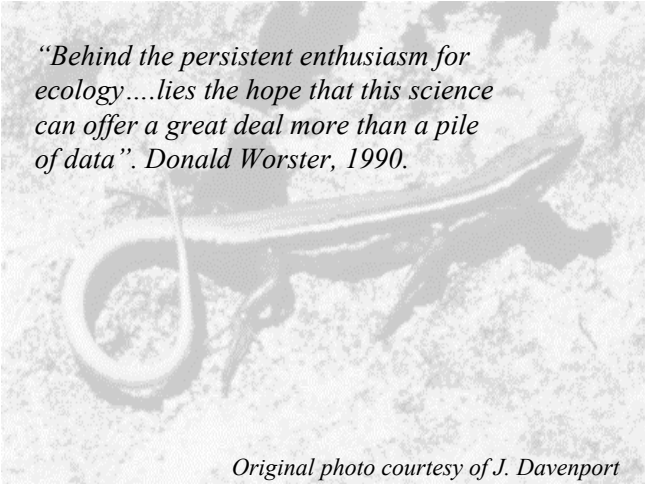
STATUS OF BERMUDA'S BIODIVERSITY



Bermuda is probably one of the best-known oceanic islands in the world. Studies began in 1609, when the first settlers arrived and described an abundance of birds and marine life.

There are now over 3,500 documents describing the Island's natural history, reviewed by Sterrer in 1998[1]. The literature consists of historical references, books, journal articles, graduate theses, unpublished student reports and informal notes in local news media. The searchable Bermuda Natural History Bibliography provides the most comprehensive compilation of these references[2]. As yet unpublished data from baseline surveys conducted through the Bermuda Biodiversity Project also serve as an important resource.

[1] Sterrer, W. 1998. How many species are there in Bermuda? Bulletin of Marine Science 62, 809-840.
[2] http://www.bamz.org

Biogeography[42]

By the beginning of the Pleistocene Ice Age (about 1.6 million years ago), the Bermuda Seamount was gradually eroded by waves to a more or less flat surface below sea level. During subsequent warm periods (e.g. 400,000 years ago), sea level rose to as much as 20 m above the present level[3], coral reefs flourished and Bermuda would have comprised just a few scattered islands and islets. As the corals and other marine organisms growing on this submerged platform died, their skeletons began accumulating as sediment, which was washed onto beaches to form sand dunes. During cold periods (e.g., 20,000 years ago) when the sea-level dropped as much as 125 m below the present level, reef growth halted, and the dunes became cemented by wind and rain to create the fossilised limestone landscape that forms Bermuda's rolling hills of today.

Further rain helped to break down the limestone on top of the dunes to form a soil cover. The soil oxidised into a whitish soil called a palaeosol. (The red-coloured soil found in Bermuda is also derived from wind-blown material, but it has blown from distant continental deserts such as the Sahara). The formation of caves also occurred during glacial periods. As the rainwater percolated through the soil layer, it combined with carbon dioxide, forming a weak acid. The acid dissolved the underlying limestone, forming cavities underground.

[3] Hearty, P.J., P. Kindler, H. Cheng, R.L. Edwards. 1999. A +20 m middle Pleistocene sea-level highstand (Bermuda and the Bahamas) due to partial collapse of Antarctic ice. Geology 27 (4), 375-378.

This “yo-yo” of alternating high and low sea level explains Bermuda's "layer cake" stratigraphy of alternating limestone and soil horizons, with the youngest, barely cemented sand stones overlapping older, harder rocks riddled with partially drowned caves.

Evidence exists that during the last interglacial flooding about 125,000 years ago, when sea levels were raised by as much as 5–8 m above today’s, much of the Island’s terrestrial biota (including birds, a tortoise and land snails) was decimated. Earlier and higher sea-level stands were presumably just as destructive. Low sea-level would have restricted shallow-water marine species to a narrow band, which coupled with the accompanying drop in temperature may explain the low rate of marine endemism.

The history of Bermuda’s pre-colonial flora and fauna was thus driven by the alternating opportunities/hazards for terrestrial/marine organisms presented by the rising and falling sea levels. (There are no data regarding Bermuda’s pre-Pleistocene biota).

Like most island ecosystems, Bermuda’s terrestrial habitats supported a limited diversity of plant species prior to human settlement. The Island’s early floral biodiversity comprised a dense forest, largely dominated by the endemic Bermuda Cedar and Bermuda Palmetto. The early forest probably also included natives such as Yellowood and Hackberry. Emerging under the sheltered canopy of these forests were Bermuda’s endemic understorey species including the Bermuda Sedge, Bermuda Maidenhair Fern and Bermuda Snowberry, as well as a variety of native species.

Bermuda’s isolation prohibited colonisation by amphibians and mammals (except bats) and most reptiles. However, birds and insects would have been abundant.

Human colonisation resulted in an immediate and dramatic change to Bermuda’s flora and fauna. Hogs were perhaps the earliest introduced animal species, but rats, cats and dogs quickly followed. The accidental introduction of a scale insect, which resulted in the loss of 96% of the endemic cedars in the 1940’s, highlighted the threat of introduced pests, and was followed by a wave of further introductions, some accidental and some intentional. Coupled with the impact of other human activities, the Island’s natural history has changed dramatically since its colonisation in the early 1600’s.

Definitions:

Endemic – Species found only in Bermuda and nowhere else, and which arrived here naturally without the aid of humans. Most of the species extinctions in the world have occurred to island endemics because, having evolved in relative isolation, they are more vulnerable to mainland diseases and predators and cannot compete with faster growing invasive species. They are also often tame, and easily harvested by humans.

Native – Species which also arrived at Bermuda without the aid of humans, but which are found in other areas too.

Introduced – Species which would not have made it to Bermuda on their own, but have been brought here by humans. These species may have been introduced accidentally, or brought here for economic or ornamental reasons, or to serve as a biological control.

Invasive – Introduced species which adapt so well to the local conditions that they become a threat to the natives species by preying on them, taking over their nests, or just over-growing them.

Naturalised – Introduced species that are not presently considered to be invasive, but are able to reproduce naturally in the wild.

Diversity Of Habitats

Open Ocean

Located on the northwestern edge of the Sargasso Sea and greatly influenced by the warming effects of the Gulf Stream, Bermuda is far removed from any continental watershed. As a result the waters surrounding the Island are virtually pristine, some of the clearest, most nutrient starved waters of the Atlantic. The extreme clarity of the ocean surrounding Bermuda betrays the low abundance of life that these waters support. Despite the scarcity of nutrients for phytoplankton and the rarity of food for higher life forms, a large number of highly adapted organisms thrive in this habitat, ranging from jellyfish and crustaceans to tuna such as the Yellowfin and whales including the Humpback which migrates past Bermuda each year. In fact, due to the highly migratory habits of many of these species, their management requires international co-operation.

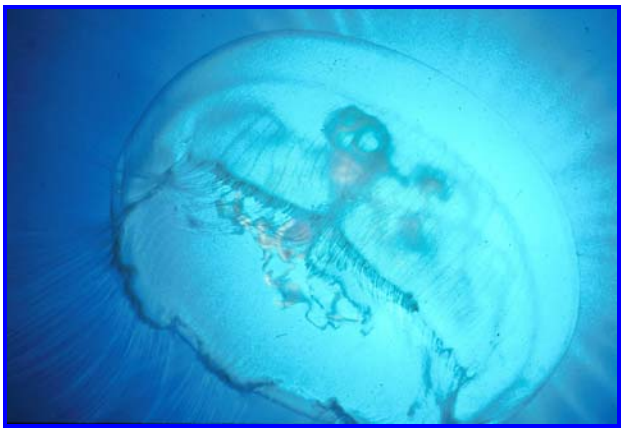


Plate 1. Moon Jellyfish, one of many species of jellyfish found in the open ocean. (Photo courtesy of I. Murdoch).

Threats

Although the environmental quality of the open ocean remains high, the impact of humans is being increasingly felt, not only at Bermuda but even in the remotest parts of the Sargasso Sea. The large amounts of oil that fouled Bermuda's coastlines in the 1970's and 1980's are virtually gone thanks to better cleaning practices on passing oil tankers. However, the presence of large quantities of plastics in this mid-oceanic gyre is a cause for considerable concern. The effect of this oceanic circulation in concentrating plastic flotsam in the same area where for millennia rafts of *Sargassum* have provided critical habitat for numerous marine species poses a serious threat. Despite being on the fringe of this gyre, Bermuda commonly receives large amounts of plastic debris on the shoreline and many of the juvenile turtles taken in by the Bermuda Aquarium Museum and Zoo for rehabilitation show signs of having ingested plastic.

Shallow Water Habitats

The truncated top of the massive seamount that is Bermuda supports a thriving quasi-tropical marine community, often dubbed an oasis in this oceanic desert. Like most tropical marine ecosystems, coral reefs, seagrass beds and mangrove swamps are the three critical habitats comprising this ecosystem. Of these, both the coral reef and mangroves carry the distinction of being the northern-most examples in the world. Although these three distinct habitats form the most important centres of biological diversity, a large proportion of the Bermuda platform is covered by soft sediments. Whilst these are home to a reduced species assemblage, these organisms are important none-the-less, primarily for the role that they play in recycling the organic matter that sinks to the seafloor.

Coral Reefs

The northerly extension of coral reefs to Bermuda is made possible by the Gulf Stream, which transports warm seawater, and associated organisms, eggs and larvae to the area of Bermuda.

Bermuda's reefs are typical of high latitude reefs, with a low level of live coral coverage (typically 50% or less), lower coral growth rates[4] and coral growth which does not extend into depths as great as it does on warmer reefs closer to the equator. For example, Bermuda has only about one third of the shallow-water coral species recorded for Jamaica[5].

There are several types of reef found in Bermuda. Extending from a depth of approximately 75 m to 20 m (250 ft to 65 ft) is the Fore Reef Slope. Average coral cover is only about 25% on these reefs, which are dominated by brain corals (*Diploria* species) great star corals (*Montastrea* species) and mustard corals (*Porites* species).

The Main Terrace reefs are found at depths of 25 m to 15 m (75 ft to 45 ft). This is the area of highest

[4] Logan, A. and T. Tomascik. 1991. Extension growth rates in two coral species from high-latitude reefs of Bermuda. Coral Reefs. 10, 155-160.

