Recovery Plan for Bermuda's Seahorses (*Hippocampus erectus and Hippocampus reidi*)

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

Recovery plan for Bermuda's Seahorses; *Hippocampus erectus* and *Hippocampus reidi*

Prepared in Accordance with the Bermuda Protected Species Act 2003

Author

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Cover photo: Male longsnout seahorse *Hippocampus reidi* by Jessica Riederer

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"To conserve and restore Bermuda's natural heritage"

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Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the Department of Environment and Natural Resources, publish recovery plans, sometimes preparing them with the assistance of field scientists, other government departments, and other affected and interested parties, acting as independent advisors to us. Plans are submitted to additional peer review before they are adopted by us. Objectives of the recovery plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved. Recovery plans may not represent the views nor the official positions or approval of any individuals or agencies involved in the recovery plan formulation, other than our own. They represent our official position only after they have been signed by the Director of Environment and Natural Resources as approved. Approved recovery plans are subject to modifications as dictated by new findings, changes in species status, and the completion of recovery actions.

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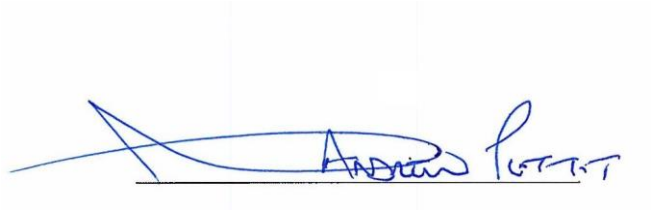

30th March 2020
Date

Andrew Pettit
Director
Department of Environment and Natural Resources
Bermuda Government

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EXECUTIVE SUMMARY

Current Species Status:
Legal protection for both the lined seahorse (*Hippocampus erectus*) and the longsnout seahorse (*Hippocampus reidi*) is provided by the Bermuda Protected Species Act (2003). Both species are classified as Vulnerable (VU) under the Protected Species Amendment Order (2016). From an international perspective, The International Union for Conservation of Nature (IUCN) lists *Hippocampus erectus* as Vulnerable (A4cd) and *Hippocampus reidi* as Data Deficient. Furthermore, all *Hippocampus* species are protected under Appendix II of the Convention on International Trade in Endangered Species (CITES), which restricts international trade, and is administered in Bermuda by the Endangered Animals and Plants Act (2006).

Habitat Requirements and Threats:
Seahorses living on the Bermuda Platform appear to inhabit coastal mangrove communities, boat moorings and docks (especially those that have heavy growth of algae and sponges), inshore bays, seagrass meadows, and coral reefs. Such environments allow seahorses to conceal themselves and also provide live food (e.g. zooplankton and small crustaceans). Seahorses are threatened globally by direct exploitation, accidental capture in non-selective fishing gear (as by-catch), and degradation of their habitats. However, the reason for their perceived decline on Bermuda is currently unknown. It is likely that the decline in seagrass meadows and loss of coastal mangroves are contributing causes.

Recovery Objective and Recovery Criteria:
The principal aim of this recovery plan is to gather information on the current status and general biology of seahorses in Bermuda in order to provide some understanding of the environmental parameters influencing growth, survival and reproduction in local waters. Additional objectives include the creation of protected areas and the employment of artificial structures which have habitat value for seahorses. Improved conservation status for these species will occur when the following has been accomplished:

- Data on general biology and recruitment dynamics is obtained,
- Sources of mortality are identified and effective measures for management are implemented,
- Legal protection of critical habitats is achieved,
- Successful juvenile production through aquaculture is developed,
- Suitable sites in the natural environment for translocation and/or introduction are identified and managed,
- Wild sentinel sub-populations are identified and self-sustainability is demonstrated.

Actions Needed:
1. Evaluate current population status for both species on Bermuda.
2. Determine local threats to seahorse survival.

3. Conserve local stock by establishing seahorse reserves in areas that have the greatest abundance.
4. Investigate the use of artificial holdfast units to aggregate seahorses.
5. Investigate the degree to which anthropogenic habitat has value for seahorses.
6. Develop captive breeding, if deemed appropriate.
7. Site selection and translocation of captive bred individuals to the natural environment.
8. Promote public awareness of the threats to the survival of Bermuda's seahorses as well as the conservation measures taken for their recovery.
9. Regular monitoring of sentinel sub-populations at select study sites.

Recovery Costs:
The total cost of recovery 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 studies. Developing budgets for each action are the responsibility of the leading party as outlined in the work plan.

PART I: INTRODUCTION

A. Brief Overview

Seahorses are marine fishes that have captivated people throughout human history but sadly their populations are reported to be declining throughout the world due to a variety of threats. Heavy exploitation for use in traditional Chinese medicines and the aquarium trade has been identified as having the greatest impact on wild populations, however incidental by-catch in trawl fisheries and habitat degradation are also contributing factors.

Smith-Vaniz et al. (1999) listed three species of seahorse on Bermuda; the lined seahorse (*Hippocampus erectus*), the longsnout seahorse (*Hippocampus reidi*) and the dwarf seahorse (*Hippocampus zosterae*). The first two species are still present within Bermuda's marine waters but the latter has not been reported since 1908. *Hippocampus erectus* was historically described as being "fairly common on weed-covered banks" (Beebe and Tee-Van, 1933) and Beebe (1932) mentioned that up to three seahorses could be collected at a time by 'pulling a small dredge slowly through some of the growth of eel-grass in Castle Harbour' during the late 1920s and early 1930s. In fact, William Beebe managed to collect 262 seahorses (all identified as *H. erectus*) from Bermuda between 1927 and 1931 (see Table 1 in Appendix). Recent anecdotal evidence, combined with field surveys, suggests that this species is much less common on Bermuda than during Beebe's time. *Hippocampus reidi*, in contrast, appears to be relatively more abundant with a greater island-wide distribution (Hinton, unpubl. data.; Riederer, 2017) than previously reported. *Hippocampus zosterae* is not believed to have an established presence on Bermuda.

