Recovery Plan for the Queen Conch, *Strombus gigas*, in Bermuda

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

Recovery Plan for the Queen Conch, *Strombus gigas*, in Bermuda

Prepared in Accordance with the Bermuda Protected Species Act 2003

Funded in part by:

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"To conserve and restore Bermuda's natural heritage"

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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, 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 approved and signed by the Director of Conservation Services. 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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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 the queen conch, *Strombus gigas*, native to Bermuda, and recently listed as "Endangered" under the Bermuda Protected Species Act 2003. Despite a complete ban from fishing and/or taking since 1978 under Bermudian legislation, queen conch populations in Bermuda have shown little recovery. This species was found to be relatively abundant in Bermuda up to the late 1960s, but by late 1970s populations reached very low levels. The species is in decline throughout its geographical range but currently remains commercially fished in some of the Caribbean islands; trade has been regulated by CITES since 1992 when *S. gigas* was listed under Appendix II. Preliminary genetic analysis suggests that queen conch in Bermuda is an isolated population from Caribbean stocks. There is currently no conservation programme specific to queen conch in Bermuda.

Habitat Requirements and Threats:

The queen conch is usually found in shallow seagrass and near reef habitats. Adult conch can easily be seen above the substrate, however, it is thought that juveniles less than 80mm bury in sand or gravel during the day. Generally, the main processes threatening the species are ease of harvest, slow development to maturity, and well-defined characteristics for nursery habitats. In Bermuda, additional concerns relate to the low densities of adult conch, which may inhibit reproductive activity, and to the location of existing breeding aggregations; these are found on the outer edge of the lagoon, possibly affecting larval retention, and successful recruitment to the natural populations. Given the lack of information on juvenile distribution, nursery/feeding grounds and movement for Bermuda's queen conch, habitat availability for this species on the platform is also questionable.

Recovery Objective:

The primary goals of this recovery plan are to promote and enhance self-sustainability of the queen conch in Bermuda waters, by increasing population levels through habitat protection, active breeding, and optimal self-recruitment. Verification of the genetic make-up of the Bermuda queen conch populations is a critical component of appropriate active intervention.

Recovery Criteria:

Down listing for the queen conch in Bermuda will be considered when:

- Population status and distribution of queen conch on the Bermuda platform are known
- Breeding, feeding and nursery grounds are identified and given due protection

- A minimum of 75% of historical sites are shown to sustain an actively breeding population with demonstrated recruitment, or a minimum of eight breeding sites with densities enabling optimal reproductive activity and self-recruitment

Actions Needed:

1. Assess genetic status, population size, distribution, demography, movements, breeding and feeding grounds
2. Identify and protect critical habitat
3. Evaluate viability of egg masses, requirements for growth and survival of early stages through captive breeding programme
4. Evaluation of spawning season and natural recruitment to the population
5. Increase area of occupancy through translocation of egg masses, adult conch and/or juveniles

Recovery Costs:

The total cost of recovery actions cannot be defined at this point. Funding needs to be secured through NGO's and other interested parties for implementing the necessary research and monitoring studies on the biology of the queen conch. Developing budgets for each action are the responsibility of the leading party as outlined in the workplan.

Date of Recovery:

Meeting the recovery objective for the queen conch in Bermuda depends on 1) the natural production of egg masses and viability, 2) habitat availability, namely for nursery grounds and 3) successful translocation techniques. It is believed that at least 15 years would be needed to assure the sustainability of the breeding populations and new habitats. Routine evaluation of the implementation should be conducted every five years. Down listing will first be considered 15 years after implementation, and only if recovery criteria have been met.

PART I: INTRODUCTION

A. BRIEF OVERVIEW

The queen conch, *Strombus gigas* (Linnaeus, 1758), also known as the pink conch, is native to Bermuda. Locally, this species has been under total protection since 1978 under the Fisheries Act 1978. It has more recently been listed locally under the Protected Species Act 2003 as "Endangered", as per criteria set by the International Union for the Conservation of Nature (IUCN). To date, there has not been a programme actively targeting conservation of the species in Bermuda.

This recovery plan discusses threats and conservation efforts for the queen conch, summarizing current knowledge of the taxonomy, distribution, habitat requirements, biology and threats. The presence of aggregations along the rim of the platform and apparent lack of recovery despite 30 years of protection raises questions on habitat availability and recruitment potential to the population. The plan first recommends a comprehensive investigation providing the current population status in Bermuda and secondly calls for active intervention to increase the extent of occupancy of the species to historically known sites and to other selected sites, focusing on maximizing larval retention. The adaptation of culture techniques for larval, post-larval and juvenile stages should be a useful tool in evaluating requirements for growth and survival of the early life stages of the species, and potentially enable stock enhancement. If population size is successfully increased across the island, it may be possible to down list *Strombus gigas* to a less threatened status and/or remove it from the Bermuda Protected Species list.

Globally, queen conch populations are declining throughout its geographical range – from Brazil, through the Caribbean and the Gulf of Mexico, to Bermuda. The species has been classified as Commercially Threatened (CT) in the IUCN Red List in 1990; however it is not currently threatened with extinction. It has been listed since 1992 in Appendix II of the Convention of International Trade in Endangered Species (CITES).

Historical Distribution

In many regions queen conch has been the basis of subsistence fisheries for centuries. However, *S. gigas* populations have proven unable to keep pace with growing pressure of commercial harvest and are in decline throughout the species' range. Similarly, in Bermuda, queen conch was at one time relatively abundant, when as late as the 1960s, large aggregations were found, from North Rock to the West End. Population numbers subsequently declined to such low numbers by the 1970s that they were listed under the Protected Species Order in 1978, making it illegal to take "anywhere within the exclusive fishing zone". Despite this complete ban from fishing and/or taking for other purposes, there has been little evidence of population recovery in Bermuda waters to date. Queen conch surveys conducted by the Department of Agriculture and Fisheries in 1988 and 1989, in 2000 by the Department of Conservation Services, and more recently observations during benthic surveys by the Department of Conservation Services showed some stabilization of the natural populations at low levels. Details of the population distribution in Bermuda resulting from these studies are provided in a later section of this document.

B. CURRENT PROTECTION STATUS

In Bermuda, the queen conch is legally protected from removal from the water under the Fisheries (Protected Species) Order 1978, and the Protected Species Act, 2003. It is classified as Endangered as per IUCN criteria (EN, B2a biii), based on the recorded low numbers of mature animals living in the natural environment. Globally, the Caribbean queen conch was listed in 1992 under CITES Appendix II by the CITES Member States, due to continuing concerns over the species' overexploitation.

