

Recovery Plan for the Bermuda Land Snail, *Poecilozonites circumfirmatus*



Government of Bermuda
Ministry of The Environment and Sports
Department of Conservation Services

Recovery Plan for the Bermuda Land Snail, *Poecilozonites circumfirmatus*

Prepared in accordance with the Bermuda Protected Species Act 2003

Funded in part by:



Primary Author

This recovery plan was prepared by:

Samia Sarkis, Ph.D.

Protected Species Coordinator

Department of Conservation Services

17 North Shore Road, Hamilton FL04

Bermuda

Contact: Samia Sarkis: scsarkis@gov.bm

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GOVERNMENT OF BERMUDA

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Department of Conservation Services

“To conserve and restore Bermuda’s natural heritage”

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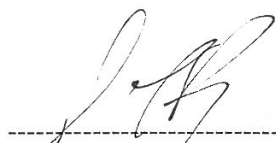
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DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the Department of Conservation Services, publish recovery plans, 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 for 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 are approved by individuals or agencies involved in the recovery plan formulation, but may not represent their official positions. They represent our official position only after they have been signed by the Director of Conservation Services 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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An electronic version of this recovery plan will also be made available at www.gov.bm and www.conservation.bm.



Acting Director
Department of Conservation Services
Government of Bermuda



Date

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EXECUTIVE SUMMARY

Current Species Status:

This recovery plan addresses the need for actions to conserve Bermuda's endemic land snail, *Poecilozonites circumfirmatus*. This species is listed locally as Critically Endangered under the Protected Species Act 2003. Believed to have once been very common in Bermuda, and then thought to be extinct, it was rediscovered in 2000. Limited conservation efforts have been underway since 2004, resulting in successful breeding populations at the Zoological Society of London. Data on current population levels in the wild in Bermuda is very limited, and the species is rarely seen. Surveys in 2002 and 2004 recorded the presence of live snails; but a more recent one conducted in 2006 on Nonsuch Island, previously found to be a suitable habitat, failed to produce any record of live *P. circumfirmatus*. Information is lacking on growth and survival requirements of the species in the natural environment, including the impact of predators and presence of other potential threats. A captive breeding population is currently maintained at the Zoological Society of London.

Habitat Requirements and Threats:

P. circumfirmatus is generally found on the underside of loose rocks lying in leaf litter under herbaceous cover. A moist habitat is necessary to their survival. It is thought that predation by the introduced snails (namely, *Euglandina rosea*), as well as that by terrestrial flatworms (more specifically, *Bipalium vagum*) may have contributed to the decline of the endemic land snail species.

Recovery Objective:

The principal aim of the recovery plan is to re-introduce *P. circumfirmatus* into the wild and establish self-sustainable populations at selected sites.

Recovery Criteria:

Down listing of the Bermuda land snail will be considered when:

- Comprehensive population status of the endemic land snail is known
- Threats and predators are identified, and measures for control of predators are determined
- Captive breeding programme is well developed and implemented at the Bermuda Aquarium Museum & Zoo (BAMZ)
- Suitable sites in the natural environment are identified and managed
- Populations of *P. circumfirmatus* are found self-sustainable at a minimum of 50% of previously known habitats, or a minimum of 10 suitable sites island-wide.

Actions Needed:

- Comprehensive island wide survey of *P. circumfirmatus* populations
- Transfer captive breeding techniques from U.K. to Bermuda

- Juvenile production at Bermuda Aquarium Museum & Zoo
- Evaluation of optimal habitat, and site selection for re-establishment of populations
- Develop and implement measures for control of predators
- Develop and implement protocol for transfer of individuals to natural environment
- Evaluation of survival, reproductive status and growth of newly established populations
- Expansion of breeding and transfer programme for island wide population re-establishment programme

Recovery Costs: The total cost of recovery actions cannot be defined at this point. Funding needs to be secured through NGOs and other interested parties for implementing the necessary research and monitoring studies on the biology of the land snail. Developing budgets for each action are the responsibility of the leading party as outlined in the workplan.