The first known attempt of a formal seahorse survey on the Bermuda Platform was undertaken in 1999 by staff and volunteers from the Bermuda Aquarium Museum and Zoo (BAMZ) with the aim of describing distribution, species composition, sex ratios and relative abundance (Hinton, unpubl. data.). The next known attempt to specifically look for seahorses occurred in 2015 and 2016 during which over 100 individual seahorses (mostly *H. reidi*) were documented from five inshore locations (one mangrove site and four private docks) (Riederer, 2017). Additional surveys that noted seahorse presence, but were not undertaken for the sole reason of locating seahorses, included the Reef Environmental Education Foundation (REEF) haphazard volunteer fish surveys which date from 1996 to the present day, and the benthic mapping and seagrass monitoring surveys undertaken by the Department of Conservation Services between 2006 and 2017. The results of the above surveys have been summarized in Table 2 of the Appendix.

This recovery plan discusses threats to seahorse survival, summarizes the current status and basic ecology of lined and longsnout seahorses, and outlines the proposed conservation activities for both species on Bermuda. It recommends research into local sources of mortality, habitat and food requirements as well as investigations into the feasibility of producing juveniles under controlled conditions. Demonstrable success with the latter will

enable grow-out trials in the wild, working towards the enhancement of existing sub-populations.

B. Taxonomy and Description of Species

Seahorses, and their close relatives the pipehorses and seadragons, belong to the family Syngnathidae. Lourie et al. (2016) recognize 45 species of seahorses globally, but all belong to a single genus; *Hippocampus*. They are generally characterized by their elongated tubular snouts and having bodies which are not covered in scales, but rather encased in a series of ring-like, interlocking bony plates. Seahorses typically maintain their bodies in a vertical position with their heads orientated horizontally. The tail is prehensile and is used to grasp and wrap around objects. The dorsal fin provides forward propulsion and the pectoral fins (which are located on the head) are used to provide stability and steering while moving. There are no pelvic or caudal fins. Seahorses are very slow swimmers and rely on camouflage to avoid predators and to capture their prey. Many species are capable of growing fleshy dermal appendages which help them better blend in with the surrounding marine vegetation.

The lined seahorse (Fig. 1)
Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Syngnathiformes
Family: Syngnathidae
Genus: *Hippocampus*
Species: *erectus* (Perry, 1810)

Humann (1999) described the lined seahorse as follows:
"Numerous lines on head and often down neck and back. Colouration varies from reddish orange to brown or even black. Marking also vary but never having black spots over body. When living in Sargasssum, they often develop fleshy tabs and appendages."

Adults can reach 19 cm in length (www.fishbase.org).

The longsnout or slender seahorse (Fig. 2)
Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Syngnathiformes
Family: Syngnathidae
Genus: *Hippocampus*
Species: *reidi* (Ginsburg, 1933)

Sterrer (1986) described the longsnout seahorse as follows:
"Body robust, head at right angles to main axis of body; caudal fin absent; caudal vertebrae forming prehensile tail; dorsal fin rays 16-19. Body covered with small round black dots on a lighter background which may itself be rather dark. Whitish bands or partial bands at regular intervals on truck and tail."

Body colouration can vary greatly from yellow to reddish-orange, brown or black. Individuals are sometimes two-toned. The snout is comparatively longer (in proportion to the head length) on *H. reidi* than it is on *H. erectus*. Adults can reach 17.5 cm in length (www.fishbase.org).

