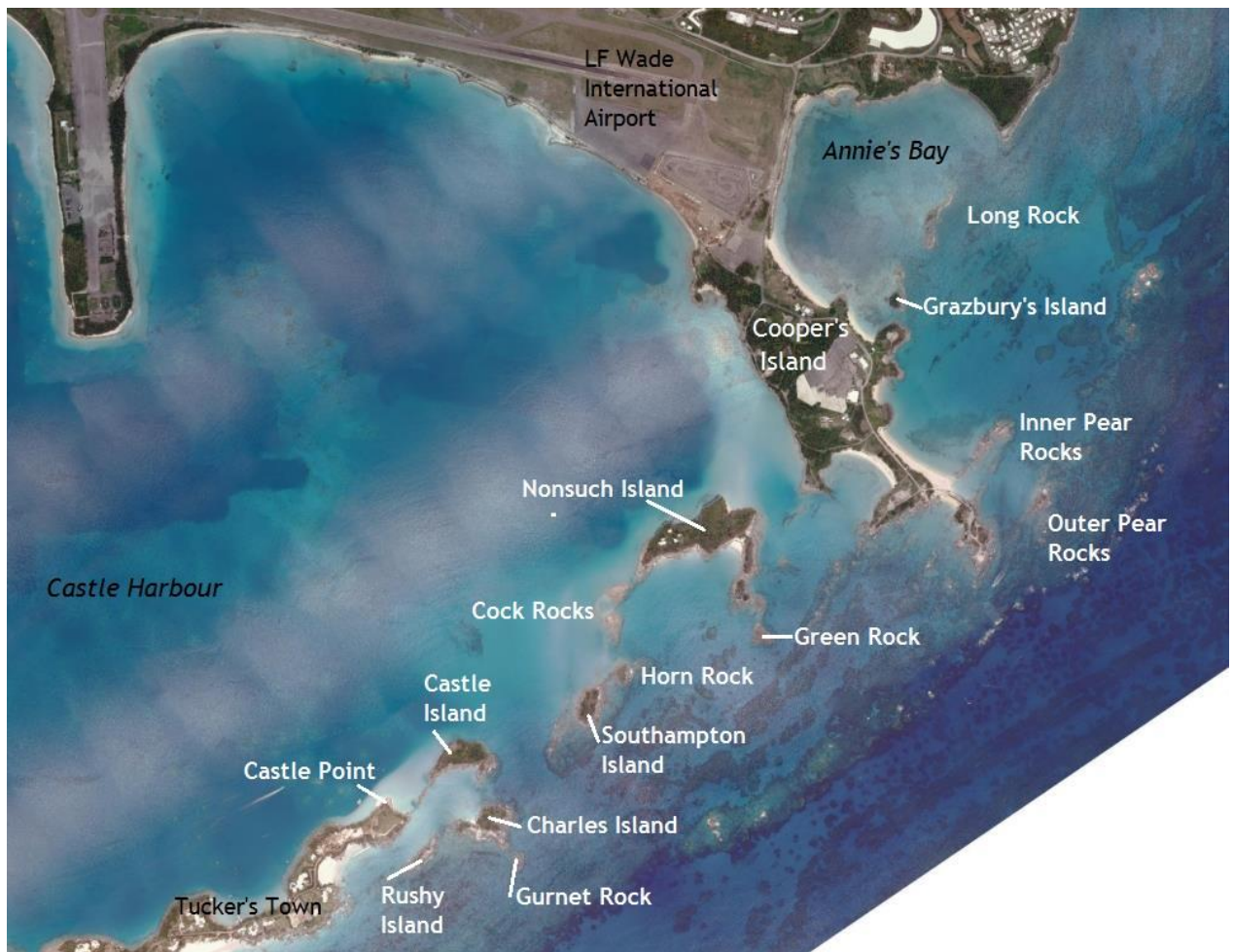
The Castle Harbour Islands Conservation Area

The area which will be referred to herein as the Castle Harbour Islands Conservation Area (or the site) includes pieces of land managed by the Department of Environment and Natural Resources (formerly the Departments of Conservation Services and Environmental Protection) and the adjacent marine areas. The aim of this report is to characterise the whole area as one interlinked conservation area.

The northern boundary of the site follows the shoreline of Annie's Bay and Clearwater Beach, and crosses the Cooper's Island peninsula following the boundary of the Cooper's Island Nature Reserve. The western boundary follows the line between deep and shallow water as visible on Figure 1 to the west of Cooper's Island and the north of Nonsuch Island toward Castle Point. The western landward boundary of the site is the tip of the Tucker's Town peninsula at Castle Point. A line running southeast from Frick's Beach, passing just west of Rushy Island, out to the breaking reef line forms the south-western boundary of the site. The southern boundary of the site traces the breaking reef line as visible on Figure 1. The north-eastern boundary is formed by a line running southeast from Ruth's Point on St. David's Island to the outer breaking reef line.

The conservation area described above covers 442.6 hectares (1,093.7 acres).

Figure 1: Key locations within the Castle Harbour Islands Conservation Area.