Date of Recovery: Meeting the recovery objectives for the endemic land snail *P. circumfirmatus* depends in great part on the dedication of personnel and facility for this project. It is anticipated that this work can be conducted as a graduate thesis, resulting in sufficient information for successful breeding and development of protocols for habitat selection and development of protocols for transfer to the wild. It is therefore anticipated that within three years, sufficient information will be obtained for the establishment of populations in the natural environment. Further implementation and monitoring following island-wide implementation will be required to achieve the establishment of self-sustaining populations in a minimum of 50% of previously known inhabited sites, or a minimum of 10 suitable sites. This will need to be conducted prior to the consideration of down listing. Given the rapid turnover of this species, a six-year period after initial implementation is recommended, prior to re-assessment of the status of the species.

PART I: INTRODUCTION

A. BRIEF OVERVIEW

The Bermuda land snail, *Poecilozonites circumfirmatus* (Redfield, 1853) is endemic to Bermuda, and has been listed locally as Critically Endangered (CR, A2, B2a), as per IUCN criteria, under the Protected Species Act 2003. *Poecilozonites* is reported as the only terrestrial endemic genus to Bermuda.

This recovery plan outlines threats and conservation efforts for the Bermuda land snail, summarising current knowledge of the taxonomy, distribution, habitat requirements, and reproductive cycle. Believed to be extinct, the re-discovery of live specimens of *P. circumfirmatus* in 2000 led to conservation efforts in assessing and enhancing population status through translocation of individuals. It is difficult to ascertain the results of these efforts, given that these were short-term intern projects with subsequent evaluations conducted on a voluntary basis. Observations on the impact of terrestrial flatworms and predatory snails imply the need to identify and control predatory species for the re-establishment of self-sustaining populations in the natural environment. A collaborative effort with scientists from the Zoological Society of London (ZSL) has successfully demonstrated the feasibility of reproducing *P. circumfirmatus* under controlled conditions, and forms the basis of this recovery programme.

The plan first recommends a comprehensive assessment of the population status, and secondly calls for active intervention in the establishment of natural populations through the transfer of captive bred juveniles to managed sites. The adaptations of techniques used at ZSL for the species should prove successful, given the anticipated dedication of resources for this programme by the Bermuda Aquarium Museum & Zoo. If predators and other threats are successfully identified and controlled, the establishment of populations of the species across the island, focusing on sites where species have been previously recorded, should be possible. This may enable the down listing of *Poecilozonites circumfirmatus* to a less threatened status and/or remove it from the Bermuda Protected Species list.

Historical Distribution

Fossils and living specimens of the Bermudian land snail, *Poecilozonites circumfirmatus* have been recorded across the island (Bieler and Slapcinsky, 2000). From these records, it is believed to have been once very common and widespread, occurring over much of Bermuda's forest habitat; shells were reportedly collected and burned for lime (Gould, 1969). The species was considered extinct by the 1990s until rediscovered by an intern at the Bermuda Aquarium Museum & Zoo (BAMZ) in 2000 (W. Sterrer, *pers.comm.*). This species is thought to be the sole survivor of an endemic genus described by the evolutionary paleontologist Stephen J. Gould as undergoing an adaptive radiation comparable in scope with that of Darwin's finches on the Galapagos Islands (Gould, 1969). Although a number

of the endemic Bermudian snails were only ever known from the fossil record, Gould estimated that many species were driven to extinction by the onslaught of non-native species introduced by man from the 16th century onwards (Gould, 1969).

Information on population status over time is limited, as surveys have varied in focus making comparisons difficult. During a 1998 survey, Bieler and Slapcinsky (2000) record a few sites with recently dead shells- in the West end of the island- and only two sites with live specimens in the central parishes. Confirmation of live specimens in four locations across the island was subsequently made in 2002 (Lines, 2002); in 2004, the survival of the species at two locations seemed promising, where >30% of the snails collected were live (Sterrer *et al.*, 2004). Unfortunately, no live specimens were found in 2006 at one of the locations surveyed (Nonsuch Island; Sterrer *et al.*, 2006), and none were found during rapid surveys conducted by ZSL experts in the same year (Pearce-Kelly, *pers. comm.*). Details of population sites are given in a later section of the document. Available information suggests a dramatic decline of the species from late 1960s to the present.