[5] Thomas, M.L.H. and A. Logan. 1992. A Guide to the Ecology of Shoreline and Shallow-water Marine Communities of Bermuda. Wm. C. Brown Publ., Iowa. 346 pp.

coral coverage (over 50%), again dominated by brain and great star corals.

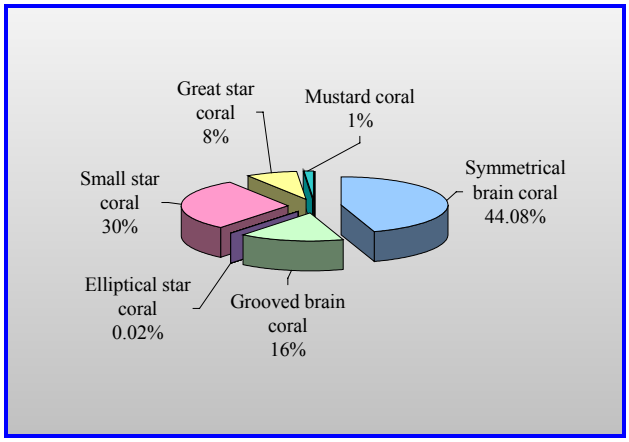


Figure 8. Coral species typically found on main terrace reefs[6].

With a coral coverage of just over 20%, the Rim reefs encircle the North Lagoon and are the most visible, lying at depths of 15 m to 1 m (45 ft to 3 ft). The corals comprising the Rim reefs are more diverse than those in deeper water, although the main reef building corals mentioned above are still dominant. Sea fans and sea rods are also common.

Plate 2. Rim reefs (Photo courtesy of W. Mitchell).

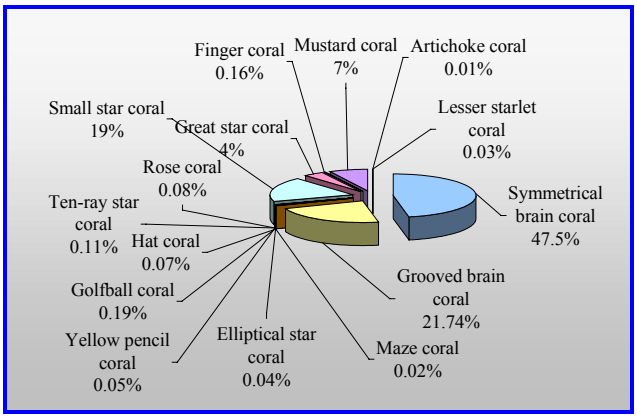


Figure 9. Coral species typically found on Rim reefs[47].

Landward of the rim reefs lies the North Lagoon, within which lie a variety of Lagoonal reef types. These range from small patches of coral (Knob reefs) to larger Pinnacle reefs up to 50 m wide. A few even larger structures exist, forming Mini-atolls and Faro reefs. The Lagoonal reefs are characterised by lower coral cover (about 14%) and smaller, branching corals such as Ivory Bush Coral, the Finger Corals, and Fire Corals. Within the sounds and harbours, the coral coverage drops to below 10% on the Inshore reefs.

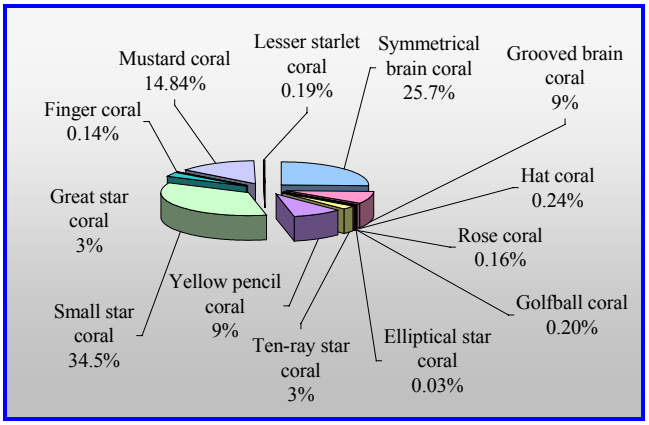


Figure 10. Coral species typically found on Lagoonal patch reefs[47].

[6] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

The reefs to the south of Bermuda are significantly different. Most obvious are the wine glass shaped cup reefs, or "boilers", which are constructed of hard coralline algae and a marine snail, and have almost no coral in their structure. Some cup reefs are to be found to the north of the Island too.

Bermuda's thriving reef communities provide a habitat for a colourful array of reef fish and invertebrates. The populations of herbivorous parrotfishes and surgeonfishes graze on the fleshy seaweeds on the reefs, effectively controlling their growth and preventing them from smothering the corals. However, some algae species can become abundant seasonally[7].

Threats

In 1966, long before the global community expressed concern for the future of coral reefs, Bermuda passed the Coral Reef Preserves Act. Then in 1978, the Bermuda Government responded to the increasing popularity of bleached corals as curios with a protected species order that completely banned the harvest of any coral, stony or soft. With this action Bermuda became, in effect, a coral preserve.

On the whole, the Bermudian reefs are in excellent condition compared to those in other locations. In large measure this may reflect Bermuda's isolated, high latitude position along with the success of conservative fisheries management in maintaining healthy populations of reef grazers. However, there are instances in which local reef communities have come under stress. These include the dredging of Castle Harbour for the airport construction, ship groundings, the deployment of anchors, pollution, and sedimentation in shipping channels[8]. Some corals show signs of disease, and there are occasional episodes of bleaching, although this is usually not fatal. This has been attributed to elevated water temperatures from global warming.

It is interesting to note that in a recent report of the current condition and potential threats to the world's coral reefs, Bermuda's reefs are ranked in the "high risk" category[9]. Although not specified, this appears to be attributed to the Island's high population density within 20 km of the coral reefs and the volume of shipping traffic and potential pollution threats from these vessels.

The Bermuda Biodiversity Project is currently mapping Bermuda's reefs in detail. Such maps will greatly assist in the environmental management of this critically important resource. Every effort should be made to ensure that reef condition is monitored as closely as possible. Ongoing monitoring studies such as those being conducted by the Bermuda Biological Station for Research Inc. and the Bermuda Biodiversity Project are essential. Measures to protect reefs against physical damage

[7] Smith, S.R. Pers. Comm. Bermuda Biological Station for Research Inc.

[8] Cook, C.B., R.E. Dodge, and S.R. Smith. 1993. Fifty years of impact on coral reefs in Bermuda. Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health Hazards and History, R.S.M.A.S., Miami. 160-166.

[9] Bryant, D. L. Burke, J. McManus and M. Spalding. 1998. Reefs at risk: A map-based indicator of threats to the world's coral reefs. World Resources Institute. Washington DC, U.S.A. p. 31.

should be increased, as there is no current legislation to levy fines or recover costs for damage to reefs.

Seagrasses

Bermuda has four species of seagrasses, Turtle Grass, Manatee Grass, Shoal Grass and Dwarf Grass. Seagrasses are marine flowering plants, which form large underwater meadows in some of Bermuda's marine ponds, inshore waters and coastal bays. The area of Bermuda's nearshore seagrasses, was believed to cover approximately 500 ha (1235.6 acres) in 1981[10]. Widely recognised as one of the most productive ecological systems, seagrasses also support a rich community of marine organisms that includes worms, crustaceans and molluscs, as well serving as an important refuge for many species of juvenile fish, and a feeding ground for immature Green Turtles. In a recent survey of three coastal seagrass bed sites, 44 species of fish were observed (excluding gobies)[51].

Fish species observed in seagrass surveys:
Endemic: *Bermuda Anchovy, Bermuda Bream, Garfish*
Native: *Pilchard, Blue Fry, Anchovy or Spanish Sardine, Sliver Jenny, Bigeye Mojarra, Tomtate or White Grunt, Blue-striped Grunt, Yellow Grunt, Slippery Dick, Bucktooth Parrotfish, Slender Filefish, Fringed Filefish, Imperial Blackfish, Bandtail Puffer, Sand Diver, Dusky Squirrelfish, Pugnose Pipefish, Longsnout Seahorse, Horse-eye Jack, Grey Snapper, Lane Snapper, Yellowtail Snapper, Mottled Mojarra, Pigfish, Whitebone Porgy, Pinfish, Spotted Goatfish, Four-eye Butterflyfish, Spotfin Butterflyfish, Hogfish, Princess Parrotfish, Rredtail Parrotfish, Redfin Parrotfish, Liza, Great Barracuda, Doctorfish, Surgeonfish.*

[10] Ward, J.A.D. 1999. Bermuda's Coastal Seagrass Beds as Habitats for Fish. Unpublished M.Sc. Thesis. University of Glasgow. 103 pp.

Additionally, the root system of the seagrasses serves to stabilise the sediment whilst their leaves trap particles suspended in the water which would otherwise smother neighbouring reefs.

Threats

Studies have shown that there have been substantial changes in the extent of the seagrass meadows around Bermuda, with some dramatic declines in the seagrasses in the North Lagoon[11]. However, in the coastal seagrass beds losses in some areas appear to have largely been compensated for by expansion in others[51]. The cause of these changes remains uncertain, and warrants further investigation. It is clear though, that the constant sweep of boat mooring chains is resulting in halos of bare sand in many inshore seagrass beds.

Plate 3. A 1997 aerial photograph showing the halos made in seagrass beds by boat moorings. (Photo courtesy of the Ministry of Works and Engineering).

[11] Smith, S.R. Pers. Comm. Bermuda Biological Station for Research Inc.

Mangroves

Bermuda's mangroves, unique in that they are the most northerly in the world, have been heavily impacted by human activities. Once occupying perhaps as much as 25 ha (61.8 acres) in pre-settlement times, mangroves are now reduced to a total area of 18 ha (44.48 acres)[12], distributed between about 30 swamps. These swamps can be classified into three types; pond mangrove swamps, (relics of periods of higher sea level), bay mangrove swamps, and fringing communities[13]. The largest is the Hungry Bay mangrove swamp, which covers an area of 2.9 ha (7.2 acres).