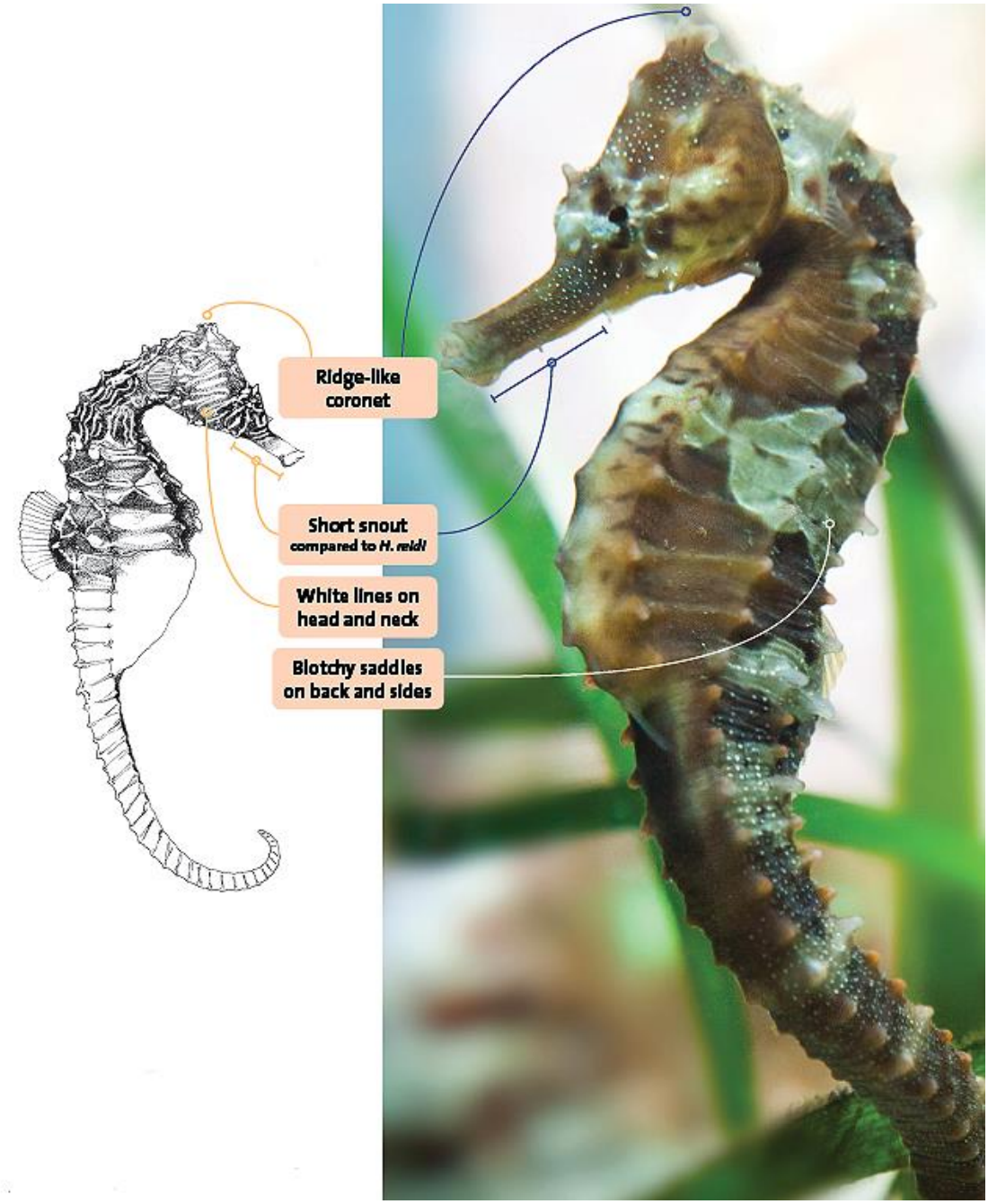

Figure 1. Lined seahorse *Hippocampus erectus*.
Image adapted from iSeahorse.org (Seahorses of the Americas)
Photo by Shedd Aquarium/Brenna Hernandez

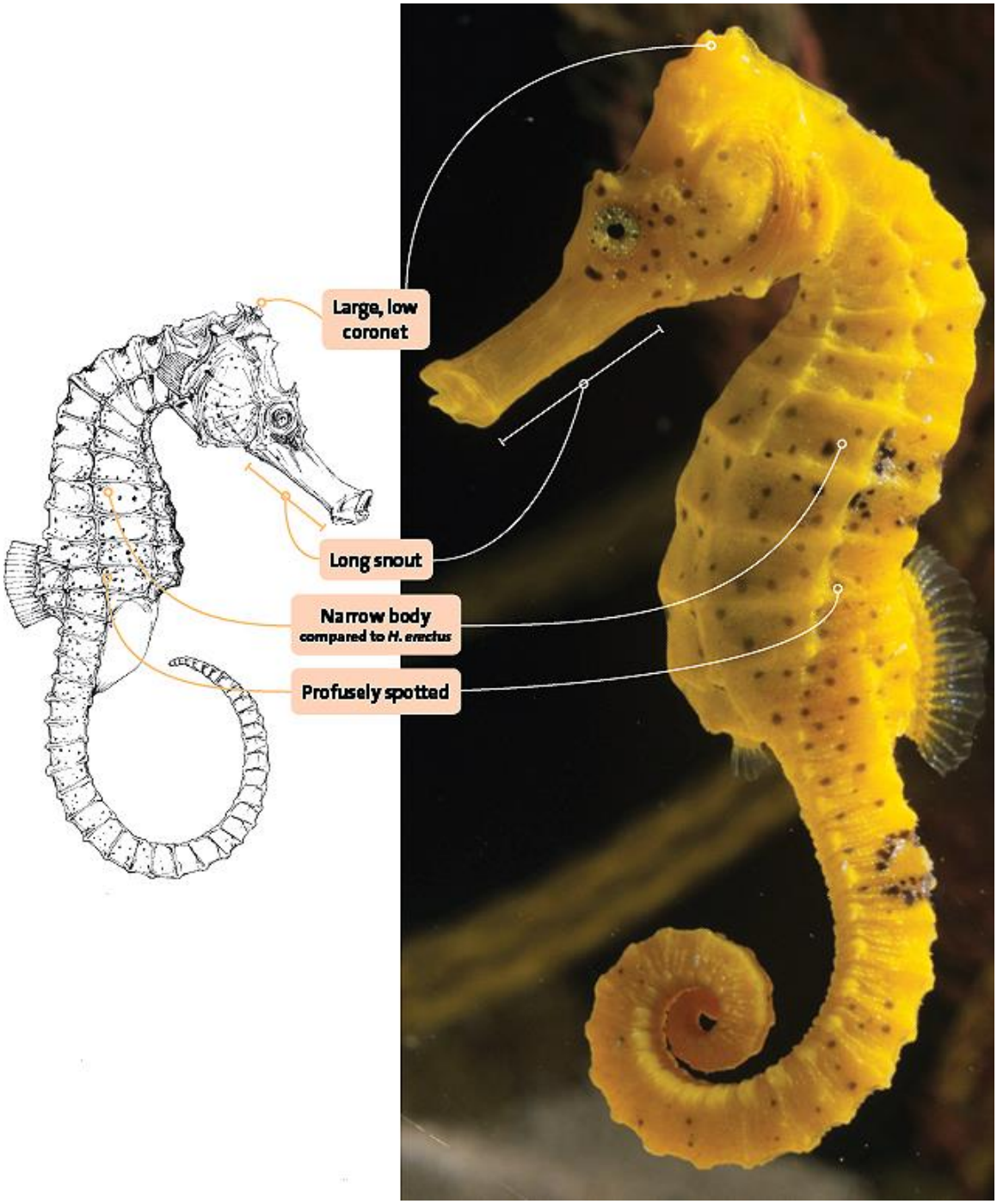

Figure 2. Longsnout seahorse *Hippocampus reidi*.
Image adapted from iSeahorse.org (Seahorses of the Americas)
Photo by Shedd Aquarium/Brenna Hernandez

C. Current Status

Global Distribution

Hippocampus erectus is found within tropical and temperate waters of the Western Atlantic along continental shelves from Nova Scotia (Canada) to Venezuela in South America as well as throughout the Caribbean (see Smith-Vaniz et al. 1999). It has also been collected from the Azores Archipelago in the eastern Atlantic (Woodall et al. 2009). *Hippocampus reidi* has a more limited distribution and is found along the Atlantic coast of North America from Cape Hatteras to Florida, among the northern islands of the Caribbean (i.e. Bahamas, Cuba, Haiti, Jamaica), the Caribbean coast of Panama and Colombia, Venezuela, the Lesser Dutch Antilles, and the Atlantic coast of South America to Rio de Janeiro (see Smith-Vaniz et al. 1999).

