Management Plan for the Land Hermit Crab (*Coenobita clypeatus*) in Bermuda

Government of Bermuda
Ministry of Home Affairs
Department of Environment and Natural Resources

Management Plan for the Land Hermit Crab (*Coenobita clypeatus*) in Bermuda

Prepared in Accordance with the Bermuda Protected Species Act 2003

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Cover photo: Land hermit crab in West Indian topshell at Cooper's Island Nature Reserve, by Alison Copeland

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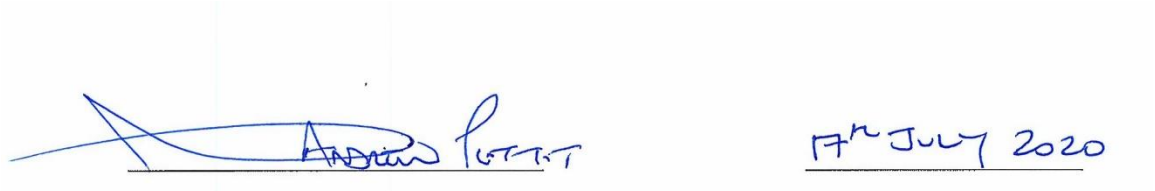

Director, Date
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Government of Bermuda

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EXECUTIVE SUMMARY

This management plan addresses the need for actions to conserve the native land hermit crab (*Coenobita clypeatus).*

Current species status
Legal protection for this species is provided by the Protected Species Act (2003). Following IUCN criteria, the Bermudian population of *Coenobita clypeatus* is listed as Vulnerable under the Protected Species Amendment Order (2016). This species has not been assessed for the IUCN Red List, nor is it protected by any treaties. The population estimate for Bermuda in the early 1990's was around 150 (Walker, 1994). No recent assessments have been made.

Habitat requirements and threats
The land hermit crab's complex life cycle requires different habitats, both on land and at sea. On Bermuda these crabs primarily inhabit vegetated upland coastal sites, saltmarshes, sand dunes, and rocky islets. Upon reaching maturity, female *C. clypeatus* require access to the sea to shed their eggs, which develop as planktonic larvae, before returning to land as juveniles. The most significant threat to land hermit crabs in Bermuda is habitat loss and alteration, through foreshore development and destruction of coastal habitats by human and natural causes. Invasive species, a deficiency of mollusc shells for shelter, pollution, habitat fragmentation, traffic and lack of public awareness are also considered local threats.

Management objective
The principal aim of this management plan is to protect land hermit crabs, sources of molluscan shells and crab habitats in Bermuda, and to conserve this species through sharing of knowledge and participation in research and monitoring, and mitigation of threats.

Management criteria
A positive conservation status for land hermit crabs in Bermuda will be achieved when there is:

1. Evidence of an increasing or stable population
2. Increased knowledge of Bermuda's land hermit crab population and its ecology
3. Critical habitats are identified and protected, and both quality and quantity are enhanced
4. Threats have been identified and addressed to the extent possible
5. The public are aware of this species and champion its conservation

Actions needed:

- An accurate assessment of abundance and distribution of the local population.
- Monitoring of critical habitat sites to establish a population trend, and rapidly respond to new threats
- Protection of critical habitats supported by public cooperation, legislation and enforcement.

- Evidence of a sustained increase of available shells from West Indian topshells and other sources
- Increased public education regarding the threats to protected crabs and their habitats.
- An improved programme for surrendering and reporting crabs in danger (e.g rehabilitation and relocation).
- Explore the possibility of establishing new colonies through translocation
- Put mitigation measures in place, where possible, against threats to crabs from human and natural sources.

Management costs

The total cost of management actions cannot be defined at this point. Funding needs to be secured through non-governmental organizations (NGO's), overseas agencies, and other interested parties for implementing the necessary research and monitoring, awareness and management activities. Developing budgets and securing funds for each action are the responsibility of the leading party as outlined in the work plan.

Figure 1: A juvenile *Coenobita clypeatus* utilising the shell of the terrestrial snail *Otala lactea*, south shore Bermuda. (Photo: Andrew Dobson).

PART I: INTRODUCTION

A. Brief Overview

The land hermit crab (*Coenobita clypeatus*) is one of several large terrestrial crabs native to Bermuda, but the only species that inhabits the shell of another animal, often a marine snail. Historically land hermit crabs would have roamed the coastal forests, beaches and rocky coasts of Bermuda. Today they are typically found in undeveloped areas of shrubby coastal vegetation adjacent to the rocky shore, and in the vegetated dunes at the back of sandy beaches.

The land hermit crab is found throughout the Caribbean and Central America as far north as Bermuda and Florida. Harvesting for bait and the pet trade occurs in parts of its range. Despite this, the species is not considered threatened at the regional level. However, in Bermuda land hermit crabs have become rare and face threats which required the local population to be legally protected to prevent extirpation (local extinction). The land hermit crab was added to Bermuda's list of Protected Species in 2012. It is listed as Vulnerable in Bermuda.

The population of *Coenobita clypeatus* has never been calculated for Bermuda but was estimated at 150 in the early 1990's (Walker, 1994). The local population is unlikely to be larger than a few hundred adults. Scattered individuals have been reported island-wide over the last 10 years (Table 2), distributed mainly along the South Shore and East End, where the majority of West Indian topshells are located.

This management plan outlines current conservation efforts for *Coenobita clypeatus*, and present knowledge of their distribution, habitat requirements, biology and the threats they face. The plan also recommends areas for future research and monitoring, focused on both the crabs and their habitats. Known threats to these crabs are discussed, and suggestions made on how these threats can be mitigated through management actions and legislation.

B. Taxonomy and Description of Species

Kingdom: Animalia
Phylum: Arthropoda
Class: Malacostraca
Order: Decapoda
Family: Coenobitidae (land hermit crabs)
Genus: *Coenobita*
Species: *clypeatus*

Taxon author: J.C Fabricius, 1787

In some historic Bermuda literature (Heilprin, 1889; Verrill, 1902; Verrill, 1907) this species is referred to as *Cenobita Diogenes*.

Common names: Common names for this species include the locally used ‘land hermit crab’ and the Caribbean hermit crab, solider crab, and purple pincher.

Coenobita clypeatus can be distinguished from other terrestrial crab species in Bermuda by its use of a gastropod shell, the narrow shape of its head and body, and the bright purple colour of the biggest front claw in larger animals.

Figure 2: Two *C. clypeatus* retracted into *C. pica* shells, showing enlarged purple claw (photo: Alison Copeland).

The land hermit crab has a pair of stalked eyes and two pairs of jointed antennae on the front of its head. Hermit crabs have five pairs of jointed legs, the first three pairs are large and outside of its shell, while the fourth and fifth pair are small and inside the shell. The front legs (chelipeds) end in large claws which become more unequal in size as the crab grows. One of the major chelipeds, usually the left one, is enlarged and bright purple in colour (Chace et al., 1986). The other four pairs of legs are shades of grey, peach, orange and red. The second and third pairs of legs are used for walking and the fourth and fifth pairs are used for tasks inside the shell like cleaning the gills and removing waste. The claws and legs are covered in stiff sensory hairs (setae). Young crabs are often paler colours while large older individuals are often brownish red in colour. De Wilde (1973) examined thousands of crabs around the Caribbean and noted that occasionally an albino could be found.

By weighing sexually mature crabs in their shells, de Wilde (1973) determined that adult *C. clypeatus* can weight from as little as 2g up to 500g. Measuring the large chelipeds is the most often reported method of sizing *C. clypeatus*, as removing the animal from it shell to measure it may kill it. In the Bermudian sub-population at Hungry Bay, large chela sizes of 13.9 to 33.2 mm were reported from the 85 crabs measured by Godsall (2000) and 16 to 35 mm in the 82 crabs measured by Walker (1994).