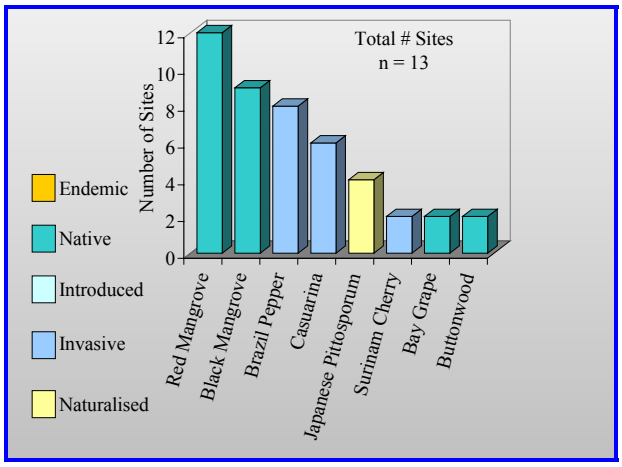


Figure 11. The most commonly observed trees in mangroves and the number of survey sites at which they were observed[53].

Mangroves occupy the intertidal zone in areas where wave action is low enough to allow sediment to accumulate. Their submerged root system provides an extensive substratum for many organisms, and an important nursery for juvenile reef fish. Their canopy supports many bird species, including the Yellow-crowned Night Heron, Belted Kingfisher, Osprey, Great Blue Heron, Great Egret, Northern Waterthrush, American Redstart. In addition to providing protection from erosion, mangroves are also areas of very high productivity, having an importance far beyond their borders as a result of this. In 1989, the International Union for the Conservation of Nature (IUCN) declared that mangroves were the most threatened habitat in the world[14].

Because Bermuda's mangroves are at the northerly extent of their range, the species diversity is less than further south. The two species found in Bermuda are the Red Mangrove and the Black Mangrove; Buttonwood often lives at the landward edge of the mangrove swamps.

Threats

Tolerant of small amounts of pollution, (which explains why they can survive in Mills Creek) mangroves are threatened by floating debris such as plastics, and destruction due the development of docks and jetties. Whilst most mangroves are now protected under the Development and Planning Act 1974, failure to rigorously enforce this has led to occasional losses. Coastal erosion is a persistent threat, particularly with rising sea levels, and has caused the seaward edge of Bermuda's largest mangrove at Hungry Bay to recede. In addition, the landward edge of many mangroves is now being

[12] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.
[13] Thomas, M.L.H. 1998. Marine and Island Ecology of Bermuda. Bermuda Aquarium, Museum and Zoo. p. 64.
[14] Ministry of Environment, Government of Bermuda. 2000. Marine Resources and the Fishing Industry in Bermuda: A Discussion Paper. p. 72.

invaded by aggressive plant species such as Surinam Cherry, Allspice, Brazil Pepper, Jumbie Bean and Fiddlewood, whilst Asparagus Fern is encroaching upon the understorey.

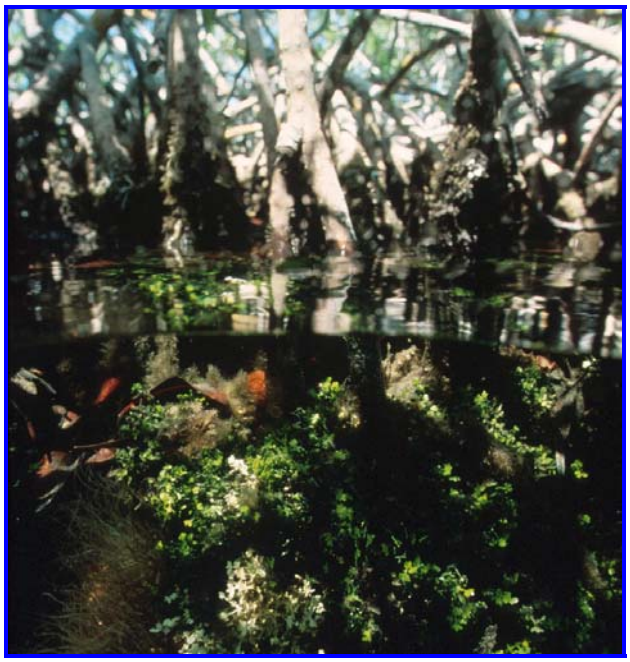


Plate 4. The roots of mangroves above and below the water showing the diversity of attached organisms. (Photo courtesy of C. Clark).

Inland Bays and Sounds

The stresses imposed by human development have a significant effect on Bermuda's inshore harbours and sounds. These semi-enclosed bodies are generally deeper than the entrances through which water exchange occurs, resulting in limited flushing which promotes the settlement of fine particles. Seepage of nutrient rich groundwater, discharges of coolant water and surface runoff enrich these bodies while massive resuspension of fine particles occurs regularly in St. Georges and Hamilton Harbours and the Great Sound whenever large ships transit these areas. Substantive ecological changes have been documented in these basins. During the 1970's a mass bloom of the alga *Cladophora* formed mats that, in areas, exceeded 1 m (3 ft) in thickness and smothered the sandy bottom animals in many coastal bays. Concern that this bloom reflected declining water quality prompted extensive research of the benthic communities and nutrient cycling in inshore waters but failed to establish a definitive link between nutrient levels and the growth of this alga[15]. However, it was determined that the system is phosphate limited with this nutrient being rapidly bound in the presence of Bermuda's calcium carbonate rock. Although the *Cladophora* bloom has abated, it still occurs in some places.

Salt Marshes

Like mangroves, salt marshes are found along sheltered coastlines where they offer protection to the shoreline. In Bermuda, there are few remaining salt marshes, and these comprise just 1.0 ha (2.47 acres)[16]. The largest is at the eastern end of Spittal Pond. The salt marsh to the east of the Hungry Bay outlet has been almost obliterated through intense storm activity over the last few years. Perhaps the best remaining salt marsh lies on the former U.S. Naval Base in St. Davids. There is evidence that before human colonisation there were extensive salt marshes at Pembroke Marsh West.

[15] Morris, B., J. Barnes, F. Brown, and J. Markham. 1977. The Bermuda Marine Environment: A Report of the Bermuda Inshore Waters Investigation 1976-1977. Bermuda Biological Station Special Publication No. 15. 120 pp.

[16] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

Plate 5. A view of the salt marsh at Spittal Pond through Sea Rush, Juncus maritimus (Photo courtesy of L. Rodrigues).

Salt marshes are important in that they support a number of rare and endangered plants and animals, including the Land Hermit Crab, which appears to be limited to less than a hundred individuals at Hungry Bay[17].

Most commonly observed Salt Marsh plants:
***Native**: Sheathed Paspalum, Sea Rush, Switch Grass, Morning Glory, Marsh Samphire, Salt Marsh Sand Spurrey, Salt Marsh Ox-eye, Seaside Heliotrope.*
Introduced: Para Grass
***Invasive**: Wedelia*
***Threatened Natives**: Marsh Samphire, Seaside Heliotrope*

Threats

The main threat to Bermuda's salt marshes is coastal erosion from storm activity.

[17] Godsall, B. 2000, Unpublished report. Survey of the Population of the Land Hermit Crab, *Coenobita clypeatus*, in Hungry Bay. Bermuda Biodiversity Project, Bermuda Zoological Society. 13 pp.

Marine Ponds

Described as one of Bermuda's national treasures, the Island has a wealth of marine ponds supporting a high diversity of marine and brackish water organisms[18]. Largely surrounded by mangroves, these ponds form rich feeding grounds with the extensive mangrove root system providing an area for settlement for marine animals from tube worms, sponges and sea squirts to oysters. DeLaubenfels described Walsingham Pond as "The Sponge metropolis of the World"[19]! The endemic Bermuda Killifish thrive in most of the ponds, whilst the endemic Bermuda Sargassum Weed can be found in Walsingham Pond. Migratory warblers join toads, whistling frogs, many species of waterfowl and countless insect species living around the edges of the ponds.

Threats

Run-off, groundwater enrichment and trash are probably the main threats to Bermuda's ponds. Anecdotal reports of mass mortalities of fish in Trotts Pond and Mangrove Lake have been received[20]. Given their rich biodiversity, some measure of protection should be extended to those ponds not already in nature reserves or parks.

[18] Ministry of Environment, Government of Bermuda. 2000. Marine Resources and the Fishing Industry in Bermuda: A Discussion Paper. p. 75.
[19] Thomas, M.L.H. 1998. Marine and Island Ecology of Bermuda. Bermuda Aquarium, Museum and Zoo. p. 40.
[20] Thomas, M. Pers. Comm. University of New Brunswick.

Caves[21]

Bermuda has one of the highest concentrations of caves in the world (150 are known). However, these are perhaps the least appreciated of the Island's habitats, despite a number of caves having been operated as commercial tourist attractions. Above sea level, the caves are characterised by extensive collapse and are therefore fairly short in section. By contrast, primarily at depths of 17 m to 20 m below sea level there is an integrated network of submerged passageways, which connect otherwise isolated cave pools. For example, Green Bay forms a large and extensive flooded labyrinth nearly two miles long. It is in the dark interiors of these caves that over 60 of Bermuda's endemic species live[22]. Recently, a team of scientists discovered one of the best and most complete Pleistocene deposits in the world in Admiral's Cave at Grotto Bay, in which they discovered a complete sequence of fossil birds dating back several hundred thousand years.

Threats

Many caves are inaccessible to the general public, and are thus fairly well protected. However, there are four main threats to Bermuda's caves. These are; construction and quarrying activities, water pollution, dumping and littering and vandalism. Bassett's Cave on the former U.S. Naval Base in Southampton, which is severely polluted with oil and sewage, exemplifies just how vulnerable the caves systems are, whilst the continued blasting in Wilkinson's Quarry adjacent to Admiral's Cave is posing a serious threat.

Plate 6. SCUBA divers in a submerged cave with impressive limestone column formations. (Photo courtesy of C. Lascu).

Beaches and Dunes

One of Bermuda's most attractive features are the spectacular sandy beaches, particularly those of the south shore, famous for their pink hue derived from the crushed skeletal remains of the single-celled foraminiferan *Homotrema rubrum*. The sand itself supports a wealth of organisms. Some are burrowing whilst others are largely invisible to the naked eye, as they live between the sand grains. More easily visible are the Ghost Crab and Land Crab, shorebirds such as Ruddy Turnstone and various plovers and sandpipers, as well as the Tiger Beetle, Rove Beetle and Sand Flea. The Bermuda Skink and Jamaican Anole may also scavenge on the beaches. The strandline that forms along the beach from organisms that have washed ashore is an important microhabitat.

[21] Iliffe, T. Pers. Comm. Texas A & M University.
[22] http://www.tamug.tamu.edu/cavebiology/fauna/bermudafaunalist.html

Forming behind the beaches, above the strand line, are the sand dunes, which support a number of specially adapted plants. Behind the fore dunes, the vegetation becomes more continuous, giving way to mature dunes that support both endemic and native species. In total, Bermuda's beaches and dunes cover an area of 77 ha (190 acres)[23].