B. CURRENT PROTECTION STATUS

In Bermuda, current legal protection for *P. circumfirmatus* is given under the Protected Species Act 2003. Its listing as Critically Endangered (CR, A2, B2a) mandates the development of a recovery plan within one year of listing (2009). The natural habitat of the snail is island-wide, and any habitat included within national parks and/or nature reserve is protected to a certain extent under the Bermuda National Parks Act 1986.

Local Protection

Legal Protection

Offenders of the Bermuda Protected Species Act 2003 are liable to a fine of \$5,000, and up to \$10,000 for continuing offences. Currently, the Protected Species Act 2003 considers as an offence the willful destruction, damage, removal or obstruction of a habitat, and the taking, importing, exporting, selling, purchasing, transporting or having in possession a protected species.

Habitat Protection

Populations found in existing nature reserves are also protected to some degree by Bermuda Parks Regulations; more specifically the taking of any flora or fauna within the park is prohibited. In addition, Nonsuch Island, where *P. circumfirmatus* has shown some recent success of survival (Sterrer *et al.*, 2004), is designated to be listed as “Critical Habitat”. This will ensure maximal habitat protection.

C. TAXONOMY AND DESCRIPTION OF THE SPECIES

Figure 1. *Poecilozonites circumfirmatus* in Bermuda.



Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
Order: *Pulmonata*
Family: Zonitidae
Genus: *Poecilozonites*
Species: *circumfirmatus* (Redfield, 1853)
Common Name: None

The genus *Poecilozonites* is an important component of the endemic land snail fauna of Pleistocene Bermuda (Schindel and Gould, 1977). Pilsbry (1924) reports that the group is special to that island, it is isolated zoologically and it has been differentiated into many strikingly diverse species. *Poecilozonites* resembles the North American continental genera *Gastrodonta* and *Ventridens* in its complicated reproductive organs, but it differs by the character of having no pedal furrows and the genital orifice is submedian on the right side (Pilsbry, 1924). The connection of the duct of the spermatheca with the penis suggests the probability of self-impregnation, also confirmed by Gould (1969). Some individuals were reported to have weak or no lamellae (Bieler and Slapcinsky, 2000), leading to the varietal name *corneus*.

Figure 2. *P. circumfirmatus* shell (apical view).



Redfield (1853) described the species for the first time as *Helix circumfirmata* as follows:

Shell umbilicated, depressed-conoidal, with faint oblique incremental striae, brownish horn-colored, obscurely rayed with yellowish brown spots above and lines beneath; spire obtuse; whorls 7 ½; very slightly convex, last one obtusely carinated, not deflected, convex beneath; umbilicus moderate; aperture lunar, strengthened within by a sharp but strong white

lamella which revolves beneath the periphery, and is plainly visible through the substance of the shell, throughout the last whorl; columella very oblique, thickened into a callus which extends inwardly around the umbilical portion of the shell; lip simple, acute.

Adults are 8.6mm diameter (apical and basal views) and 7.8mm in diameter (apertural view) (Figure 2; Bieler and Slapcinsky, 2000).

D. ECOLOGY

Very little is known on the requirements for growth and reproduction of Bermuda's endemic snail species in its natural environment. Some information on its reproduction and growth during early life stages has been obtained through captive breeding efforts of the past few years.

Habitat Requirements:

P. circumfirmatus is generally found in upland coastal habitats, such as Spittal Pond, on the underside of loose rocks lying in leaf litter under herbaceous cover (Figure 3). A moist habitat is necessary to their survival. Bay grape trees (and leaves) are often seen in the vicinity of land snails (Lines, 2002).



Figure 3. Bermuda endemic snail found on leaf litter.