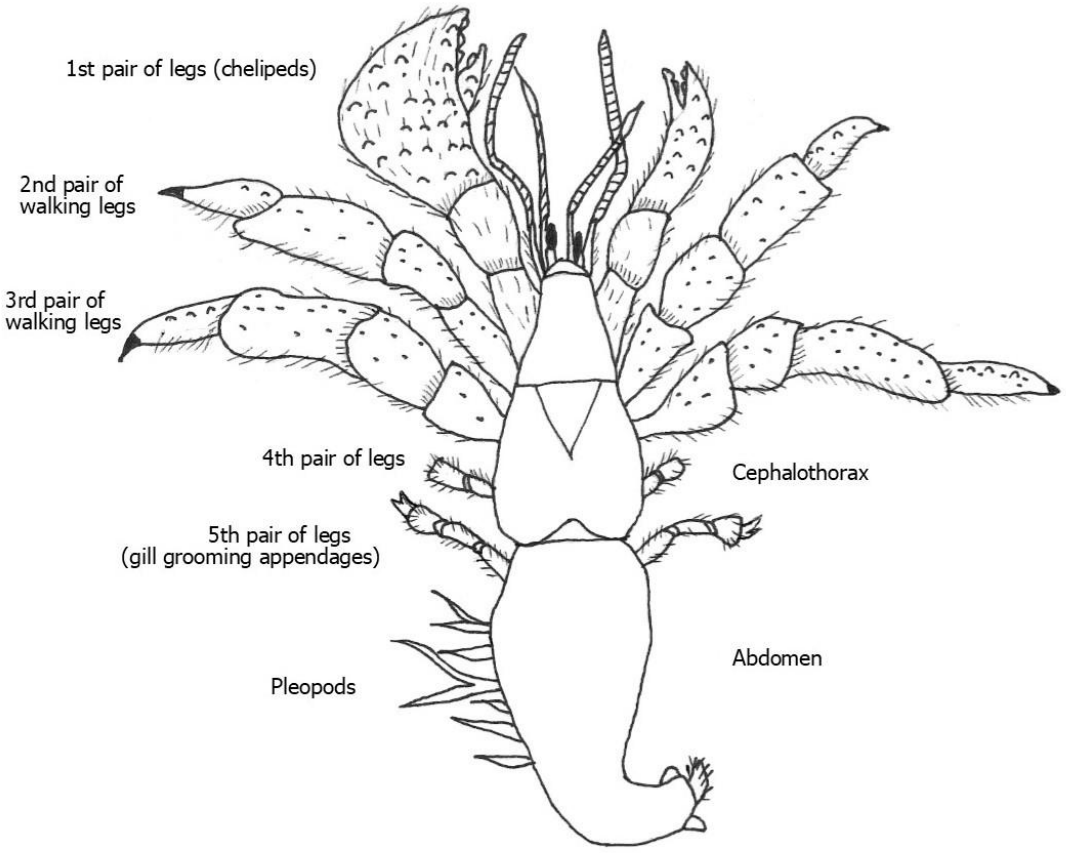

Figure 3: Dorsal view of a female *Coenobita clypeatus* showing arrangement of appendages. © Alison Copeland (Bermuda DENR).

C. Ecology

General information on the ecology of the land hermit crab has been summarized below from the literature, and data more specific to Bermuda have been incorporated when available.

Unlike other crab species, *Coenobita clypeatus* is gregarious and can be found assembled in mixed-size groups in the wild. *C. clypeatus* use a variety of sounds, chemical cues and behaviours such as claw and antennae movements to communicate with each other. The sensory organs and social behaviours of *C. clypeatus* have been widely researched and reported in the literature.

Habitat requirements

Land hermit crabs spend their adult life on land, however this species ability to colonise inland habitats is limited, due to continued reliance on the sea throughout its life. Land hermit crabs rely on the sea as a source of gastropod shells needed for shelter, and also must release their eggs into sea water for larval development.

In Bermuda, land hermit crabs are most often found in undeveloped areas of shrubby coastal vegetation adjacent to the rocky shore, and in the vegetated dunes at the back of sandy beaches. Occasionally they are found on un-vegetated or sparsely vegetated rocky islets, but in these habitats they are vulnerable to predation. Hermit crabs are almost always found in terrestrial habitats adjacent to a calm body of seawater with a gently sloping coast, which allows crabs access to the sea and an accumulation of gastropod shells. The use of inland saltwater ponds by this species has not been studied, but may be possible if suitable large gastropod shells were available. Contrary to what may be expected, de Wilde (1973) notes that *C. clypeatus* avoids permanently wet, marshy habitats.

Land hermit crabs are mainly nocturnal and are most active at night or after rainfall on cloudy days. During the day the crabs bury themselves to avoid desiccation and overheating. They will burrow under the roots of trees, or bury themselves under rocks, leaf litter or by digging holes in the sand. There is evidence they use thick deposits of *Casuarina* needles to bury themselves (de Wilde, 1973). Captive crabs in a sand-filled tank were observed creating a network of cavities, sometimes with multiple entrances (Author observation). At Hungry Bay, they hide under rock ledges, in caves and in rotten stumps and logs. A number of crabs will occupy a particularly desirable, moist spot.

When land hermit crabs need to shed their exoskeleton, they bury themselves and their shell in moist sand or soil, for up to several months at a time. During this moult, crabs are vulnerable to desiccation and predation, particularly cannibalism from other crabs.

Shells

All species of hermit crabs require a hard shell to cover the soft parts of their abdomen, as their exoskeleton is not as well armoured there as the tough claws at the front of the body. As *Coenobita clypeatus* can become quite large, they require a variety of different sized shells over a lifetime. *Coenobita clypeatus* pick up empty shells in the sea as newly hatched juveniles, and then acquire them on land or the shoreline as larger juveniles and adults. Hatchling land hermit crabs leaving the sea must compete with marine hermit crabs for shells (Morrison and Spiller, 2006).

A land hermit crab in a well-fitting shell is able to retract completely into its shell and block the entrance with its large claw when faced with danger or unfavourable environmental conditions (Fig. 2). Crabs will change shells when they outgrow their current shell or if it becomes damaged and no longer provides adequate protection. In coastal woodlands inhabited by land hermit crabs, it is not unusual to find marine shells some distance from the shoreline. The availability of an empty shell has been shown to trigger a cascade of shell-switching with hermit crabs lining up in size order to receive a larger, newly-vacated shell (Lewis and Rotjan, 2009; Hornbeck, 2011). Laboratory experiments have shown that chains of shell-switching behaviour usually terminate at damaged shells (Lewis and Rotjan, 2009), and in this way, if an adequate supply of shells are available, damaged shells will continually work their way out of the population. In extreme situations when shells are unavailable, land hermit crabs will shelter in plastic or other marine debris or calcified polychaete tubes (Lewis and Rotjan, 2009).

In Bermuda the shell most often used by land hermit crabs of all sizes is the West Indian topshell (*Cittarium pica*). Other shells that have been observed being used by younger crabs include those of the beaded periwinkle (*Tectarius muricatus*) (Fig. 4) and several species of nerites (*Nerita spp.).* On occasion land hermit crabs have been observed utilising shells from terrestrial snails such as the milk snail (*Otala lactea*) (Fig. 1), but this is relatively uncommon and may be due to the inappropriate internal shape of the shell, or because it is relatively thin compared to marine molluscs. Walker (1994) reported *Coenobita clypeatus* from Hungry Bay using primarily *Cittarium pica* shells, but also rarely mangrove periwinkle (*Littorina anguilifera),* and four-toothed or variegated nerite (*Nerita versicolor).* Godsall (2000) also reported one occurrence of a triton shell being used.

Figure 4: A young *Coenobita clypeatus* in the shell of a beaded periwinkle *(Tectarius muricatus).* This crab was found in a shell-poor environment and is using a shell that is too small for its body (Photo: Mark Outerbridge).

Godsall (2000) found that only 23% of the 85 crabs studied at Hungry Bay, had shells which were of a large enough size and not damaged. He also noted that 81 of the 85 crabs used *Cittarium pica* shells.

In the mid-1800s the West Indian topshell (*Cittarium pica)* was extirpated (became locally extinct) in Bermuda following overharvesting (Meyer, 2012). After this time, the hermit crab population began to decline due to a shortage of available shells (Chace et al., 1986; Olson and Hearty, 2013). Some writers suggested that the land hermit crab managed to survive on Bermuda by utilising fossil and subfossil topshells eroded from the limestone and fossil dune deposits (Verrill, 1907; Verrill, 1908; Walker, 1994), but later publications challenge this (Olson and Hearty, 2013).

Walker (1994) stated that the number of available fossil *Cittarium pica* shells was declining in the early 1980's leading to fears that *Coenobita clypeatus* would become locally extinct. She noted that Bermuda was a 'shell-limited' habitat in 1990 and that crabs she encountered appeared to occupy any shell regardless of size. She catalogued shell modifications in West Indian topshells from Bermuda that indicated they had been used by hermit crabs, including wearing on the bottom of the shell from dragging and a characteristic outer lip ridge within the aperture of the shell where the crabs carapace rubbed the lip of the shell, and abrading or removing the columellar area of the shell. These modifications to the shell's interior are to allow the crab to store water to prevent their gills from drying out (Walker 1994).