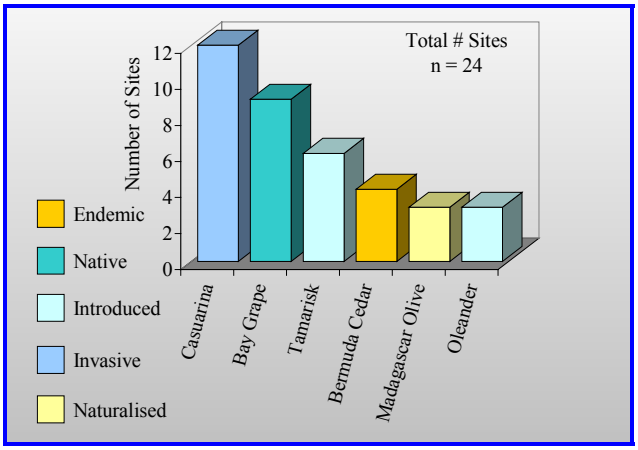


Figure 12. The most commonly observed trees in beach and dune habitat and the number of survey sites at which they were observed[64].

Most commonly observed understorey species on Beaches and Dunes are:
Endemic: *Bermudiana*
Native: *Crab Grass, Seaside Goldenrod, Spanish Bayonet, Bay Grape, Seaside Morning Glory, Bay Bean, Tassel Plant, Scurvy Grass, Sea Ox-eye, Sheathed Paspalum, Cape Weed, Beach Croton, Prickly Pear, Coast Spurge, Morning Glory, Seaside Evening Primrose, West Indian Grass*
Naturalised*: Fennel, Star of the Veldt, Common Sage Bush*
Invasive*: Wedelia*
Threatened Endemics and Natives*: Beach Alternanthera, Beach Lobelia, Seaside Heliotrope, Bay Lavender, Darrell's Fleabane, Diffuse Starwort.*

[23] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

Threats

The major threat to the beaches and dunes is coastal erosion from storm surge. Intense storms may temporarily, but significantly reduce the beaches and dunes around the Island. Trash is another major problem, and the raking of beaches for tourism also impacts upon the associated flora and fauna making the continued preservation of the few protected beaches a priority. Invasive species present another threat. Authorised and unauthorised camping may cause considerable damage to the south shore dunes in the summer.

Plate 7. The beach at Nonsuch Island fringed by rocky coastal habitat. (Photo from BAMZ slide collection).

Rocky Coastal

With breaks for beaches and dunes, the rocky coastal habitat extends around most of Bermuda's shoreline from the high water tide mark inland up to 15 m, an area of approximately 149 ha (368 acres)[64]. Only the most salt-tolerant species flourish in this habitat. Prior to human settlement, these would have

included Buttonwood and Bay Grape[24]. Despite perhaps being the most resistant of all Bermuda's terrestrial habitats to invasive species, the native and endemic species of the rocky coast are nevertheless threatened by Casuarina and Brazil Pepper.

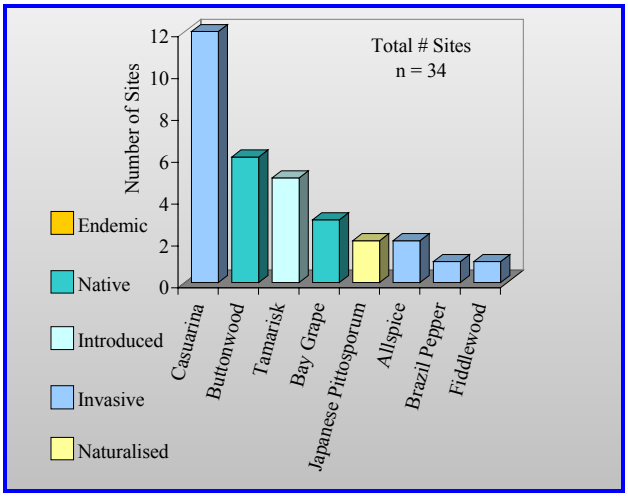


Figure 13. The most commonly observed trees in rocky coastal habitats and the number of survey sites at which they were observed[25].

The most commonly observed understorey species in Rocky Coastal areas are:
Endemic: *Bermudiana*
Native: *Sea Ox-eye, Seaside Goldenrod, Coast Spurge, Crab Grass, Sheathed Paspalum, Prostrate Spurge, Buttonwood, Cape Weed, Prickly Pear, Joseph's Coat, Seaside Purslane, West Indian Grass*
Invasive: *Asparagus Fern*
Threatened Endemics and Natives*: Beach Alteranthera, Beach Lobelia, Seaside Heliotrope, Bay Lavender, Darrell's Fleabane, Diffuse Starwort*

A good example of Rocky Coastal habitat with a high native biodiversity is Spittal Pond and the area north of the Railway Trail, west of Shelly Bay.

Sightings of the Sally Lightfoot Crab as well as several heron species, Longtails, Common Terns, Cranes, Cormorants and Kingfishers are common. A patient observer may also be rewarded with a glimpse of a skink.

Threats

The major threat to this habitat is pollution, particularly from oil, and destruction for development of boathouses and docks. Given the porous nature of the rock, coastal erosion is also a problem.

Upland Coastal

Extending inland from the rocky coastal to the top of the old foredune, (an area of about 346 ha or 855 acres)[66], the upland coastal habitat also supports vegetation well adapted to salt spray, and capable of rooting in shallow soil. There are some differences between sheltered and exposed habitats: The flora of sheltered upland coastal areas such as Lovers Lake in St. George's more closely resembles that of upland hillsides with salt-intolerant species such as Forestiera present.

Pre-settlement species would have included endemics such as Bermuda Cedar and Bermuda Palmetto, as well as natives such as Bay Grape, Forestiera, and Buttonwood. Many of the same

[24] Wingate, D.B. 1971. Bermuda's Prehistoric Flora. In: The Bermuda Jubilee Garden. E.L. Wardman (Ed.). pp. 131-149.
[25] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

understorey species would have been present as in the rocky coastal, with the addition of Darrell's Fleabane, Spanish Bayonet, Poison Ivy, Cape Weed, Common Sage, Ink Berry, and Seven Year Apple. One of the best examples of the upland coastal habitat with a high endemic and native biodiversity is High Point in Southampton Parish. Unfortunately, the Brazil Pepper and Casaurina tree have taken hold in most areas, and of increasing concern are the presence of Surinam Cherry and Allspice seedlings, both of which threaten the endemic Bermuda Palmetto and Darrell's Fleabane, and native Forestiera, Coast Sophora and Inkberry.

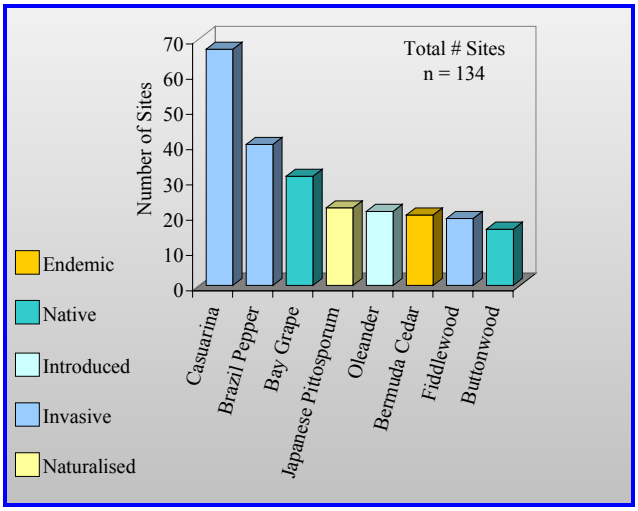


Figure 14. The most commonly observed trees in upland coastal areas and the number of survey sites at which they were observed[26].

Animals such as the Land Crab, Yellow-crowned Night Heron, the endangered native Land Hermit Crab, and endemic Skink, as well as Orb Web Spiders, Leaf-Scarring Beetles, and Leaf-Cutting Bee are often associated with the upland coastal habitat.

[26] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

The most commonly observed understorey species in Upland Coastal areas are:
Endemic*: Bermudiana*
Native*: Crab Grass, Seaside Goldenrod, Cape Weed, Joseph's Coat, Sea Ox-eye, Prickly Pear, Morning Glory, Sheathed Paspalum, Jamaica Dogwood, West Indian Grass*
Invasive*: Wedelia, Asparagus Fern*
Naturalised*: White Beggar's Tick, Fennel, Beard Grass, Common Sage Bush*
Threatened Endemics and Natives: *Coast Sophora, Seven Year Apple, Darrell's Fleabane, Ink Berry*

Threats

Ongoing development, invasive species, and hurricanes threaten coastal hillsides.

Upland Hillside

Occupying a total area of 908 ha (2,244 acres)[67], only a few pristine upland hillside habitats still survive, the best example being Abbott's Cliff. Most have been cleared for agricultural or residential use. Characterised by deeper soil and fairly sheltered locations, pre-settlement species would have included trees such as the endemic Bermuda Cedar, Bermuda Palmetto, Bermuda Olivewood, as well as Forestiera, White Stopper, and Jamaica Dogwood. Whilst understorey species such as endemic Bermuda Snowberry, Shrubby Fleabane, Doc-bush, Bermuda Bedstraw, Poison Ivy, Virginia Creeper, Turnera, St. Andrew's Cross, Sword Fern and Paspalum grasses would have prevailed.

Plate 8. Upland Hillside habitat at Abbott's Cliff. (Photo courtesy of H. De Silva).

The deep soil and protection from wind and salt spray in these areas has nowadays enabled faster, taller growing introduced, invasive plants such as Brazil Pepper, Allspice and Surinam Cherry to take a foothold, displacing the existing native and endemic species.