General Biology:

Temperatures of 20–25 °C and a soil acidity of 6.5 appear suitable to growth and survival (Pearce-Kelly and Walker, 2006). Mortalities were recorded *in situ* when air temperatures reached 36 °C. *P. circumfirmatus* is a soil living species, implying a detritivorous diet. Fecal samples of snails transported in the laboratory were examined in March 2004 and tested positive for “scanty adult helminthes” and flagellates, and in some cases helminthes ova were also recorded. The helminth species were not identified (Pearce-Kelly and Walker, 2006). In samples collected from snails in captivity, ciliates were continuously recorded.

P. circumfirmatus are predominantly active during periods of darkness or subdued lighting, according to observations made *in vitro* (Pearce-Kelly and Walker, 2006). It is unusual to observe any activity in daylight conditions supporting a view that they are predominantly nocturnal but also active during periods of rainfall.

Reproduction

There is no information on mating behaviour. Furthermore, no direct mating events were observed in captive populations, due in great part to their nocturnal behaviour (Pearce-Kelly and Walker, 2006).

The shell of a hatchling snail was recorded to be 1.36mm across the longest axis (Pearce-Kelly and Walker, 2006). Observations made under controlled conditions indicate that eggs are laid in a chamber in the soil apparently constructed with the shell of the adult (the chambers are almost the same size as the adult snail). Eggs are white and almost spherical, approximating 1.32 x 1.67 mm (across the diameter). Under controlled conditions, it appears that snails naturally locate a hard surface to lay against, which may provide partial protection against predation and desiccation; on the other hand, this may be a factor of the rearing conditions, providing insufficient soil depth. On one recorded

occasion a clutch of eggs was laid on the surface of the substrate but under the leaf litter. The eggs are usually grouped together in a ball like structure but are not noticeably adhesive as they easily separate when disturbed. They are brittle and will break under pressure. Although the majority of the eggs are discovered grouped in chambers, small numbers are found in close proximity to the “main clutch” suggesting that the adult may begin oviposition prior to completion of the chamber, or that it continues to lay as it leaves, or perhaps it just carries the odd egg away with it as it exits the laying chamber.

Life Cycle

The following information relates to observations made during captive breeding efforts.

- Adults lay eggs in 15 days after fertilisation
- Incubation time is 35 – 44 days maximum
- Development time from hatching to adult size (8mm) approximates 5 ½ months

Population numbers of various life stage groups (loosely defined as hatchling, post 2mm young and adult) throughout the time this species has been held at ZSL suggests that the life span of *P. circumfirmatus* in captivity (under conditions described by Pearce-Kelly and Walker) is around 18 months and that the reproductive state is reached between five and six months.

E. CURRENT THREATS

The introduction of other snail species in Bermuda, as a food product or a biological control, proved troublesome to the native populations (Gould, 1969). Several of these introductions are detailed in Table I. The introduction of the predatory snail, *Euglandina rosea*, as a biological control for *Otala*, resulted in a rapid spread over the entire Island, becoming so abundant in the 1960s that more than 1,000 were exported (Hughes, 1962). Bieler and Slapcinsky (2000) state that “although ultimately failing to control either *Otala* or *Rumina*, *Euglandina* has become widespread in Bermuda and may well be the cause of decline for several of Bermuda’s native snails, including the members of the now nearly extinct endemic genus *Poecilozonites*”. In recent years, *Euglandina* seems to have become uncommon again; an anecdotal observation that needs to be followed up by a systematic survey. Of the two *Gonaxis* species, only *G. quadrilateralis* seems to have become moderately established.