2012 aerial photo © Government of Bermuda, Department of Land Surveys & Registration

Figure 2: View west from the southwest point of Nonsuch Island across the Castle Harbour Islands



Habitats

The Castle Harbour Islands are considered the best preserved example of rocky marine shore, sea cliffs and rocky islet habitat in Bermuda. The rocky shore within the site is extensive and almost pristine. The Castle Harbour Islands conservation area also includes examples of coral reef, seagrass bed, submerged sand flats and sandy beach habitats that are representative of the Bermuda ecoregion.

Bermuda represents the northern-most location of coral reef habitat within the Tropical Atlantic realm (Spalding et al., 2007); therefore the coral reefs and seagrass beds within the site are representative examples of the northern-most occurrences of these two habitat types in the tropical Atlantic. The coral reefs within the site include examples of algal-vermetid cup reef habitat (locally known as boiler reefs), the distribution of which is limited within the Bermuda ecoregion. This is also a rare reef type worldwide (Coates et al., 2013). The site also contains representative examples of rim reef and lagoonal patch reef (Coates et al., 2013).

Table 1: Habitat Types and Extents

Habitat type	Habitat Name	Area (ha)
Marine	Permanent shallow marine waters (mostly sandy bottom)	237.2
Marine	Coral Reef & Boiler Reef	134.0
Marine	Seagrass Beds	25.3
Marine	Rocky marine shores (rocky coast and islets)	11.8
Marine	Sandy beach and dune	3.04
Marine	Mudflat	0.0071
Marine	Saltmarsh	0.028
Man-made	Saltwater pond	0.07
Man-made	Freshwater pond (with liner)	0.04
Man-made	Concrete water catchment	3.163
Terrestrial	Restored indigenous forest (Nonsuch Island)	6.706
Terrestrial	Native-dominated, low growing coastal vegetation	5.883
Terrestrial	Invasive dominated coastal forest	32.03

Plant Species and Plant Communities of Conservation Importance

Threatened Plant Species

Bermuda is the northern-most location for tropical seagrasses in the Northwest Atlantic (Manuel et al., 2013). The waters surrounding the Castle Harbour Islands contain three of the four species of seagrasses occurring in Bermuda; these are Turtle Grass (*Thalassia testudinum*), Manatee Grass (*Syringodium filiforme*) and Shoal Grass (*Halodule sp.*). All three species are listed as locally Vulnerable on the Bermuda Protected Species Amendment

Order 2016. These plants are key contributors to marine biodiversity within the ecoregion. They occur in mixed-species beds with associated macroalgae. These mixed-species beds support foraging Green Turtles, Queen Conch, Seahorses and other internationally threatened fauna. Seagrass beds have declined in extent and occurrence across Bermuda (Murdoch et al., 2007).

The terrestrial plants listed below are key species which make the Castle Harbour Islands a centre of endemism and a biodiversity hotspot on Bermuda. The isolation of the islands allows them to be kept relatively rat-free, which enables endemic plants to complete their lifecycle here, while on mainland Bermuda fruits and seeds are destroyed by rats and other causes. The restored forest on Nonsuch Island has a forest canopy which is dominated by the endemic trees Bermuda Cedar, Bermuda Palmetto and Bermuda Olivewood, with scattered Yellowwoods, and other rare natives such as Forestiera, Southern Hackberry and Jamaica Dogwood. The understory of the forest contains significant populations of the grass-like Bermuda Sedge, the succulent herb Wild Bermuda Pepper and the Bermuda Bean vine. Coastal habitats throughout the Islands contain healthy populations of the endemic flowering shrub Darrell’s Fleabane.

The Castle Harbour Islands also contain important native beach and dune plant communities, made up of grasses, rushes, vines, herbaceous plants, cacti and coastal shrubs. In Bermuda sand dune and beach plant communities are threatened by development and disturbed by beach raking. Cooper’s Island, Nonsuch Island and Charles Island together contain a significant area of un-raked beach habitat, which supports a diverse native plant community not found elsewhere in the country.

Table 2: Threatened plant species with important populations within the study area

Common Name	Scientific Name	Local Status (Protected Species Order 2016)	IUCN Red List Status	Notes
Turtle Grass	<i>Thalassia testudinum</i>	Vulnerable		Native. Northern limit of native range.
Manatee Grass	<i>Syringodium filiforme</i>	Vulnerable		Native. Northern limit of native range.
Shoal Grass	<i>Halodule sp.</i>	Vulnerable		Native. Northern limit of native range.
Bermuda Sedge	<i>Carex bermudiana</i>	Critically Endangered	Endangered (Copeland et al., 2014)	Endemic
Wild Bermuda Pepper	<i>Peperomia septentrionalis</i>	Critically Endangered	Endangered (Bárrios et al., 2015)	Endemic
Wild Bermuda Bean	<i>Phaseolus lignosus</i>	Critically Endangered	Critically Endangered	Endemic