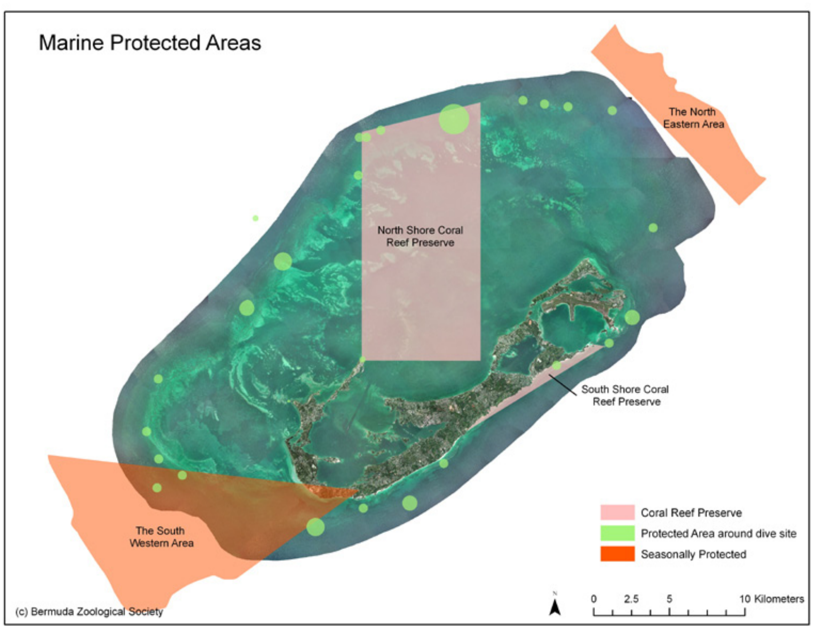
Local Protection

Legal Protection

In Bermuda, the Fisheries Order 1978 considers as an offence the taking of queen conch anywhere within the exclusive economic zone of the island. Anyone found in violation of this law, with the exception of those holding a permit for scientific research or conservation, is subject to a fine up to $5,000 and imprisonment up to a year, as stated by the Bermuda Statutory Instrument Fisheries (Protected Species) Order 1978.

In addition, 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. Offenders are liable to a fine of $5,000 and up to $10,000 for continuing offences. The Bermuda Customs Tariff also imposes restrictions involving queen conch. The importation or exportation of queen conch, whether live, dead, in whole or in part is prohibited. Special licence from the Department of Environmental Protection can be requested.

Figure 1. Protected Areas of the Bermuda Platform



Habitat Protection

The Bermuda Coral Reef Preserves Act 1966 considers an offence to remove, willfully damage or impair any marine fauna or flora within the preserve. Only one of the queen conch sites in Bermuda occurs partly within the North Shore Coral Reef Preserve (Figure 1). Those offending the law are liable to fines of $480 and/or imprisonment for six months.

Global Protection

On the international scale, species listed under Appendix II of CITES are protected in accordance to Article IV, where the export, re-export and import of any specimen of the species requires prior grant and presentation of an export permit, monitored by a scientific authority. In addition, the introduction from the sea of any specimen of a species requires the prior grant of a certificate from a Management Authority. There are country-specific export quotas listed in CITES, referring to specimens of wild origin unless otherwise specified. For further information, see www.cites.org. In 1995 the CITES Animals Committee included *Strombus gigas* in the Review of Significant Trade process following concerns about the continuing growth of the industry, and problems with enforcement in several range states. The Review, performed by CITES and IUCN, concluded that local queen conch populations, and hence fisheries, were threatened, despite the survival of the species as a whole not being at risk. The Review concluded that illegal fishing and trade added pressures to this valuable resource. One of the main recommendations of the Animals Committee was to develop a regional management regime for the species. Queen conch became the first large scale fisheries product to be regulated by CITES.

Queen conch is recognized under Annex II of the SPAW (Specially Protected Areas and Wildlife) Protocol, as a species that may be used and requires protective measures. Harvest of queen conch is prohibited in the majority of U.S. federal waters surrounding Puerto Rico and the U.S. Virgin Islands (USVI) and in Florida, but can be harvested in territorial waters of Puerto Rico, and St. Croix. Queen conch is regulated in these areas by the United States' Caribbean Fishery Management Council (CFMC). Harvest levels, closure period, size limits (3/8″ lip thickness) and number of conch per boat have been set by the CFMC.

While there is no international regional fishery management organization in the Caribbean, several countries have been implementing management measures such as the introduction of export quotas and trade bans, and technical measures such as restrictions in the use of scuba and hookah gear by conch fishers. These diverse management regulations have been in place in Caribbean nations since the 1980s (Appeldoorn, 1994). Regulations range from complete closure of the fishery in Florida in 1986 to SCUBA gear restrictions in some of the Caribbean islands allowing for the survival of small, deepwater "refuge" populations (Berg *et al.*, 1992b). Resource managers from Caribbean countries created the International Queen Conch Initiative promoting a common management strategy in 1996.

C. TAXONOMY AND DESCRIPTION OF SPECIES

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
Order: Mesogastropoda
Family: Strombidae
Genus: *Strombus*
Species: *gigas*
Taxon: *Strombus gigas* Linnaeus, 1758
Common Name: Queen Conch, Pink Conch

Strombus gigas is a marine snail, more commonly known as the queen conch, and was described by Linnaeus (1758); the type locality was given as "America". Besides conch, they are also known as botuto (Venezuela), cambobia (Panama), carrucho (Puerto Rico), cobo (Cuba), guarua (Los Roques), lambie (Windward Islands) , and frequently called pink conch (Berg, 1976).

The queen conch is one of five species that form the genus *Strombus,* the others being *S. raninus, S. gallus,* and *S. costatus* (Sterrer, 1986). It is readily distinguished from other species by its deep pink aperture, a feature lacked by all other western Atlantic species (Randall, 1964). Its larger size is similar only to *S. goliath*, but the queen conch differs in the lack of pronounced spiral grooves on the body whorl and exterior surface seen in *S. goliath's* expanded lip (Sterrer, 1986).

The queen conch has a strong, smooth shell with a row of nodes at the shoulder of a whorl. The shell's aperture is long and narrow, and generally rose pink, sometimes yellow or light orange (Sterrer, 1986). The range in length (measured from the apex of the spire to the most distant edge of the anterior siphonal canal) of adults in the Caribbean has been recorded as of 143mm to 264mm. Queen conch age categories have been defined based on the formation of the lip (CFRAMP, 1999). The characteristic flared lip of the queen conch is not formed until the animal has reached its maximum or near-maximum size (Figure 2).

Figure 2. Juvenile (below) and adult queen conch

The lip of the queen conch when first laid down is thin and delicate but very broad. The shell of *S. gigas* actually decreases in its outer dimensions with time after the lip is developed. The shell, and particularly the lip, becomes thicker, but this does not represent growth of the whole organism. Boring organisms cause crumbling of the thin outer lip. With age, the lip becomes progressively shorter but thicker, as it is repaired with new shell. Relationships for both juvenile and adult *S. gigas* have been calculated for meat weight, wet-tissue weight, shell weight as a function of shell length and/or shell lip thickness for several populations in the Caribbean and summarised in CFRAMP (1999).

Like other snails, *S. gigas* is soft bodied, consisting of a black-speckled foot, a snout-like proboscis, a pair of tentacles, and two eyestalks topped with distinctive, colourful yellow eyes (Figure 3) (Randall, 1964).