Table 1. Some species of snails introduced in Bermuda (W. Sterrer, *pers.comm.*)

Species	Date of Introduction
<i>Bradybaena similaris</i> (Rang, 1831)	Before 1889
<i>Oligyra convexa</i> (Pfeiffer, 1849)	Before 1853
<i>Polygira plana</i> (Dunker, 1843)	Before 1853
<i>Prietocella Barbara</i> (Linné, 1758)	Before 1853
<i>Euglandina rosea</i> Férussac, 1821	1958–1960; intentional introduction to control <i>Otala lactea</i> and <i>Rumina decollata</i>
<i>Gonaxis kibweziensis</i> (E.A. Smith, 1894)	1960; intentional introduction to control <i>O. lactea</i> and <i>R. decollata</i>
<i>Gonaxis quadrilateralis</i> (Preston, 1910)	1968 & 1972; intentional introduction to control <i>O. lactea</i> and <i>R. decollata</i>

Terrestrial flatworms (Turbellaria) may represent a more recent threat to our native snails. Jones and Sterrer (2005) recorded seven species of terrestrial planarians in Bermuda of which three are new to science; two of these (*Bipalium vagum* and *Gigantea gubernoni*) have been observed to kill and eat *P. circumfirmatus* (Figure 4. Sterrer, *pers.comm.*).

Figure 4. Predatory behaviour of *Bipalium vagum* on *P.circumfirmatus* in Bermuda.



This potential threat is furthermore implied by the results of one of the more recent assessments; Sterrer *et al.* (2004) reported that in the absence of predatory snails (*Euglandina* and *Gonaxis*) and flatworms, the percentage of live *P. circumfirmatus* tends to be higher. These authors compared the percentage of live individuals at Nonsuch Island – free of predatory snails and flatworms – and Coral Beach Club, where three specimens of *Bipalium sp.* were found; at Nonsuch Island there was 68.2% live endemic snails (n=22;

where n is the total of both live and dead individuals), compared to 27% live at Coral Beach Club (n=135).

Finally, Argentine ants may also be a contributory factor in the decline of *P. circumfirmatus* (Pearce-Kelly and Walker, 2006).

F. CURRENT STATUS

Global Distribution

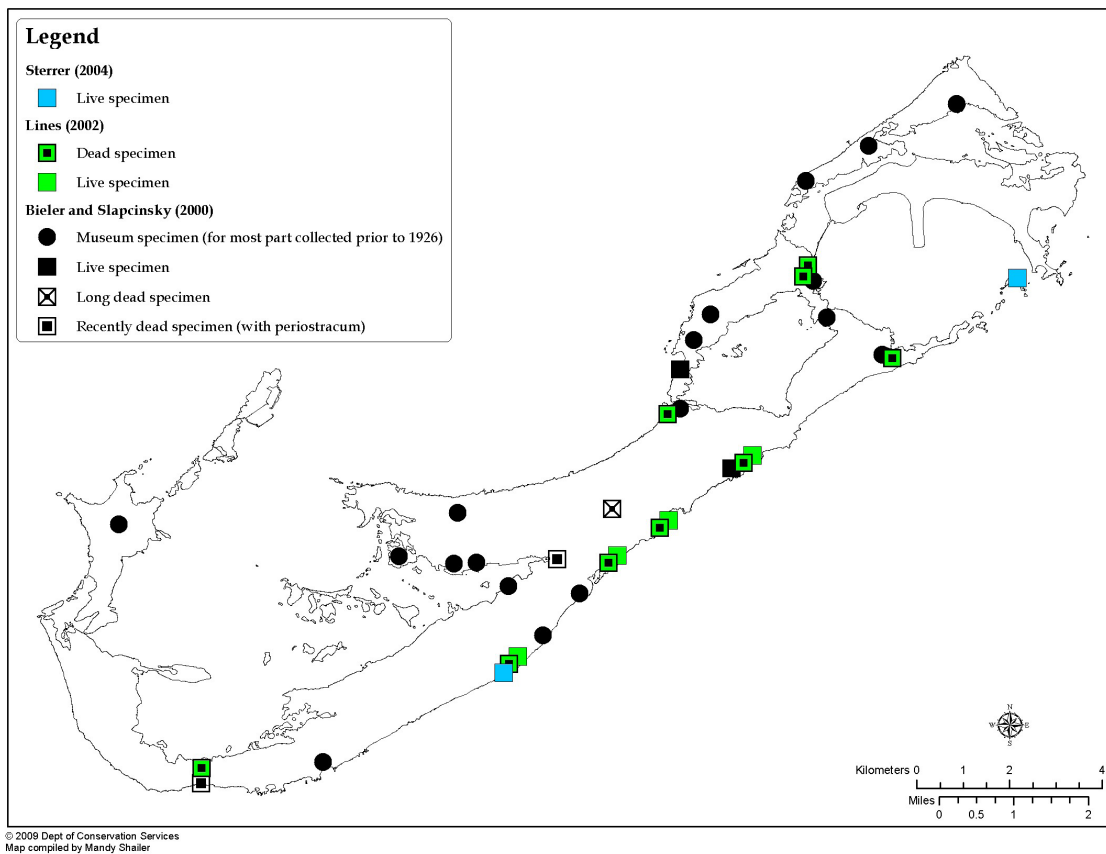
Poecilozonites circumfirmatus is endemic to Bermuda.

