Castle Island Management Plan
as part of
Castle Harbour Islands Nature Reserve

November 2023

Government of Bermuda
Department of Environment and Natural Resources

Contents

This management plan was prepared by Mark Outerbridge (Senior Biodiversity Officer, Department of Environment and Natural Resources) in consultation with other technical officers of DENR and has been approved by the Director as well as the Minister of Public Works.

_____ _____

Drew Pettit — Date
Director, Department of Environment and Natural Resources

_____ _____

Lt. Col. the Hon. David Burch, JP, MP — Date
Minister, Department of Public Works

List of Figures

List of Tables

Executive Summary

Castle Island is a 4.37 acre Government owned nature reserve managed by the Department of Environment and Natural Resources. It is one of 13 named islands and islets that make up the 34 acre Castle Harbour Islands Nature Reserve established in 1979. The islands, located in St. George's Parish at the eastern end of Bermuda, are a biodiversity hotspot with high levels of endemism. Not only is the site protected as part of the UNESCO World Heritage Site, but it also serves as the last refuge on modern Bermuda for several globally threatened species. The islands have a unique character, largely derived from the absence of insect pests, a lack of mammalian predators, limited public access, and intensive habitat and species management. Land use is controlled by both the Planning and Development Act (1974) and the Bermuda National Parks Act (1986). The general area provides the public year-round recreation centered on water sports and nature observation including tours and educational trips, boating, jet skiing, kayaking, sailing, diving, snorkelling, and birdwatching.

This area comprises some of Bermuda's most pristine habitats and is home to some of the country's largest populations of indigenous protected species such as the Bermuda skink *Plestiodon longirostris*, the Bermuda petrel (aka cahow) *Pterodroma cahow*, and the white-tailed tropicbird *Phaethon lepturus catesbyi*.

Castle Island itself is a site of biological and cultural significance due to the presence of a variety of rare indigenous plants and animals as well as historical fortifications which date back to the early 17th century. Management of both the hugely important historical archaeological remains and the rich biodiversity of Bermuda's unique flora and fauna can be complimentary. There is presently a dense woodland of invasive vegetation on the island that has created unfavourable conditions for both the native biodiversity and the historical structures. Sensitive removal of this vegetation will benefit both the wildlife and archeological remains.

Habitat enhancement measures currently include culling invasive plants and controlling invasive animals. The ultimate management goal is to have Castle Island free of invasive species and replanted with low-growing native-dominated coastal vegetation. This should, in turn, create a more favourable environment for the survival of resident native wildlife leading to increases in abundance of skinks, land-hermit crabs, leafcutter bees, and nesting tropicbirds. Creating new signage, well-marked public foot-paths linking the fortifications, and ensuring that the historical buildings are repaired and protected from continuing erosion are important additional management activities.

Introduction

This management plan is written as per the requirement of Sections 11 and 12 of the Bermuda National Parks Act 1986.

Due to the variety of islands within the Castle Harbour Islands Nature Reserve the decision has been made to develop individual management plans; this plan focuses on Castle Island.

This management plan shall serve as a guide for all activities related to the management and administration of the protected area so that the purposes for which it was established are met and maintained. The plan provides for the following:

A) The long-term goals and purposes of the protected area and the problems that must be considered in order to achieve those goals and purposes;
B) The boundaries and existing natural or historic features of—
    i. the area as a whole;
    ii. any classes or zones within the area;
    iii. any peripheral areas which will require special attention in order to safeguard the purposes of the protected area;
C) The management, administrative, scientific and support needs required to accomplish the goals and purposes of the protected area;
D) The kinds of activities that will be regulated or prohibited within the protected area or within particular zones of the protected area;
E) Such other information as may be necessary to satisfy the requirements of the Bermuda National Parks Act.

Location

The Castle Harbour Islands Nature Reserve is comprised of four main islands (Nonsuch Island, Southampton Island, Castle Island, Charles Island) and nine smaller rocky islands and islets (Fig. 1). Castle Island is the second largest island within this reserve. It is located between the terminal end of the Tucker's Town peninsula (i.e. Castle Point) and Southampton Island and is characterized by sheer 15 meter north-facing cliffs and a declining slope to sea level on the south.

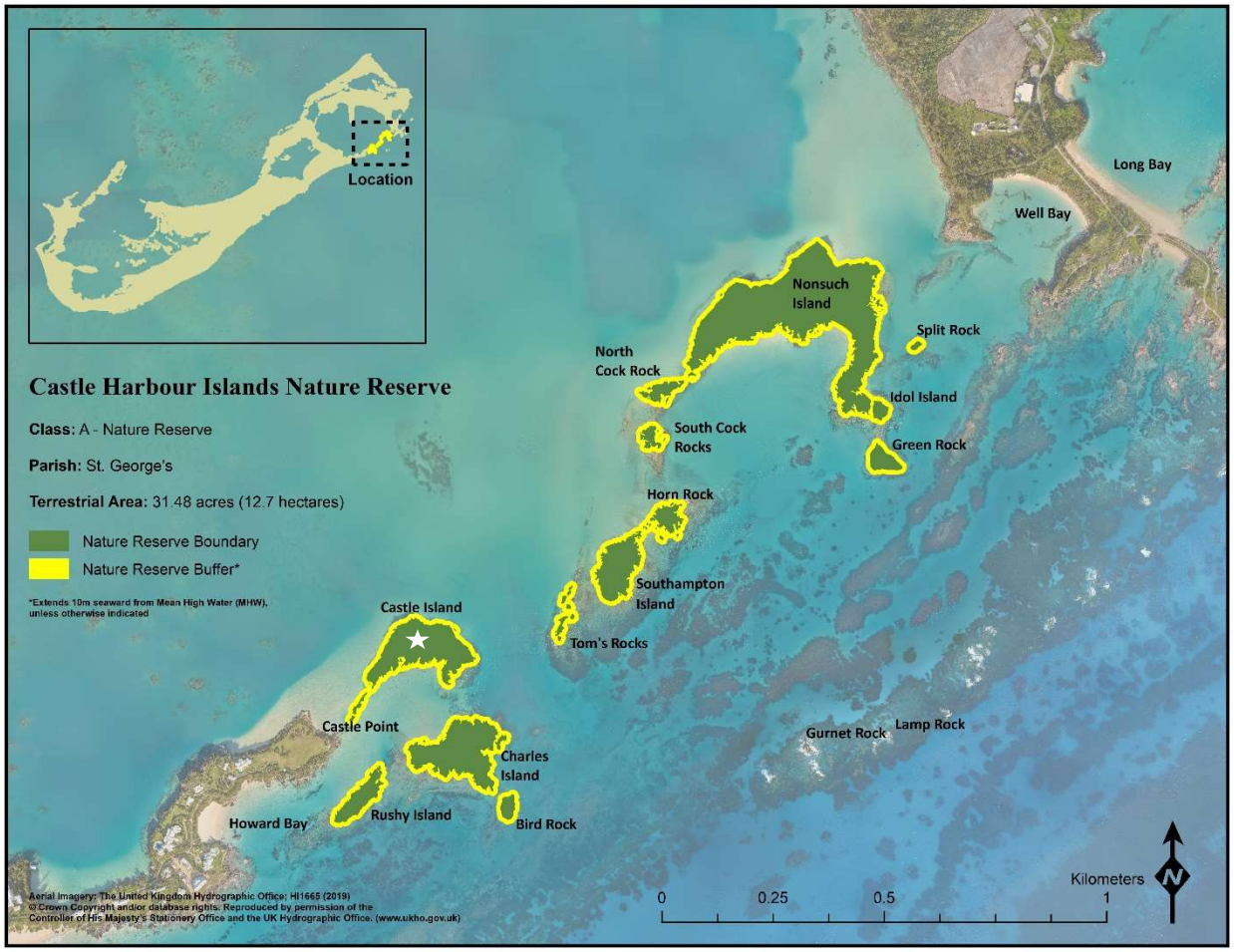


Figure 1. Location Plan of the Castle Harbour Islands Nature Reserve

Management

All of the Castle Harbour islands are designated as Class 'A' Nature Reserves, and are managed by the Department of Environment and Natural Resources as per the Bermuda National Parks Act 1986 and the Bermuda National Parks Regulations 1988. The Department of Parks provides enforcement of the Act and the National Parks Commission provides advice to the Minister responsible for the Act.