Figure 3. Queen conch eyes

D. ECOLOGY

Habitat Requirements

Queen conch can be found in open water to depths as great as 100m, but most are found in shallow, clear water of oceanic or near-oceanic salinities at depths generally less than 75m and most often in water less than 30m deep (McCarthy, 2007). This limit may be associated with the occurrence of seagrass and algae (or with the depth of the photosynthetic zone in the area). They are found in groups of individuals, and adult conch seem to prefer seagrass meadows, primarily turtle grass, *Thalassia testudinum*, or manatee grass, *Syringodium filiforme* (Boettcher and Targett, 1996), but have also been commonly seen on sand flats (Randall, 1964), coral rubble and coral reefs (McCarthy, 2007). In Bermuda, queen conch are more commonly found on the outer reefs as opposed to inshore (Berg *et al.,* 1992a; Sterrer, 1992).

There is evidence that conch may remain partially buried for a considerable period of time, with only the opening of the anterior siphonal canal and the adjacent stromboid notch above the sand. While buried it is believed that these conch may be laying down a new layer of shell on the lip and body whorl near the aperture. The burying in the sand would aid in water flow reduction, facilitating the deposition of calcium carbonate on the shell. This behaviour is suspected especially in juveniles < 80mm, which are thought to bury during the day; however, they have been reported to emerge at night, becoming active on the bottom. This behaviour may explain in part low numbers reported during routine surveys. Juvenile conch greater than 80mm length have been observed to be more abundant on coral rubble bottom in 10–12m (30–40 feet) of water in the Virgin Islands, than in seagrass beds (Randall, 1964). All queen conch reported in Bermuda have been found in <20m depth (Berg *et al.,* 1992a; Manuel and Coates, *pers.comm.*)

General Biology

It has been suggested that the operculum is used by *Strombus* species as a defensive weapon against predators (Abbott, 1960). *Strombus gigas* moves in short hops, unlike other gastropods which glide by muscular wave action of the foot. The queen conch extends its foot forward, fixes it on the substrate, and does a vigorous muscular contraction, where the animal's shell is thrown forward. It is able to right itself when overturned.

Movement by queen conch seems to be a function of size. Tagging studies indicate that juvenile conch do not demonstrate much movement (<100´ or 30m over 2 months period), travelling from unvegetated areas to adjacent seagrass meadows at approximately 35–54mm shell length (Randall, 1964; Sandt and Stoner, 1993). However, with increasing size, the movements of the tagged conch become progressively greater, with a maximum of 950 feet (290m) from the point of tagging recorded for an adult conch (Randall, 1964). More recently, acoustic telemetry was used to study movements of adult queen conch within aggregations in the Florida Keys over a 12-month period (Glazer *et al.*, 2003). Mean home range was calculated to be 5.98 ha, based on latitude and longitude bi-weekly records and estimates of minimum speed and degree of site fidelity.

The main predators of queen conch are loggerhead turtles, sharks, eagle rays, and spiny lobsters (Randall, 1964). High predation induced mortality is most likely for juveniles, but decreases among larger individuals (Ray *et al.,* 1994). Spiny lobsters are known to use their mandible to break away the edge of the conch shell until an inner whorl is exposed which is small enough to be crushed between the mandibles (Delgado *et al.*, 2002). Spotted eagle rays are believed to crush conch between 83–143 mm in their jaws, and are thought to be one of the most devastating predators to queen conch populations in general. Tiger shark gut contents imply that queen conch is an important part of their diet in the Florida Keys. Xanthid crabs less than 5mm in carapace width have been shown to be important predators of conch in the first weeks after settlement (Stoner, 1997).

Feeding

Strombus gigas is herbivorous, and does not seem to show any discrimination in the plant material they eat. In general, the dominant plants in a particular habitat in which conch are found are the principal food of these conch. For example, queen conch from a bed of *Halophila baillonis* were seen to feed almost exclusively on this angiosperm; whereas, in beds of *Syringodium*, this species was predominant in conch stomach contents, as cylindrical segments up to 35mm long (Randall, 1964). In addition, conch living on sand ingest much sand, as it is intermingled with filamentous algae. Diatoms, algae (*Halophila baillonis*, *Thalassia testudinum*, *Syringodium*), blue-green algae, as well as *Cladophora*, *Laurencia*, *Caulerpa*, sand and foraminifera have been reported in conch stomach contents.

Feeding activity has been recorded during the day and at night for adults; it is assumed that juveniles only feed at night when they emerge from the sand.

Reproduction and Life Cycle

The life cycle stages of the queen conch have been well described (Davis, 2005). Adult conch have separate sexes and are sexually mature at about four years, after the lip has fully flared. In unfished populations, conch are found at a 1:1 sex ratio (Davis, 2005), an observation also made by Barrett (2000) in Bermuda's offshore queen conch aggregations. Fertilisation in *Strombus* is internal following copulation, which generally occurs from mid-March to November in the Caribbean, and reported between May and September in Bermuda with a seawater temperature range of 27–29 ºC (Randall, 1964; CFRAMP, 1999; Berg *et al.,* 1992b).

Sandy substrate is thought to be a requirement for spawning as generally, females produce egg masses in clean coral sand with a low organic content. In Bermuda, migration patterns of queen conch are not known; migrations into shallow water during the summer months to breed may occur, as was reported in the Bahamas (Stoner and Sandt, 1992). Spawning aggregations have been identified in Bermuda and continually reported as such since 1992 (Berg *et al.,* 1992b). Active mating and laying of egg masses was reported in most of these aggregations (Figure 4) (Berg *et al*., 1992b; Barrett, 2000).

Figure 4. Queen conch mating and laying egg mass, Bermuda

Reported breeding activity for each aggregation in Bermuda is given in Table 1; however, monitoring was not regular, and some activity may have occurred at other times, but not observed. Ten years later, mating and egg laying was still observed at Castle Roads and Hogfish Cut, but not seen at North Rock (Barrett, 2000); Ledge Flats was not surveyed at this time. More recently, observations made during benthic surveys continue to indicate the presence of mating and egg laying of queen conch between June and September, with one record at North Rock (2006–2008; Manuel and Coates, *pers.comm.*) Information during the winter months on reproductive activity is minimal. Reports by Manuel and Coates (*pers.comm.*) during benthic surveys in December and March do not indicate breeding activity, however a more focused investigation is needed to verify the extent of the spawning season in Bermuda, as queen conch are known to reproduce throughout the year in some regions (Brownell and Stevely, 1981).

Table 1. Preliminary observations on breeding activity of queen conch at each site, 1989. Monitoring was conducted between 8 May and 6 October, with more regular observations made starting 13 July. Two hurricanes passed by Bermuda during that summer, 6 August and 6 September. Berg *et al.*, 1992b.