Local Distribution

Locations of live and dead *P. circumfirmatus* recorded during surveys conducted between 1998 and 2006 are illustrated in Figure 5. Dead specimens refer to recently dead, identified by the presence of periostracum; these do not represent a comprehensive assessment, but provide some insight into potential habitats for the species. The latter surveys (2002–2006) were not island-wide, and hence it is possible that this snail species is found elsewhere in Bermuda.

As seen in Figure 5, Bieler and Slapcinsky (2000) report live specimens in only two locations in the middle parishes of the island. Lines (2002) reports four locations with live specimens – Spittal Pond, Happy Talk Lane, Devonshire Bay, and Coral Beach Nature Reserve. Translocation of the Bermuda land snail to Nonsuch Island was attempted at this time, where 16 individuals were released (forest near South Beach) (Lines, 2002). A rapid survey conducted in 2004 indicated the presence of 15 live specimens of *P. circumfirmatus* at this location; in the same year, 36 live specimens were also recorded at Coral Beach Club.

Figure 5. Locations of dead and live specimens of *P. circumfirmatus* in Bermuda.



G. CURRENT CONSERVATION ACTION

Conservation efforts have been driven by Dr. W. Sterrer at the Natural History Museum (BAMZ), focusing on the assessment of snail population status across Bermuda, and on the preservation of the species through translocation and captive breeding. Based on one preliminary translocation effort, the potential for establishing populations at new sites is present, but requires the control and/or removal of predators. These results warrant further investigations on growth, reproduction and survival at selected sites.

Given the low population levels, captive breeding for a supply of juveniles is necessary to the recovery of the species. First attempts at rearing snails under controlled conditions were described in Lines 2002, and success was minimal, due in great part to lack of dedicated resources, time and expertise. A second attempt was made in February 2004, when snails (12 adults and 44 juveniles) were shipped to the Zoological Society of London, enabling the development of a captive population. Rearing has proved relatively simple and successful. A captive breeding population is currently maintained at ZSL.

The identification of predators is a critical issue, a concern justified by previous observations made in the field. However, this has not been confirmed through comprehensive tests. The only scientific evidence available is that reported by ZSL, testing the predatory effect of a millipede species, collected at Spittal Pond in 2006, on *P. circumfirmatus*; results were negative, and predation did not occur (Pearce-Kelly, *pers.comm.*).

PART II: RECOVERY

A. RECOVERY GOAL

The principal aim of the recovery plan is to re-introduce *P. circumfirmatus* to suitable habitats in the wild, in order to develop a self-sustaining population.

The short-term goals (three years) are to assess the population status of the endemic land snail on Bermuda, identify suitable habitats, and evaluate the potential for survival in the natural environment; the latter includes thorough investigation on predatory species and their impact on snail survival, as well as the implementation of captive breeding in Bermuda.

The long-term goal (six years) is to re-establish populations in the natural environment and increase the area of occupancy, relying on the supply of captive-bred individuals. The self-sustainability of new populations will be assessed through the monitoring of growth, reproduction and survival.