			(Copeland et al., 2014)	
Darrell's Fleabane	<i>Erigeron darrellianus</i>	Vulnerable	assessment underway	Endemic
Bermuda Cedar	<i>Juniperus bermudiana</i>	Critically Endangered*	Critically Endangered (list version 2.3) (Wingate et al., 2011).	Endemic *Protected species listing only applies to pre-1940's trees.
Bermuda Palmetto	<i>Sabal bermudana</i>	de-listed 2016 (previously VU)	Endangered (list version 2.3) (Johnson, 1998).	Endemic
Bermuda Olivewood	<i>Cassine laneana</i>	de-listed 2016 (previously VU)	Vulnerable (list version 2.3) NB. This species appears on the Red List as <i>Elaeodendron laneanum</i> (World Conservation Monitoring Centre, 1998).	Endemic. The majority of the reproductive population of this tree is on Nonsuch Island.
Yellowwood	<i>Zanthoxylum flavum</i>	Critically Endangered	Vulnerable (Areces-Mallea, 1998).	Native. Northern limit of native range.

Invasive Plants

The dominance of invasive plant species in the plant communities of most of Bermuda's terrestrial habitats is a well-documented problem (Anderson et al., 2001; Pettit, 2008; Wingate & Adams, 2011; Copeland et al. 2014). Within the Castle Harbour Islands invasive plants are intensively managed by the Department of Environment and Natural Resources, particularly on Nonsuch Island. The most significant invasive species on the Islands is the Australian Whistling Pine (*Casuarina equisetifolia*) which has major impacts, including advancing coastal erosion, altering Tropicbird and Bermuda Skink habitat, and outcompeting native plants. Other invasive plants that are found mainly in the coastal vegetation zone of the Islands are the Seaside Creeping Daisy (*Sphagneticola trilobata* syn. *Wedelia trilobata*) and Beach Naupaka or Hawaiian Half-flower (*Scaevola taccada*). The latter closely resembles the native Beach Lobelia (*Scaevola plumieri*) which is found in low densities on the Islands.

The inland portions of the larger islands, particularly Cooper's and Castle Islands, are sheltered enough from wind and salt spray, that a number of invasive plants, more typical of upland forests can be found. Of these, the species having the most impact are Brazil Pepper (*Schinus terebinthifolius*) and Jumbie Bean (*Leucaena leucocephala*). Other invasive plants that are numerous in the woodlands of the Castle Harbour Islands are Asparagus Fern (*Asparagus densiflorus*), Suriname Cherry (*Eugenia uniflora*), Fiddlewood (*Citharexylum spinosum*), Chinese Fan Palm (*Livistona chinensis*), Queensland Umbrella Tree (*Schefflera actinophylla*) and Velvetleaf Mallow (*Abutilon theophrasti*). The small annual Bitterweed

(*Helianium amarum*) has been recorded in large patches on the roadside of Mercury Road, adjacent to the airport fence. This plant is thought to have been recently introduced to Bermuda via landing aircraft. The patches were treated with herbicide by the Department of Environment and Natural Resources, and will be monitored for regrowth. As yet, this species has not been noted on any of the other Castle Harbour Islands.

Animal Species of Conservation Importance

Threatened Animal Species

Birds

The Castle Harbour Islands provide vital foraging, resting and over-wintering habitat for migrant birds, and also play a critical role as a breeding site for several seasonally resident seabirds. The Cooper's Island and Castle Harbour Islands area was designated as an Important Bird Area by BirdLife International in 2009, due to its significance as a breeding ground for the Bermuda Petrel and White-tailed Tropicbird (BirdLife International, 2013).

The Castle Harbour Islands are the only breeding location in the world for the Bermuda Petrel or Cahow (*Pterodroma cahow*). This species, Bermuda's National Bird, is listed as Endangered on the Protected Species Amendment Order 2016 and the IUCN Red List. It also has Appendix I protection under the Convention on Migratory Species. The most recent population survey recorded 111 nesting pairs on six islands, with 53 chicks successfully fledging in 2015 (Madeiros, 2015).

Bermuda supports the largest single breeding population of the Western Atlantic subspecies of White-tailed Tropicbird (*Phaethon lepturus catsbyii*), with an estimated local population of 2,500 – 3,000 nesting pairs (Madeiros, 2011). The western North Atlantic population of *P.lepturus catesbyi* was reported by Lee and Walsh-McGehee (2000) as 4,546 to 5,276 breeding pairs. The Castle Harbour Islands are the only area of Bermuda where the number of breeding Tropicbirds has remained largely stable over the last 40 years, with 500 – 600 nesting pairs recorded in 2008 (Madeiros, 2008). This represents about 20% of the Bermuda population, and about 10% of the world population of this subspecies nesting on the Castle Harbour Islands.

The Common Tern (*Sterna hirundo*) periodically nests in the area of the Castle Harbour Islands and uses them as a summer foraging site. There is recent evidence that the Bermuda population of the Common Tern is an endemic subspecies, consisting of only about eight individuals (Szczyś et al., 2012). The Islands also provide nesting and feeding grounds for two species of resident herons, the Green Heron (*Butorides virescens*) and the Yellow-crowned Night Heron (*Nyctanassa violacea*).