Site	Castle Roads	Hogfish Cut	Ledge Flats	North Rock
Breeding Activity	8 May–14 Aug	None after 11 Aug	15 July–14 Sept	2 Aug–14Sept

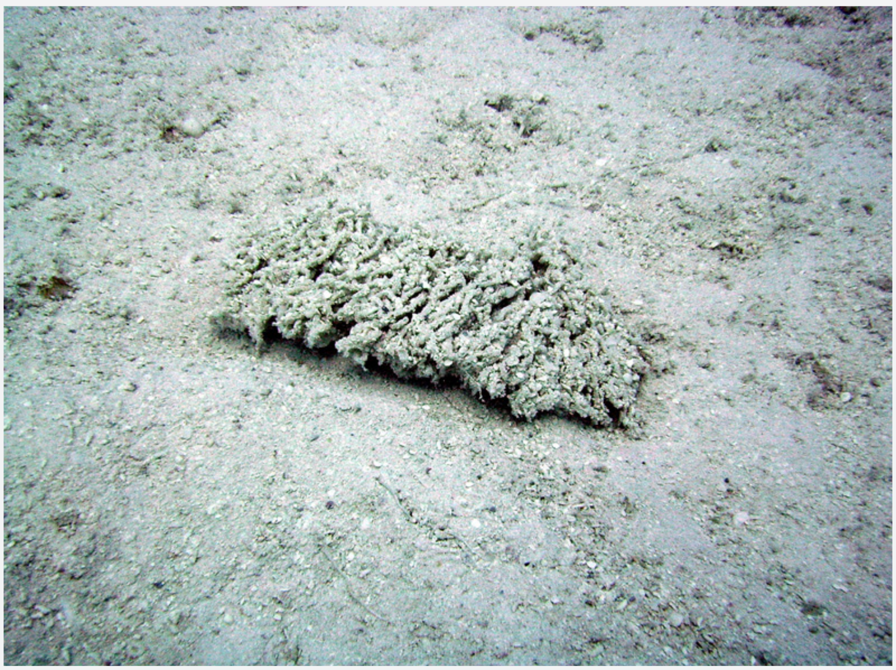
The viability of egg masses was verified following incubation in the laboratory in late 1980s and in 2008 (Berg *et al.*, 1992b; Sarkis, unpub.). Generally, each female lays an average of nine egg masses during one breeding season; each crescent-shaped egg mass contains approximately 400,000 eggs (Davis, 2005). The egg mass consists of a single continuous tube, which is sticky when first extruded; sand grains adhere to it. A thread of eggs is coiled within the tube, with five or six eggs per coil for *S. gigas*. The tube is folded back and forth upon itself, resulting in a compact mass which is slightly elongate and somewhat curved, evidently molded by the shape of the shell aperture. The adhering sand grains may provide camouflage and discourage predation (Figure 5).

Embryonic development proceeds quickly after fertilization, reaching the gastrula stage after 16 hours, the trochophore stage after 58 (Randall, 1964). The larvae, or veligers, emerge from the egg cases after approximately five days, and immediately assume a pelagic lifestyle, feeding on small phytoplankton. Larvae can be found in the open water as deep as 100m, but generally occur in the upper ocean layers above the thermocline. If conditions are right, the veligers settle to the bottom at 17–22 days after hatching, and continue to feed on plankton. Metamorphosis is complete at 28–33 days, when veligers lose the velar lobes, and the proboscis develops, if substratum cues are right (Davis and Stoner, 1994). After a month, the conch is shelled and resembles an adult.

Estimated growth rates yield mean length (tip of spire to distal end of siphonal canal), of 7.6–10.8cm for one year, 12.6–17.0cm for two years, and 18.0-20.5cm for three years (Brownell and Stevely, 1981). Hesse and Berg (1976) estimated that at an age of 2.5–3 years the conch stops building the shell in a spiral fashion and starts building the flaring lip. At this time, the animal will continue to grow more meat.

Queen conch reach market size of 18.8cm with a total weight of 845g, and a meat yield of 100g at 2.5 years (Berg, 1976). Adult specimens can weigh up to 2 kg (Catarci, 2004).

Figure 5. Queen conch egg mass, Bermuda



E. CURRENT THREATS

While the queen conch is not currently threatened with extinction, the observed decline throughout its geographical range has warranted its inclusion in Appendix II of CITES, demonstrating the necessity to regulate its commercia quency in shallow waters make this species an extremely easy target for fishers. Conch are mainly taken by hand or by simple fishing gears, such as a long pole bearing two metal tines or forks (Catarci, 2004). The meat is sold either fresh or dried, and the shells are utilized in pottery and jewelry. The queen conch fishery has a long tradition in the Caribbean region, but commercial fishing only expanded in the mid-late 1970s. This was due to an increase in demand for *Strombus* meat both within the Caribbean and in foreign markets, and to the growing tourism industry increasing the demand for shells and jewellery (Catarci, 2004).

TRAFFIC reports the expansion of the fishery between 1992 and 2002, developing into a large-scale commercial fishery with almost industrial characteristics in some Caribbean countries (Theile, 2002) and becoming one of the most important marine fisheries in the

Caribbean region. The economic and social value of queen conch fisheries for producing countries is reported in Catarci (2004). This led to the over-harvesting of the species throughout much of its geographical range and despite diverse management regulations put in place in the Caribbean since the 1980s, natural populations declined (Appledoorn, 1994). Trade, although known or suspected to be unsustainable from many Caribbean countries, continued as a result of strong export demand. Illegal harvest, including fishing of the species in foreign waters and subsequent illegal international trade is believed to be a widespread problem in the Caribbean region (Theile 2001). Increasing fishing pressure on a naturally slow growing species led to closure of some of the fisheries.

Although there is no documentation on the level of queen conch harvesting in Bermuda, anecdotal records imply their abundant occurrence until the late 1960s with population decline observed thereafter, leading to a complete ban on harvesting in 1978. Despite prohibitions on taking of queen conch, concerns of stock preservation are ongoing as there has been little evidence of recovery 30 years later; similar observations were made for the Florida populations, protected since 1986 (Stoner and Ray-Culp, 2000). This lack of population growth may be related to stock size, as hypothesized by Appeldoorn (1988), attributed in part to the limited ability of locating a mate at low population density and to the potential stimulation of gametogenesis in females by contact with males. Studies by Stoner and Ray-Culp (2000) in Bahamian queen conch populations indicated no mating behaviour where density was less than 56 conch.ha^{-1}, and an increase in reproductive activity where density was near 200 conch.ha^{-1}.

Predation may affect recruitment to natural populations, potentially inducing mortality namely in juveniles as reported in other regions (Ray *et al.*, 1994). In Bermuda, there is little documentation on the impact of predators on the queen conch population, although both spiny lobsters and spotted eagle rays are present on the platform.

There are no threats per se to the queen conch population in Bermuda; however, the lack of recovery despite 30 years of protectionism raises a number of questions. These include: the extent of occurrence of breeding activity, the availability of productive nursery and feeding grounds, and the recruitment level to the natural populations.

I. The extent of occurrence of breeding activity

Is stock size in Bermuda populations affecting reproductive activity? This factor was discussed by Stoner and Ray-Culp (2000). These authors conclude that most conch populations in the Bahamas are probably at or near densities where Allee effects (or depensation) present a serious obstacle to stock recovery (< 200 conch.ha^{-1}), and recommend that management plans include preservation of reproductive stock structure- i.e. enhancing local adult densities by transplanting.

II. Productive Nursery and Feeding Grounds

Aggregations listed in Bermuda are identified as breeding grounds, but the location of feeding grounds and nursery grounds is uncertain. It is unknown as to whether the feeding grounds are at the same location as the breeding grounds, or whether conch travel for feeding. Seasonal migrations of adult queen conch have been recorded in the Bahamas between sites of different substrate type (Stoner and Sandt, 1992). In addition, documentation on the relative changes in abundance between *S. costatus* and *S. gigas* in Bermuda raises questions on habitat availability (Abbott and Jensen, 1967).