B. RECOVERY OBJECTIVES AND CRITERIA

Favourable conservation status will be achieved when:

- Comprehensive population status of the endemic land snail is known
- Threats and predators are identified, and measures for control of predators are determined
- Captive breeding programme is well developed and implemented at BAMZ, ensuring a supply of *P. circumfirmatus* individuals
- Suitable sites in the natural environment are identified and managed
- Populations of *P. circumfirmatus* are self-sustainable at a minimum of 50% of previously known habitats, or a minimum of 10 suitable sites island-wide.

The short-term goal (three years) is to develop a standard survey method for assessment of population distribution, numbers and genetic variation across the island. To identify major threats to the survival of land snail in the natural environment. To investigate population status of predatory species and test their impact on *P. circumfirmatus* under controlled conditions. To adapt breeding techniques developed at ZSL to Bermuda, and dedicate resources for the production of a reliable supply of juveniles. To identify the suitability of previously inhabited sites for the survival and growth of captive bred land snails, and identify new sites for the establishment of land snail populations. To design and implement experiments testing the survival and growth of juveniles in the natural environment.

The long-term goal (six years) is to develop a captive breeding programme enabling a larger

scale production of land snail juveniles, ensuring the genetic management of the breeding pool. To develop and implement a protocol for a series of juvenile transfers to suitable sites over a two-year period, maximising success of establishment of the population. To develop and implement a monitoring protocol of snail populations in new sites and a management protocol of predators.

C. RECOVERY STRATEGY

The lack of a dedicated programme and standardisation among surveys may explain in part the absence of land snails recorded in recent years; in order to verify the current population status, a comprehensive survey is required. In addition, verification of predator impact provides insight into the causes of past snail population decline, but is also required for maximising the potential for successful growth and survival of newly established populations.

The availability of captive *P. circumfirmatus* at ZSL and proven rearing techniques provide the fundamentals for establishing a recovery programme in Bermuda. The controlled production of juveniles for subsequent release into the natural environment seems to be the most promising option in the re-establishment of snail populations, given the recorded low levels in the natural environment. For a long-term breeding programme, a review of the current genetic variation and associated management regime is needed. Maximising the captive breeding gene pool by including individuals found in the natural environment, during comprehensive surveys, is therefore recommended. **Note:** This is dependent on population numbers in the natural environment.

There appears to be a relationship between the survival of the land snail in the natural environment and the absence of predatory snails and flatworms; in light of this, the approach to recovery would be the preparation of selected sites, and subsequent management programme for predator control ensuring successful stocking of juvenile and adult snails.

D. TOOLS AVAILABLE FOR RECOVERY

The availability of fossil and live records provide a starting point for a comprehensive survey, as does the information relating to first translocation efforts. The original remit of successfully breeding and rearing the snails has been realised with the species proving to be relatively straightforward to maintain in culture.

Techniques for transporting snails have been tested and proved successful in minimising stress and allowing for successful reproduction in captivity. Pearce-Kelly and Walker (2006) describe in detail protocols for maintaining snails including soil type, temperature, light, pH, and diet optimising conditions for reproduction. In brief, snails were kept in “old style” ZSL Partula tank positioned on its side using clingfilm. Snails were provided with leaf litter and a range of food plants (lettuce, carrot, cabbage, cauliflower, sweet pea). A

soil substrate composed of a mixture of coir compost and sand was provided. Soil acidity was 6.5. A first clutch of eggs was discovered 15 days later. By June 2005 (16 months later), a total of 144 juveniles were counted, and 25% survival of the initial “parent” batch was recorded. Juveniles observed were presumed to be both of F1 generation (n= 49 individuals), and F2 generation (n=95 individuals) (P. Pearce-Kelly, *pers.comm.*).

E. STEP-DOWN NARRATIVE OF WORKPLAN

The following abbreviations are used:

BAMZ – Bermuda Aquarium Museum & Zoo, Bermuda

DCS – Department of Conservation Services, Bermuda

ZSL – Zoological Society of London, U.K.