The Parks Heritage Officer is responsible for all the fortifications located in the Amenity Parks throughout the National Parks system; however, those located within protected Nature Reserves, such as the Castle Harbour islands, fall under the responsibility of the Terrestrial Conservation division within the Department of Environment and Natural Resources. Management activities include maintaining the buildings, walls, and the grounds around them.

The general public are not permitted to land upon the majority of the islands within the Castle Harbour Islands Nature Reserve, however Castle Island is one of the locations where they are (Charles Island is the other). Given the fact that there are no docks to facilitate landing, boats must be anchored and the occupants have to swim ashore to gain access to either island. This minimizes the risk of accidentally introducing non-native pest species not already present.

Goals and Objectives

The management plan has been designed to:

A) Safeguard and maintain plants and animals as well as geological, marine and other natural features, and fragile ecosystems in order to protect and preserve them;
B) Protect and maintain historic monuments and buildings (including forts), sites of particular historic, archaeological, or aesthetic value and to manage them so as to protect them from deterioration;
C) Provide for the use of the area in its natural state with a minimum of commercial and mechanized activity.

In order to effectively accomplish these objectives the management plan will:

- Ensure the preservation of historic buildings
- Conduct habitat and indigenous species enhancement activities
- Minimize all human use activities that negatively impact vulnerable species
- Minimize the risk of introducing invasive species
- Conduct control activities on non-indigenous species

Assessment

Historical significance

The location is a site of historical significance because a number of very old military buildings are scattered across the island; specifically the Devonshire Redoubt, the Seaward Fort, the Landward Fort, and the barracks building (Figs. 2 and 3). The first fortifications on this island appeared in 1612 and were made from wood, but stone structures began to appear by 1620 (Verrill, 1902). These were repeatedly reconstructed and strengthened during the course of the 17th, 18th and 19th centuries.

These forts are included within the UNESCO St. George's World Heritage site because they were the first English masonry fortifications in the Americas and are the oldest standing English forts in the New World (https://whc.unesco.org/en/list/983/). While detailed descriptions of the history and structure of each fortification on Castle Island have been provided by Harris (2006) it is useful to summarize that the fortifications comprised three main works: Devonshire Redoubt at the highest point of the island and located on the northern side fronting Castle Harbour; the Seaward Fort located at the south eastern point fronting the entrance into Castle Harbour; the Landward Fort located at the south western point of the island opposite the mainland. The Seaward and Landward Forts were also linked by a curtain wall. It should be noted that there is some confusion in regards to what constitutes "King's Castle". It seems that the many inspection reports made over the centuries sometime referred to the Seaward Fort or Devonshire Redoubt as the King's Castle, while Cunningham (1811) assumed that the King's Castle referred to all of the fortifications on the island.

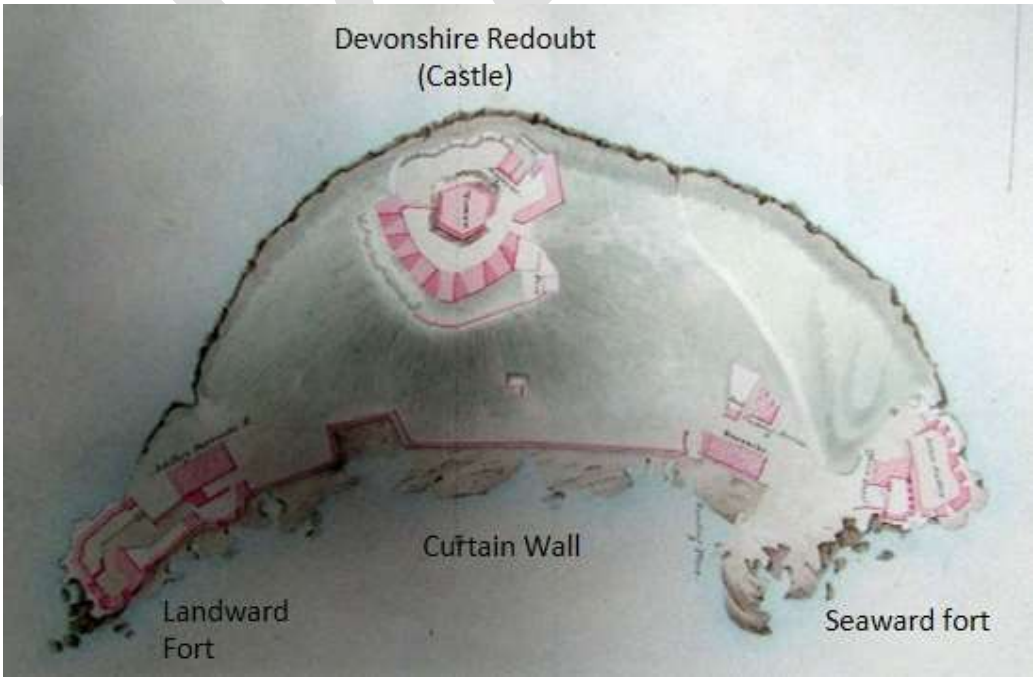


Figure 2. Castle Island Cunningham Survey of 1811.

Castle Island was the principal fortification for Bermuda for nearly 200 years, from the onset of settlement in 1609 until the discovery of Murray's Anchorage in 1795. Its purpose, in conjunction with the works on the adjacent Southampton Island, was to guard the entrance into Castle Harbour on the south east coast. Castle Harbour was the principal harbor for the British Royal Navy until the turn of the 19th century. After this time the importance of the fortifications was significantly diminished and the island's forts were not rearmed beyond the smoothbore cannon phase.

The Cunningham Survey of 1811 depicts the last phase of military development:

'The next points of defence in the district of St. Georges, are the Kings Castle and Fort Southampton commanding the entrance into Castle Harbour. Castle Island on the west side of the entrance is about 270 yards long and 90 yards broad, accessible only on a small part of south side.

On the southeast point, two batteries are built one directly above the other. The lower one is well situated and commands the entrance of the harbor (see Fig. 3B, Seaward Fort); *it is in a very bad state of repair, the merlons almost in ruins, and only one pine platform remaining in a similar state. There are three 12 and one 18 pr. mounted. The upper Battery appears to have been formed on the solid rock and is in a very good repair, with a parapet 5 feet high and 3 feet thick. There are three 4 prs. mounted, but no platforms.*

About 100 yards from this point is the only landing place on the Island, adjoining to which, is a good barracks for 50 men, together with a cooking house, cistern (see Fig. 3D) - *from hence, along the edge of the rock, is a thin wall for Musquetry on the southwest point of the Island, terminated by an irregular Battery* (see Fig. 3C, Landward Fort), *mounting one 12 and two 6 pdrs on good cedar platforms, and one 4 and two 9 pdrs on pine platforms, in a bad state. There is here a small barracks and store for the artillery.*

On the North or highest point of the Island, the Castle (see Fig. 3A, Devonshire Redoubt) *is situated, an irregular hexagonal tower from 20 to 25 each side founded on a rough mass of rocks and executed in this rudest and worst manner; 'tis about 20 feet high to the top of the parapet, solid, and the interior of the parapet which is in barbette towards the harbour, forms an irregular heptagon. There are three 4 pdrs mounted on cedar carriages, and the platform of pine is in ruins. The tower on the land side is enclosed by a very considerable enciente, with a parapet from 15 to 18 feet thick and 7 feet thick high. There are four 12 pdrs on cedar carriages and cedar platforms in good condition, but the cheeks of the embrasures have given way from firing of the guns.'*

The island and the forts would be used in the late 19th century as camps for isolating the garrison from the worst of the yellow fever epidemics that plagued Bermuda during that time. In 1986 Castle Island was annexed into the National Parks System.