Local Distribution

Seahorses in Bermuda were likely never abundant. They may be common in some localized areas which have suitable habitat and good prey availability, but seahorse distribution is very patchy across the Bermuda Platform. Seahorses have been observed throughout Bermuda's marine environment, especially within inshore and nearshore habitats (Fig. 3; Table 1 in Appendix). Of the nearly 40 separate locations where seahorses have been collected or observed (and reported) since the 1870s, over 90% occurred within inshore and nearshore waters. This, however, may be an artifact of survey and collection effort rather than true distribution.

Collections:
Various individuals have, over the years, collected seahorses from Bermuda and placed them within a number of institutional depositories including the Academy of Natural Sciences (Philadelphia), the Field Museum of Natural History (Chicago), the Smithsonian National Museum of Natural History (Washington), the Harvard Museum of Comparative Zoology (Cambridge), and the Natural History Museum at the Bermuda Aquarium Museum and Zoo (BAMZ). These collections are summarized in Table 1 of the Appendix and provide some insight into historical distribution and habitat use. At the time of writing at least 380 seahorse specimens were accessioned in the USA depositories mentioned above and six seahorses were found in the Natural History collection at BAMZ. Additionally, 15 live *H. reidi* seahorses were brought to BAMZ by members of the public between 2004 and 2017 – the majority of which were returned to the wild (B. Outerbridge pers. comm.).

Surveys:
Ward (1999) captured 43,638 fishes during 90 separate seine net sets at three different seagrass meadows (Flatt's Inlet, Bailey's Bay, Walsingham Bay) between April 1995 and July 1997, of which only three (0.007% frequency occurrence) were seahorses (species not reported). In 2000, weekly diver-transect surveys were undertaken by BAMZ staff over a 12 month period at 39 locations, which included seagrass meadows, boat moorings, docks, inshore bays and one marine pond. Less than 30 seahorses were encountered, the majority of which were identified as *H. erectus* (Hinton, unpubl. data). A total of 26 records exist of seahorse sightings (all *H. reidi* from five inshore locations, but some are likely repeat sightings) made during 3,484 haphazard volunteer dive surveys of marine fishes between April 1996 and February 2018 (REEF data, 2018). During more recent years seahorses have

been observed in Pilchard Bay (*H. erectus* and *H. reidi*), at least three private docks in Hamilton Harbour (*H. reidi* only) and in Jews Bay (*H. reidi* only) (Riederer, 2017). Finally, only three seahorses (species not identified) were recorded in over 1,594 transect surveys involving 536 different marine sites that included inshore, nearshore and offshore seagrass meadows, coral reefs and rocky-algal benthos during a 12 year period by the Department of Conservation Services (Massey-Outerbridge, pers. comm.).

Figure 3. Map of known seahorse collections and reported sightings on Bermuda between 1870 and 2017.

Species Protection

International protection

Both *Hippocampus erectus* and *H. reidi* are listed under Appendix II of CITES (15/05/04). CITES (the Convention on International Trade in Endangered Species of wild fauna and flora) controls the international trade of plants and animals in order to avoid utilization which is incompatible with species survival. Species listed under Appendix II are not necessarily now threatened with extinction but may become so unless trade is closely controlled.

National protection

Following IUCN criteria, the lined seahorse was listed as 'Vulnerable' (A4c, d) and the longsnout seahorse was also listed as 'Vulnerable' (D) under the Protected Species Amendment Order (2016). Current legal protection for both is provided by the Protected Species Act (2003) and the Protected Species Amendment Act (2014). These acts consider the willful destruction, damage, removal or obstruction of habitats, and the taking, importing, exporting, selling, purchasing, or transporting either of these species an offence. Offenders are liable to a fine of up to $25,000 or two years imprisonment.

Habitat Protection

Seagrass, mangroves and coral reef environments are afforded various levels of protection in Bermuda. All seagrasses, mangroves and corals are listed under the Protected Species Amendment Order (2016) as level 2 protected. Their willful destruction or removal in Bermuda carries a fine of up to $15,000 or 1 year imprisonment. The Coral Reef Preserves Act (1966) protects marine flora and fauna within two separate areas representing 24% of the Bermuda Platform (calculated to the 10 meter depth contour); the South Shore Coral Reef Preserve and the North Shore Coral Reef Preserve (A. Shailer, pers. comm.). This act considers it an offense to remove, damage or be in possession of plants and animals (whether dead or alive) which are attached to any reef, the sea-bed or the coast in the two preserves.

D. Ecology

Habitat Requirements

Seahorses are generally restricted to shallow coastal marine areas. Temperate species predominantly inhabit seagrasses and algae, while tropical species appear to frequent coral reefs (see review in Foster and Vincent, 2004). In Bermuda, seahorses seem to especially favour locations that are well covered by macro-algae, sponges, and other marine epibionts (e.g. pilings, old boat mooring lines, underneath floating docks). These types of coastal development on Bermuda appear, ironically, to benefit seahorses by creating artificial habitats that are conducive to seahorse survival.

General biology

Seahorses are well known for curling their tails around objects attached to the benthic environment, however they are occasionally observed swimming freely in the water column. Both *H. erectus* and *H. reidi* exhibit sexual dimorphism; males are larger and also have longer tails than females. Home range for *H. reidi* is rather small; 13.3 m^2 for females and 3.5 m^2 for males (Dauwe, 1992) and densities have been reported to range from 0.006–0.51 individuals m^{-2} (Dias and Rosa, 2003). In captivity, juvenile *H. reidi* appear to be positively phototactic, having been observed rising to the surface of the water column immediately after leaving the pouch (P. Talbot, pers. comm.). This suggests that they may be planktonic during early life stage. This may also be true for juveniles of *H. erectus,* which have been observed attached to floating *Sargassum* weed (Fish and Mowbray, 1970).