The Castle Harbour Islands provide important foraging and resting habitats for a number of species of migrant birds. The following are seasonal migrants, recorded from the Islands, which are listed on Appendix II of the Convention on Migratory Species (and therefore reported by the Dept. of Environment and Natural Resources): Ruddy Turnstone (*Arenaria interpres*), Sanderling (*Calidris alba*), Great Egret (*Casmerodius albus albus*) and Osprey (*Pandion haliaetus*). The Piping Plover (*Charadris melodus*) is listed on the IUCN Red List as Near Threatened, and is a seasonal visitor to the beaches of the Castle Harbour Islands.

Reptiles

Internationally threatened sea turtles spend their juvenile years foraging within the site, before returning to breed at rookeries in the Caribbean and Central America. Bermuda plays a critical role in the life history of both the Green Turtle (*Chelonia mydas*) and Hawksbill Turtle (*Eretmochelys imbricata*) by providing developmental habitat to juveniles of the Caribbean population (Meylan et al., 2011). The Castle Harbour Islands host a large aggregation of Green Turtles; however no estimates of abundance are available. Multi-year tagging has shown a resident Green Turtle population at Clearwater Beach, but the actual number of animals is unknown (Bermuda Turtle Project). Hawksbills are occasionally seen on reefs in the Castle Harbour area, but again, no population estimate has been made. Bermuda is the northern limit of the range of the Hawksbill Turtle in the Western Atlantic.

The Loggerhead Turtle (*Caretta caretta*) is not often seen in inshore waters; however Cooper's Island contains the only known nesting site used by this species in Bermuda in the last 25 years (Bacon et al., 2006).

All three turtle species occurring around the Castle Harbour Islands are protected internationally, as they are listed on Appendix I of CITES and Appendix I of the Convention on Migratory Species. In local waters, they are all protected under the Protected Species Act 2003. The local Green Turtle and Loggerhead Turtle populations are listed as Endangered on the Protected Species Amendment Order 2016, while the Hawksbill Turtle is listed as Critically Endangered.

The Castle Harbour Islands host the single largest remaining population of the Critically Endangered Bermuda Skink. This endemic lizard has been almost wiped out on the populated islands of Bermuda, but the isolation of the Castle Harbour Islands allows them to act as important refugia for this species. The Bermuda Skink is listed as Critically Endangered on both the Protected Species Amendment Order 2016 and the IUCN Red List (Conyers & Wingate, 1996).

The interactions between two species of nesting seabirds, (the Bermuda Petrel and White-tailed Tropicbird), and the Bermuda Skink, which take place on the Castle Harbour Islands are unique in the world. The nest-cleaning services of the Skink, and the food and shelter

provided to the Skink by Petrels nesting in the winter and Tropicbirds nesting in the summer, are only beginning to be understood. This relationship between two endemic island species (the Skink and Petrel) represents an ecosystem service which has been lost from mainland Bermuda.

Fish

Cooper's Island pond is the single most important breeding site in Bermuda for the Killifish (*Fundulus relictus*). This pond supports the only population of this endemic species that was found to be increasing during a Bermuda-wide 2012 survey. The restored tidal pond at Cooper's Island had a population of 2,329 fish, representing about 33% of the global population of this Endangered fish (Copeland, 2013).

The Bermuda Bream (*Diplodus bermudensis*) is one of only a small number of marine fish that are endemic to Bermuda. It is fairly common, and is found in various marine habitats around the Castle Harbour Islands. Other endemic marine fish reported regularly from the Islands include the Bermuda Halfbeak (*Hemiramphus bermudensis*) and the Hogmouth Fry or Bermuda Anchovy (*Anchoa choerostoma*).

Seagrass beds and coral reefs around the Castle Harbour Islands provide habitat for seahorses. Two species are known from Bermuda, the Lined Seahorse (*Hippocampus reidi*) and the Longsnout Seahorse (*Hippocampus erectus*). Both species are listed as Vulnerable on the Protected Species Amendment Order 2016. The sand flats and seagrass beds of Castle Harbour also provide foraging habitat for the Spotted Eagle Ray (*Aetobatus narinari*) which is also listed as Vulnerable on the Protected Species Amendment Order 2016.

Invertebrates

The marine habitats around the Castle Harbour Islands contain important breeding sites for the Queen Conch (*Lobatus gigas*) (Sarkis and Ward, 2009). Decades of protection under the Fisheries Act 1972 have failed to increase the Bermudian population of Queen Conch, therefore it is listed as locally Endangered on the Protected Species Amendment Order 2016. Bermuda is the northern limit of this species range. Several species of Helmets and Bonnets (Mollusca: Cassididae) are also found around the Castle Harbour Islands. These large shells are locally rare, and all species of helmets and bonnets are protected under the Fisheries Protected Species Order 1978.

West Indian Topshells (*Cittarium pica*) are economically important in the Caribbean, but are protected in Bermuda under the Fisheries Act (Fisheries Protected Species Order 1978). This species was extirpated locally and re-introduced in 1982 at Nonsuch Island. Castle Harbour remains the centre of their distribution, with an estimated 27% of the Bermudian

population. The most recent survey in 2015 recorded 8,491 animals in the area (Meyer et al. 2015).