III. Recruitment

Preliminary allozyme analyses suggest that the queen conch population in Bermuda may be genetically isolated from Caribbean populations (see Section F for details). As queen conch populations in Bermuda are often found on the outer edge of the platform, the question of larval retention and recruitment level to the natural populations is raised. Verification of the genetic difference between Bermuda and Caribbean populations, as well as the association of larval settlement with current patterns on the Bermuda platform is needed. Furthermore, enhancing recruitment of first year class individuals has been addressed in preliminary studies by translocating viable egg masses from offshore aggregations to protected inshore bays by Berg *et al.* (1992b). These authors collected 260 egg masses from four queen conch breeding sites and released these in Shelly Bay, a protected inshore bay; successful hatching of larvae and successful growth to juvenile stage was speculated based on the subsequent presence of first-year class individuals.

F. CURRENT STATUS

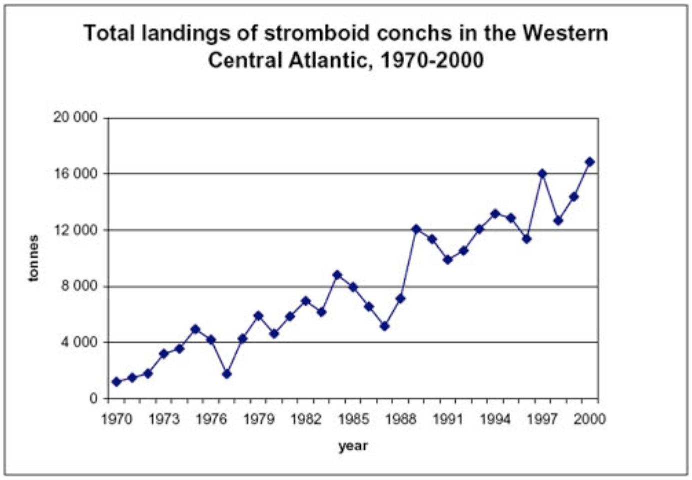
Global Distribution

Strombus gigas is found throughout the Caribbean, in the Gulf of Mexico, Brazil, South Florida, the Bahamas and Bermuda (Figure 6). It forms an important food for many local communities.

Figure 6. Geographical distribution of the queen conch, *Strombus gigas*, in the Caribbean region. Not showing northernmost and southernmost points (Bermuda and Brazil respectively).

The FAO database Fishstat + has been the main data source used for the analysis of queen conch production and trade figures (Catarci, 2004). The following information on global distribution can be found online at www.fao.org/DOCREP/006. Landings of stromboid conch nei (*Strombus* spp.) in the Western Central Atlantic increased from 1,200 MT in 1970 to the record peak of 16,857 MT in 2000, with fluctuations in the mid-1980s and at the beginning of the 1990s (Figure 7). However, Fishstat + data do not include conch landings in the United States, but according to the National Marine Fisheries Service (NMFS), United States' landings of "Snails (Conch)" increased from 433.9 MT in 1970 to 1,292 MT in 2001, peaking in 1994 at 3,319 MT (NMFS landings data).These landings refer to live weight (meat and shell; meat is 7–8% of total live weight).

Figure 7. Total landings of *Strombus spp.* in the Western Central Atlantic, 1970–2000



Exports of conch, whether fresh, frozen or chilled, from developing countries in the Western Central Atlantic area, followed an almost constantly growing trend from 183 MT in 1979 (US$689,000), to 698 MT in 1997 (US$5.4 million). In 1998, exports declined to 351 MT (US$3.87 million), to recover in the following years and reach 545 MT (US$4.5 million) in 2000 (Figures 8 and 9). The United States are the main world importers of conch, with imports of fresh/chilled conch totalling 975MT in 2000 (US$5.9 million) and 1,250 MT in 2001 (US$6.6 million) (NMFS trade data).

Figure 8. Exports of conch from Western Central Atlantic developing countries, quantity 1979–2000

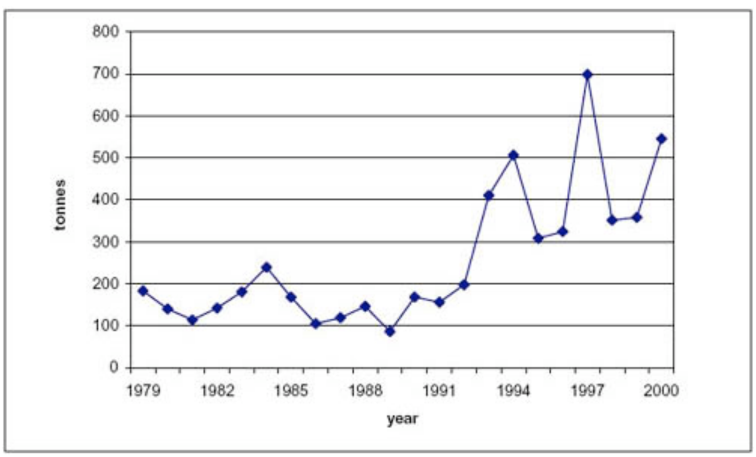
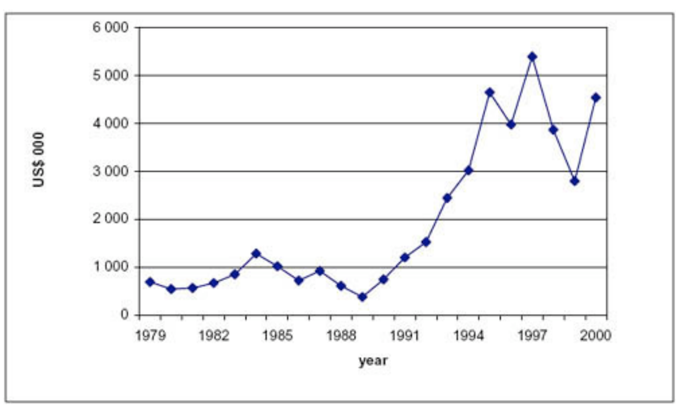


Figure 9. Exports of conch from Western Central Atlantic developing countries, value 1979–2000

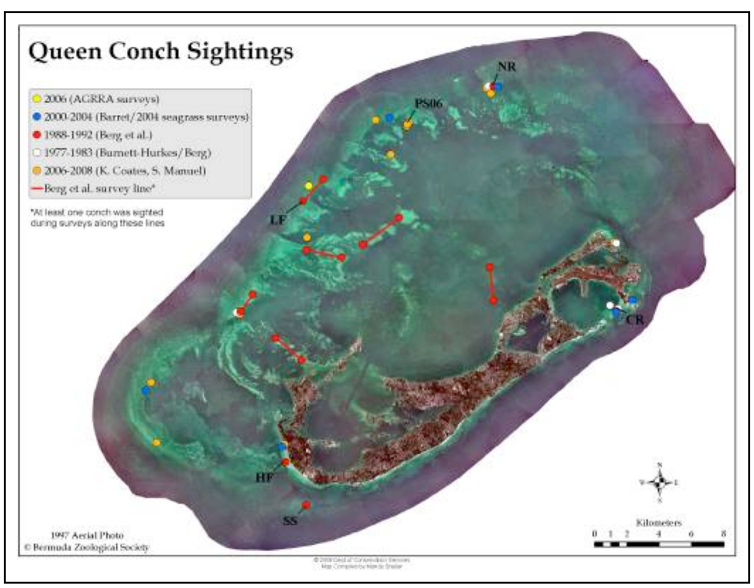


Local Distribution

There is a possibility that queen conch in Bermuda is genetically isolated from Caribbean populations, as suggested by Mitton *et al.* (1989) following allozyme analyses. Comparisons were made for queen conch samples from eight localities across the Wider Caribbean. Variations of 18 enzyme systems were assayed with gel electrophoresis, and seven of the 18 loci were polymorphic; these were used to describe population structure. Results showed that allelic frequencies in Bermuda were different from Caribbean populations for two alleles (Lap and Mdh), demonstrating little gene flow with other populations. Although this reproductive genetic isolation needs to be ascertained, the need for action towards the preservation of this Bermuda stock is further emphasized.