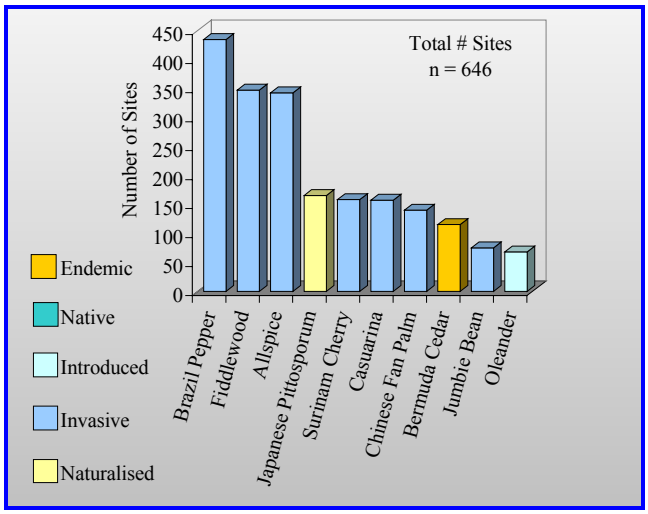


Figure 15. The most commonly observed trees in upland hillside habitats and the number of survey sites at which they were observed[27].

Birds, including the Grey Catbird, White-eyed Vireo, European Goldfinch, and Northern Cardinal can regularly be observed in the upland hillside, along with pests such as Sparrows and Kiskadees. The introduced lizards, the Barbados Anole, Antiguan Anole (Warwick Lizard), and Jamaican Anole are also common. Dead cedars are hosts to termites, whilst other commonly observed insects include the Argentine Ant, Big Head Ant and the Paper Nest Wasp. The Golden Silk Spider and Spiny-Bellied Orb Weaver are also common.

Most commonly observed understorey species in the Upland Hillside are:
Native: *Morning Glory, Crab Grass, Poison Ivy, Cape Weed, Virginia Creeper, Seaside Goldenrod, White Stopper*
Invasive*: Asparagus Fern, Wedding Fern*
Naturalised*: Flopper, Mock Orange, Fennel, Common Sage Bush*
Threatened Endemics and Natives: *Bermuda Bedstraw, Ink Berry, Doc-bush, St. Andrew's Cross, Brier Bush, Rhacoma, Turkey Berry, Wood Grass*

Much of the remaining upland hillside is found in Smith's and Hamilton parishes, as well as Devonshire and the western part of Southampton.

Threats

One of Bermuda's most threatened habitats, the upland hillside is heavily impacted by habitat loss through development, as well as being particularly susceptible to invasive species.

[27] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

Upland Valley

These areas comprise the sheltered valleys and depressions with deep soil along the central axis of the Island. They have become completely developed for arable, residential and garden use. There are no undisturbed upland valleys, but the former Chief Conservation Officer, David Wingate, has restored an area of upland valley on Nonsuch Island. In pre-colonial times, the endemic Bermuda Cedar, Olivewood and Palmetto, and trees like Yellowood and Southern Hackberry would have dominated this habitat. The dense canopy would have supported native and endemic ferns and mosses.

The upland valley in Somerset which is now the National Trust's Gilbert Nature Reserve, might be a suitable site for another upland valley habitat restoration project.

Limestone Sink

A limestone sink is a depression, sometimes with a steep-sided rock face, that is the site of a collapsed cave. This is a very localised habitat, and most are found in the areas of oldest limestone, the Walsingham Formation, in Hamilton Parish. Because of their rugged topography, which historically has been difficult to develop, many sink holes have served as a refuge for endemic and native species that have disappeared from other locations. Coupled with their moist environment, they provide ideal conditions for ferns, including the endemic Bermuda Shield Fern, mosses and liverworts such as Long Spleenwort and Toothed Spleenwort, as well as the endemic Wild Bermuda Bean and Bermuda Wild Pepper.

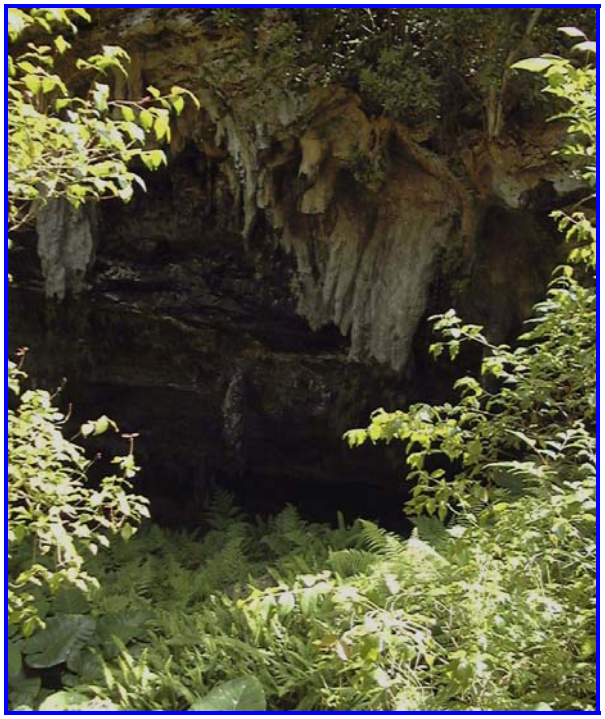


Plate 9. Sear's Cave, a limestone sink with native and endemic fern species (Photo courtesy of H. De Silva).

Threats

The major threats to these sink holes are dumping of trash and development.

Peat-Filled Marshes

Peat marshes, which are confined to low lying inland areas, form the most extensive freshwater habitat in Bermuda. Their area has declined dramatically since colonisation. In 1900 there were about 121 ha (298 acres) of peat marsh, which by 1997 had been reduced to approximately 67 ha (165.5 acres)[28]. Of

[28] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

these, Paget Marsh, is the largest at 9.25 ha (22.8 acres).

Plate 10. A view of Paget Marsh showing Bermuda Palmettos and various fern species. (Photo from BAMZ slide collection).

Marshes were historically used as areas to dump garbage, which provided an efficient way to eliminate mosquito breeding grounds. They were also cleared for lowland agricultural areas. Some marshes (or parts thereof), such as Mills Creek, have been filled to allow development, whilst others such as The Pampas, Smith's Parish and The Lagoon Estate in Paget have been grassed over after being filled with waste and rubble to form lawns or wayside habitats.

Peat Marshes have a high diversity of native and endemic species. Dominating the canopy in areas above the water-table are the Bermuda Palmetto, Bermuda Cedar, and Wax Myrtle. The invasive Brazil Pepper, and in some areas Surinam Cherry and Guava must also be added to the current list of dominant species.

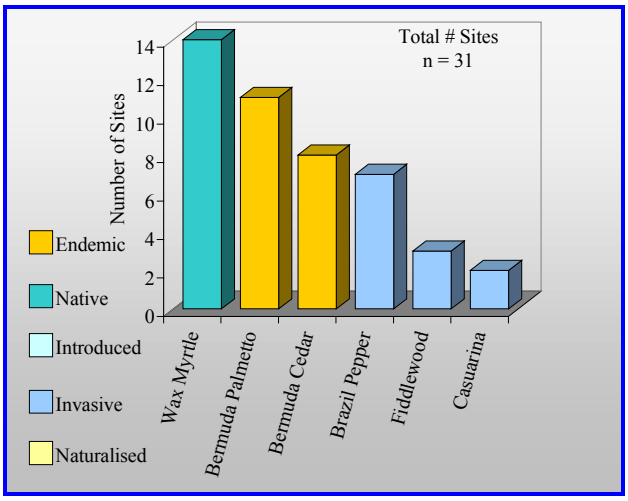


Figure 16. The most commonly observed trees in peat marshes and the number of survey sites at which they were observed[29].

The most commonly observed understorey species in the Peat Marshes are:
Native: *Cinnamon Fern, Wax Myrtle, Morning Glory, Southern Bracken Fern, Virginia Chain Fern, Creeping Day Flower, West Indian Cissus, Giant Fern, Royal Fern, False Nettle, Saw Grass*
Invasive*: Ardisia, Asparagus Fern, Wedelia*
Threatened Endemics and Natives: *Bermuda Sedge, Ten Day Fern, Virginia Chain Fern, St. Andrew's Cross, Psilotum*

Wildlife supported in the peat marshes includes the Barn Owl, Migratory Bats, the Yellow-rumped Warbler and other migratory warblers, Cane Toad, one species of whistling frog, the Grey Catbird, Chick-of-the-Village, Great Blue Heron, as well as ducks, herons, egrets, rails and other waterfowl, and a wide variety of insects.

[29] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

Threats

Expanded industrial development poses a potential threat to Devonshire Marsh, whilst the impact of various introduced animals such as the Ram's Horn Snail and Red Eared Slider Turtles, discarded by local pet owners, warrants study.

Fresh-Brackish Pond

There are about a dozen freshwater ponds in Bermuda, totalling an area of 7 ha (17 acres)[30]; Warwick Pond is the largest. Natural fresh water ponds have thick peat deposits on the bottom and around the edges, which prevent water from draining away. Several, such as David's Pond at Paget Marsh, Bartrum's Pond at Stokes Point Nature Reserve, and one at Nonsuch Island have been artificially created. There are also ponds on golf courses and many residential properties.

The most commonly observed species found in Fresh/ Brackish Ponds are:
Native: *Narrow Leaved Cattail, Sheathed Paspalum, Olney's Bulrush, Knotted Spike Rush, Creeping Day Flower, Morning Glory, Valdivia Duckweed, Mermaid Weed*
Invasive: *Water Fern*
Naturalised: *Para Grass, Umbrella Sedge*
Threatened Endemics and Natives: Valdivia *Duckweed, Mermaid Weed*

Freshwater ponds are important for a diversity of resident and migrant waterfowl, as well as Mosquito Fish, Giant toads, tree frogs, and aquatic insects such as dragonflies, midges and water snails.

Threats

Pollution from run-off of animal wastes from livestock/ dairy farming and fertilisers and pesticides from vegetable farming all threaten the freshwater pond habitat.

In addition to those described above, there are a number of habitats created by humans that warrant mention.

Hedgerow

Comprising the hedges bordered by roads or footpaths, hedgerows are dominated by attractive ornamental plants. Many of these are self-seeding invasives (Surinam Cherry, Chinese Fan Palm, Allspice, Fiddlewood, Brazil Pepper, Elephant's Ear and Asparagus Fern) which threaten endemics such as the Bermuda Cedar and Palmetto, and natives including Joseph's Coat, Morning Glory and Cape Weed. Other introduced species in the hedgerows, include Wire Weed, Sow Thistle, Fumitory, Mock Orange, Nasturtium and Flopper Plant. Hedgerows provide an important habitat for many species of birds (including the European Goldfinch, Chick-of-the-village and Northern Cardinal, as well as Crows, European Starlings and Kiskadees) and numerous insect species.