The Land Hermit Crab (*Coenobita clypeatus*) relies on the West Indian Topshell for shelter, as this crab must use the shell of another species to hide its soft body. Being large, and now relatively available, the Topshell is the crab's shelter of choice. This Caribbean crab species is at the northern limit of its range in Bermuda, and the Castle Harbour Islands support a healthy population. This crab was listed as Vulnerable on the Protected Species Amendment Order 2016.

Observations suggest the Castle Harbour Islands contain most of the Bermudian population of the Solitary or Leaf-Cutter Bee (*Megachile sp.*). Little is known about this species, and it may prove to be an endemic species or subspecies. The Solitary Bee was added to the Protected Species Amendment Order 2016.

Invasive Animal Species

Many of the Castle Harbour Islands have been spared the effects of many of the invasive animal species that plague the rest of Bermuda, due to their isolation from the mainland. The most heavily impacted are Castle Island, which is close to the mainland, and Cooper's Island which is now connected to St. David's and the airport.

The invasive bird species that are having major impacts on the Islands include the Great Kiskadee (*Pitangus sulphuratus*), American Crow (*Corvus brachyrhynchos*) and European Starling (*Sturnus vulgaris*). Observed impacts of these birds include preying on the endemic Skink (Kiskadee), preying on Tropicbird chicks (Crow), preying on fry and Killifish (Kiskadee) and transporting seeds of invasive plants out to the Islands (Kiskadee and Starling). Other invasive birds that are having minor impacts on the Islands include the House Sparrow (*Passer domesticus*), the Feral Pigeon (*Columba livia*) which is known to foul Tropicbird nests when they are unoccupied in the winter. There is also a population of feral Chickens (*Gallus domesticus*) at Cooper's Island, which are regularly culled.

Invasive mammals pose a very serious potential threat to the biodiversity of the Castle Harbour Islands. Both the House Mouse (*Mus musculus*) and Black Rat (*Rattus rattus*) have been reported on the Islands. The rat in particular, poses a substantial risk to both the chicks and adults of burrow-nesting seabirds such as Bermuda Petrel and White-tailed Tropicbird. Rats are capable swimmers and are able to reach the nesting sites from the mainland. They are also an effective predator at songbird nests, and have had a significant impact on the reproductive success of a number of endemic plants. Rat poison is laid regularly on all of the islets used by nesting Petrels, and in the woodlands on Southampton, Castle and Nonsuch Islands. A population of feral cats (*Felis catus*) has become established on Cooper's Island, which is not being managed at present.

The Marine Toad (*Rhinella marina*) is present on Cooper's Island and toads occasionally swim across the channel to Nonsuch Island in an attempt to populate the freshwater pond there. A barrier has been erected around the pond to deny them access, and any toads found on Nonsuch Island are returned to the mainland, so the impact of this species is minor.

The Argentine Ant (*Linepithema humile*) is present on Cooper's Island. This invasive has the potential to have major impacts on the wildlife of the Castle Harbour Islands if it is able to spread. At present it has not been transported to the other islands, and biosecurity protocols are in place to prevent its introduction to Nonsuch Island. The establishment of Argentine Ants on Nonsuch Island would have devastating consequences for the ground-nesting Bermuda Petrel and White-tailed Tropicbird.

Lionfish (*Pterois volitans*) have become increasingly prevalent around the Castle Harbour Islands in recent years (see www.oceansupport.org/bermuda-lionfish-map). This voracious predator poses a serious threat to reef fish populations. Periodic culling takes place around the islands, by trained members of the public who are licensed to spear only Lionfish in nearshore waters. Culling data collected from this recreational fishery will allow monitoring of this species within the conservation area.

Ecological Character Description

The Castle Harbour Islands and reefs are characterised by high biodiversity, a high level of endemism, and serve as the last refuge in modern Bermuda for several globally threatened species. The site is a high-energy marine environment, characterised by the juxtaposition of seagrass, algal-vermatid cup reef, coral reef, sand flat and rocky islet habitats within a small area. The islands have a unique character, largely derived from the absence of invertebrate pests, a lack of mammalian predators, limited public access and intensive habitat and species management.

Anthropogenic factors, rather than geomorphology or climate, most strongly influence the ecological character of this site. Past land use of the islands and the surrounding area, along with the current management regime, have mostly determined the present ecological character of the Castle Harbour Islands. The isolation of the Castle Harbour Islands from the major population centres of Bermuda, along with historical exclusion of people from the area due to the presence of military installations have left the site little disturbed for the last 60 years. The present use as a strict nature reserve continues to limit public access to many of the islands, which coupled with active terrestrial habitat restoration, has contributed to their unique ecological character within the Bermuda Archipelago.

The absence of invasive Argentine Ants from the smaller islands in the Castle Harbour chain allow burrow-nesting seabirds like the Bermuda Petrel and White-tailed Tropicbird to

inhabit the islands. The islands are kept largely rat-free through intensive management, which also allows seabird colonies to thrive. On Nonsuch Island the absence of rats has allowed endemic plants, particularly the Bermuda Sedge, Bermuda Palmetto and Bermuda Olivewood, to form self-sustaining populations. These plants rarely reproduce in the wild elsewhere in Bermuda due to rat predation of the seeds. The combination of indigenous forest in a pest-free environment, maintained through management and the geography of the islands, will allow future expansion of the Bermuda Petrel population.