The re-introduction of *Cittarium pica* to Bermuda from the Caribbean in 1982 successfully re-established a population of large shell-providing molluscs (Walker, 1994; Godsall, 2000; Meyer, 2012). The legal protection of *C. pica* under the Fisheries Act 1972 has allowed the population to grow without harvesting pressure. Today, all life stages of *C. pica* can be found along much of Bermuda's South Shore and around the East End, and they are becoming more common on North Shore and the West End, which means that a wide range of shell sizes occur in most areas. *Cittarium pica* is not yet common within the Great Sound, Little Sound or on the islands of Hamilton Harbour (Mark Outerbridge, pers. comm.). *C. pica* is mostly found on rocky shores with high wave energy (Meyer, 2012), and not around beaches or other soft shorelines and places with suspended sand or sediment. *Coenobita clypeatus* population expansion will therefore likely be limited to habitats that overlap the distribution of *C. pica* as described by Meyer (2012).

The dependant relationship between the land hermit crab (*Coenobita clypeatus*) and West Indian topshell (*Cittarium pica)* has led jurisdictions like the US Virgin Islands and Cayman Islands to manage these species concurrently (DaCosta-Cottam et al., 2009; Hornbeck, 2011). There is presently no management plan for *C. pica* in Bermuda, therefore some recommendations for *C. pica* management as it pertains to *C. clypeatus* recovery will be made here.

Diet and Feeding Behaviour

Coenobita clypeatus is omnivorous, feeding on scavenged animal remains and plant material. They feed on fruit, palm flowers, seeds (including drift seeds in the strand line), new shoots, fresh and decaying plant material (de Wilde, 1973; Lewis and Rotjan, 2009; Tedford, 2017). Land hermit crabs will eat the fruit of the prickly pear cactus (*Opuntia sp*.) and reportedly gnaw the pads of the cactus for moisture in dry weather (de Wilde, 1973). In Puerto Rico it is reported that the faeces of iguanas are an important component of the land hermit crabs diet, and they are also reportedly attracted to the droppings of horses and cows (de Wilde, 1973; Nieves-Rivera and Williams, 2003). Cannibalism has been observed in captive *C. clypeatus* (de Wilde, 1973).

Land hermit crabs are attracted to anthropogenic sources of food such as garbage dumps, compost piles, bird pens and fishing camps to scavenge (Hornbeck, 2011). They will also gather in numbers at orchards and productive fruit trees. *C. clypeatus* has been observed climbing up to 3 metres into trees to feed on bark and tender plant material (Nieves-Rivera and Williams, 2003). On the Castle Harbour Islands *C. clypeatus* are attracted to the bait boxes used for rat

control, where they eat the rodenticide in large quantities, seemingly remaining unaffected by the poison (Jeremy Madeiros, pers. comm.).

Water

Coenobita clypeatus gets water from its food, but also actively takes in water for both drinking, and storing in its shell to keep its gills wet. De Wilde (1973) describes how crabs use water drops on surfaces for drinking by transferring drops to its mouth and gill chamber using its claws and hairs on its legs. He noted the importance of drinking places to crabs in Curaçao, and reported concentrations of crabs where relatively fresh water was available, either from seepage in the limestone, or from anthropogenic sources. In dry weather *C. clypeatus* have been observed eating porous limestone to obtain trapped water.

Several behavioural adaptations allow the land hermit crab to manage water – such as its nocturnal lifestyle, inclination to seek out moist microhabitats and shelter from the sun, storage of shell water, and use of a well-fitting shell which can be sealed.

When a hermit crab is disturbed and withdraws into its shell, much of the stored shell water is lost. Shell water is held between the shell and the abdomen, and in the empty space behind the crab in the back of the shell. Thus, a crab with a large, well-fitting shell can carry a more adequate water supply than one inhabiting a poorly fitted or damaged shell. The salt concentration of the shell water is kept constant by the crab, by adding freshwater to account for increased saltiness due to evaporation. For crabs living on a coast with easy access to seawater, carrying shell water is less important than for inland sub-populations (de Wilde, 1973).

Diurnal and seasonal activity

Evidence from Bermuda suggests that the common red land crab (*Gecarcinus lateralis*) is less active in the winter when the daytime temperature falls below 70°F (21°C), but will emerge for brief periods during winter warm spells (Dunstan, 1959). There is no information on seasonal activity for *Coenobita clypeatus* in Bermuda, but they likely follow a similar pattern. In a laboratory setting, de Wilde (1973) noted that *C. clypeatus* kept at 20-22°C (68-72°F) moved slowly, and at 18°C (64°F) they became lethargic; with highest activity achieved between 28-32°C (82-90°F) and over 90% humidity.

Land hermit crabs are mainly nocturnal and are most active at night or after rainfall on cloudy days. In an experimental setting in Curacao, hermit crab activity increased sharply just after sunset and peaked between 8 and 9pm (de Wilde, 1973).

Reproduction

The female land hermit crab has branched pleopods on the left side of her abdomen (Fig. 3) which are used to hold freshly laid eggs inside her shell to keep them moist while they develop and she makes her migration to the sea. The eggs of *C. clypeatus* are dark reddish brown when freshly laid, and turn grey and slightly blue as they develop (de Wilde, 1973). Female *C. clypeatus* also have a visible pair of gonopores on the underside of the thorax, at the base of the 3rd pair of legs.

When the egg-bearing females reach the sea, they release the eggs, which hatch into planktonic larvae. The larvae transition through a free swimming stage to a benthic (bottom-dwelling) stage, at which point they seek shelter in an empty shell and make their way ashore as tiny crabs. *C. clypeatus* has a relatively short larval stage of about one month (Hornbeck, 2011), and given that passage from Florida to Bermuda via the Gulf Stream has been reported to take approximately three weeks (Lessios et al., 1984), it is likely that Bermuda's localized population largely self-recruiting.

In Curaçao, hermit crabs ventured into rockpools at low tide and attached developed eggs to stones above the water level, but did not go into the water (de Wilde, 1973). Some observations and laboratory experiments suggest females do not enter the sea to shed eggs, but instead place them in the intertidal zone or throw them into the water from shore (de Wilde, 1973). Others report direct observations of females on beaches entering the water to depths of up to 60 cm to wash off eggs (Nieves-Rivera and Williams, 2003).

Reproduction of *Coenobita clypeatus* in the Caribbean occurs over several months in summer and autumn. In Bermuda the timing of reproductive activity has not been studied. Evidence suggests spawning is slightly earlier in the northern part of the crab's range, which would include Bermuda, possibly early June to early November (de Wilde, 1973). In the warmer parts of its range *Coenobita clypeatus* populations may have as many as three breeding cycles in a single season, but de Wilde (1973) notes that due to Bermuda's northern location only one spawning period occurs.

The timing of the seaward migration of females is linked to the lunar cycle. De Wilde (1973) reported that a medium-sized crab could move 500m in a single night, and there is evidence that less experienced crabs follow more experienced animals toward the coast. On Mona Island mass spawning was observed over three or four days, close to the crescent moon in August and early September (Nieves-Rivera and Williams, 2003). Godsall (2000) searched Hungry Bay for *C. clypeatus* from one to three days after the full moon in July. On July 17th 2000, he recorded a crab at Hungry Bay peninsula with a large claw height of 22.1 mm and shell height of 52.7 mm with a notation that it was spawning. This crab was retrieved from under a fibreglass sheet one day after the full moon. It is unclear, but assumed, that this observation represents an egg-bearing female. On July 22nd 2010 Heather DeSilva recorded an egg-bearing female with a shell height of 57.8 mm and a large claw length of 30.8 mm on the peninsula at Hungry Bay (DeSilva, 2010). This record would have been four days before the July full moon on July 26th 2010.

Sex ratio

Sex ratios for crabs examined in Bermuda have not been reported. Female crabs can be determined by the presence of egg masses or pleopods on the left side of the abdomen (Fig. 3); however it is difficult to determine sex without removing the shell, which risks injuring the animal.

D. Current Status

Global distribution

Coenobita clypeatus is the only crab in its genus found in the western north Atlantic. Its native range is from the east coast of Florida, along the Gulf of Mexico and Central America, to the coast of Venezuela (Walker, 1994; Lewis and Rotjan, 2009). It is found throughout the Caribbean islands, from the Florida Keys, to Trinidad. Bermuda is the northern-most extent of its range (de Wilde, 1973; Walker, 1994).