[30] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

The most commonly observed understorey species in Hedgerows are:
Native: *Crab Grass, Cape Weed, Bull Grass, Morning Glory, Poison Ivy*
Invasive: *Asparagus Fern, Elephant's Ear*
Naturalised: *English Plantain, Rye Grass, Bermuda Grass, Sow Thistle, Toothed Medic, Flopper, Fumitory, Hairy Horse-weed*

Garden

Terrestrial habitat surveys conducted at 127 sites in residential gardens, playing fields and public parks, documented the dominance of invasive trees[31]. However, it is worth noting that the planting of ornamentals in gardens has actually helped increase the numbers of native and endemic species, by providing more space for them to grow.

Gardens provide an important habitat for many animals, including the Bluebird (threatened by the Kiskadee, Sparrow and Starling), European Goldfinch, Ground Dove, Mourning Dove, as well as a wide variety of migratory warblers and other songbirds. Common insects include the Field Cricket, Long-Horn Grasshopper, Short-Horn Grasshopper, Surinam and American Roaches, Monarch Butterfly, Buckeye Butterfly, Cloudless Sulphur Butterfly and Cabbage White Moth. Wolf spiders, toads and whistling frogs are also common.

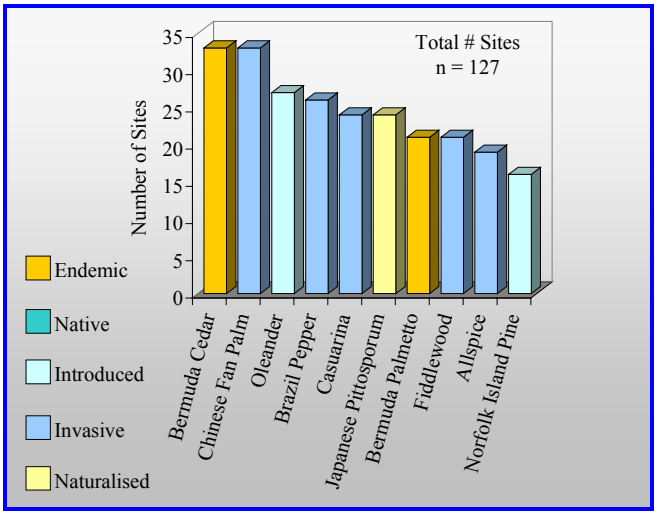


Figure 27. The most commonly observed trees in gardens, and the number of survey sites at which they were observed[72].

Golf Courses

Golf courses cover an extensive area (243 ha or 600 acres[71]) and serve as important habitats for many bird species including migratory warblers and swallows, Bluebirds, the European Goldfinch, Common Ground-dove and Mourning Dove and other song birds. Water hazards often support waterfowl and shorebirds.

The most commonly observed understorey species on Golf Courses are:
Native: *Crab Grass, Cape Weed*
Invasive: *Asparagus Fern, Wedding Fern*
Naturalised: *Bermuda Grass, Rye Grass, Annual Meadow Grass, Wire Weed, Dandelion, Japanese Hawksbeard, Wood Sorrel, Toothed Medic*

Threats

The liberal use of fertilisers and pesticides is probably the major threat to the wildlife supported on Bermuda's golf courses. Integrated pest

[31] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

management techniques should be encouraged. Adoption of principles such as those outlined in the "Environmental Principles for Golf Courses in the United States" and following the U.S. Audubon Cooperative Sanctuary Program and the Audubon Signature Program should be considered.

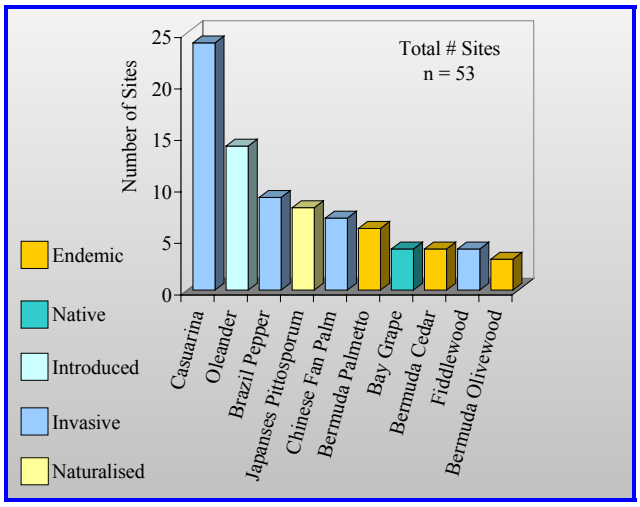


Figure 18. The most commonly observed trees on golf courses and the number of survey sites at which they were observed[32].

Field and Wayside

Areas of land at the edges of main roads, unmown grassed areas and sites where building demolition has occurred as well as land formerly used as a dump (amounting to about 34 ha or 84 acres[72]), can be classified as wayside. They provide a surprisingly diverse species assemblage with over 120 species in total recorded in the understorey; however, 75% of these are self-propagating introduced species, which threaten the few natives and endemics found in this habitat. They are important areas nevertheless, as they often serve as corridors for various animals.

[32] Bermuda Biodiversity Project. 2001, Unpublished data. Bermuda Zoological Society.

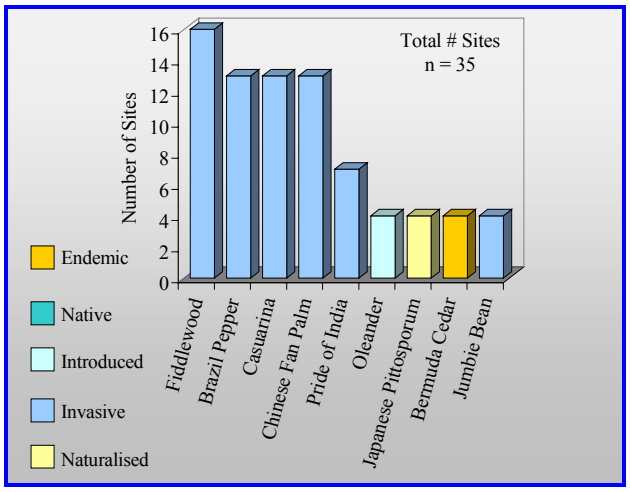


Figure 19. The most commonly observed trees in the wayside canopy and the number of survey sites at which they were observed[73].

Species Diversity[33]

Sterrer (1998) undertook a comprehensive review of the literature, concluding that at least 8,301 species have been recorded from Bermuda, of which 3.0% are endemic. Of these, 4,597 are marine and 3,702 are terrestrial.

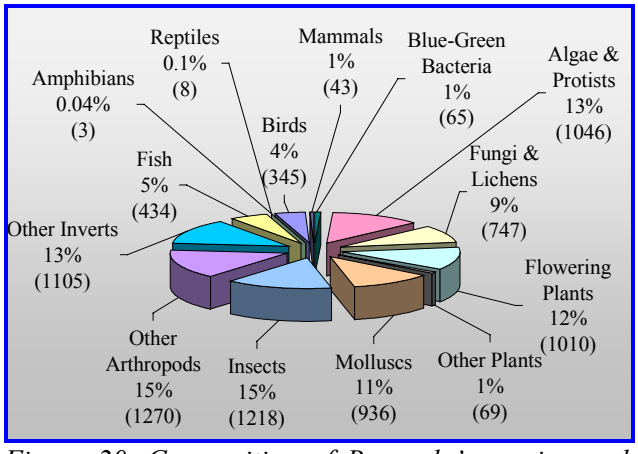


Figure 20. Composition of Bermuda's marine and terrestrial flora and fauna.

[33] Sterrer, W. 1998. How many species are there in Bermuda? Bulletin of Marine Science. 62, 809-840.

Cyanobacteria (Blue-Green Bacteria)

Cyanobacteria are well represented in Bermuda with 65 species having been reported, largely from rocky intertidal and sub-tidal surfaces, but also from sandy substrates and mangrove roots.

Marine Algae

Nine of the 473 species of macro-algae reported from Bermuda are endemic. An estimated 269 species of marine micro-algae have been reported.

Protozoa

There are 269 protozoan species known locally; 200 of these are the predominately benthic foraminiferans, of which *Homotrema rubrum* is perhaps best known for the pink hue its skeleton gives to Bermuda's sand.

Myxomycota, Fungi And Lichens

Of 783 species recorded 50 are endemic. The marine mycota of Bermuda is reported to be almost identical with that of other tropical and subtropical areas, such as Florida, the Caribbean, and the tropical part of the Pacific Ocean.

Terrestrial Plants

In spite of major changes in Bermuda's terrestrial ecology, especially since 1942, very little botanical work has been done since Britton in 1918, and the numbers reported below need revising.

Bryophytes (mosses and liverworts)

Fifty species have been recorded, of which 2 are endemic.

Ferns

Four of Bermuda's 19 species of fern were thought to be endemic, but one *(Dryopteris speluncae)*, is now considered to be only a native population of the more widely distributed *Ctenitis sloanei*. Another endemic, Governor Laffan's Fern is locally extinct in the wild; there are just five remaining at the Bermuda Botanical Gardens.

Gymnosperms and Angiosperms (Flowering plants)

Of 1010 species of flowering plants recorded by Britton, 11 are endemic. In 1976, it was estimated that more than 1500 species of plants have been introduced to Bermuda, of which about 800 have become naturalised.

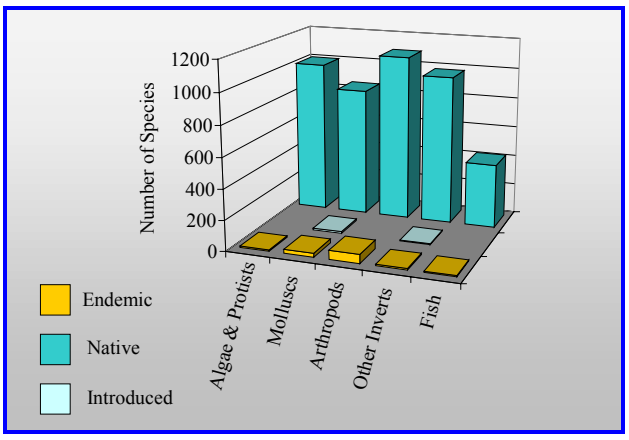


Figure 21. The number of marine plants and animals that are endemic, native, or introduced. Introduced includes invasive and naturalised species.