Reproduction

Seahorses are ovoviviparous; males carry the eggs in a brood pouch and later give birth to live young. The breeding season of *H. erectus* and *H. reidi* has been observed to last more than eight months under laboratory conditions and males undergo several pregnancies during a single season. Egg diameter is 1.2 mm and the young are approximately 7 mm at birth (www.fishbase.org). Seahorses have a crown-like bony crest located on the top of the head known as a coronet which can be manipulated to produce a clicking sound during courtship. Vincent (1990) gives a detailed account of courtship and reproduction of captive-held *H. reidi*. Courtship can last for three days and is associated with changes in body colouration of both sexes. Ripe eggs are transferred by the female to the brood pouch of the male via an ovipositor. The newly deposited eggs are fertilized during, or just after, entry into the pouch. Incubation lasts approximately two weeks and after hatching, the young are expelled from the brood pouch (usually at night). Brood size can be as numerous as 1,500, although an average size is 250-300 eggs (Fritzsche, 2002). After emergence, the hatchlings are fully independent and do not receive any parental care.

Life Cycle

Seahorses are monogamous in the wild; having only one mate at a time. Some species are known to perform a short daily greeting ritual which is thought to help maintain the pair bond. Unpaired females in the wild have a small home range, however lone males are known to range widely in search of a potential mate. Both *H. erectus* and *H. reidi* reach sexual maturity within one year of birth (typically between 6–12 months). In their review, Foster and Vincent (2004) reported inferred life spans averaging 3–5 years.

Diet

Seahorses feed on zooplankton, small crustaceans, and other small invertebrates. Prey items are rapidly inhaled by a powerful suction force through the snout and swallowed whole. They do not possess a true stomach, so ingested food items pass through the gastro-intestinal system fairly rapidly. This means that individuals must constantly forage for live food.

E. Current Threats

Seahorses are threatened globally by over-harvesting for the aquarium trade (live specimens), traditional Oriental medicine (dried specimens), sale as curios, by-catch in net fisheries, and loss of habitat. Demand for seahorses has increased over the past few decades as China's economy has prospered; the greater personal wealth of its citizens has fueled greater levels of consumption of wild caught seahorses. Natural threats include predation from other fishes and storm surge which can tear them loose from their holdfasts and cast them adrift or wash them ashore. Seahorses held in captivity are susceptible to fungal, bacterial and parasitic ailments (see review in Foster and Vincent, 2004).

The low rates of reproduction, monogamous lifestyle, sparse distribution, limited mobility, small home ranges, and mate fidelity mean that seahorses are vulnerable to disruption and less able to quickly reform into breeding pairs and recolonize depleted areas.

Seahorses in Bermuda are not commercially harvested but are negatively impacted by illegal collecting for home aquariums, the use of inshore seine nets (which the local fishing community uses to capture baitfishes), possibly from the historical loss of coastal

mangroves (Sterrer and Wingate, 1981), and likely from large-scale seagrass declines which have been observed over the last three decades (Murdoch et al. 2007; Fourqurean et al. 2010). Much of the seagrass decline was observed to occur offshore rather than inshore; however recent investigations have revealed that heavy grazing from green sea turtles *Chelonia mydas* is putting the survival of Bermuda's remaining inshore and nearshore seagrass meadows into question (Fourqurean et al. 2019).

F. Current Conservation Actions

There are no conservation actions presently being done for either *H. erectus* or *H. reidi* on Bermuda.

PART II: RECOVERY

A. Recovery Goals

The principal aim of this recovery plan is to gather information on the current status and general biology of seahorses in Bermuda in order to provide some understanding of the environmental parameters influencing growth, survival and reproduction in local waters and help to inform management activities that will enhance recruitment to the breeding populations of both species. Self-sustainability will be assessed by monitoring reproduction and survival of sentinel sub-populations. Additional objectives include the creation of protected areas and the employment of artificial structures which have habitat value for seahorses.

The short-term goals are (1) determine areas within Bermuda's marine environment that support aggregations of seahorses, (2) determine local threats to seahorse survival and (3) establish seahorse reserves in order to conserve the remaining local stock.

The longer-term goals include investigating culture techniques for the production of juveniles and understanding how different anthropogenic habitats have value for seahorses.

B. Recovery Objective and Criteria

Favourable conservation status will be achieved when:

- Data on general biology and recruitment dynamics is obtained,
- Sources of mortality are identified and effective measures for management are implemented,
- Legal protection of critical habitats is achieved,
- Successful juvenile production through aquaculture is developed,
- Suitable sites in the natural environment for translocation and/or introduction are identified and managed,
- Wild sentinel sub-populations are identified and self-sustainability is demonstrated.

C. Recovery Strategy

Assess the current population status for both *H. erectus* and *H. reidi*, identify and mitigate threats which contribute to losses, undertake activities that encourage the survival of extant populations, take steps to facilitate population increase and range expansion on Bermuda. Monitoring of select sub-populations to detect changes over time is highly desired. The recommended actions outlined in Part III further identify the practical steps that need to be taken to achieve the action plan targets.

D. Tools Available for Strategy

The patchy distribution, rarity and cryptic nature of seahorses make them notoriously difficult to find and can bias survey results. Aylesworth (2016) concluded that the presence/absence survey method which uses detection probabilities was an efficient way to search for seahorses in the wild. At the individual level, artificial marking and tagging (i.e. the use of necklace-style tags or injecting visible implant fluorescent elastomer beneath the skin) has been used to study reproductive ecology, behaviour, movement, activity patterns, growth and social structure (see reviews in Caldwell et al., 2011). Photo-identification has also been shown to be a useful tool for non-invasive mark–recapture studies, provided there are sufficient differences in natural marks and patterns between individuals (Correia et al., 2014). Such capture-recapture studies have provided valuable information for *H. erectus* (Masonjones et al. 2010) and *H. reidi* (Castro et al., 2008; Freret-Meurer and Andreata, 2008) in other regions and can be used to inform local research design.

The use of artificial holdfast units (AHU) to encourage seahorse settlement should be trialed in suitable locations around Bermuda. Correia et al. tested (2013) and subsequently deployed (2015) grids comprised of 40 cm long polyethylene strands at densities of 100 holdfasts m^{-2} in an effort to determine their effect on seahorse density in southern Portugal. The authors reported all AHU were colonized by seahorses within one month of placement, thus research into AHU design for *H. erectus* and *H. reidi* on Bermuda is warranted.