Local distribution

In Bermuda *Coenobita clypeatus* is primarily distributed along the South Shore and around the East End (Fig. 4; Tables 1 and 2). The two largest extant sub-populations of *Coenobita clypeatus* are likely those found within and adjacent to the Hungry Bay Nature Reserve on the South Shore in Paget, and the Cooper's Island Nature Reserve at the east end of Bermuda. Walker (1994) estimated a population of approximately 150 land hermit crabs on mainland Bermuda in the early 1990's, and found a population of 82 at Hungry Bay. This location is the only site where *C. clypeatus* has been studied in Bermuda, and likely represents the largest sub-population.

The rocky peninsula at the mouth of Hungry Bay contains small caves and limestone ledges, along with a variety of plant species in a multi-tiered coastal woodland (Ellison, 1991; Godsall, 2000; DeSilva, 2009). A survey on the day of the full moon in August 2009 found 19 crabs on the peninsula, including 7 clustered together under the same rock ledge. It is unknown if they were taking advantage of a moist habitat or gathering to breed. These crabs had shell heights ranging from 40.4 to 55 mm and large claw lengths ranging from 23.9 to 29.6 mm (DeSilva, 2009).

Another survey of the Hungry Bay peninsula on July 22nd 2010, four days before the full moon, found 20 crabs. All crabs were on the northern (landward) side of the peninsula, and none were found in the adjacent saltmarsh. Recorded crabs had shell heights ranging from 40.6 to 69.8 mm and large claw lengths ranging from 24.7 to 38.5 mm (DeSilva, 2010).

Godsall (2000) reported 29 crabs at the peninsula the day after a full moon in July 2000 and 20 crabs on a re-survey of the site two days later. No hermit crabs were found in the mangrove habitat. Of the 82 crabs found at Hungry Bay by Sally Walker in September 1990, 54 of these were found on the peninsula (Godsall, 2000). Godsall reports finding evidence that hermit crabs used the less dense mangroves and sand bar area of Hungry Bay, but only one crab was found in this habitat.

Meyer (2012) noted that approximately one quarter of Bermuda's West Indian topshell population resided on Cooper's Island, therefore it is not surprising that *C. clypeatus* is relatively abundant there as well. Abundance estimates for Cooper's Island as a whole, or sites within it, have not been calculated. It does appear from collected observations (Table 2) that land hermit crabs of various sizes are regularly seen at Officer's Beach and elsewhere.

There are also likely significant sub-populations within the Castle Harbour Islands nature reserve, but the lack of vegetation and other cover, and the steep-sided nature of some of the islands will limit crab abundance there. *C. clypeatus* have been observed on Southampton Island (Fig. 4), which is a shell-poor habitat because its coast is too steep for shells to accumulate. Hermit crabs are occasionally relocated to Nonsuch Island (see Table 2), but they are not often seen here as they disappear in the dense woodland shortly after release. Nonsuch Island could probably support a large sub-population if empty shells were made available, since it has high plant diversity, some low relief shoreline and receives few visitors.

Walker (1994) reported "a survey of the un-inhabited outer islands revealed the presence of small *C. clypeatus*…", but it is unclear which islands were visited. The islands of the Little Sound, Great Sound and Harrington Sound, while offering suitable habitat for hermit crabs, do not have populations of West Indian topshells. These islands may have small *C. clypeatus* in other shell types, but are unlikely to support larger crabs. *C. clypeatus* have been observed on islands at the East End in St. George's and St. David's (Fig. 4; Table 2). On mainland Bermuda, *C. clypeatus* has been reported along the South Shore from Tucker's Town (unconfirmed) and Pink Beach, westward to Granaway Heights, Southampton (Fig. 4; Table 2).

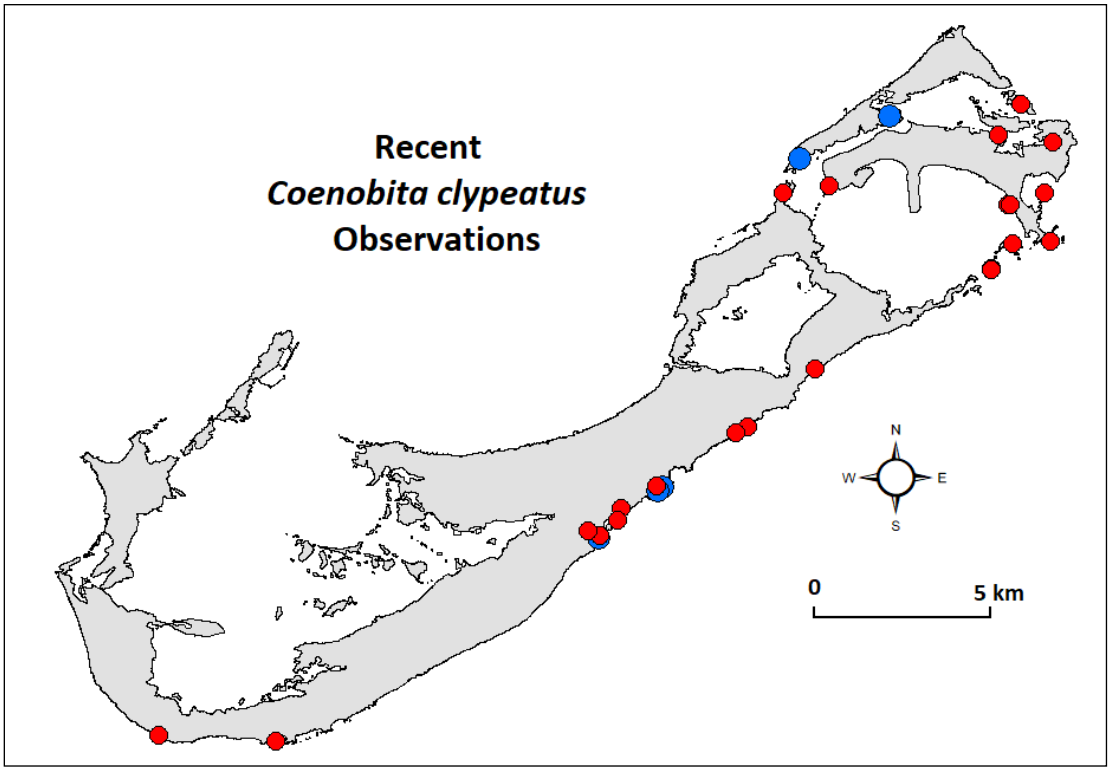

Figure 5: Map of the known distribution of *Coenobita clypeatus* in Bermuda. Sightings from Table 2 are shown in red, locations given by Godsall (2000) are shown in blue.

E. Current Threats

Globally

Threats in the Caribbean include collecting for pets and sale into the pet trade, and collection for fishing bait (Nieves-Rivera and Williams, 2003; DaCosta-Cottam et al., 2009; Hornbeck, 2011). The soft abdomen of *Coenobita clypeatus* is known as excellent bait to fishermen throughout the region, and several hundred may be collected at once for this purpose (de Wilde, 1973; Hornbeck, 2011). *Coenobita clypeatus* is also one of the most commonly kept crab species in the pet trade. Many online resources exist on the keeping of this species in captivity. Its relatively easily fulfilled requirements and gregarious nature make it a popular choice for beginner crab keepers. This species is not bred in captivity so all specimens in the pet trade have been collected from the wild.

In the Caribbean and Latin America, the West Indian topshell (*Cittarium pica*) is a culturally valuable recreational fishery resource, with some limited commercial exploitation (Hornbeck, 2011; Meyer, 2012). Meyer (2012) reports that *C. pica* has also recently entered the aquarium trade, which will put additional harvesting pressure on wild populations. The potential decline of the hermit crabs shell of choice, through overharvesting has regional conservation implications.

In Bermuda

Bermuda has a high-latitude, isolated population of *Coenobita clypeatus*, which will limit natural recruitment. Some of the historic threats to these crabs have been reduced, but a number remain which are difficult to mitigate.

Pet trade

There has been at least one recent request to import two pet hermit crabs from overseas (on 20th Sept. 2009). Also, in May 2011 DENR receive a report that a local pet store was selling *C. clypeatus*. Two pet hermit crabs were confiscated by HM Customs from an arriving air passenger in 2017. It is unclear what impact imported pet hermit crabs - both *C. clypeatus* and other species - could have on the native population. There is a possibility of introducing pests or diseases, or mixing of genetic stock if the pets were released. It is also impossible to prove the origin of pet crabs.