The ecological character of the islands is influenced by the presence of some invasive species (*Casuarina equisetifolia* in particular) and largely by the absence of many invasives (rats, plants) that are problematic in the rest of Bermuda. Intensive management of invasive species contributes significantly to the character of the site. The prevalence of invasive plants varies widely across the site, from invasive-dominated woodlands on Cooper's Island, to virtually invasive-free woodland on Nonsuch Island and native-dominated low coastal vegetation on the other islands. A large part of the variation in vegetation results from the lack of soil on the smaller islands, their exposure to salt spray and their occasional submersion during storms. The ecological character of the terrestrial portions of the site are also strongly influenced by the presence or absence of songbirds, including invasive species like the European Starling and Great Kiskadee, which deliver the seeds of invasive plants to the islands, and in the case of the latter, prey on the Bermuda Skink.

The open situation of the islands and reefs, exposed to the open sea and nearby deep water, influences their ecological character. For the smaller islets of the Castle Harbour Island chain, the strongest influences on their ecological character are a lack of soil, exposure to salt spray, submersion in storms and active coastal erosion of the limestone. The larger islands of the chain are less prone to saltwater inundation, but are also affected by coastal erosion. The islands provide storm protection services for other habitats and valuable infrastructure, but take the brunt of incoming wave energy. High wave energy at the site also influences the formation of cup reefs.

The coral reefs inside Castle Harbour, such as those in the northern part of the site by Cooper's Island, are in a recovery phase after dredging and land reclamation between 1941 and 1943 at the adjacent airport.

Geomorphology and Hydrology

The Castle Harbour Islands are composed of Aeolian limestone. The dominant rock and soil types are fossil dune formations, sandy beach deposits and sandy soils. On the islands, soils are generally thin deposits, high in calcium carbonate and low in organic matter; however the larger Nonsuch and Cooper's Islands have pockets of deeper, sandy-loam soils with more organic material.

The salt water and fresh water ponds in the conservation area both permanently contain water. The water level in the salt pond, and the corresponding area of exposed mudflats around it, vary considerably with the tidal and lunar cycles. The water depth in the deepest part of the salt pond is about 2 m on an average high tide. The saltwater pond is flushed by tidal exchange with Castle Harbour via a subterranean karst system. There is seawater exchange via tidal currents between Castle Harbour and the open sea to the south through various channels between the islands. Strong tidal currents are particularly found in Nonsuch Scaur between Nonsuch and Cooper's Islands and between Castle Island and mainland Bermuda at Castle Point. The tidal range for Bermuda is approximately 1 m.

Coastal erosion and sediment transport at the site are strongly influenced by passing tropical cyclones in the summer and autumn, and by winter storms. There are significant tidal currents between Castle Harbour and the open sea through Castle Roads and Nonsuch Scaur, with corresponding sediment movement in these areas. The primary sedimentary processes within the site are erosion of soft limestone rock (particularly by storm surge), transport of sand during storms and by tidal currents, wind transport of sand on beaches and possibly dissolution of limestone rock by increasing ocean acidification. Seagrasses reduce sediment transport in the nearshore waters of the site, and accumulated *Sargassum spp.* seaweeds trap sand on the beaches. Wind-driven *Sargassum* is responsible for episodic delivery of nutrients to coastal beaches and embayments. *Sargassum spp.* in the wrack line supports at least two species of endemic Enchytraeidae. (Healy and Coates, 2003).

To date, seawater chemistry has been monitored at only one location within the conservation area. Since March 2007, salinity, pH and nutrient levels have been measured on a monthly basis on the north side of Grazbury's Island (Briceño and Boyer, 2013) and seasonally (mostly summer) at random locations. These data show the site to be euhaline and alkaline (over 7.4). The waters are poor in nutrients and have low primary productivity (they are oligotrophic).

Ecosystem Services

The Castle Harbour Islands and adjacent reefs provide significant **regulating services** to the nearby population. While most of these regulating services are hydrological, there is some evidence that the islands play a role in agricultural pest control, as they support predators, namely the Barn Owl.

As a primarily marine site, the Castle Harbour Islands provide a significant number of **hydrological services**. Coates et al. (2013) note that the south eastern coastline of Bermuda is highly impacted by long period swells moving ahead of tropical cyclones, as the reef line is closest to shore here. Both the reefs and islands provide significant hazard reduction

services and storm protection. The site provides a protective barrier for infrastructure of national importance, namely the Bermuda International Airport and St. Georges causeway.

The seagrass beds within the site play a key role in sediment and nutrient retention. Globally, seagrass beds have been shown to act as a carbon sinks to buffer climate change (Duarte et al., 2011; Fourqurean et al., 2012). The *Sargassum* seaweed that is carried onto the beaches and subsequently buried in the sand also plays a role in sediment and nutrient retention within the site, and shoreline stabilisation.