Figure 3. Aerial view of Castle Island showing fortifications and elevation contours. A. Devonshire Redoubt, B. Seaward Fort, C. Landward Fort, D. Barracks Building, E. Curtain Wall

The historical occupation of Castle Island has significantly influenced its ecological character. By the beginning of the twentieth century this island was described as '*barren…with thin dry soil… supporting a scanty crop of wiry grasses, weeds, and seaside shrubs*' (Verrill, 1902). It was also devoid of any large trees Figs. 5 and 6), however this may have been as a result of harvest for firewood by the stationed garrison. It is presently characterized by a fringing mix of indigenous coastal shrubbery and salt-tolerant trees (e.g. buttonwood and baygrape); however most of the island is covered in a dense non-native canopy forest with largely non-native understory vegetation (e.g. casuarina, Brazil pepper, rouge plant, asparagus fern).

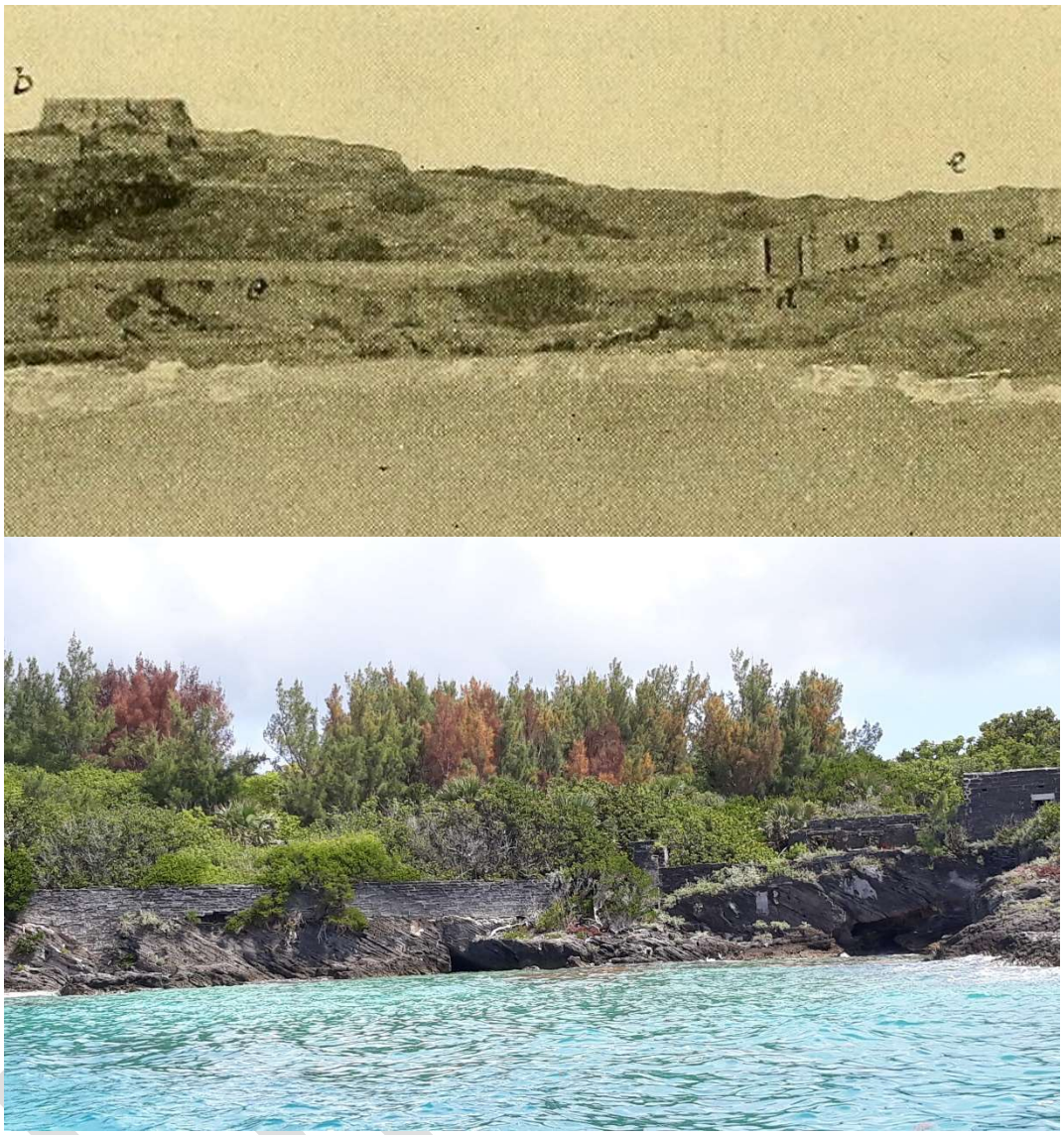


Figure 4. (Top) Historical photograph from Verrill (1902) showing the Devonshire Redoubt (b) and the barracks building (e). (Bottom) Photograph of the same vista taken in August 2022.

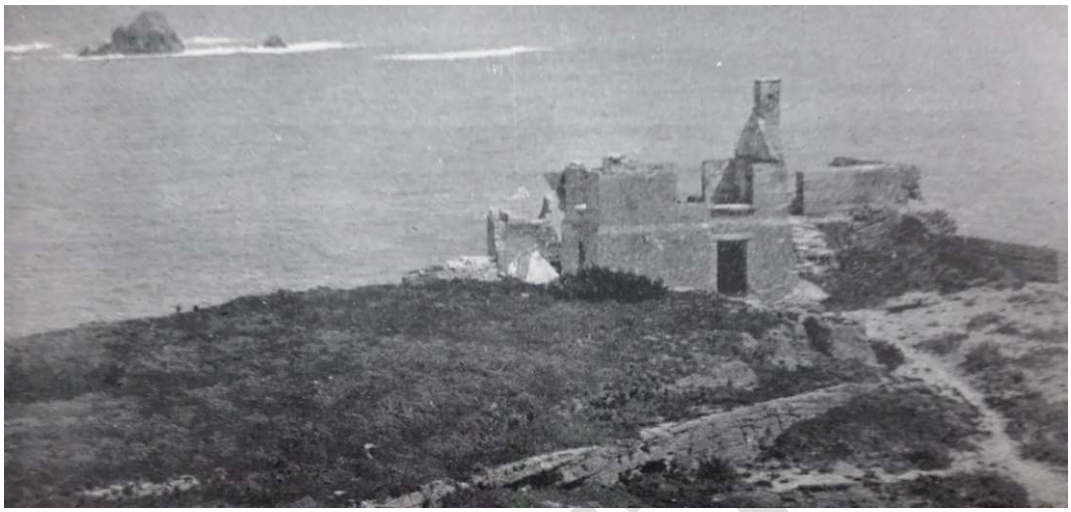


Figure 5. Historical photograph of the Seaward Fort (South East Battery).
Photo credit: Verrill 1902.

Figure 6. Historical photograph showing the Landward Fort (left) and a portion of the Devonshire Redoubt ramparts (top right). Also the barracks, kitchen and curtain wall in the foreground.
Photo credit: Verrill 1902.

Figure 7. Aerial view of the Devonshire Redoubt C.1990s.
Photo credit: Scott Stallard.

Figure 8. Aerial view of the Seaward Fort C. 1990s.
Photo credit: Scott Stallard

Ecological significance

The Castle Harbour Islands Nature Reserve is the only nesting site in the world for the Bermuda petrel (aka cahow), and for this reason it is already globally recognized as an Important Bird Area by BirdLife International. Additionally, the area contains at least 600 breeding pairs of white-tailed tropicbirds (Madeiros, 2008), representing 10% of the entire Caribbean population. Both species of seabird nest seasonally; the cahows during the winter and spring (November-April) and the tropic-birds during the summer and fall (April-October).

Some species, such as the Bermuda skink, are resident year round. Population estimates of this endemic reptile have been made at a few locations:

- Castle Island ca. 322 individuals (Hammond, 2000); ca. 277 (Turner et al., 2019)
- Charles Island ca. 123 individuals (Raine, 1998)
- Southampton Island ca. 414 individuals (Davenport et al., 1997); ca. 582 (Glasspool & Outerbridge, 2005); ca. 547 (Turner et al., 2019)
- Horn Rock ca. 66 individuals (Glasspool & Ward, pers. comm., 2011)

Skinks are also present on Rushy Island, Nonsuch Island, Cooper's Island, and both the Inner and Outer Pear Rocks, however estimates of abundance are not available for these sub-populations. It is thought that the total island-wide (hence global) population of Bermuda skinks is around 3,500 adults (Edgar et al., 2010), therefore the Castle Harbour Islands Nature Reserve is clearly the most important area for this critically endangered reptile.