As a level 2 protected species under the Protected Species Act 2003, the local collection of *C. clypeatus* is prohibited, as is the sale and purchase of specimens sourced from overseas.

Habitat loss and change

Fragmentation of habitats by the construction of buildings, roads, fences and walls has separated land hermit crabs from resources such as food, shelter, mates and safe ocean access. The hardening and steepening of Bermuda's coastline to protect coastal developments from erosion makes it more difficult for female crabs to safely reach the sea to deposit eggs, and reduces the ability of the shoreline to accumulate undamaged gastropod shells.

Historic habitat loss, particularly the construction of the airport, was likely a significant contributor to *Coenobita clypeatus* decline in Bermuda, and habitat loss remains an ongoing and difficult to mitigate threat.

Climate change

The most significant climate-related challenge *C. clypeatus* face in Bermuda relates to habitat. The predicted increase in hurricane frequency and severity will impact *C. clypeatus* and their habitats. As Bermuda is the northern limit of the range for land hermit crabs, any climate change-related rise in air or water temperature may not severely impact them here. However changing rainfall patterns, coastal flooding and ocean acidification could have negative impacts on adult and larval life stages.

The rocky peninsula on the south side of Hungry Bay protects the interior of the bay from open ocean conditions. An erosional gap in this protective barrier has been cause for concern for since the 1980's (Ellison, 1991). Subsequent hurricanes have continued to expand the gap, and killed a number of mangrove trees within the adjacent swamp. The continued erosion will seriously impact the stability of the rocky coastal habitat that supports one of the largest *C. clypeatus* sub-populations, and may lead to its eventual loss in the future. Officer's Beach at Cooper's Island is similarly exposed to ocean swells traveling into Castle Harbour during storm events. It is unknown if *C. clypeatus* are able to survive inundation of these habitats during storm surge.

Poisoning and predation

Bermuda historically supported a large population of the red land crab (*Gecarcinus lateralis)* which was considered a nuisance and an agricultural pest. Bermudians have undertaken various methods of land crab control since the 1600's, and in the mid-20th century effort intensified to control *Gecarcinus lateralis*, including the introduction of biocontrol agents and extensive use of poison. In the 1950s poisoned bait was available from the Health Department, and the Department of Agriculture "devoted considerable time to devising a cheap and effective method of controlling land crabs. Low cost is essential if crabs are to be eliminated in large tracts of land, such as parklands and on farms" (Dunstan, 1959). This intense persecution of *Gecarcinus lateralis* likely had a considerable negative effect on the *Coenobita clypeatus* population, given that poison baits would have been consumed by both species.

The yellow-crowned night heron (*Nyctanassa violacea*) was introduced from Florida in 1976 as a biocontrol agent to reduce the use of toxic baits across the island (Wingate, 1982). This heron was a known crab-eater that visited Bermuda seasonally. The intention was to fill the ecological niche left empty by the extinction of what was believed to be an endemic heron which specialized in eating crabs, and bring *Gecarcinus lateralis* numbers back into balance (Wingate, 1982). The yellow-crowned night heron is abundant on Bermuda today, and no doubt they prey upon *Coenobita clypeatus*. Godsall (2000) noted evidence of pecking damage on the shells of land hermit crabs at Hungry Bay, which he attributed to the yellow-crowned night heron. He further observed dismembered remains near empty shells which suggested that hermit crabs had been predated by herons.

The effect of invasive species on *Coenobita clypeatus* in Bermuda is not well understood. The great kiskadee (*Pitangus sulphuratus*) is abundant in coastal habitats and likely predates small *C. clypeatus*. Other potential threats are the Argentine ant (*Linepithema humile*) brown rat (*Rattus norvegicus*) and black rat (*Rattus rattus*). In the Bahamas, ants are known to outcompete *C. clypeatus* for food (Morrison and Spiller, 2006), so it isn't unreasonable to expect the same with *L. humile* in Bermuda.

Light, noise and traffic

C. clypeatus responds to threats by hiding in its shell instead of taking flight (Chan et al., 2010); a behaviour that is counterproductive when encountering traffic. As the orientation mechanisms used by crabs during their reproductive migrations are not known, it is possible that they are based on light and sound cues such as ocean surf and the reflection of the moon from the sea surface. Therefore, anthropogenic sources of light and noise in coastal habitats may negatively affect a crab's ability to cross busy roads to spawn, find food or find mates, and avoid predators. Research suggests *C. clypeatus* relies on sight and sound for risk assessment, and anthropogenic light and noise affect the land hermit crab's predator avoidance behaviour (Chan et al., 2010). *C. clypeatus* that were experimentally distracted with loud noises allowed significantly closer approach before they reacted than did crabs in silent habitat (Chan et al., 2010). Therefore, coastal lighting and human-produced noise probably increase the likelihood of crabs being killed by predators or traffic. Human activity on coasts and beaches at night during the summer months will also impact spawning females which are shy and will retreat if disturbed (Nieves-Rivera and Williams, 2003).

Shell collecting & souvenir hunting

A shortage of shells was historically cited as a chief reason for the decline of this species in Bermuda (Chace et al., 1986; Walker, 1994). The West Indian topshell is currently the most commonly confiscated shell taken from departing visitors at Bermuda's international airport (Copeland, 2019). In one typical 2-week period, eight pounds of seashells were taken from passengers on departing flights and returned to Bermuda's beaches (DENR, 2019). The number of shells taken by departing cruise ship passengers is unknown. This level of souvenir hunting is not sustainable, and is depleting the stock of good quality shells available to *Coenobita clypeatus*. There is also a significant risk that hermit crabs will be removed accidentally, or even intentionally by souvenir hunters. These actions are illegal, but prosecuting departing tourists is problematic.

Meyer (2012) reported that the population of West Indian topshells at Officer's Beach on Cooper's Island fell by half between 2000 and 2004, particularly in the larger size classes, suggesting illegal harvesting at this site. Convictions for topshell harvesting for use as food and bait in recent years have brought the issue to public attention, but may not be a deterrent. A cache of 165 harvested West Indian topshells were found by Fairmont hotel employees during a trash clean up in September 2011 (Fig. 6). The shells were donated to the DENR and placed in land hermit crab habitats around Castle Harbour.

Figure 6: The 165 illegally harvested West Indian topshells (*Cittarium pica*) donated to DENR in 2011 (Photo: Alison Copeland).

It is possible that illegal collection of land hermit crabs for fishing bait or pets still occurs in Bermuda, but it is unlikely to be substantial given low crab numbers and ready availability of alternatives. It is possible that hermit crabs could cause damage to crops and coastal gardens, however in Bermuda the targeted killing of land hermit crabs is prohibited by the Protected Species Act 2003. These issues can be dealt with through education, compromise and the mitigation measures permitted by the Protected Species Act 2003.

F. Current Protection Status

International protection

None. The IUCN Red List of Threatened Species contains assessments of the extinction risk faced by a species across its global range. *Coenobita clypeatus* has not been assessed at the global level, so it does not appear on the Red List. The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) protects species from over-exploitation through international trade, but no crabs are currently protected by CITES. *Coenobita clypeatus* remains common over most of its range, and it not considered of conservation concern at present.

National protection

In Bermuda legal protection for the land hermit crab is provided by the Protected Species Act (2003). Under this legislation the wilful destruction, damage, removal or obstruction of crab habitats is an offence. Further, it is an offence to wilfully damage, destroy, injure, disturb or kill a protected species. The Protected Species Act (2003) also prohibits the taking, importing, exporting, selling, purchasing, or transporting a protected species or its parts. The land hermit crab is listed as a Level 2 protected species, therefore anyone who commits an offense involving this species is liable to a fine of $15,000, or 1-year imprisonment. Following IUCN Red List

criteria, the land hermit crab is listed as 'Vulnerable' [VU] under the Protected Species Amendment Order (2016).

Habitat protection

The migratory nature of this species makes habitat protection a challenge. The Bermuda National Parks Act 1986 protects all land hermit crabs found in the nature reserves of the National Parks System at Hungry Bay, Cooper's Island, Spittal Pond and the Castle Harbour Islands (including Nonsuch). Of the thirty four sightings reported in Table 2, nineteen, (56%) were found within protected areas. It should be noted that while the mangrove habitat at Hungry Bay is within the Government nature reserve boundary, the rocky peninsula at the bay mouth is not; however the peninsula does have a nature reserve zoning (Department of Planning, 2018).