Genetic assessment should prove useful in determining the standing levels of genetic variation, effective population sizes, the size of local breeding aggregations, and evolutionarily significant management units (see Mobley et al. 2011). It should also help determine the extent to which Caribbean and USA populations contribute to local recruitment via larval dispersal in oceanic eddies.

Hippocampus erectus and *H. reidi* have both been recognized as good candidates for aquaculture (Correa et al. 1989, Lin et al. 2008, Zhang et al. 2010, Fonseca et al. 2015), therefore the development of captive breeding techniques, possibly with partner organizations overseas, should be explored. The multi-species fish hatchery on the Coney Island field station could be used for the controlled local production of juvenile seahorses and the study of early life stages. Additionally, the use of floating grow-out cages that have natural flow-through of wild plankton and other sources of natural food could also be trialed (see Fonseca et al. 2015). Such cages could be placed within sheltered in-land marine ponds which have high periphyton based communities (e.g. Mangrove Lake). However, captive breeding and restocking activities should not be undertaken until the pressures which led to local population declines in the wild are understood and have been mitigated.

Finally, the use of seahorses in exhibits at BAMZ will help to increase public education and awareness.

E. Step-down Narrative of Work Plan

Abbreviations used in Section E and Part III:

DENR – Department of Environment and Natural Resources, Bermuda Government
BAMZ – Bermuda Aquarium Museum and Zoo, Bermuda Government
DCI – Department of Communication and Information, Bermuda Government
Planning – Department of Planning, Bermuda Government
Student – MSc or PhD candidate supervised by DENR staff
Volunteers – DENR volunteer interns, keen field ecologists, and members of the general public

The actions needed to achieve recovery are as follows:

1. Evaluate current population status for both species on Bermuda.
2. Determine local threats to seahorse survival.
3. Conserve local stock by establishing seahorse reserves in areas that have the greatest abundance.
4. Investigate the use of artificial holdfast units to aggregate seahorses.
5. Investigate the degree to which anthropogenic habitat has value for seahorses.
6. Develop captive breeding, if deemed appropriate.
7. Site selection and translocation of captive bred individuals to the natural environment.
8. Promote public awareness of the threats to the survival of Bermuda's seahorses as well as the conservation measures taken for their recovery.
9. Monitor sentinel sub-populations at select study sites.

1. Evaluate current population status for both species on Bermuda.

   Actions proposed:

- Solicit help from the general public in reporting seahorse sightings (e.g. the World Seahorse Survey Form developed by the Seahorse Trust),
- Undertake seahorse surveys to establish a current baseline of population status,
- Identify specific aggregations for closer study (i.e. sentinel populations) identifying habitat preferences, species composition, relative abundance, and population structure.

   Work Team: DENR, the Seahorse Trust, student, volunteers.
   Outputs: Baseline report on the existing seahorse sub-populations on Bermuda.

2. Determine local threats to seahorse survival.

   Actions proposed:

- Quantify the level of seahorse by-catch in seine nets used by local fishers,

- Examine to what degree habitat degradation is affecting seahorse aggregations,
- Examine to what degree changes in water quality are affecting seahorse aggregations.

Work Team: DENR, student, volunteers.
Outputs: A more thorough understanding of the causes of local mortality which, in turn, will aid in determining if captive breeding and translocation into the wild are feasible for Bermuda.

3. Conserve local stock by establishing seahorse reserves in areas that have the greatest abundance.

Actions proposed:
- Designate locations with the greatest seahorse abundance to be 'Critical Habitats' as described under Section 6 of the Bermuda Protected Species Act (2003),
- Publish public notices describing the restricted activities within the marine reserves,
- Create buffer zones between road drains and inshore reserves to reduce the amount of environmental contaminants entering marine waters.

Work Team: DENR, Attorney General's Chambers, DCI, Works and Engineering.
Outputs: Legally protected areas created for optimal seahorse survival.

4. Investigate the use of artificial holdfast units to aggregate seahorses.

Actions proposed:
- Identify environmentally degraded locations that historically had seahorse aggregations,
- Experiment with various benthic AHU designs to determine which are (1) most favoured by *H. reidi* and *H. erectus* and (2) the longest lasting once deployed,
- Determine, over time, if these areas are capable of supporting seahorses in the same manner as control sites.

Work Team: DENR, volunteers.
Outputs: Increased range across the Bermuda Platform.

5. Investigate the degree to which anthropogenic habitat has value for seahorses.

Actions proposed:
- Determine to what extent floating docks, concrete pilings, mooring lines and heavily fouled boats provide suitable environments for seahorse survival in comparison to control sites,
- Investigate ways in which the favourable structures can be enhanced to increase their value as habitat.

Work Team: DENR, student, volunteers.
Outputs: Improved knowledge about habitat requirements, increased range across the Bermuda Platform.

6. Develop captive breeding, if deemed appropriate.

   Actions proposed:

- Design optimal newborn seahorse rearing system,
- Collect brood stock,
- Transfer into floating grow-out cages,
- Transfer of juveniles into the wild.

   Work Team: DENR, BAMZ, and potential overseas partner.
   Outputs: Report on culture techniques for *H. erectus* and *H. reidi*.

7. Site selection and translocation of captive bred individuals into the natural environment.

   Actions proposed:

- Identify suitable locations within the various bays and harbours of Bermuda,
- Rank sites in order of priority,
- Transfer appropriate number of individuals to new locations,
- Monitor the survival of newly released individuals.

   Work Team: DENR, volunteers, student.
   Outputs: List of suitable sites for future releases; reports on the outcome of the translocations.

8. Promote public awareness of the threats to the survival of Bermuda's seahorses as well as the conservation measures taken for their recovery.