Southampton Island presently has the largest sub-population of skinks on Bermuda, and Castle Island has the second largest. The latter, however, has the potential to become the most important refuge for Bermuda's skinks. It is nearly twice the size of Southampton Island (4.37 acres vs. 2.34 acres) and may therefore be able to support twice the number of skinks, once the landscape has been optimized for skink survival. At the moment there is no evidence that cahows are nesting on Castle Island but it may serve as a rookery (after the installation of artificial nest burrows) in the future.

Indigenous wildlife

The following fauna are currently inhabiting Castle Island:

Species name	*Status*	
Bermuda skink *Plestiodon longirostris*	Endemic	Level 1 listing on the Bermuda Protected Species Order (2016); Critically Endangered.
Land hermit crab *Coenobita clypeatus*	Native	Level 2 listing on the Bermuda Protected Species Order (2016); Vulnerable.
White-tailed tropicbird *Phaethos lepturus catesbyi*	Native sub-species	Level 1 listing on the Bermuda Protected Species Order (2016); Vulnerable.
White-eyed vireo *Vireo griseus bermudianus*	Endemic sub-species	Level 1 listing on the Bermuda Protected Species Order (2016); Vulnerable.
Leafcutter bee *Megachile pruina pruina*	Native sub-species	Level 2 listing on the Bermuda Protected Species Order (2016); Vulnerable.
Trap-jaw ant *Odontomachus ruginodis*	Possible native	Not protected by local legislation.
West Indian topsnail *Cittarium pica*	Native	Protected by the Fisheries Protected Species Order (1978).

Table 1. Indigenous wildlife found on Castle Island.

Bermuda skink
Verrill (1902) described skinks as being common on Castle Island '*along the ruins of the old forts and crevices of the cliffs'*. Hammond (2000) estimated a total of 322 skinks for the entire island and Turner et al. (2019) did three separate annual assessments between 2015 and 2017 during which they reported an average population of 277 skinks. The latter described the population as unstable because it fluctuated over the three year study period. Trapping surveys have shown that native coastal shrubs are considered to be the optimum habitat for this reptile. This supports the observation that the reforestation of neighbouring Nonsuch Island since the 1960s was thought to have been detrimental to the resident skink population (D. Wingate, pers. comm.).

Land hermit crab
This species is the only terrestrial crab on Bermuda that inhabits the empty shells of snails. It relies on the West Indian topsnail for shelter, but smaller individuals are also known to use the shells of nerites, periwinkles and tritons. Crabs roam all over Castle Island and are typically found sheltering in patches of dense vegetation during the day. This Caribbean crab species is at the northern limit of its range in Bermuda.

White-tailed tropicbird
Bermuda is home to the largest single breeding population of the Western Atlantic subspecies of White-tailed tropicbird, with an estimated local population of 2500-3000 nesting pairs; 600-700 (approx. 24% of the local population) of which nest within the Castle Harbour Islands Nature Reserve (Dobson and Madeiros, 2008; Madeiros, 2011). These islands are the only area of Bermuda where the number of breeding tropicbirds has remained relatively stable over the last 40 years. Tropicbirds are a cavity nesting species and prefer laying eggs and raising chicks in rocky crevices along limestone cliff faces, although some will occasionally nest upon the open ground.

Nesting colonies of seabirds, like the tropicbird, are also important to the survival of skinks because they provide a much needed seasonal supply of food through the scavenging of regurgitated fishes, dead chicks, and addled eggs.

White-eyed vireo
Individuals were sighted on the island in August 2021, but no research has been undertaken on the species at this location.

Leafcutter bee
Little is known about this rare insect, but it may prove to be an endemic species or subspecies (see Outerbridge and Sinclair, 2018). Observations suggest that the Castle Harbour islands contain most of the Bermudian population.

Trap-jaw ant
Little is known about this rare, but remarkable (see Outerbridge, 2022), insect either. Some have suggested that it may be native to Bermuda (Wetterer and Wetterer, 2004; Wetterer, 2017).

West Indian topsnail
This marine mollusk inhabits the inter-tidal zone of the coast and is protected in Bermuda under the Fisheries Act (Fisheries Protected Species Order 1978). It was historically extirpated on Bermuda and re-introduced in 1982 at Nonsuch Island. Castle Harbour remains the center of their distribution, with an estimated 27% of the Bermudian population. The most recent survey recorded 8,491 animals in the area (Meyers et al., 2015). The empty shells of dead snails are a very important resource for land hermit crabs.

Indigenous vegetation

The following flora are currently growing on Castle Island:

Species name	*Status*	*Importance*
Bermudiana *Sisyrinchium bermudiana*	Endemic	Cultural value; Bermuda's national flower.
Darrell's fleabane *Erigeron darrellianus*	Endemic	Level 3 listing on the Bermuda Protected Species Order (2016); Vulnerable.
Bermuda palmetto *Sabal bermudana*	Endemic	Flowers and fruits are important to local wildlife.
Bermuda cedar *Juniperus bermudiana*	Endemic	Cultural value; Bermuda's national tree.
Bermuda maidenhair fern *Adiantum bellum*	Endemic	
Prickly pear *Opuntia stricta*	Native	A salt and wind tolerant cactus that produces fruit which is an important source of food for skinks. Flowers are an important source of pollen for leaf-cutter bees.

Sea ox-eye *Borrichia arborescens*	Native	A salt and wind tolerant coastal plant. Flowers are an important source of pollen for leaf-cutter bees. This plant also forms dense clumps that are frequented by skinks.
Seaside goldenrod *Solidago sempervirens*	Native	This plant forms dense clumps that are frequented by skinks. Flowers are important to pollinating insects.
Baygrape *Coccoloba uvifera*	Native	This plant forms dense clumps that are frequented by skinks and land hermit crabs.
Ink berry *Passiflora suberosa*	Native	Host plant for the Gulf fritillary caterpillar.
Bermuda snowberry *Chiococca alba*	Native	Flowers and fruits are important to local wildlife.
Buttonwood *Conocarpus erectus*	Native	
Spanish bayonet *Yucca aloifolia*	Native	

Table 2. Indigenous vegetation found on Castle Island.

Bermuda palmettos and cedar trees are not well represented on Castle Island (Fig. 9). The majority of the palmettos are mature specimens, although some recruitment has been observed in recent years. The lack of saplings is likely due to seed predation from rats. Only one Bermuda cedar tree is known to be on the island; a stunted specimen growing in the vicinity of the Seaward Fort. Baygrape and buttonwood trees are comparatively more abundant and are found growing in a narrow fringe along the southern coastline (Fig. 9).

Figure 9. Distribution map of the main vegetation on Castle Island in 2019.

Copeland (2020) reported that the Castle Harbour Islands nature reserve contains a significant number of Bermuda's Darrell's Fleabane plants and that at least 132 specimens were found growing on the walls of all three forts on Castle Island. This shallow rooted, endemic shrub is not a threat to the structural integrity of those historical buildings and should not be removed. Turner et al. (2021) highlighted the importance that scrubby coastal vegetation, such as prickly pear cactus, has on skink presence and distribution. These types of plants provide both a food source of invertebrates and fleshy fruits as well as good cover for safe movement over the ground. Skinks are also found in association with other types of salt-tolerant plants such as bay grape and sea ox-eye (Raine, 1998; Glasspool and Outerbridge, 2005). These species should be encouraged to grow in areas where invasive plants are removed.