The habitats of protected species are afforded protection under the Protected Species Act 2003. Additionally, coastal habitats are protected by various conservation measures. For example, the Coastal Reserve conservation zoning offers rocky shore and coastal vegetated habitats some protection from development (Department of Planning, 2018).

G. Current Conservation Action

The unfavourable conservation status of the land hermit crab has been recognised for a number of years (Chace et al., 1986; Walker, 1994), but despite this, little formal conservation action has been undertaken, aside from listing on the Protected Species Order in 2012.

The Bermuda Aquarium, Museum and Zoo (BAMZ) and Department of Environment and Natural Resources (DENR) both receive crabs from members of the public when they are found in the road, in buildings or other places where they are not wanted or may be in danger. Received crabs are released as soon as possible at protected sites with known hermit crab sub-populations.

The land hermit crab's primary source of shelter, the West Indian topshell, has been protected from harvesting since 1989 (Meyer, 2012) under the Fisheries Act 1972 (Fisheries Protected Species Order 1978).

PART II: MANAGEMENT

A. Management Goals

The principal aim of this management plan is to protect land hermit crabs, sources of molluscan shells and crab habitats in Bermuda, and conserve these crabs through sharing of knowledge, participation in research and monitoring, and mitigation of threats.

At present little is known of the ecology of Bermuda's land hermit crabs. It is unclear if the population is stable, but small following historic reduction; or if it is continuing to decline and therefore at high risk of extirpation. In the short term, assessing abundance and distribution is a priority. In the longer term, researching hermit crab ecology so that informed management decisions can be made is critical.

The short-term goals (5 years) are to undertake a comprehensive population assessment, to identify and minimize threats where possible, and to identify and protect critical habitats.

The long-term goals (20 years) are to monitor trends in abundance of land hermit crabs across the island, improve knowledge of land hermit crab ecology through research, respond to emerging threats, establish and enforce habitat protection, obtain comprehensive data on critical habitat use, and where possible establish new sub-populations in appropriate protected habitat.

B. Management Objectives and Criteria

A favourable conservation status for land hermit crabs in Bermuda will be achieved when there is:

1. Evidence of an increasing or stable population
2. Increased knowledge of Bermuda's land hermit crab population and its ecology
3. Critical habitats are identified and protected, and both quality and quantity are enhanced
4. Threats have been identified and addressed to the extent possible
5. The public are aware of this species and champion its conservation

These overall objectives translate into specific actions outlined below.

Actions needed:

- An accurate assessment of the abundance and distribution of land hermit crabs the local population.
- Monitoring of critical habitat sites to establish a population trend, and rapidly respond to new threats.

- Protection of critical habitats supported by public cooperation, legislation and enforcement.
- Evidence of a sustained increase of available shells from West Indian topshells and other sources.
- Increased public education regarding the threats to protected crabs and their habitats.
- An improved programme for surrendering and reporting crabs in danger (e.g. rehab and relocation).
- Explore the possibility of establishing new colonies through translocation
- Put mitigation measures in place, where possible, against threats to crabs from human and natural sources.

C. Management Strategy

Once sub-populations of land hermit crabs have been mapped and assessed, it will likely become clear that the threats faced by each are different, with a few common elements. Similarly, the conservation opportunities at each sub-population will differ, based on factors like land ownership, sub-population size, shell availability and habitat quality. Therefore, management of Bermuda's land hermit crabs will require a multi-scale strategy that includes actions for the island-wide population as a whole, and targeted actions necessary to safeguard each sub-population.

The strategy will also need to be flexible. As the tools outlined in part D are applied to the actions proposed in part E, priorities will change; both as knowledge is gained, and in response to emerging threats, such as major coastal developments and hurricanes or emerging opportunities like new collaborations and policies. This management plan should be re-visited and updated regularly.

D. Tools Available for Strategy

A repeatable method of population assessment including abundance estimates should be prepared using published techniques and repeated every 5 years to see a population trend over a 15-20 year time frame.

There is available literature on methods for timed baited trapping, pitfall trapping, hand capture and other techniques for attracting and capturing *C. clypeatus* for ecological studies (Woodcock, 2004; Morrison and Spiller, 2006; Drake et al. 2007; Hornbeck, 2011). Timed baiting can be used to obtain a relative abundance of hermit crabs quickly and easily, as *C. clypeatus* are attracted to aggregations of conspecifics. Hornbeck (2011) left baits in place for 1 hour in late afternoon from 1600-1700 along baited transect lines, while Morrison and Spiller (2006) placed baits in the open and determined the proportion occupied after 45 minutes.

Pitfall trapping was used in population assessment in the Bahamas, using tuna in oil as bait, however the authors note that hermit crabs will avoid recently eaten foods (Morrison and Spiller, 2006), so subsequent trapping should use different baits. Hornbeck (2011) suggested

used coffee grounds attract hermit crabs successfully without attracting mammalian predators. Other baits suggested in the literature are wet dog food and bacon grease (Hornbeck, 2011). Although effective, pitfall trapping is not the best method to capture a protected species, as the fall could injure the crab, and there is a risk of overheating and stress if the traps are not emptied quickly, but repeated visits to the traps risk scaring away uncaptured crabs. Active capture methods would be preferable.

The timing of spawning migrations should be understood before any trapping is attempted because it will inform how many and which animals may be available for capture and therefore minimize bias in survey design.

Guidance on qualitative abundance estimates are given in Drake et al. (2007). Marking *C. clypeatus* for short-term mark-recapture studies (i.e. several weeks) is a suitable quantitative method to establish abundance. Paint marks have been successfully used on the shell (see Wiewandt, 1975 reported in Nieves-Rivera and Williams, 2003; Godsall, 2000; Morrison and Spiller, 2006); however both the shell and major chelipeds must be marked to confirm that the crab is wearing the same shell as it was originally marked in. Individuals can also be marked with adhesive number tags applied to the shell (de Wilde, 1973). de Wilde (1973) reported that crabs marked on the shell and left cheliped with fluorescent paint, oil paint or India ink all lost their marks within two or three months. Long-term marking of hermit crabs is difficult, as marks or tags on the crabs will be lost during moulting, and marks on shells will be lost or transferred during shell switching. Notching the chelipeds leaves a mark which remains after moulting (de Wilde, 1973), but this may harm the animal.

A preliminary presence/absence survey of sites that may be occupied by land hermit crabs should precede time-intensive abundance surveys. Land hermit crabs are cryptic, while West Indian topshells are large and obvious, therefore identifying areas with abundant topshells and then checking them for *Coenobita clypeatus* might be a good strategy to focus search efforts.

The Government of Bermuda commissioned updated air photo mosaics of the islands in late 2019, which will provide a valuable tool for crab habitat mapping. The GIS capabilities of the DENR are available for implementation of this plan, including previously mapped *Coenobita clypeatus* and *Cittarium pica* observations. The delineation of crab habitats can be paired with ongoing shoreline classification for oil spill emergency response planning to make it cost effective.

Section 6 of the Protected Species Act 2003 provides tools for legal protection of hermit crab habitat. Opportunities should be sought to zone crab habitat on private property as nature reserve, to transfer land into the national park system or other innovative public/private management arrangements. The quantity of hermit crab habitat can be increase by liaising with NGOs undertaking coastal restoration projects to encourage the creation of gentle shorelines, aggregation areas of gastropod shells, cover objects and low-growing, dense vegetation and drinking water sources. A summary of habitat challenges at Hungry Bay and management responses can be found in Ellison (1991), and implementation of these should be considered.

The DENR should build relationships with academic institutions and researchers studying the ecology of *Coenobita clypeatus*. Collaborations should be explored, including the use of students and volunteers in the implementation of this plan. Sources of expertise, such as for genetic analysis should be identified, and funding sought.

The existing consultation arrangement between the Department of Planning and the Ecology Section of the Department of Environment and Natural Resources can be used to implement actions in this plan; particularly for reporting hermit crabs at development sites and including land crab considerations in conservation management plans (CMPs) for coastal developments. Landowners willing to host translocation trials on their property will also be valuable assets which can be identified through this process.

Targeted awareness programmes in neighbourhoods where crabs live would be a valuable tool for mitigating a number of threats, particularly related to traffic, coastal lighting and barriers. The DENR has an active pest bird control programme, and the resources of this programme could be used to mitigate the threat of avian predators in key habitats.

The scattered distribution of *Coenobita clypeatus* around the island will make identification of undiscovered sub-populations difficult, particularly on private property. An online reporting form, email address and phone number will be valuable tools for soliciting public reporting of crabs. New public awareness materials combined with existing events should be used to raise the profile of this species and its needs, and encourage reporting.