Ph.D. student at DCS – Doctoral candidate supervised by DCS staff

Volunteers – drawn from the pool of BAMZ volunteer interns and/or keen field ecologists

The actions needed to achieve recovery are as follows:

1. Population assessment of *P. circumfirmatus*

Actions proposed:

- Standardised survey of endemic snail island-wide
- Assessing genetic variation in field populations
- Assessment of introduced, predatory snails and flatworms populations in land snail habitats

Work team: DCS, BAMZ

Team leader: Ph.D. student (DCS)

Assistance: Field volunteers

Outputs: Comprehensive island wide population status report.

List of equipment required: survey material, including handheld GPS. Funding for collection and analyses of population-level genetics.

2. Captive breeding programme

Actions proposed:

- Transfer of techniques from ZSL to BAMZ
- Develop small breeding programme, including genetic management, in Bermuda
- Investigations on requirements for growth and predator impact

Work team: ZSL, DCS, BAMZ

Team leader: Ph.D. student (DCS)

Assistance: BAMZ volunteers

Outputs: Production of juveniles with report outlining techniques and results.

Report on predators and their impact on snail growth and survival.

List of equipment required: Captive breeding facility dedicated to endangered terrestrial species. Rearing materials based on ZSL procedures.

3. Transfer of juveniles to the natural environment

Actions proposed:

- Identification and preparation of suitable habitats, considering previously known sites
- Development and investigation of measures for control of predators
- Transfer trials of juveniles to selected sites
- Investigate survival and growth in the natural environment

Work team: DCS, BAMZ

Team leader: Ph.D. student (DCS)

Assistance: Field volunteers

Outputs: Selection of suitable habitats based on snail survival and growth across the island. Protocol on site preparation and management.

List of equipment required: Materials for habitat preparation, grow-out equipment (exclusion cages if needed).

4. Increase Extent of Occupancy

Actions proposed:

- Expand scope of breeding programme
- Natural population enhancement by transfer of captive bred juveniles
- Develop and implement monitoring and site management programme for growth and survival

Work team: DCS, BAMZ

Team leader: DCS

Assistance: Ph.D. student (DCS), BAMZ volunteers

Outputs: Establishment of new populations across the island. Transfer protocol and monitoring programme developed.

List of equipment required: Captive breeding facility, handheld GPS, survey material.

F. ESTIMATED DATE OF DOWN-LISTING

Meeting the recovery objectives for the endemic land snail *P. circumfirmatus* depends in great part on the dedication of personnel and facility for this project. It is anticipated that this work can be conducted as a graduate thesis, resulting in sufficient information for successful breeding and development of protocols for habitat selection and development of

protocols for transfer to the wild. It is therefore anticipated that it will take three years to develop a breeding programme for *P. circumfirmatus* and obtain sufficient information on growth and survival requirements in the natural environment and existing threats. It is anticipated that at least three more years will be necessary prior to the establishment of self-sustaining populations in a minimum of 50% of previously known sites, or a minimum of 10 sites across the island. Given the rapid turnover of this species, a six-year period after commencement of recovery action is recommended, prior to re-assessment of the status of the species.

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		Population assessment	6 months	
	1	Island-wide survey	6 months	Ph.D. (DCS)
	2	Population genetics	6 months	DCS
	3	Predator population assessment	6 months	Ph.D. (DCS)
1		Captive breeding programme	12 months	
	4	Transfer breeding techniques to Bermuda	12 months	BAMZ, ZSL, Ph.D. (DCS)
	5	Breeding and genetic management programme	12 months	BAMZ
	6	Growth and predator impact investigations	12 months	Ph.D. (DCS)
1		Transfer of juveniles to natural environment	24 months	
	7	Optimal habitat identification	3 months	Ph.D. (DCS)
	8	Control of predators	3 months	Ph.D. (DCS)
	9	Juvenile transfer trial series	12 months	Ph.D. (DCS), BAMZ
	10	Field survival and growth investigations	12 months	Ph.D. (DCS)
2		Establish populations island wide	24 months	
	11	Expand breeding programme	12 months	BAMZ
	12	Natural population enhancement	24 months	DCS, BAMZ
	13	Snail monitoring and site management	24 months	BAMZ

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