Risks

Non-indigenous wildlife

The following problematic fauna are currently inhabiting Castle Island:

Species name	*Status*	*Problem*
Pigeon (rock dove) *Columba livia*	Invasive (pest)	Cliffs are attractive to feral pigeons where they outcompete tropicbirds for cavity nest sites.
American crow *Corvus brachyrhynchos*	Invasive (pest)	Predate upon tropicbird eggs (Mejias, 2014; Fig. 9) and chicks.
Great kiskadee *Pitangus sulphuratus*	Invasive (pest)	Known predator of skink hatchlings (Griffith et al., 1991) and suspected to be a predator of juvenile land hermit crabs. Also transports seeds of invasive plants out to the island (via defecation).
European starling *Sturnus vulgaris*	Invasive (pest)	Transports seeds of invasive plants out to the island (via defecation).
Rats *Rattus norvegicus* *Ratus rattus*	Invasive (pests)	Pose a substantial risk to chicks and adults of both burrow-nesting seabirds (e.g. cahow and tropicbird) and songbirds (e.g. white-eyed vireo), as well as skinks. Rats also have had a significant impact on the reproductive success of a number of endemic plants.
Jamaican anole *Anolis grahami*	Naturalized	Known predator of skink hatchlings (Griffith & Wingate, 1994).

Table 3. Non-indigenous wildlife found on Castle Island.

Pest birds

Pigeons, crows, kiskadees, and starlings are resident on Bermuda year-round. Pigeons can breed throughout the year if food is abundant enough, but peak reproduction occurs between the spring and the fall. Not only do pigeons displace tropicbirds from cavity nests by actively using them but they also defecate copiously in them (and their coastal rookeries), which appears to deter tropicbirds from subsequently using the site in later years for their own nesting. Crows are intelligent scavengers and predators that are known to raid the nests of native breeding birds for eggs and chicks. On Bermuda they have been observed targeting tropicbirds (Mejias, 2014; http://bernews.com/2013/09/crows-threatening-bermudas-longtail-population), which typically only produce one egg each year. Of particular note, Mejias (2014) found that crow predation was significantly higher among island sites compared to mainland sites.

Rats

Rats are capable swimmers and are able to reach all of the islands within the Castle Harbour Islands Nature Reserve from neighboring Cooper's Island and Castle Point in Tucker's Town. Eradication from an island is usually temporary, therefore continued monitoring and control will be required.

Anole lizards
There are four species of anolis lizards presently established on Bermuda; the Jamaican anole *Anolis grahami*, the Antiguan anole *Anolis leachii,* the Barbados anole *Anolis extremus,* and the Cuban anole *Anolis sagrei*. Only the Jamaican anole is found on Castle Island. Griffith and Wingate (1994) observed an adult male Jamaican anole eating a hatchling-sized skink on Castle Island and Wingate (1998) found evidence to suggest that Jamaican anoles negatively affect skinks through competition. Although there are no reports of Antiguan anoles preying upon skinks, the former is a known predator of smaller anolis lizards (Kolbe et al., 2008) and *Hemidactylus* geckos (Trageser et al., 2018) and would therefore very likely eat Bermuda skinks as well if they became established on Castle Island. Antiguan anoles are widely distributed throughout Bermuda, the closest having been observed on Cooper's Island (Macedonia et al., 2016). The brown anole *Anolis sagrei* is a relatively recent arrival to Bermuda and it too poses a potential threat to Bermuda's skinks (see Stroud et al. 2017). The closest known sub-population of brown anoles to the Castle Harbour Islands Nature Reserve is at the airport waste management facility.

The following are currently not inhabiting Castle Island and every effort should be made to exclude them:

Argentine ant
This species is present on Cooper's Island, but is currently not recorded on any of the other island in the Nature Reserve. This invasive pest has the potential to have major impacts on the wildlife of the Castle Harbour Islands if it is able to spread. For example, the establishment of Argentine Ants on Nonsuch Island, Southampton Island, or Horn Rock would have devastating consequences for the ground-nesting cahows and tropicbirds.

Giant Asian centipede
Scolopendra subspinipes was an unintentional introduction to Bermuda and is commonly encountered in St George's parish. Andrew et al. (2018) identified this large arthropod as a predator of New Zealand's blue-tailed skink (*Cryptoblepharus egeriae*), a species that is slightly smaller than Bermuda's skink. The most likely arrival pathway for this centipede onto Castle Island would be as a stowaway on construction material (i.e. sand and aggregate) used to repair the historical buildings. Its presence on Castle Island would be deleterious to hatchling and juvenile skinks.

Non-indigenous vegetation

The following problematic flora are currently growing on Castle Island:

Species name	*Status*	*Problem*
Asparagus fern *Asparagus densiflorus*	Invasive (pest)	This fast growing understory plant can form dense monoculture stands which excludes native shrubs.
Casuarina (aka Australian whistling pine) *Casuarina equisetifolia*	Invasive (pest)	Advances coastal erosion during storms, alters tropicbird and skink habitat, and outcompetes native plants. Also damages the stonework of the historical buildings.

Brazil pepper *Schinus terebinthifolia*	Invasive (pest)	Outcompetes native plants and provides a wind break allowing additional invasive plant species to grow on the island.
Indian laurel *Ficus microcarpa*	Invasive (pest)	Damages the stonework of the historical buildings and destabilizes cliffs.
Umbrella tree *Schefflera actinophylla*	Invasive (pest)	A fast growing plant with an aggressive root system that grows as an epiphyte on other plants or in the cracks of rock faces and walls.
Shrubby clerodendron *Clerodendron sp.*	Invasive (pest)	A fast growing plant with an aggressive root system that quickly forms a monoculture once established.
Fiddlewood *Citharexylum spinosum*	Invasive	A fast growing plant that forms a monoculture once established. The brittle branches easily break during storms.
Rouge plant *Rivina humilis*	Invasive	This fast growing understory plant can form dense monoculture stands which excludes native shrubs.
Natal plum *Carissa macrocarpa*	Naturalized	None
Pittosporum *Pittosporum spp.*	Naturalized	None
Common sage bush *Lantana involucrata*	Naturalized	None
French tamarisk *Tamarix gallica*	Introduced	None

Table 4. Non-indigenous vegetation found on Castle Island.

While wiry grasses and weeds are still common on Castle Island, the plants deemed most invasive are the casuarina, Brazil pepper, Indian laurel, and umbrella tree. These are canopy species and form dense thickets outcompeting slower-growing native plants. The casuarina, Indian laurel, and umbrella trees are also capable of growing out of rocks, including the masonry of the historical buildings, which severely damages the integrity of the buildings and the limestone bedrock, thereby speeding up erosional forces on the coast. Prior to 2019 the non-native plants with the most biomass on Castle Island were the Brazil pepper and casuarina, which covered over 50% of the island (Figs. 9 and 10). The spread of these plants across the island can be seen through a series of aerial photographs taken from 1962 to 2012 (see Appendix). Although an introduced species, the French tamarisk is not considered to be problematic on Bermuda. It appears to be incapable of producing viable seeds which greatly limits this plants ability to spread. Furthermore, some research has shown that skinks take refuge within large, sprawling tamarisk trees (Glasspool and Outerbridge, 2005; Turner, 2018). There are a limited number of tamarisk trees presently on Castle Island. Most are located along the top of the west and north facing cliffs, but only those showing signs of damaging the fortifications should be removed.

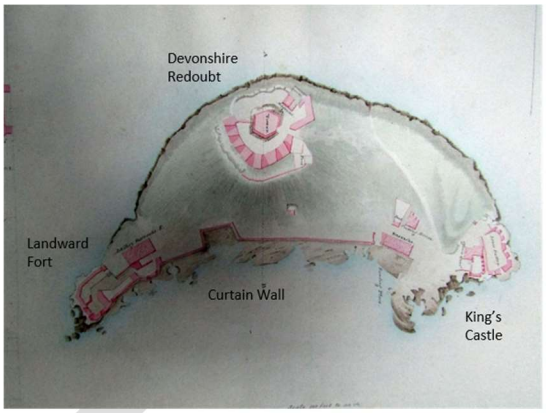
Figure 10. Aerial image showing the extent of casuarina tree coverage on Castle Island in 2014

Climate change

A number of hurricanes have affected Bermuda over the past two decades, some of which resulted in partial damage to the historical buildings on Castle Island. The most impacted currently appears to be the southern curtain wall (see Fig. 11.2) built between the Landward Fort and the barracks building where small sections have fallen away because of erosion to the underlying bedrock. Casuarina trees were also toppled by the high winds experienced during some of the hurricanes which caused localized damage to some of the masonry, particularly in places along the Great Battery of the Devonshire Redoubt.