The waters of Castle Harbour, both within and adjacent to the site, serve a regulating function through dilution of chemical pollution from the bulk waste disposal dump at the airport (Jones, 2010).

The Castle Harbour Islands and nearby reefs provide **provisioning services** in the form of both commercial and recreational fishing opportunities. Several species of native marine fish are harvested within the site, and there is a growing opportunity for spearing invasive lionfish.

This site is very important for the provision of **cultural services**. The Castle Harbour Islands have significant historic cultural value. Castle and Southampton Islands both contain historic fortifications which are included in the St. Georges World Heritage Site. Castle Island contains three forts dating back as early as 1612, making them the earliest standing English masonry structures in the Americas. Southampton Island also has a colonial fort dating back to 1620 which has been unmodified since that time. The historical military occupation of these islands, and the limiting of public access in modern times, has influenced their ecological character.

The site also provides opportunities for education and scientific research (both biological and archaeological) that are unmatched in Bermuda. For example, the submerged peat deposits at Well Bay and submerged tree stumps at Cooper's Island and Gurnet Rock have contributed evidence to inform sea level change models, and provide a paleo-environmental archive.

The site provides year-round tourism and recreation opportunities centred on water sports and nature observation. The main activities that occur on and around the Castle Harbour Islands are: nature tours, educational trips, picnics, boating, jet skiing, kayaking, sailing, diving and snorkelling, recreational fishing, bird watching and whale watching.

The Castle Harbour Islands offer **supporting services** in a number of areas, including biodiversity, soil formation, nutrient cycling and pollination.

Threats to the Conservation Area

Bermuda's international airport lies on the northern boundary of the Cooper's Island nature reserve. Its construction in the 1940's caused considerable alteration of the ecological character of the area, most significantly, the joining of Cooper's Island to St. David's Island through land reclamation; and significant dredging of Castle Harbour and loss of mangrove habitat (Sterrer and Wingate, 1981). Light and noise from the airport pose an actual threat to the conservation area. The northern part of the conservation area is directly under the flight path. The actual impacts of this are low and limited to occasional bird strikes by aircraft, controlled shooting by airport personnel and noise and light pollution. There is however, a high potential threat from the airport as a pathway of introduction for invasive species. The dumping of solid waste in the waters adjacent to the airport as part of an ongoing land reclamation project is a threat to the nearby conservation area. This form of legal marine dumping has resulted in toxins leaching into the waters of Castle Harbour (Prouty et al., 2013; Jones, 2010). Solid waste is a threat to the site, from both local sources and marine debris from the Atlantic gyre. Other sources of pollution in the surrounding area include the light pollution from the Tucker's Point Hotel and St. David's lighthouse, and noise and dust from the motor cross track adjacent to the site.

Fishing is not a threat to the site if done legally, obeying site and species exclusions and fishing seasons. However illegal fishing for protected species, using illegal methods, fishing outside of species-specific fishing seasons, and fishing within protected areas are all threats within the site and in the surrounding area. Fishing for lionfish has positively impacted the character of the site. Vegetation clearance and land conversion are having a moderate impact on the site, but mostly a positive one. All of the vegetation cleared has been invasive species, and an active planting programme for endemic and native species has been undertaken. Land conversion has mostly been removal of former military installation buildings, and planting the building footprints with indigenous trees. A number of installations remain on Cooper's Island which causes some disturbance to the site. These include a small arms firing range used by law enforcement officers, a weather Doppler radar tower, and various antennae and satellite dishes used to support several international space programmes. The main disturbances are guy lines on towers and antennae which are a threat to birds and localised radiation around the weather radar. A number of buried underwater cables for telecommunications and other applications run through several parts of the site.

The development of renewable energy projects within Castle Harbour is a potential threat to the conservation area and its surroundings. Wind, wave energy and solar energy projects in particular have been considered in the past. The redevelopment of the St. Georges Causeway and Longbird Bridge is also a potential threat to the site, due to disturbance caused during construction. More importantly, the proposed reopening of the waterway into Castle Harbour via Longbird Bridge will result in increased commercial and recreational boat traffic into Castle Harbour, and a corresponding increase in human disturbance.

Designations

Protected Areas within the Castle Harbour Islands chain include the 25.9 ha Cooper's Island Nature Reserve, the Castle Harbour Islands Nature Reserve which encompasses 13.7ha and was established in 1979, and the Cooper's Island Amenity Park (8.1ha). Adjacent to the Islands and the waters of Castle Harbour is the South Shore Coral Reef Preserve.

The Castle Harbour Islands are an important part of the [Historic Town of St. George and Related Fortifications](#) World Heritage Site.

Several non-statutory designations have been given to the Castle Harbour Islands. BirdLife International designated an Important Bird Area (IBA) called [Cooper's Island and Castle Islands \(BM001\)](#). The Castle Harbour Islands and surrounding reef were also proposed as a Wetland of International Importance (or Ramsar Site), although this designation was never finalised.