   Actions proposed:

- Remind the public that the collection of seahorses for any reason is prohibited,
- Promote the protection of seagrass beds and coastal mangroves,
- Promote the use of environmentally friendly boat moorings,
- Liaise with the Planning Department to ensure the installation of AHUs in new marine developments,
- Add additional information to the tank exhibiting seahorses at BAMZ to help raise public awareness among visitors,
- Promote seahorse recovery work through public lectures and local media outlets.

   Work Team: DENR, DCI, BAMZ, Planning.
   Outputs: Engagement of the local community.

9. Regular monitoring of sentinel sub-populations at select study sites.

   Actions proposed:

- Devise a monitoring programme which assesses the impact of conservation actions and

also studies changes in population dynamics within specific sub-populations.
Work Team: DENR, volunteers, general public.
Outputs: Feedback on the success of the Species Recovery Plan.

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 action necessary to provide for full recovery of the species.

Priority #	Task #	Task description	Task Duration	Responsible Party
1		**Evaluate current population status for both species**		DENR
	1	Promote public survey	1 year	DENR, DCI
	2	Undertake presence/absence surveys	3 years	DENR, volunteers
	3	Identify aggregations for closer study	1 month	DENR
1		**Determine local threats to survival**		DENR
	4	Impact of seine netting	1 year	DENR
	5	Impact of habitat degradation	1 year	DENR
	6	Water quality assessments	1 year	DENR
1		**Conserve local stock by establishing seahorse reserves**		DENR
	7	Designate critical habitats	6 months	DENR, AG Chambers
	8	Publish list of restricted activities	1 month	DENR, DCI
	9	Create buffer zones between road drains and inshore reserves	3-5 years	DENR, Works & Engineering
2		**Investigate the use of artificial holdfast units**		DENR
	10	Identify degraded habitats	1 month	DENR
	11	Install AHUs	6 months	DENR, volunteers
	12	Determine effectiveness	3-5 years	DENR, volunteers
2		**Investigate anthropogenic habitats**		DENR
	13	Identify various artificial structures	6 months	DENR
	14	Enhance structures	6 months	DENR, volunteers
3		**Develop captive breeding**		DENR
	15	Design seahorse rearing system	1 month	DENR
	16	Collect brood stock	1 month	DENR, volunteers

	17	Transfer into floating grow-out cages	As needed	DENR, volunteers
	18	Transfer of juveniles into the wild	As needed	DENR, volunteers
3		**Site selection and translocation of captive bred individuals**		DENR
	19	Identify suitable locations	6 months	DENR
	20	Rank sites in order of priority	1 month	DENR
	21	Transfer individuals to new locations	As needed	DENR, volunteers
	22	Monitor survival of newly released individuals	1-3 years	DENR, volunteers
3		**Create PR campaign**		DENR
	23	Remind the public about responsible behaviour towards seahorses	Ongoing	DENR, DCI
	24	Promote the protection of seagrass beds and coastal mangroves	Ongoing	DENR, DCI
	25	Promote environmentally friendly boat moorings	Ongoing	DENR, DCI, Marine & Ports
	26	Liaise with the Planning Department to install AHUs	Ongoing	DENR, Planning
	27	Provide more information at BAMZ	Ongoing	DENR (BAMZ section)
	28	Promote seahorse recovery work	Ongoing	DENR, DCI
3		**Regular monitoring of sentinel sub-populations**		DENR
	29	Create a monitoring programme	Ongoing	DENR

APPENDIX

*Acronyms for sources:
ANSP=Academy of Natural Sciences, Philadelphia
FMNH=Field Museum of Natural History, Chicago
USNM=Smithsonian National Museum of Natural History, Washington
MCZ=Museum of Comparative Zoology, Harvard
BAMZ WRC=Bermuda Aquarium Museum and Zoo Wildlife Rehabilitation Center
DCS=Department of Conservation Services, Bermuda Government
REEF= Reef Environmental Education Foundation

Table 1. Summary of recorded seahorse collections from Bermuda.

Month-Year	**Species**	**Location**	**Source***
March 1907	*H. zosterae* n=18	Hamilton Harbour	Smith-Vaniz et al (1999), FMNH database (#49019)
March 1908	*H. zosterae* n=33	South side of Agar's Island	Smith-Vaniz et al (1999), FMNH database (#49020)
1879	*H. erectus* n=1	No information	USNM database (#23795)
1888	*H. erectus* n=1	No information	ANSP database (#826)
No dates	*H. erectus* n=1 x4	Flatt's Inlet	FMNH database (#48999, #49002, 49008, 49012)
No date	*H. erectus* n=1	Great Sound	FMNH database (#49003)
No date	*H. erectus* n=1	St David's (Castle Harbour)	FMNH database (#49005)
No date	*H. erectus* n=1 x2	Castle Harbour	FMNH database (#49006, #49011)
No date	*H. erectus* n=1	Ely's Harbour	FMNH database (#49007)
No date	*H. erectus* n=1	Coot Pond	FMNH database (#5495)
No date	*H. erectus* n=1	Challenger Bank	FMNH database (#49018)
No date	*H. erectus* n=1	(Ferry?) Reach	FMNH database (#48998)
No date	*H. erectus* n=1	Rock	FMNH database (#49009)
No date	*H. erectus* n=2	No information	FMNH database (#49010)
No date	*H. erectus* n=2	No information	FMNH database (#48997)
No date	*H. erectus* n=2	No information	FMNH database (#49001)