The relatively high elevation of Castle Island (the north-facing cliffs are 15 meters above sea level) and its position behind Charles Island provides a measure of protection against coastal erosion during hurricanes but it is anticipated that as the effects of climate change continue to increase, Castle Island will be more and more negatively affected.

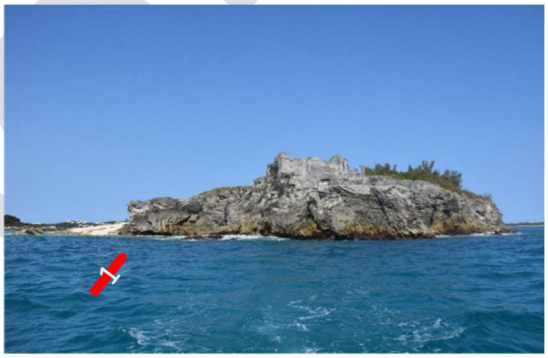
Castle Island, Aerial 2017



Castle Island, Cunningham Report, 1811

1 Southern Curtain Wall showing damage from Hurricanes Paulette and Teddy

2 New damage to southern Curtain Wall (5m)



1 Sloughing of coastal surface to small peninsula south of King's castle.

2 Some undercutting of cliff face below main fortification structure (L 4m x D 2m x H 2m)

3 No visible damage to fortification caused by Hurricanes Paulette or Terry

Figure 11. Visual inspection of hurricane related damage 2022.

Management Activities

Prohibited activities

1. Camping, taking or consuming food and drink on the island, lighting bonfires, removal of plants, animals, or shells of any kind, landing with dogs, cats, or other domesticated animals, defacement of fortifications, walls, or vegetation.

2. Beaching boats and tying boats directly to the foreshore.

3. Fishing within the Nature Reserve buffer that surrounds the island (e.g. a distance of 10 meters or 33 feet that extends seaward from the low tide level).

Ecological activities

Current:

1. Skinks are periodically surveyed for estimates of abundance and some tropicbird chicks are banded annually.

2. Rats are sporadically culled by deploying containers baited with rodenticides.

3. Crows and pigeons are controlled by targeted shooting. Between 2004 and 2006, 93 feral pigeons were shot (average of 31 per year) in the Castle Harbour area, however intentional feeding of the feral flock lead to a localized increase in abundance which resulted in 760 being culled between 2016 and 2019 (average of 190 per year). Feeding has presently ceased and the number of feral pigeons in the area has dropped significantly.

4. Manual removal of invasive plant seedlings using weed wrenches, direct application of herbicides (Tordon and Garlon) to the bark of saplings, felling, girdling, and employing the drill and fill method on large trees. The cambium layer of felled and girdled trees is spot treated with herbicide to increase the chances of mortality. The drill and fill method involves using a cordless drill or hand operated auger with a ½ inch drill bit that penetrates at least six inches into the trunk close to the roots. The hole is then filled with a Garlon:diesel solution (1:3). The use of repelling gear to remove casuarina seedlings growing on the cliff faces is also periodically undertaken.

Proposed:

1. Prophylactic rat control. The presence of rats should be checked annually using rodent detectors (i.e. cards, wax blocks) or opened dried coconut seeds (see Wilmshurst and Carpenter, 2020). When used properly, these detectors allow for the timely and targeted eradication of rats. Rats can be controlled using rodenticides in bait boxes, live-capture traps (e.g. HavaHart or Duke), and baited captive bolt traps (i.e. Goodnature A24 automatic

traps). To initially control a heavy infestation, rodenticides can be employed in combination with baited capture traps. Subsequent control can be accomplished using Goodnature A24 traps which should be placed strategically across the island to provide ongoing biosecurity on Castle Island. Based on rat eradication efforts in New Zealand (see Peters, 2015), 12 A24 traps set at 50 meter intervals would be an appropriate number to deploy on Castle Island (Fig. 11); however six could be used if their positions are rotated every few months. Monitoring for rat re-invasion (see Gillies and Williams, 2013) should be done annually before the tropicbird and skink breeding season begins in March or April. Using live-capture and A24 traps is beneficial in that it diversifies the methods of rodent control as well as doing so in a manner that is not harmful to other wildlife. The use of rodenticides is hazardous to non-target wildlife such as predators (i.e. barn owls *Tyto alba)* and scavengers (i.e. skinks) which may consume poisoned rodents. Evidence exists showing that local owls do die from secondary poisoning events, especially when second-generation poisons are used (Wingate, 2021). Exposure to skinks occurs via scavenging on a rat corpse, but it is currently thought that the amounts consumed are unlikely to cause death in the skinks (Hoare and Hare, 2006; Mauldin et al., 2019); however, the effects of sub-lethal doses on skink health are not understood.

Figure 12. Proposed locations of automatic rat traps

2. Anolis lizard management. No practical control methods for Jamaican anoles are known at present but efforts should be made to prevent introducing more to the island. It is imperative that the other non-native lizard species are kept from colonizing Castle Island.

3. Pest bird control. Pigeons and crows will continue to be controlled using targeted shooting. The periodic control of great kiskadees, especially during the time of year when naïve skink hatchlings are present (i.e. August and September), is recommended. Their control is more challenging but possible with targeted shooting and possibly with the use of letterbox (aka ladder) traps. No practical control methods for starlings are known at present. Eradication of kiskadees and starlings from Castle Island is deemed unfeasible given the ease of return from the neighbouring main island.

4. Invasive plant control. Casuarina, Brazil pepper, and Indian laurel trees are to be phased off the island. There are currently an estimated 80 large mature casuarina trees scattered across the island, many of which date back to the late 1960s and early 1970s. There appears to be slightly fewer large Brazil pepper trees, and most of them are confined to the center of the island; however there are several hundred smaller Brazil pepper trees with a wider distribution. Cutting the mature trees down and leaving the felled materials to decompose where they lay is not desirable, neither is stacking the trunks and tree limbs into piles. The former would create an unsightly and impenetrable thicket of dead vegetation; the latter would be a fire hazard and would also likely become inhabited by rats. Using a wood chipper to reduce the volume of the felled material is preferable, however its use on the island is impractical given the scattered distribution of the trees, the size of the trees, and the logistical challenges of transporting a chipper to the island and across it. The most practical solution is to girdle or use the drill and fill technique to kill all of the large trees and leave them standing in-situ, thus allowing them to slowly decompose over time. The Brazil pepper trees are expected to decompose much quicker than the casuarina trees, thereby creating patchy areas on the island that will be available to replant with native coastal shrubs. The proposed removal of the canopy forest is likely to be unfavourable to white-eyed vireos, however abundance is low on Castle Island and the species appears to be doing well across the rest of Bermuda (Mejias, 2021).

5. Phased plantings of salt and wind tolerant coastal species such as sea ox-eye, tassel plant, Spanish bayonet, seaside purslane, seaside goldenrod, scurvy grass, prickly pear, iodine bush, beach croton, coast sophora, Darrell's fleabane, and buttonwood. The plantings should be augmented by the sowing of seeds at appropriate times of the year. Rooted shrubs (1-3 gallon container size) and transplanted specimens from other locations must be landed in a manner that does not introduce unwanted pests onto Castle Island.

6. Existing baygrape trees should be managed to prevent expansive dense thickets from forming.

7. Periodic skink surveys should be undertaken to monitor the sub-population's response to the habitat modifications proposed within this management plan.

8. Empty West Indian topsnail shells of various sizes should be scattered across the island for land hermit crab use (see Copeland, 2020).

9. Leafcutter bee surveys should be undertaken and natural stone nesting blocks should be discretely installed in suitable locations (see Outerbridge and Sinclair, 2018).

10. Artificial nesting burrows should be installed for tropicbirds and cahows at suitable locations.

11. The use of mist nests to capture and relocate vireos to another suitable site (e.g. Nonsuch Island) is recommended following the methodology in Mejias (2021) before major modification to the invasive woodland occurs on Castle Island.

12. Castle Island should be formally designated a 'Critical Habitat' for Bermuda skinks as described under the Protected Act (2003).