There is a body of knowledge, mostly available from enthusiasts, online retailers and via online sources, on the keeping of *Coenobita clypeatus* in captivity. This could perhaps be leveraged for a head starting programme for juveniles or another short-term *ex situ* programme. Aquaculture of *C. clypeatus* does not appear to have been explored to date beyond laboratory experiments on larval development. The hatchery facility at Coney Island may present an opportunity for this, if a protocol can be developed. If genetic analysis indicates Bermuda's *C. clypeatus* are identical to Caribbean populations, augmentation through the importation of additional animals would be possible.

Published species action plans for *Coenobita clypeatus* from other jurisdictions (e.g. DaCosta-Cottam et al., 2009) are available for guidance when implementing this plan.

E. Step-down narrative of work plan

Abbreviations:
DENR – Department of Environment and Natural Resources
BAMZ – Bermuda Aquarium, Museum and Zoo
NHM – Natural History Museum
UKOT – United Kingdom Overseas Territories
GPS – Global Positioning System
NGO – Non-Governmental Organisations

The actions needed to achieve species recovery to an improved conservation status are as follows:

1. Evidence of an increasing or stable population

Actions proposed:

- Undertake presence/absence surveys
- Estimate current hermit crab population through surveys
- Survey and map the distribution of sub-populations (in tandem with habitat identification in action 3).
- Revisit both population estimate and distribution map every 5 years to establish trends
- Promote the voluntary expansion of species distribution onto private property
- Perform genetic analysis to: a) confirm if the Bermuda population is genetically different from Caribbean and Floridian populations, b) inform possible population augmentation from overseas c) investigate if the local population is self-sustaining

Work Team: DENR, coastal landowners, academic institutions

Team Leader: DENR

Assistance: volunteers, graduate students, academic institution with genetic analysis capability, overseas colleagues to collect genetic samples

Outputs: current population estimate, distribution map, increased area of occupancy, confirmation of population genetic status, population trend once repeated

Needed Resources: Funds for collection, shipment and analysis of genetic samples (possible project cross-territory UKOT grant), population survey equipment, mapping software, hand-held GPS, field survey team, student stipend, access to private property

2. Increased knowledge about Bermuda's land hermit crab population and its ecology

Actions proposed:

- Establish timing of breeding activity (months of the year, and phase of the moon) and seasonal inactive period
- Investigate how far hermit crabs move, and the need for corridors between foraging habitat, breeding habitat and the sea
- Investigate diet preferences including use of introduced plants and native plants, which could be planted at restoration sites
- Investigate impacts of invasive species, including competition with ants and other introduced species, use of invasive plants, and predation by birds
- Investigate the possibility of captive breeding or head-starting
- Determine if shells used are adequate, and if there is significant change from previous studies (Walker, 1994; Godsall, 2000)

Work Team: DENR, academic collaborators

Team Leader: DENR

Assistance: public reporting, coastal landowners, graduate students, volunteers

Outputs: breeding season defined, inactive period identified, migration routes identified, migration corridors established, diet known, invasive species impacts understood and mitigated, *ex situ* conservation started if possible, adequacy of shell supply known

Needed Resources: field survey team, student stipend, access to private property, *ex situ* holding and breeding facility, aquaculture facility, resources to mitigate threats, policy to establish migration corridors

3. Critical habitats are identified and protected, and both quality and quantity are enhanced

Actions proposed:

- Classify habitat types occupied by land hermit crabs (in tandem with mapping in action 1).
- Enhance habitat quality – including invasive plant removal, installation of culvert pipes and crab stairs to maintain habitat connectivity.
- Identify shell-poor habitats and augment with empty shells in a range of sizes
- Prevent shoreline hardening and steepening at locations near known crab sub-populations, and discouraged elsewhere.
- Create policy to include land crabs as part of the Environmental Impact Assessment process and create a national standard quick survey method for land crabs at development sites.
- Include habitat for crabs in ongoing restoration projects (e.g. NGO-led projects) and consider additional introductions to Nonsuch Island
- Identify areas where crabs could be introduced and make necessary modifications in habitats to support land hermit crabs.

Work Team: DENR, Department of Planning, landowners, NGOs

Team Leader: DENR

Assistance: volunteers, landscape architects, environmental consultants, policy analyst

Outputs: habitats used by crabs classified, loss of habitat halted, breeding crabs safely able to reach the sea and return to home range, crabs introduced to restored habitats, national standard survey for land crabs created, policy to prevent shoreline hardening and steepening, policy requiring land crab survey at coastal developments

Needed Resources: field survey team for habitat mapping, field team for habitat restoration, field team to carry out standardised quick survey at development sites, access to private property, and land for restoration

4. Threats have been identified and addressed to the extent possible

Actions proposed:

- Ensure hermit crabs are not used for food or bait through awareness and prosecution
- Work to prevent roadkill of hermit crabs
- Investigate the level of predation from yellow-crowned night herons and kiskadees on land hermit crabs, and reduce predation through culling if necessary.
- Support HM Customs and airport staff in confiscation of shells from souvenir hunters

Work Team: DENR, judiciary, HM Customs, residents near crab habitat, pest control shooters

Team Leader: DENR

Assistance: general public, students

Outputs: public awareness materials, confiscated shells returned to habitats, understanding of avian predation, birds culled if required

Needed Resources: funds for production of awareness materials, contacts for neighbours near crab hotspots, student stipend, salary and resources for pest control shooter

5. The public are aware of this species and champion its conservation

Actions proposed:

- Ensure the public know to bring at-risk crabs to BAMZ or to call DENR for assistance. Furthermore, ensure staff are ready to deal with incoming crabs. Emphasize the message to ‘leave them be’ if crabs are not in immediate danger.
- Promote community appreciation for hermit crabs and their habitats
- Encourage reporting of sightings to DENR and the Natural History Museum (NHM)

- Publicise the protected status of land hermit crabs and penalties for offences against the Protected Species Act
- Develop educational resources for children and adults on protected crabs
- Make visitors and locals aware that shell collecting threatens hermit crabs, and West Indian topshell removal is illegal.

Work Team: DENR, BAMZ, NGOs

Team Leader: DENR

Assistance: general public, overseas collaborators, educators

Outputs: Land hermit crab sightings recorded in database, BAMZ staff and volunteers briefed on what to do with land crabs, educational resources created, awareness events held, shell collecting reduced

Needed Resources: funds to create and distribute awareness materials, sightings database

F. Estimated Date of Down-listing

It is estimated that it will take at least three years to identify and map critical habitats for land hermit crabs, and invasive species control within those habitats will have to be continually ongoing. Given the at-sea larval stage of the lifecycle, it will only be once young crabs come ashore and mature that any increase in recruitment will be seen. A reduction in adult mortality from identified threats will be observed much more quickly. Population changes attributable to management activities will only be detected once actions have been undertaken and then evaluated. It is proposed that after an initial baseline population assessment (within 2-3 years of publication of this plan), this species be re-evaluated every ten years, possibly sooner if major hurricanes occur. Down listing should only be considered if a positive population trend can be maintained over consecutive assessment periods, possibly as long as 30 years, and if habitat quantity and quality remain stable.

PART III: IMPLEMENTATION

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
Priority 2: An action that must be taken to prevent a significant decline in the species population/habitat quality, or some other significant negative impact short of extinction.
Priority 3: All other actions necessary to provide for full management of the species.