Surveys conducted 10 years after the ban (1988/1989) to determine population status of *Strombus gigas* in Bermuda indicated low population levels; 81 transects of 2,443 m^2 each, covering approximately 0.16% of the platform, resulted in 39 adult queen conch in 1988 (Berg *et al.,* 1992a). A second survey in 1989, covering 0.0575% of the platform resulted in a total of 91 queen conch (Berg *et al.,* 1992b). Estimated density for the submerged platform was reported as 0.52 ± 1.6 $ind.ha^{-1}$ and 2.94 ± 9.6 $ind.ha^{-1}$ respectively. During more recent benthic surveys, Manuel and Coates (*pers.comm.*) report queen conch in other localities, with an average count of 1.4 ind per transect and 2.6 ind per transect at North Rock and PS 06, based on 50m x 1m transects surveyed a minimum of six times between 2006 and 2008 (Figure 10). A summary of queen conch sightings made over the years during surveys of the platform is illustrated in Figure 10. Other records have been noted by divers; these include areas on either side of Cooper's Island, West of North Rock (P. Rouja, *pers.comm.*), Fort St. Catherine, West of Western Blue Cut (J. Gray, *pers.comm.*), and East of Eastern Blue Cut (J. Ward, *pers.comm.*). A more comprehensive survey is required to assess the status of conch populations in these areas.

Figure 10. Survey Summary for queen conch on Bermuda (1988–2008): sightings and five breeding aggregations: CR=Castle Roads, HF=Hogfish Cut, LF=Ledge Flats, NR=North Rock, SS=South Shore



Unfortunately, queen conch surveys have been sporadic, using different methodologies, hence making it difficult to establish population status and changes. Nonetheless, results seem to indicate some stabilization of the population since 1992. The number of queen conch reported in Bermuda are similar to those reported for the Florida Keys between 1987 and 1990 (Berg and Glazer, 1995), but much lower than those reported in other Caribbean populations during the 1990s (CFRAMP, 1999). In Bermuda, queen conch are usually seen on the edge of the platform, with no individuals observed in the inshore basins; in 1988, Berg *et al.* (1992a) found no *S. gigas* inshore, but did report an abundance of another strombid species, *S. costatus*, in the protected bays.

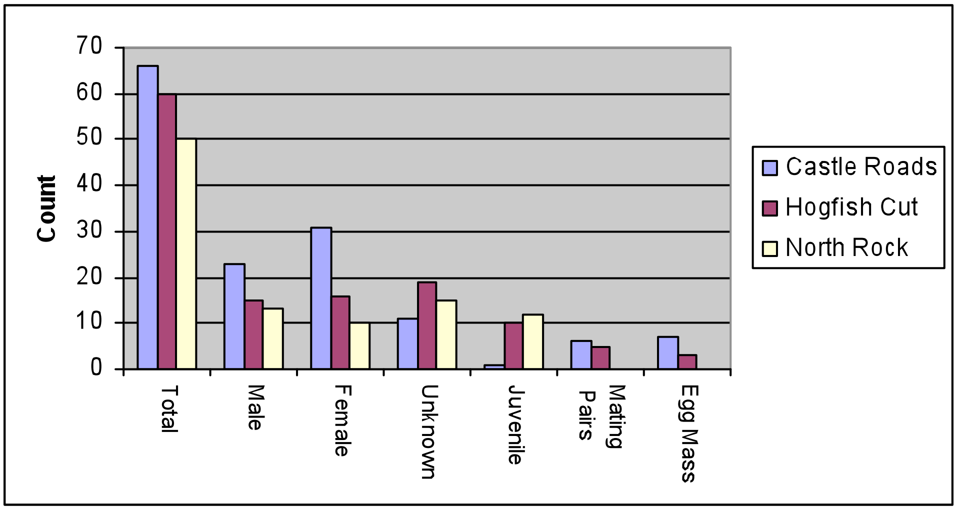
Five aggregations were identified at the periphery of the platform (Figure 9; Berg *et al.,* 1992b). For the most part, adult conch were found on a sandy bottom with light cover of seagrasses, *Thalassia sp.*, *Halodule sp.* and *Syringodium sp.* The number and density of adult queen conch found for each aggregation is reported in Table 2. Density was estimated, for the purpose of this document, based on the area surveyed (0.2923 ha, using a 30.5m radius circle).

Table 2. Densities at four queen conch breeding aggregations, data from Berg et al. (1992b). CR=Castle Roads, HF=Hogfish Cut, LF=Ledge Flats, NR=North Rock

Site	CR	HF	LF	NR
No. of conch	40	51	116	193
Density (in.ha^{-1})	137	174	397	660

Differences in age distribution among aggregations were determined, based on shell length and shell thickness (Berg *et al.,* 1992b). First and second year class individuals were recorded at Ledge Flats and North Rock, but most were old adults. The only two sites where there was no significant difference among size were Castle Roads and Hogfish Cut. Mean shell length ranged from 22.94 ± 1.34cm at Ledge Flats to 25.76 ±1.70 cm at Castle Roads, and shell thickness from 1.43 ± .27 cm at Hogfish Cut to 2.57 ± .42 cm at Ledge Flats. This agrees in part with subsequent results by Barrett (2000), who reports the highest number of juveniles at North Rock – constituting 24% of the aggregation – and lowest at Castle Roads – only 2% of the aggregation. A summary of the demographic analyses of the three aggregations is given in Figure 11, illustrating a relatively equal male:female ratio at Hogfish Cut and North Rock, and slightly in favour of females at Castle Roads. Reproductive potential was implied to be low at North Rock, as there were no mating pairs or egg masses recorded. On the other hand, although juvenile records were lowest at Castle Roads, six mating pairs and seven egg masses were observed. Hogfish Cut appeared to be the "healthiest" site with 17% of recorded conch being juveniles, and five mating pairs observed along with three egg masses.

Figure 11. Demographic data on queen conch populations in three breeding grounds in Bermuda (Barrett, 2000).