Historical preservation activities

During the late 1980s a Forts Committee was temporarily created to care for the fortifications on Castle Island and Southampton Island. It was composed largely of members of the general public who were interested in Bermuda's forts and much of their time was spent clearing the invasive vegetation away from the masonry. In the late 1990s an archaeological dig was carried out at the Landward Fort and in June of 2003 a team of local and international archaeologists performed a preliminary examination of the Devonshire Redoubt which included clearing all of the vegetation from the upper gun battery, the vertical faces of the tower, the lower gun battery, and the ditch of the Great Battery. Unfortunately some of the vegetation cleared during the 1990s was piled in areas known to be inhabited by skinks and subsequently burned. Surveys following the burning event showed significantly fewer skinks at those areas (J. Conyers, pers. comm). It was also found that removal of the thick scrubby native vegetation resulted in subsequent colonization by invasive plant species. Currently, the periodic removal of invasive vegetation growing upon stone structures occurs (i.e. casuarina, umbrella tree, Indian laurel).

Proposed:

1. No repairs of fortification masonry have been made over the past two decades therefore DENR should liaise with the Planning Heritage Officer, an archaeological consultant, and a structural engineer to have the fortifications assessed and make recommendations to protect fort structure from continuing erosion. Repairs should be planned for a time of the year that will have minimal impact upon nesting skinks which lay eggs and guard them in April, May, and June. Plans should also be made keeping biosecurity in mind so that no new invasive species are introduced to the island and damage to existing indigenous wildlife and vegetation is kept to a minimum. Biosecurity protocols should include:

i. Limiting the number of work crew on the island at any one-time,
ii. Stipulating that any excavated rock and sand must be carefully stock piled on areas of bare, exposed bedrock to avoid damaging indigenous vegetation,
iii. Stipulating that access to the fortifications will be along single routes to avoid unnecessary damage to indigenous vegetation,
iv. Stipulating that all tools and equipment should be thoroughly cleaned and be free of biological material prior to arriving and stored on-island for the duration of the project,
v. Stipulating that all building materials (i.e. lumber, form ply, sand, aggregate, cement, etc.) should be free of biological material (i.e. ants, tropical centipede) prior to arriving,
vi. Stipulating that all clothes and shoes should be inspected for clinging seeds and burrs before landing on the island,
vii. Building a pontoon to provide temporary landing for work crews. The pontoon should be removed from the site if it is not going to be used for a period of 72 hours or more,
viii. All food items and unnecessary baggage remains on the work boat during the day. Food is to be eaten on the boat, pontoon or foreshore adjacent to the pontoon. All garbage is to be removed at the end of each day,
ix. Bottles should be stoppered with fitting caps to prevent skinks from crawling in them when placed on the ground,
x. Vegetation should not be cleared away without prior approval,
xi. All fill, rubble, screenings, etc. removed from approved excavations are to be put back in its original location upon completion of the project.

2. The Department of Parks has produced a two volume Forts and Historical Sites Preservation Manual that details preservation standards and management, as well as treatment and maintenance procedures for the structures which should be used to guide restoration activities. An additional resource is the 2014 World Heritage Site management plan, which includes the fortifications within the Castle Harbour Islands Nature Reserve. This plan is available for viewing on the Planning Department's website: planning.gov.bm/wp-content/uploads/2018/11/world_heritage_site_management_plan.pdf

Additional activities

1. New signage needs to be made and erected at the two main landing sites on the island (the Landward Fort and the main gate of the south facing perimeter wall). The previous sign was damaged during a hurricane and has been missing for a number of years. In addition to stating which activities are permitted (i.e. swimming and sightseeing) the sign should also include a list of forbidden activities (i.e. no camping, no food or drink, no fires, no removal of plants, animals, or shells of any kind, no dogs or other domestic animals, no defacement of fortifications, walls, or vegetation). Emphasizing that garbage attracts rats which kill seabirds and empty bottles and cans are death traps to the skinks on the island is also warranted. Specific mention of fines for ignoring forbidden activities should be made clear to readers.

Figure 13. An example of signage previously posted on Castle Island

2. Create a clearly defined public foot-path that links the three main fortifications. Limiting pedestrian traffic to marked trails will minimize unnecessary damage to native vegetation growing on other areas of the island as well as reduce disturbance to skinks, land hermit crabs, and nesting tropicbirds.

Activities timetable

Activity	**Timeline**
Prophylactic rat control	Annual; lures and gas canisters replaced as advised in the A24 instruction manual
Pigeon control	Ongoing; minimum 1-2 visits each year
Casuarina control: mature trees	1 month to kill all mature trees
Casuarina control: seedlings	Every 6 months for the first 2 years; annual thereafter
Brazil pepper control: mature trees	6 months to kill all mature trees
Brazil pepper control: seedlings	Every 6 months for the first 4 years; annual thereafter
Phased plantings	Ongoing
Tropicbird igloo installation	Ongoing; minimum 5-6 each year while suitable locations are available
Skink survey	Every 10 years as per the Skink Recovery Plan
Capture and translocate vireos	Ongoing until all individuals are caught
Scatter empty topsnail shells	Ongoing; until 300 shells have been added (160 small, 110 medium, 30 large)
Designate island as critical skink habitat	6 months
Survey historical buildings and curtain wall	Annual
Create public foot path	1 month
Maintain public foot path	Annual
Create signage	3 months
Install signage	1 day

Table 5. Summary of management activities and associated timelines.

Bibliography

Andrew, P., Cogger, H., Driscoll, D., Flakus, S., Harlow, P., Maple, D., . . . Woinarski, J. (2018). Somewhat saved: A captive breeding programme for two endemic Christmas Island lizard species, now extinct in the wild. Oryx 52(1):171-174. doi:10.1017/S0030605316001071

Copeland, A. 2020. Management plan for the land hermit crab *Coenobita clypeatus* in Bermuda.

Copeland, A. 2020. IUCN Red List assessment of Bermuda's endemic plants 2013-2016. Technical report of the Biodiversity Section, Department of Environment and Natural Resources, Bermuda Government. 105 pp.

Davenport, J., Hills, J., Glasspool, A., Ward, J. 1997. A study of populations of the Bermudian Rock Lizard (Skink), *Eumeces longirostris,* Cope (1861), on the islands of Nonsuch and Southampton, Bermuda. Report for the Department of Agriculture and Fisheries, Government of Bermuda 45 pp.

Dobson, A. and Madeiros, J. 2008. Threats facing Bermuda's breeding seabirds: measures to assist future breeding success. Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics, 223–226.

Edgar, P., Kitson, L., and Glasspool, A.F. 2010. Recovery Plan for the Bermuda skink, *Eumeces longirostris*. Department of Conservation Services, Government of Bermuda. 32 pp.

Gillies, C.A. and Williams, D. 2013. DOC tracking tunnel guide v2.5.2: Using tracking tunnels to monitor rodents and mustelids. Department of Conservation, Science and Capability Group, Hamilton, New Zealand. www.doc.govt.nz.

Glasspool, A.F. and Outerbridge, M. 2005. A population re-survey of the Bermuda skink, *Eumeces longirostris* Cope (1861), on Southampton Island, Castle Harbour. Bermuda Biodiversity Special Publication 2005-001. 37 pp.

Griffith, H., Wingate, D.B., and deLaey, R. 1991. Introduced birds as probable agents of population changes in the Bermuda rock-lizard. Department of Agriculture and Fisheries Report, Government of Bermuda. 9 pp.

Griffith, H. and Wingate, D.B. 1994. *Eumeces longirostris* (Bermuda rock lizard or skink) predation by *Anolis grahami* (Jamaican Anole). Herpetological Review 25:26.

Hammond, M.P. 2000. An analysis of Bermuda skink (*Eumeces longirostris*) populations on Castle Island, Bermuda. Bermuda Biodiversity Report. 18 pp.

Harris, E.C. 2006. Bermuda Forts, 1612-1957. Bermuda Maritime Press.

Hoare, J.M. and Hare, K.M. 2006. The impact of brodifacoum on non-target wildlife: gaps in knowledge. New Zealand Journal of Ecology 30(2):157-167.

Kolbe, J.J., Colbert, P.L., and Smith, B.E. 2008. Niche relationships and interspecific interactions in Antiguan Lizard communities. Copeia 2008(2):261–272.