Priority #	Task #	Task description	Task Duration	Responsible Party
		Population & distribution		
1	1	current population estimated through surveys	1 year	DENR
1	2	distribution of current population mapped	1 year	DENR
2	3	Both population estimate and distribution map revisited to establish trends	every 5 years	DENR
2	4	expansion of distribution	3 years	DENR, landowners
3	5	genetic analysis	1 year	Overseas collaborator, DENR
		Ecology		
2	6	Establish timing of breeding activity and seasonal inactive period.	1 year	DENR
1	7	Investigate movement, migration routes and need for corridors	1 year	DENR
2	8	Investigate diet	6 months	DENR
2	9	Investigate interactions with introduced species	1 year	DENR
3	10	Investigate possibility of head starting and captive breeding	ongoing	DENR
		Habitat		
3	11	Classify occupied habitats (with mapping)	1 year	DENR
2	12	Enhancement of habitat quality and connectivity	ongoing	DENR, landowners
1	13	Shell-poor habitat identified and augmented	ongoing	DENR
2	14	Shoreline hardening and steepening prevented	ongoing	DENR, Planning

2	15	Create policy to include crab habitat in EIA process (with national standard survey)	6 months	DENR, Planning
3	16	Include land crab habitat in ongoing restoration projects	ongoing	DENR, NGOs, landowners
2	17	Identify suitable habitat for introduction	1 year	DENR, NGOs, landowners
		Threats		
1	18	ensure crabs are not used for food or bait through awareness and prosecution	ongoing	DENR, public
1	19	work to prevent roadkill	ongoing	DENR, public
1	20	investigate the impact of yellow-crowned night herons and kiskadees and cull if necessary	1 year, then ongoing	DENR
2	21	Support confiscation of shells from souvenir hunters	ongoing	HM Customs, airport staff, DENR
		Awareness		
2	22	Public know to contact BAMZ/DENR about crabs, and staff are prepared to handle them	ongoing	BAMZ, DENR, public
1	23	Promote appreciation of crabs and their habitats	ongoing	DENR, NGOs
3	24	Sightings reported to the NHM and DENR	ongoing	DENR, BAMZ
2	25	Develop educational resources on crabs	2 months	DENR, NGOs
2	26	Publicise protected status, offences and penalties	1 month	DENR
2	27	Make visitors and locals aware that shell collecting threatens hermit crabs, and West Indian topshell removal is illegal.	ongoing	DENR, NGOs

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Appendix

Appendix I: Recent and historic *Coenobita clypeatus* observations

Table 1: *Coenobita clypeatus* sub-populations reported in the literature

Location	Date	Note	Source
	1859-1908	Ubiquitous on mainland Bermuda	Jones 1859; Verrill 1908
Wistowe, Flatts Inlet. (#21 North Shore Road, Hamilton Parish) It is likely the crabs at this location were not a wild sub-population	Ca. 1889	"Cenobita Diogenes, Latr. A number of living specimens obtained at Wistowe, opposite Flatt's Village, and kindly presented to us by Miss Edith Allen, daughter of the American Consul. Most of the animals are still living (July), and apparently flourishing, twelve months after their capture. The shells occupied by the largest individuals are those of *Natica catenoides*."	Heilprin, 1889
	Ca.1906	… "the land hermit crab (*Cenobita diogenes*), which is still living here in considerable numbers."	Verrill, 1907
Island-wide	ca.1949	"Everywhere in gardens and hearth-covered hillsides"	Haas, 1950 (Ecology, Vol. 31, No. 1)
	c. 1986	"On the high sand hills and in the woods some distance from the shores; uncommon in Bermuda, probably owing to the lack of suitable shells."	Chace et al., 1986 pg. 335.
	Ca. 1990	Considered to be extinct or near extinction on Bermuda	S. Cook referenced in Walker, 1994.
Hungry Bay	September 1990 (dates not given)	82 individuals in Hungry Bay (54 on peninsula); less than 150 individuals island-wide; in Walker, 1994	Walker, 1994
Hungry Bay	17-19th July 2000	85 found on peninsula.	Godsall, 2000
Devonshire Bay	July 2000		Godsall, 2000
Rocky Bay	July 2000		Godsall, 2000
Whalebone Bay	July 2000		Godsall, 2000
Stokes Point	July 2000		Godsall, 2000

Table 2: Recent *Coenobita clypeatus* observations

Location	Date	Shell Type	Note	Observer
Hungry Bay	8 April 2009	*Cittarium pica*	Four M3's from Clearwater Middle School measured crabs on peninsula	Heather DeSilva, Alison Copeland
Hungry Bay	6 August 2009	*Cittarium pica*	19 land hermit crabs were measured at Hungry Bay peninsula. Volunteer report and data at DENR	Heather DeSilva
Hungry Bay peninsula	22 July 2010	*Cittarium pica*	20 crabs measured by Clearwater students and volunteers at the peninsula. NB one was egg-bearing. Data report from H. DeSilva at DENR.	Heather DeSilva, Alison Copeland
[redacted]	May 14th 2011	Not reported	Found by Clearwater Middle School students during beach clean-up. Photographed and left alone	Heather DeSilva
[redacted]	16 September 2011	*Cittarium pica*	2 very large crabs photographed under rock ledge. Have seen them here before	Alison Copeland
[redacted]	10 April 2012	*Cittarium pica*	4 small and 1 large crab found in 2 rat bait boxes.	Jeremy Madeiros, Alison Copeland
[redacted]	3 June 2013	Not reported	Found one juv. individual in vegetation south of the wildlife watch tower during skink survey; left alone	Mark Outerbridge
[redacted]	4 June 2013	*Vermicularia sp.*	Found one juv. individual on high ground along coastline during skink survey; left alone	Mark Outerbridge
[redacted]	18 August 2013	Not reported	WRC 3878. Found along the shoreline at the end of Great Bay; brought to BAMZ; released at capture site	Brandon Rogers
[redacted]	1 October 2013	*Otala lactea*	Found one juv. individual on high ground along coastline during skink survey (had garden snail shell as a home); left alone	Annie Glasspool
[redacted]	27 June 2014	*Nerites sp.*	Multiple small crabs found during Catlin work day	Alison Copeland
[redacted]	30 July 2014	*Otala lactea*	WRC 4034. Found walking across road (had a garden snail shell as a home); brought to BAMZ where it changed into a top snail shell; released at capture site	Peter Fari
[redacted]	31 July 2014	*Cittarium pica*	WRC 4035. Found in banana patch on Bill Mitchell's property; brought to BAMZ; released on Nonsuch Island	Robin Marirea
[redacted]	3 August 2014	Not reported	WRC 3990. Found in backyard of house; brought to BAMZ; released on Nonsuch Island	Lauren Simons
[redacted]	27 June 2014	*Nerita spp*	Found a number of small individuals among rocks and in grass at the back of the beach during volunteer workday; left alone	Alison Copeland
[redacted]	1 September 2014	*Cittarium pica*	Found on grass between woodland and saltmarsh pond; released on Officer's Beach	Mark Outerbridge

Location	Date	Shell Type	Note	Observer
[redacted]	1 June 2015	*Cittarium pica*	Found in backyard; left alone	Peter Drew
[redacted]	5 June 2015	*Cittarium pica*	Found in skink trap (glass jar #29) within a stand of bay grape trees; released	Mark Outerbridge
[redacted]	23 June 2015	*Cittarium pica*	1 large crab from BAMZ released at [redacted] (cover photo, this document)	Alison Copeland
[redacted]	1 July 2015	*Cittarium pica*	Found (and videoed) on path; left alone	Peter Drew
[redacted]	12 September 2015	*Cittarium pica*	Found (and photographed) hermit crab tracks in sand on [redacted]	Mark Outerbridge
[redacted]	17 September 2015	*Cittarium pica*	Found (and photographed) in corner of garage beside water pump; left alone	Matt Carr
[redacted]	16 November 2015	*Cittarium pica*	Crab from Local Tails exhibit at BAMZ released on Nonsuch and photographed by JR.	Jessica Riederer, Alison Copeland
[redacted]	22 July 2017	*Tectarius muricatus*	Trapped on edge of the bay grape forest. Shell too small (Figure 3 this document)	Mark Outerbridge
[redacted]	11 May 2016	*Cittarium pica*	Reported seeing 2 crabs while performing skink survey	Helena Turner
[redacted]	3 June 2016	*Cittarium pica*	Given to BAMZ, released on beach in [redacted] by Choy Aming	Member of the public
[redacted]	8 June 2016	*Cittarium pica*	Given to BIOS, released on [redacted] by Tim Noyse	Member of the public
[redacted]	1 July 2016	*Cittarium pica*	Found (and photographed) by participants. Contacted Mark Norman who commented that the number of crabs appears to be diminishing over time	Outward Bound participants
[redacted]	24 July 2016	*Otala lactea*	Photographed on the beach and left alone. Figure 1 this document	Andrew Dobson
	16 September 2016		Dropped at Plant Protection Lab. Released by Mark O.	
[redacted]	31 October 2016	*Cittarium pica*	Found under beach grass and photographed after 2-hour search. Ping-pong ball sized.	Jessica Riederer
[redacted]	?2019	?*Otala lactea*	[redacted]	Alex Davidson
[redacted]	Often sighted	*Cittarium pica*	Commonly found in the rat bait boxes; fond of eating rat bait	Jeremy Madeiros
[redacted]	Occasionally sighted	*Cittarium pica*	Difficult to find in forest	Jeremy Madeiros