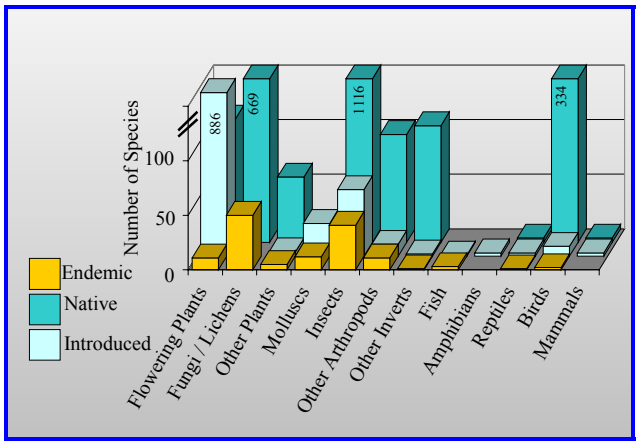


Figure 22. The number of terrestrial and freshwater plants and animals that are endemic, native, or introduced. Introduced includes invasive and naturalised species.

Porifera (Sponges)

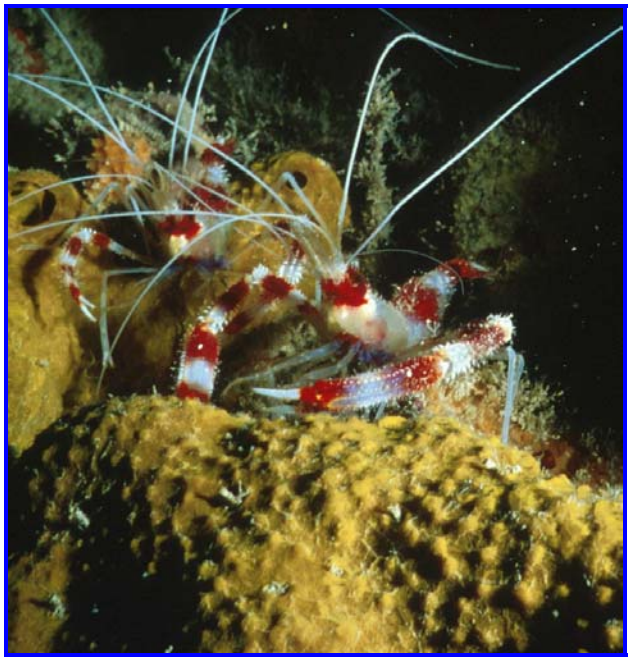


Plate 11. Pair of Banded Coral shrimp on one of Bermuda's many sponges. (Photo courtesy of I. Murdoch).

Bermuda's sponge fauna is relatively well known. At least 70 shallow-water species have been recorded, although recent studies suggest that actual number may be in excess of 100 species[34]. Commercially usable sponges of the keratose family Spongiidae were apparently common in Bermuda in the late 1800's. However, all of these seem to have disappeared.

Cnidaria

Hydrozoa (Hydroids)

Commonly occurring on rocks, rubble, turtle grass, pilings as well as other invertebrates, 90 shallow-water hydroid species have been recorded of which 79 are also known from the Caribbean and West Indian regions. Three species are considered endemic to Bermuda. There are 45 species of the colonial, planktonic Siphonophora known from local waters as well as 2 species of Chondrophora one of which, *Physalia physalis,* is commonly seen stranded on Bermuda's beaches in the Spring.

Scyphozoa (Jellyfish)

None of the 10 species recorded from Bermuda are endemic.

Anthozoa (Sea Anemones, Corals)

Soft corals and sea fans (Alcyonaria) are a visually dominant component of most Bermuda's reefs and 25 species have been reported. There are 38 species of stony corals (Scleractinia). This includes 13 ahermatypes, which lack zooxanthellae and inhabit

[34] Ritter, J. Pers. Comm. Bermuda Biological Station for Research Inc.

the caves and deep water. Nine zoanthid and 21 Zoantharia species are also known locally. Of the 5 species of black coral recorded from Bermuda, 3 were collected in a single deep dive to 60 m, which suggests that even shallow-water Antipatharia are still insufficiently known.

Ctenophora (Comb-Jellies)

Only 5 species are known from Bermuda.

Simple Worms (Flatworms, flukes, roundworms)

There are 253 simple worms known from Bermuda. Of the flatworms, 67 are parasitic (50 having been recorded from Bermudian fishes), whilst 12 of the 78 species of round worm are also parasitic. One of the jaw worms is endemic.

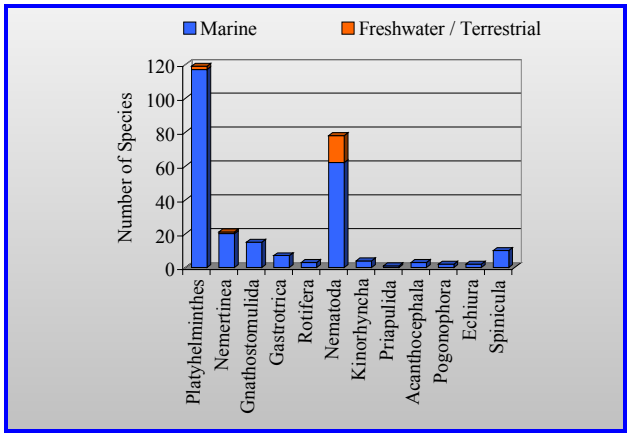


Figure 23. Marine and freshwater simple worms from Bermuda (by class).

Bermuda's tree frogs and toads are hosts to 11 helminth parasites. One species is a parasite of lizards, and one of land crabs. Four intestinal helminths have been found in dogs and cats, whilst *Ascaris lumbricoides, Trichuris trichura* and *Enterobius vermicularis* are the most commonly seen nematodes in humans.

Annelida (Bristle worms, leeches)

A total of 211 annelids have been reported primarily from the marine environment. The marine bristle worms Oligochaeta (40 species) and Polychaeta (over 250 species[35]) are reasonably well known. Six species of Archiannelida (of which 1, the "marine earthworm" *Pontodrilus bermudensis* Beddard is the only endemic macro-oligochaete), and 1 species of marine leech have also been reported. A survey of terrestrial Oligochaeta in 1996 added 6 species to the 8 recorded previously.

Arthropoda

Crustacea

Of the 130 marine ostracods, 14 are cave-dwelling endemics. Other endemics include one barnacle, six marine amphipods, one marine isopod, and six endemic decapods. Of these, the caridean shrimp *Periclimenes anthophilus* is possibly synonymous with the Caribbean *P. pedersoni*. Three other caridean species from marine caves are endemic as is one deepwater crab. The sixth endemic decapod is the astacid *Eunephrops luckhursti.*

[35] Pocklington, P. Pers. Comm. Bermuda Biological Station for Research Inc.

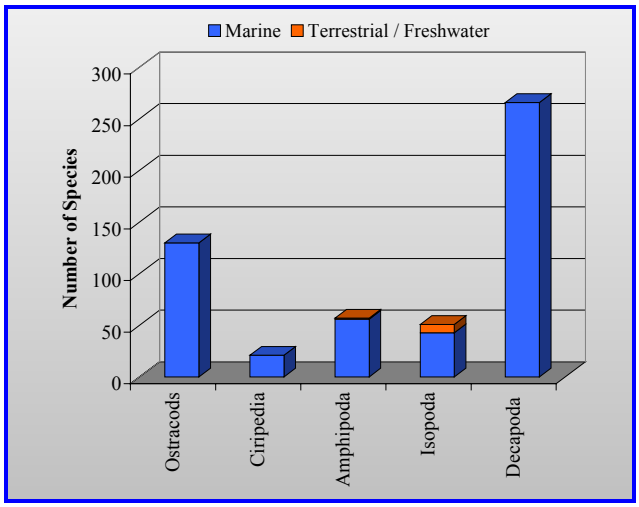


Figure 24. Marine and terrestrial/ freshwater Crustacea from Bermuda (by class).

Araneae (Spiders)

Of the 59 known species of spiders, one is a new species (*Anyphaena bermudensis*) and therefore a potential endemic. We know that several species were already residents at the time of Bermuda's colonisation.

Insecta

Of the 183 species of Lepidoptera (Butterflies), about 125 are thought to be established residents, while the remainder are assumed to be vagrants. Eleven species and three subspecies are endemic, and one of these, *Semiothisa ochrifascia* is believed to be extinct. This moth was dependent on the endemic Bermuda cedar. There are 228 species of Coleoptera (beetles), none of which are endemic, and 258 species of Diptera (flies), including 17 endemics of which 7 are possibly extinct. Of about 44 endemic insect species, 16 (36.4%) seem to have become extinct in this century, the most conspicuous being the Bermuda Singer or Cicada, and the Bermuda Flightless Grasshopper. There are 7 dragon- and 3 damselflies known locally.

Plate 12. This grasshopper is one of over 1,000 insects known from Bermuda. (Photo courtesy of R. Ground).

Mollusca (Snails, bivalves, squid, etc.)

Bermuda's marine molluscs, including those from deeper waters as well as micro-gastropods, are well known. Of 88 species of marine Pleistocene molluscs (48 Gastropoda, 40 Bivalvia) recorded, 6 no longer survive in Bermuda. Of 594 marine gastropods, 22 are endemic and of 205 marine bivalves, 4 are endemic. Nine chitons (Polyplacophora), 4 tusk shells (Scaphopoda), 69 Cephalopoda and 2 worm molluscs (Aplacophora) have also been documented.

The 47 species of terrestrial slugs and snails known to occur here are from 20 families. Of these, 11 are endemic, 7 are native, and there have been at least 25 accidental introductions, while 4 were deliberately introduced. Several endemics, including the last two extant species of *Poecilozonites*, are feared to be extinct, probably fallen victim to

Euglandina rosea and other introduced carnivorous snails.

Of 6 freshwater molluscs described from Bermuda, two (the gastropod *Ancylus bermudensis* and the bivalve *Pisidium volutabundum*) reported from Pembroke Marsh were probably endemic but are now extinct.