No date	*H. erectus* n=3	No information	FMNH database (#49013)
No date	*H. erectus* n=1	No information	FMNH database (#48996)
No date	*H. erectus* n=1	No information	FMNH database (#49000)
No date	*H. erectus* n=18	No information	FMNH database (#49004)
No date	*H. erectus* n=1	Devonshire Bay	FMNH database (#49022)
July 1905	*H. erectus* n=1	North of Tyne's Bay	Smith-Vaniz et al (1999), MCZ database (#29127)
1905, 1905, No date	*H. erectus* n=1 x3	Flatt's	FMNH database (#5064, #5066, #49051)
1905	*H. erectus* n=1	Cable Bay	FMNH database (#5065)
Feb 1906	*H. erectus* n=1	Long Bird Island	Smith-Vaniz et al (1999), FMNH database (#5494)
June 1927	*H. erectus* n=1	Castle Roads	Smith-Vaniz et al (1999), USNM database (#169947)
Sept 1929	*H. erectus* n=1	Off Nonsuch Island	USNM database (#170079)
1929	*H. erectus* n=1	Off Nonsuch Island	USNM database (#170086)
April 1930	*H. erectus* n=1	No information	Smith-Vaniz et al (1999), USNM database (#169945)
July 1930	*H. erectus* n=1, n=15	No information	Smith-Vaniz et al (1999), USNM database (#169950), USNM database (#169957)
July 1930	*H. erectus* n=237	No information	USNM database (#170074)
Sept 1930	*H. erectus* n=1	Off Nonsuch Island	USNM database (#170080)
July 1931	*H. erectus* n=4	Off Nonsuch Island	USNM database (#178830)
July 1981	*H. erectus* n=1	Castle Harbour 'grass beds'	Smith-Vaniz et al (1999), ANSP database (#168573)
June 1985	*H. erectus* n=2	Off Nonsuch Island	Smith-Vaniz et al (1999), ANSP database (#168572)
2009	*H. erectus* n=1	East shore off Cable & Wireless	BAMZ specimen collection
2003	No ID n=1	John Smith's beach	BAMZ specimen collection
1870s	*H. reidi* n=1	No information	Smith-Vaniz et al (1999), USNM database (#21933)
1877	*H. reidi* n=1	No information	Smith-Vaniz et al (1999), USNM database (#23805)
No date	*H. reidi* n=1	Catherine's Bay	FMNH database (#49021)
No date	*H. reidi* n=1	No information	FMNH database (#49082)
March 1914	*H. reidi*	No information	Smith-Vaniz et al (1999),

	n=1		FMNH database (#49016)
Sept 1936	*H. reidi* n=1 x2	Red Bay, Harrington Sound	Smith-Vaniz et al (1999), FMNH database (#49015, #49017)
Oct 1937	*H. reidi* n=1	Off Nonsuch Island	Smith-Vaniz et al (1999), USNM database (#169958)
July 1975	*H. reidi* n=1	NW edge of platform	Smith-Vaniz et al (1999), ANSP database (#134103)
Aug 1975	*H. reidi* n=1	Off Trunk Island, Harrington Sound	Smith-Vaniz et al (1999), ANSP database (#134102)
Aug 1975	*H. reidi* n=2	Western Blue Cut	Smith-Vaniz et al (1999), ANSP database (#134104)
July 1977	*H. reidi* n= not reported	Harrington Sound	Smith-Vaniz et al (1999)
Sept 1997	*H. reidi* n=1	Between Town Cut & St David's Head	BAMZ specimen collection
1998	*H. reidi* n=1	Tucker's Town dock	BAMZ specimen collection
Dec 2004	*H. reidi* n=2	No information	BAMZ WRC records Accession #604021, #604022
May 2012	*H. reidi* n=2	No information	BAMZ WRC records Accession #WR3470, #3621
July 2013	*H. reidi* n=1	Flatt's Inlet	BAMZ WRC records Accession #WR3829
May 2015	*H. reidi* n=2	Flatt's Inlet, Shorelands beach	BAMZ WRC records Accession #615075
Feb 2016	*H. reidi* n=1	Gibbet Island	BAMZ WRC records Accession #616027
2016	*H. reidi* n=1	Beach in Warwick	BAMZ specimen collection
May 2016	*H. reidi* n=1	Horseshoe Bay beach	BAMZ specimen collection, Accession #WR4417
May 2016	*H. reidi* n=1	Cooper's Island beach	BAMZ WRC records Accession #WR4386
June 2016	*H. reidi* n=1	Burchall's Cove	BAMZ WRC records Accession #WR4391
June 2017	*H. reidi* n=1	Mill's Creek	BAMZ WRC records Accession #617050
July 2017	*H. reidi* n=2	No information	BAMZ WRC records Accession #617057, #617058
Dec 2017	*H. reidi* n=1	Boss' Cove	BAMZ WRC records Accession #617077

Table 2. Summary of reported seahorse observations from Bermuda.

Month-Year	Species	Location	Source
February 1997	No ID n=2	[redacted]	Ward (1999)
1999-2001	No IDs n=<30		BAMZ surveys, (Hinton unpub. data.)
2002	No ID n=1+		Peter Hopkins, pers. comm.
2002	No ID n=1		Mark Outerbridge, pers. obs.
2002	No ID n=2		Mark Outerbridge, pers. obs.
July 2007	No ID n=1		DCS benthic survey
June 2009	No ID n=1		DCS benthic survey
March 2010	No ID n=1		DCS benthic survey
2016	No ID n=1		Mark Outerbridge, pers. obs.
April 2019	No ID n=2		Mark Outerbridge, pers. obs.
April 2019	No ID n=1		Mark Outerbridge, pers. obs.
May 2016	*H. erectus* n=not reported		Jessica Riederer, 2017 Report
May 1995	*H. reidi* n=1		Ward (1999)
April- Oct 2002, 2004	*H. reidi* n=1 x10		REEF surveys (x10)
Aug 2004	*H. reidi* n=2		REEF survey (x1)
Aug 2005	*H. reidi* n=1		REEF survey (x1)
Sept 2006	*H. reidi* n=1		REEF survey (x1)
April-Aug 2015, 2016, 2017	*H. reidi* n=1 x10, n=2 x3		REEF surveys (x13)
Dec 2015	*H. reidi* n=1+		Jessica Riederer, 2017 Report
Sept 2015, Feb-May 2016, Oct 2016	*H. reidi* n=≤15/day		Jessica Riederer, 2017 Report
Jan-April 2016	*H. reidi* n=≤15/day		Jessica Riederer, 2017 Report

Nov 2016	*H. reidi* n=1+	[redacted]	Jessica Riederer, 2017 Report
Jan-March 2016, Dec 2016 Jan 2017	*H. reidi* n=≤6/day	[redacted]	Jessica Riederer, 2017 Report

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