G. CURRENT CONSERVATION ACTION

Total protection of queen conch is in effect in Bermuda, prohibiting the taking of this species for any purpose. Special permits are required for research. Observations are made during benthic surveys, but there is currently no specific programme for queen conch conservation put in place locally. However, there have been efforts on a regional scale. A stock rehabilitation hatchery for *Strombus gigas* was put in place at the Keys Marine Laboratory at Long Key, Florida by the United States Fish and Wildlife Conservation Commission (Catarci, 2004). The first experimental releases of farmed specimens in the wild did not meet the expected results as released conch were very vulnerable to predators. Further experimental releases were more successful as scientists introduced the timing factor as one of the variables to be considered prior to the release, and thus minimizing predation. Survival during the tests that followed ranged from a low of 0 per cent for small size juveniles during the spring season to a high of 49.7 per cent of larger juveniles during autumn (Florida Keys National Marine Sanctuary, 2001). Transfer of queen conch hatchery-produced juveniles to the natural environment has been the object of several studies, as high mortality has plagued conch planting efforts in Venezuela, the Bahamas and Puerto Rico in the 1980s (Creswell, 1994). A number of factors need to be taken into consideration, including conch size, season, abundance of predators, density of conch, structural complexity of the habitat, and artefacts associated with hatchery rearing. For example, hatchery-reared conch have lower rates of burial and shorter apical spines on the shells, potentially negatively influence long-term survival (Stoner, 1997).

The potential relationship of breeding aggregations to patterns of larval settlement driven by oceanic currents, imply that the recruitment of queen conch larvae to nursery grounds depends upon upstream spawners. This leads to the presence of 'sources' and 'sinks' in the Caribbean region, a relationship which needs to be considered in management and recovery programmes (Stoner, 1997). This may not affect Bermuda, as there may be little gene flow with Caribbean populations (Mitton *et al.,* 1989), but should be considered when assessing nursery grounds.

Distributional pattern in early post-settlement conch also indicates that most settlement occurs in the immediate vicinity of the long-term nursery grounds (Stoner *et al*. 1992). The uniqueness of queen conch nursery habitats has important implications for both fisheries management and stock enhancement of this resource. Despite the presence of very large seagrass meadows in certain conch-producing areas such as the Bahamas, Belize, Mexico, and Florida, only relatively small sectors of the meadows may actually have production potential for queen conch, either because they lack larval recruitment features or suitability as benthic habitat. Transplant experiments indicate that most seagrass beds, in fact, cannot support juvenile conch. The most productive nursery habitats appear to be determined by complex interactions of physical oceanographic features, seagrass and algal communities and larval recruitment. These critical habitats need to be identified, understood, and protected to ensure continued queen conch population stability (Stoner, 1997).

PART II: RECOVERY

A. RECOVERY GOAL

This Recovery Plan first addresses the degree of gene flow between Bermuda and Caribbean populations, allowing for a clear understanding of the actions necessary to enhancing natural stocks on the Bermuda platform. The primary goals are to provide protection for critical habitats of the queen conch, *Strombus gigas*, and promote active breeding by investigating the density factor of adult conch in aggregations and the re-establishment of historical breeding sites and/or new breeding grounds. In addition investigating recruitment to the natural populations and evaluating the environmental parameters required for productive nursery grounds are key to enhancing the number of reproductively mature conch in Bermuda aggregations. If successful, this will ensure self-sustainability in Bermuda queen conch populations, and provide the potential for an increase in populations to historically known levels.

The short-term goal (three years) is to ascertain the genetic isolation of Bermuda's queen conch and assess more accurately the current status of mature and juvenile conch, including the identification of their breeding, feeding and nursery grounds. Simultaneously, the adaptation of known culture protocols in the hatching of egg masses and larval rearing under controlled conditions to Bermuda, will enable the assessment of egg viability, larval and post-larval growth and survival from all current aggregations.

The long-term goal (15 years) is to first attempt the restoration of the historical area of occupancy of queen conch on the Bermuda platform, following the evaluation of the current environmental status of these sites. Should this not be possible due to environmental changes, the adequacy of new sites as breeding grounds and/or nursery grounds will be investigated through the translocation of egg masses, hatchery-produced juveniles and/or adult individuals. The ultimate goal is to ensure a degree of larval retention on the Bermuda platform yielding sufficient recruitment for a self-sustainable population.

B. RECOVERY OBJECTIVE AND CRITERIA

Favourable conservation status will be achieved when:

- Population status and distribution of queen conch on the Bermuda platform are known
- Breeding, feeding and nursery grounds identified and given due protection
- A minimum of 75% of historical sites are shown to sustain an actively breeding population with demonstrated recruitment, or a minimum of eight breeding sites with densities enabling optimal reproductive activity and self-recruitment

These overall objectives translate into specific targets outlined below:

Short-term target (three years): Genetic analysis of Bermuda's queen conch populations. Survey known locations, assessing the density of juvenile and sexually mature conch. Provide legal protection of selected critical habitats identified as breeding and/or feeding, nursery grounds if needed. Analyse environmental requirements for productive nursery grounds and impact of predation on smaller size classes. Compare egg masses from current breeding sites for hatching rate, larval and post-larval growth and survival under controlled conditions. Investigate juvenile rearing and transfer to the natural environment. The development of a hatchery programme at the multi-species facility at the Field Station of Coney Island will provide the tools for providing data on the early life stages of this species and its requirements for growth and survival.

Long-term target (15 years): Investigating current larval retention and natural recruitment to the existing populations. Assess need for establishing breeding populations to historical sites and/or in more protected bays inshore. Evaluate selected sites, considering biological, physical and chemical factors required for larval retention, and current patterns to productive nursery grounds. Investigate translocation of adults to new breeding grounds, monitoring mating and egg laying. Investigate translocation of egg masses in light of recruitment to nearby productive nursery grounds, investigating hatching, post-larval settlement growth and survival compared to simultaneous transfers of hatchery-produced juveniles. Field trials taking into account factors associated with hatchery-produced juveniles will provide some information on suitability of habitats selected. A monitoring programme will be implemented evaluating growth, survival, reproductive potential and recruitment to the population at selected sites.

C. RECOVERY STRATEGY

Queen conch populations have been protected since 1978 in Bermuda, with little evidence of change and recovery. Causes for this are uncertain and need to be investigated to develop a successful recovery plan. All recent surveys have been conducted in conjunction with other studies or as short-term student projects. These have been useful but need to be more focused towards the gathering of specific information, assessing namely, density of breeders per site, juvenile numbers per site, as well as determining the location of feeding and nursery grounds, if different from breeding grounds. This should fill the gaps in our current knowledge of the population demography and movement. In light of this, it is considered worthwhile as a first step in the implementation of this recovery plan to conduct comprehensive surveys for this species, and assess recruitment potential for the existing population. Assessing queen conch juveniles has always been reported as a difficult task, attributed in part to their behaviour. A preliminary study on a known conch site in Bermuda, determining whether juvenile conch come to the surface at dusk would provide the basis for a more comprehensive survey programme and allow for a more accurate estimate of the existing population.

Furthermore, self-sustainability of Bermuda's queen conch populations may prove crucial to the preservation of the species, based on preliminary results on Allozyme frequency. The suggestion of genetic isolation of Bermuda population from the Caribbean populations (Mitton *et al.,* 1989) needs to be confirmed, as it may further emphasize the importance of this recovery programme.