Macedonia, J.M., Clark, D.L., and McIntosh, A.P. 2016. Differential range expansion and habitat use among the naturalized *Anolis* lizards of Bermuda. Herpetological Review 47(4)

Madeiros, J.L. 2011. Breeding success and status of Bermuda's Longtail population (White-tailed Tropicbird) *Phaethon lepturus catsbyi* at ten locations on Bermuda 2009-2011. Terrestrial Conservation Division, Department of Conservation Services, Government of Bermuda. Report, pp.21.

Mauldin, R.E., Witmer, G.W., Shriner, S.A., Moulton, R.S., and Horak, K.E. 2019. Effects of brodifacoum and diphacinone exposure on four species of reptiles: tissue residue levels and survivorship. Pest Management Sciences 76(5):1958-1966.

Mejias, M. 2014. Nest cavity selection and success of breeding white-tailed tropicbirds (*Phaethon lepturus catesbyi*) on the Bermuda islands. MSc. Thesis. Memorial University of Newfoundland. 18 pp.

Mejias, M.A. 2021. Management plan for the Bermuda white-eyed vireo *Vireo grisues bermudianus*. Department of Environment and Natural Resources, Government of Bermuda. 36 pp.

Meyers, E.L., Matzke, N.J., and Williams, S.J. 2015. Remote sensing of intertidal habitats predicts West Indian topsnail population expansion but reveals scale dependent bias. Journal of Coastal Conservation. DOI 10.1007/s 11852-014-0371-7.

Outerbridge, M.E. and Sinclair, T.J. 2018. Recovery plan for the leafcutter bee *Megachile pruina pruina* on Bermuda. Department of Environment and Natural Resources, Government of Bermuda. 22 pp.

Outerbridge, M.E. 2022. The prodigious power of trap-jaw ants. Envirotalk: quarterly newsletter of the Department of Environment and Natural Resources. 86(1):11-12.

Peters, D. 2015. Native Island rat eradication project report. Department of Conservation, New Zealand Government DOC 2562032.

Raine, A. 1998. A study of morphological differentiation, fluctuating asymmetry, and the threats facing isolated populations of the critically endangered Bermuda rock lizard *Eumeces longirostris.* MSc thesis. University College London. 78 pp.

Stroud, J.T., Giery, S.T., and Outerbridge, M.E. 2017. Establishment of *Anolis sagrei* on Bermuda represents a novel ecological threat to Critically Endangered Bermuda skinks (*Plestiodon longirostris*). Biological Invasions. DOI 10.1007/s10530-017-1389-1.

Trageser, S.J., Wiscovitch, A., and Hamilton, P. 2018. Predation by an Antigua Bank Tree Anole, *Anolis leachii* (Duméril and Bibron 1837), on an introduced Tropical House Gecko, *Hemidactylus mabouia* (Moreau de Jonnés 1818). IRCF Reptiles and Amphibians 25(2):155

Turner, H., Griffiths, R.A., Outerbridge, M.E., and Garcia, G. 2019. Estimating population parameters for the Critically Endangered Bermuda skink using robust design capture–mark–recapture modelling. Oryx 55(1):81-88.

Turner, H., Griffiths, R.A., Outerbridge, M.E., and Garcia, G. 2021. Dynamic occupancy modelling to determine the status of a Critically Endangered lizard. Oryx First View https://doi.org/10.1017/S0030605321000843

Verrill, A.E. 1902. The Bermuda Islands: an account of their scenery, climate, productions, physiography, natural history and geology, with sketches of their discovery and early history, and the changes in the flora and fauna due to man. Transactions of the Connecticut Academy of Arts and Sciences 11:413-956.

Wetterer, J.K. and Wetterer, A.L. 2004. Ants (Hymenoptera: Formicidae) of Bermuda. Florida Entomologist 87(2):212-221.

Wetterer, J.K. 2017. Invasive ants of Bermuda revisited. Journal of Hymeonptera Research 54:33-41.

Wilmshurst, J.M. and Carpenter, J.K. 2020. Rodent detection and monitoring for conservation on islands. New Zealand Journal of Ecology 44(1):1-9.

Wingate, D.B. 2021. The barn owl – our unsung hero of rat control. Bermuda Audubon Society Newsletter 32(2):5-6.

Appendix

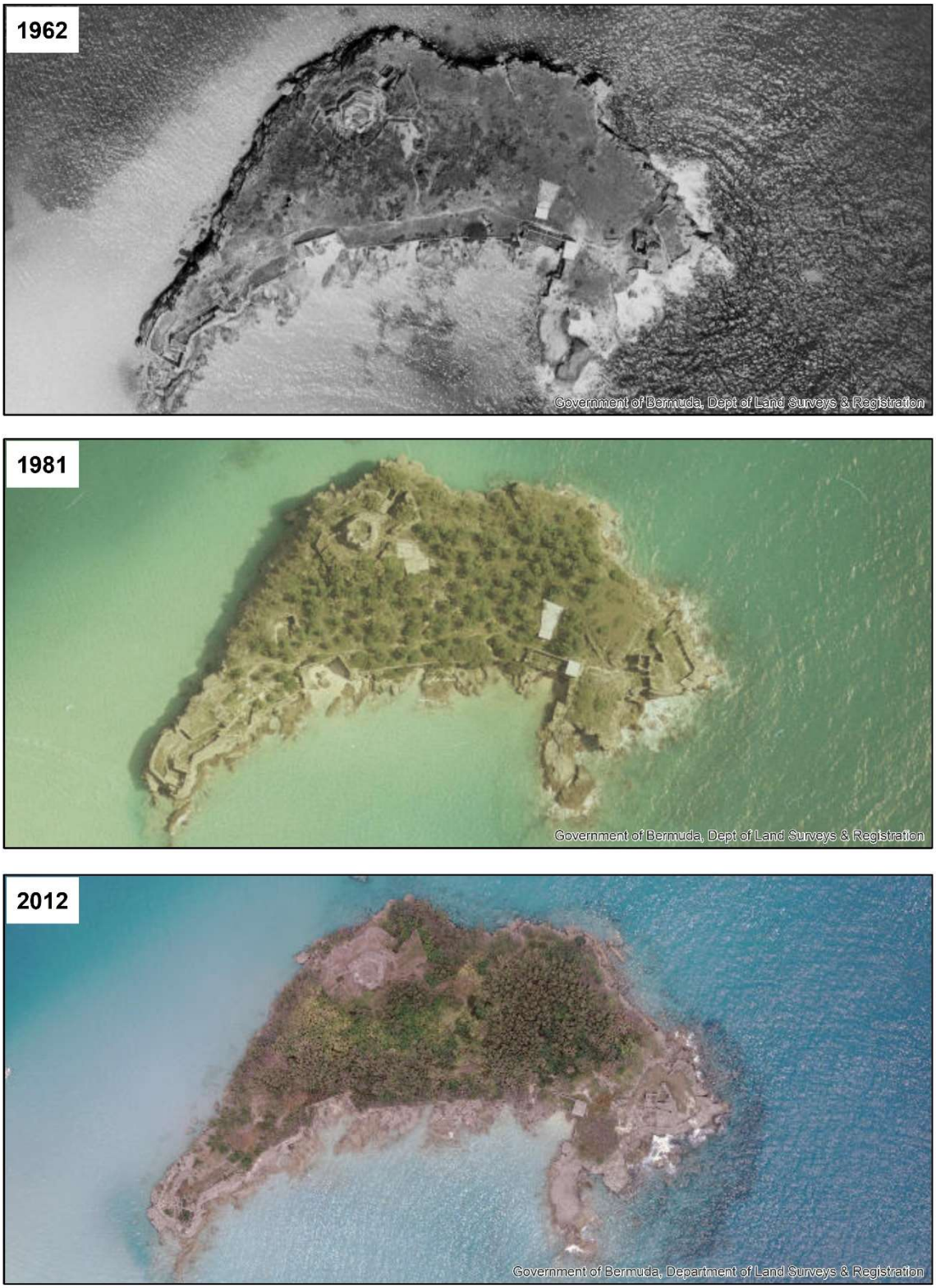


Fig 14. A time series of aerial photographs for Castle Island; 1962, 1981, 2012