Echinodermata (Sea urchins, sea cucumbers, sea stars)

None of the 72 species of Echinoderms known from Bermuda are endemic. Of four species of starfish (Asteroidea) recorded in the early 1900's, two (*Asterina folium* and *Luidia clathrata*) have disappeared. Several other seastars, including the conspicuous *Oreaster reticulatus*, only turn up occasionally as isolated waifs giving a total of 12 recorded species. There are 21 species of brittle star (Ophiuroidea), and 20 species of sea urchin (Echinoidea), of which *Lytechinus variegatus* is by far the most conspicuous in Bermuda's inshore waters. The Spiny Sea Urchin, *Diadema antillarum*, never particularly abundant in Bermuda, was decimated in 1983 by a pathogen that spread rapidly throughout the northwestern Atlantic; it seems to be slowly recovering. There are 18 species of sea cucumber (Holothuroidea) known, ranging from the intertidal to deep water.

Hemichordata

Of 6 species of Hemichordates documented from local waters, 4 are acorn worms (Enteropneusta), and the other 2 are Pterobranchia. The latter, *Cephalodiscus gracilis* and *Rhabdopleura normani,* are interesting in that most species from this class are known from colder, deeper habitats; few have been reported from shallow tropical areas.

Chordata

Tunicates (Sea squirts, salps)

Of the 96 species of tunicates (Thaliacea, 29; Larvacea, 20; Ascidiacea, 47) recorded from Bermuda, 5 are endemic sea squirts (Ascidiacea). Interestingly, of approximately 70 species of Larvacea known globally, more than 20 have been reported from the Sargasso Sea.

Cephalochordata (Lancelets)

Three species of this fish-like chordate have been reported from Bermuda.

Fishes

As many as 433 species (9 endemic) in 107 families of mostly inshore fishes have been listed for Bermuda, the majority from depths above 200 m. Of these, three endemic species of *Fundulus*, and the introduced *Gambusia affinis* are found in the Island's brackish ponds and marshes. The Bermudian ichthyofauna consists almost exclusively of species found elsewhere in the tropical western Atlantic. It is relatively depauperate in comparison, with only about 50-55% of the number of resident species found in the Florida Keys or Bahamas.

Amphibia

All three established species of amphibians (the Giant Toad and the two species of West Indian whistling frogs) have been introduced. One species of whistling frog has not been seen since the mid-1990's.

Reptilia

Four species of marine turtles are recorded from Bermuda: the Green Turtle, the Hawksbill, the Loggerhead and the occasional Leatherback. The Green Turtle is by far the most abundant, but Bermuda's breeding population was decimated decades ago, and the Island now serves as an important nursery for juvenile turtles from other regions.

Bermuda boasts only one native land reptile, the endemic Skink, which is believed to be most closely related to a species in Florida. The description of a recently excavated fossil land tortoise adds an extinct endemic. Three introduced species of West Indian *Anolis* are well established.

Plate 13. Bermuda Rock Lizard or Skink (Photo courtesy of R. Ground).

Birds

Only 2 of the 360 birds[36] recorded from Bermuda, are endemic; these are the Bermuda Petrel or Cahow, and a subspecies of the White-Eyed Vireo, locally called Chick-of-the-Village. Fossil records exist for several species that no longer breed here including the Audubon Shearwater, and an albatross, probably the Short-Tailed Albatross, which survives in the Pacific. A few more species, probably all endemic, are now extinct: a crane (*Baeopteryx latipes),*a duck (*Anas pachyscelus)*, 4 species of rail (Rallidae), as well as a woodpecker, a hawk, a heavy-billed passerine, and a small owl - the latter two having been noticed by the first settlers.

Mammalia

There are no native, resident land mammals. The list comprises 4 visiting bats and the introduced rodents: the House Mouse, the Black Rat, and the Norwegian Rat; but excludes domestic mammals of which some (e.g., cats and rabbits) are considered feral.

There have been 36 species of whales, porpoises and dolphins (Cetacea) reported from Bermuda's waters. The most frequently sighted are the Common Dolphin, the Pilot Whale, the Sperm Whale, Cuvier's Beaked Whale, the Minke Whale and the Humpback Whale.

[36] Dobson, A. Pers. Comm. Current bird list at http://www.audubon.bm

Threatened Species

The International Union for the Conservation of Nature (IUCN) has developed categories and criteria for the classification of threatened species[37]. The categories provide a way of highlighting those species that are under higher extinction risk so as to prioritise conservation measures. These categories are "extinct", "extinct in the wild", "critically endangered", "endangered", "vulnerable", and "lower risk". One criterion for the classification of "critically endangered" is that a species has an estimated occurrence of less than 100 km^2 (38.6 $miles^2$). In effect, this means that all of Bermuda's terrestrial and freshwater endemics should be considered "critically endangered".

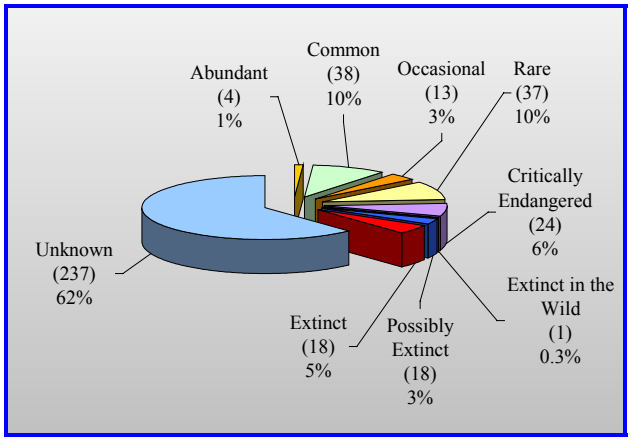


Figure. 25. Status of Bermuda's endemic species.

Marine Species

A number of Bermuda's native marine species including turtles, all mammals, corals, and many molluscs are considered threatened both locally and internationally. They are all locally protected from harvesting. Some, such as the Green Turtle, have been over-harvested to the extent that there is no longer a Bermuda breeding population. All of the Green turtles found locally today are the juveniles of another breeding population.

Of particular concern are the local Bermuda Scallop and Queen Conch populations. The latter, although not endemic, have shown some evidence of genetic variation from the Caribbean stock.

The native West Indian Top Shell is another species that was locally extirpated, but has recently been re-introduced. The population is still considered vulnerable.

Common Name	Species Name	Origin	IUCN Red List 2000 Status
Green Turtle	*Chelonia mydas*	Native	• Endangered • Population reduced by 50% over three generations
Northern Right Whale	*Eubalaena glacialis*	Native	• Endangered • Population < 2500 individuals • Expected decline of 20% within 2 generations • Population < 250 mature individuals
Pilot Whale	*Globicephala macrorhynchus*	Native	• Lower Risk • Conservation dependent survival
Lined Seahorse	*Hippocampus erectus*	Native	• Vulnerable • Expected decline of 20% in next 10 years • Decline in area of occurrence
Humpback Whale	*Megaptera novaeangliae*	Native	• Vulnerable • Expected decline of 20% over 3 generations
Marine Shrimp	*Somersiella sterreri*	Native	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat

Table 5. Bermuda's marine species found on the 2000 IUCN Red List[38].

Terrestrial Species

In comparison with Bermuda's marine flora and fauna, the Island's terrestrial species are under significantly greater threat. A number of endemics, including a woodpecker, a hawk and a small owl, have already become extinct, whilst one, Governor

[37] http://www.redlist.org/categories_criteria.html

[38] http://www.redlist.org

Laffan's Fern, is extinct in the wild. Some, such as the Bermuda Cicada, the Flightless Grasshopper and several *Poecilozonites* snail species are also feared to be extinct[39]. Many more, such as the Cahow and the Bermuda Rock Lizard as well as plants including, Bermuda Spike Rush, and Bermuda Sedge are now threatened. The threat to all of Bermuda's terrestrial and freshwater endemics is likely escalating given the continued loss of habitat and increasing number of introductions. Native species are not immune from these threats either.

Common Name	*Species Name*	*Origin*	*IUCN Red List 2000 Status*
Piping Plover	*Charadrius melodus*	Native	• Vulnerable • Population est. < 10,000 individuals • Continuing decline in numbers due to severe fragmentation
Bermuda Olivewood	*Elaeodendron laneanum*	Endemic	• Vulnerable • Population is very small and occupies a small area
Bermuda Rock Skink	*Eumeces longirostris*	Endemic	• Critically Endangered • Severely fragmented habitat • Decline in area, habitat, mature individuals
Bermuda Cedar	*Juniperus bermudiana*	Endemic	• Critically Endangered • Small area and extent of habitat
Bermuda Land Nemertean	*Pantinonemertes agricola*	Endemic	• Possibly Extinct • Data Deficient • More research is required
Bermuda Petrel	*Pterodroma cahow*	Endemic	• Endangered • Population < 250 mature individuals
Bermuda Palmetto	*Sabal bermudana*	Endemic	• Endangered • Severely fragmented habitat • Continuing decline in area and population
Yellowood Tree	*Zanthoxylum flavum*	Native	• Vulnerable • Observed decline of 20% over 3 generations • Decline in extent of occurence

Table 6. Bermuda's terrestrial species found on the 2000 IUCN Red List[40].

Cave Species

Bermuda's cave systems harbour a wealth of endemic species, which are under increasing threat from development and pollution. Of these, 25 are currently listed as critically endangered because of their restricted range, many having only been found in a single cave or cave system.

Common Name	*Species Name*	*Origin*	*IUCN Red List 2000 Status*
Cave Copepods	*Antriscopia prehensilis* *Nanocopia minuta* *Paracyclopia naessi* *Speleoithona bermudensis* *Speleophria bivexilla* *Speleophria scottodicarloi* *Eroboneces nesioicus*	Endemic Endemic Endemic Endemic Endemic Endemic Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat
Cave Isopods	*Atlantasellus cavernicolus* *Bermudalana aruboides* *Currassanthura bermudensis*	Endemic Endemic Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat
Cave Shrimp	*Barbouria cubensis* *Mictocaris halope* *Platyops sterreri* *Procaris chacei* *Typhlatya iliffei*	Native Endemic Endemic Endemic Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat
Cave Amphipods	*Bogidiella bermudensis* *Idunella sketi* *Ingolfiella longipes* *Cocoharpinia iliffei* *Pseudoniphargus grandimanus*	Endemic Endemic Endemic Endemic Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat
Cave Worm	*Mesonerilla prospera* *Phallodrilus macmasterae*	Endemic Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat
Cave Ostracod	*Spelaeoecia bermudensis*	Endemic	• Critically Endangered • Known only at a single location • Decline due to area / quality of habitat

Table 7. Bermuda's cave species found on the 2000 IUCN Red List[81].

[39] Thomas, M. Pers. Comm. University of New Brunswick, Canada

[40] http://www.redlist.org