Portions of the site fall within the following categories of the 2008 IUCN classification of protected areas: Ia Strict Nature Reserve (protected area managed mainly for science), IV Habitat/Species Management Area (protected area managed mainly for conservation through management intervention).

Land Tenure and Responsibilities

All of the land within the Castle Harbour Islands chain is owned by the Bermuda Government, and mostly managed by the Department of Environment and Natural Resources (formerly Dept. of Conservation Services). Many of the islands have limited public access to protect the flora and fauna. The marine area around the islands is freely accessible to the public.

The residential area known as Tucker's Town forms the southwestern boundary of the Castle Harbour Islands Nature Reserve. This area consists of low density private homes. The nature reserve at Cooper's Island is bounded to the north by the Clearwater Beach National Park which is owned by the Government of Bermuda and managed by the Department of Parks. The northern side of the Cooper's Island nature reserve is also adjacent to the LF Wade International Airport. The airport lands are owned by the Bermuda Government and managed by the Department of Airport Operations. The land on the northeastern side of Cooper's Island nature reserve is owned by the Bermuda Land Development Corporation, a quango established to manage the lands returned to the Bermuda Government by the US Navy.

The land surrounding Castle Harbour is significantly different from the Castle Harbour Islands. The level of development, the density of human uses and the types of land use and habitats are different.

Most of the terrestrial portions of the Castle Harbour Islands are intensively managed for invasive species; therefore the species composition of the site is quite different from the surrounding area. There are no full-time residents living within the site, and human visitation to the islands (other than Cooper's Island) is by permission only. Much of the marine area within the site is similar to the immediately adjacent surrounding area in terms of habitat, but the human uses of the area are different.

Conservation and Restoration Measures Being Implemented

A number of habitat management measures and controls are being implemented within the Castle Harbour Islands conservation area. Land conversion is controlled by both the Development and Planning Act 1974 and the Bermuda National Parks Act 1986. Habitat enhancement measures which are ongoing include culling of invasive plants, re-vegetation with indigenous plants and construction of artificial nesting sites for Petrels and Tropicbirds. Species-specific conservation measures that are ongoing in the area include control of invasive animals and plants, reintroductions, rare species management programmes and species monitoring.

Measures to manage human activities within the conservation area are in place. The fisheries regulations are full enforced within the area. Measures to promote communications regarding the conservation area, educational activities, research and awareness raising are all being fully implemented. There is a need to develop policy to regulate recreational activities within the site, and to fully implement it.

Management Planning

A management plan for the Cooper's Island portion of the site was approved by the Bermuda Cabinet in 2008 (Pettit, 2008). The plan is being actively implemented. A management plan exists for Nonsuch Island; it was written in 2005. This plan is being implemented and is currently being reviewed and updated. The unique management needs of Nonsuch Island require that it has a separate plan from the other islands within the Castle Harbour Islands Nature Reserve. A management plan for the rest of the Castle Harbour Islands Nature Reserve is in preparation.

Planning for Restoration

Restoration planning is incorporated into the site specific management plans for Cooper's Island, Nonsuch Island and the Castle Harbour Islands Nature Reserve and will eventually cover all terrestrial parts of the conservation area. Restoration work within the site has been undertaken to address the on-going threat from invasive species, the recovery of threatened species and the historical effects of military installations on the islands.

Habitat restoration activities include the re-opening of the saltwater pond which had historically been filled by land reclamation at Cooper's Island, and the clearing of invasive vegetation and replanting with indigenous species. The most significant restoration project in Bermuda is the Nonsuch Island Living Museum which recreated the endemic-dominated pre-colonial forest. The restoration of Nonsuch Island was carried out in response to the decimation of the endemic Cedar forest in the 1940's by introduced insects.

The first phase of the Cahow Translocation Project was carried out between 2004 and 2008 to address the threat posed to nesting *Pterodroma cahow* pairs from rising sea level, coastal erosion and over-washing of the neighbouring nesting islands by storm waves.

Control programmes for invasive animals including lionfish, feral chicken, pigeon and crow, along with rat baiting are ongoing throughout the site.

Monitoring programmes that are being implemented at the site include water quality, plant community (seagrass monitoring and terrestrial plant monitoring), plant species (for those planted as part of restoration – health and mortality monitoring), animal species (killifish, skinks, rats) and birds (Cahow, tropicbird, invasive species such as crow, pigeon and chicken), along with coastal erosion monitoring.

Public Outreach and Engagement

A small museum building with interpretive signs exists on Nonsuch Island. Regular educational tours of Nonsuch Island are conducted by the Senior Terrestrial Conservation Officer for school children and groups of adults from local NGOs. An intensive week-long Nonsuch Island Natural History Camp runs each year for teenagers on the island.

A series of interpretive signs are present inside the base of the wildlife observation tower at Cooper's Island. Tours of Cooper's Island are regularly conducted for school children and special interest groups. Volunteer work days are held several times a year on many of the Castle Harbour Islands, supervised by the Department of Environment and Natural Resources. During these work days community volunteers learn about the flora and fauna of the islands, while helping to remove invasive species from the islands and replace them with indigenous species.

There are no educational or visitor facilities on any of the other islands because they are limited access nature reserves.

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