It is the goal of this plan to first investigate the potential of restoring historical breeding sites. Environmental changes may have occurred and need to be investigated prior to enhancement efforts. The possibility of poor larval retention currently occurring attributed to the location of breeding aggregations on the rim of the platform, thus entraining larvae offshore rather than on shallower nursery grounds, warrants further investigation guiding site selection for breeding grounds. Should historical sites no longer be adequate, other sites located in more protected areas inshore will be assessed. The current abundance of *Strombus costatus*, the harbour conch, in inshore bays, may limit habitat availability for *S. gigas*, and may be a factor for consideration. The impact of predation is another factor which has not been assessed in Bermuda, and may prove of importance to the survival of the smaller size classes.

In light of the information available and the questions raised, the use of culture techniques for *S. gigas* will provide a tool for research into egg viability, development of the early life stages and possibly habitat suitability for juveniles. The existence of well known hatchery techniques and the presence of a ready to run culture facility in Bermuda facilitate this part of the programme, providing an additional opportunity for successful recovery. A monitoring programme evaluating recruitment, growth, survival and reproduction of the species at selected sites will be critical to the recovery plan.

D. TOOLS AVAILABLE FOR STRATEGY

The tools available for recovery have already been tested to a certain extent, either in Bermuda, or in the Caribbean region. The current knowledge of queen conch sites in Bermuda will provide the basis to more comprehensive surveys. As the most recent survey targeting queen conch was conducted eight years ago, it is advised to return to all known breeding grounds. Due to the low density of conch, it is recommended that the density of adult conch be determined at each site by counting all conch within three closely spaced but non-overlapping circles (20m radius), arranged in a triangular pattern. This strategy has been employed to facilitate surveys of the largest possible area, and to reduce heterogeneity in population density. Each conch counted should be sexed as male or female, and each mating pair should be recorded. Juvenile conch (i.e., those without a flared shell lip) should not be considered in these density estimates. An initial density survey should be conducted during the known breeding season (May to September). However, in order to obtain accurate data regarding the number of mating pairs, it is recommended that the duration of the survey run from April to the time where mating pairs are no longer observed. For this it is not necessary to survey all sites, but select two sites with known breeding activity.

In order to assess movement, conch can be tagged using various methods. A high percentage of recovery has been obtained by other authors, when drilling a hole through the base of a spine, and tying a tag by monofilament line through the hole. A simpler method may be the gluing of a tag with crazy glue; this has proved extremely effective for other mollusc species. A tagging programme for at least three of the major sites (Castle Roads, Tudor Hill and North Rock) should be established, following breeding season to assess any movement and other sites of importance to their survival. The number of conch tagged will be dependent on the numbers found at each site; a sample size of 20 should provide the necessary information. Should a tracking system be available at this time, it would be worthwhile investigating. Previous translocation of egg masses has been successfully attempted in Bermuda, with subsequent observations of year 1 Class individuals; it is recommended that similar studies are conducted with an in-depth investigation into the viability of egg masses collected. Translocation of adults has also been investigated in Florida queen conch populations, and the ability to regain reproductive capacity by translocated individuals was demonstrated (Delgado *et al.*, 2004).Techniques for juvenile production under controlled conditions are well known and documented (Davis, 2000). Overexploitation of wild queen conch stocks led the United States, Mexican and Caribbean fishing industries to develop conch aquaculture strategies. In the Caribbean, queen conch culture has been practised since 1984 at the Caicos Conch Farm in the Turks and Caicos Islands. In the United States, the Florida Straits Conch Company opened in Key West in 1999. The company performs both research and commercial activities. In Merida, Mexico, the Aquaculture Division of the Harbor Branch Oceanographic Institution performs aquaculture research and public education. These techniques may easily be adapted in Bermuda given a hatchery facility; preliminary work on hatching of egg masses has been successful in Bermuda.

Recent investigations have demonstrated successful breeding in captive stocks, maintained in indoor tanks (Shawl *et al.,* 2003). Under controlled conditions, settlement of veligers is induced by exposure to *Laurencia* algae or using hydrogen peroxide (Davis 2000; Shawl *et al.*, 2003). Settled larvae grow in the nursery from 1–4mm for a period of five weeks. Thereafter, they can be reared in sand trays in a recirculating system at a density of 3,200 conch.m^{-2} until they reach 40mm in size. Outdoor tanks are used for further grow-out prior to transfer in the field. Constraints in reproduction techniques of conch are availability of space for juvenile grow-out.

Finally, several studies have been conducted on the transfer of hatchery-reared juveniles to the field, providing the basis for the establishment of a protocol in Bermuda. There is a general concern as to the survival of hatchery juveniles in the field, and Stoner (1997) has recommended a transfer size of 7.5cm (or one-year-old conch).

E. STEP-DOWN NARRATIVE OF WORKPLAN

The following abbreviations are used:

BBP: Bermuda Biodiversity Project

DCS: Department of Conservation Services

Hatchery: Government hatchery situated at Coney Island Field Station

The actions needed to achieve recovery are as follows:

1. **Evaluation of Current Population Status and Distribution**

   Actions proposed:

   - Assess density of breeders and reproductive activity in known aggregations
   - Assess size class distribution
   - Verify reproductive genetic isolation of Bermuda queen conch populations
   - Assess current feeding grounds, nursery grounds and/or movement
   - Identify critical habitats for legislative protection
   - Assess impact of natural predation

   Work Team: DCS, BBP

   Team Leader: DCS

   Assistance: BBP, Hatchery

   Outputs: Determination of queen conch population status, including size frequency, as well as breeding, feeding and nursery grounds.

   List of Equipment: Boat, survey materials, hatchery materials. Funding for hatchery personnel required

2. **Captive Breeding Programme**

   Actions proposed:

   - Determining viability of egg masses and early stages development comparing offshore aggregations
   - Investigation of optimal environmental parameters for growth and survival of larvae, post-larvae and juveniles using culture techniques

   Work Team: DCS, Hatchery

   Team Leader: Hatchery manager

   Assistance: DCS

   Outputs: Determination of reproductive potential of existing population and of culture techniques for juvenile production

   List of Equipment: Hatchery equipment specific to conch rearing. Funding for hatchery staff (one full-time manager; one full-time technician). Funding for overseas consultant (part-time).

3. **Evaluation of spawning season and natural recruitment**

   Actions proposed:

   - Monitoring of egg masses over 10-month period
   - Qualitative and quantitative larval monitoring during 12-month period.
   - Monitoring programme for one- and two-year-old juveniles over two-year period

   Work Team: DCS, Hatchery

   Team Leader: Hatchery manager

   Assistance: DCS

   Outputs: Determination of spawning period and larval retention

   List of Equipment: Plankton sampling materials, small boat and SCUBA gear. Funding for hatchery staff (one full-time manager; one full-time technician).

4. **Increasing Extent of Occupancy**

   Actions proposed:

   - Habitat assessment of existing, historical sites and new sites including environmental parameters (water quality, sediment type, biota and food availability)
   - Translocation of adults
   - Translocation of egg masses
   - Transfer of hatchery-reared juveniles
   - Monitoring programme assessing juvenile settlement and growth

   Work Team: DCS, Hatchery

   Team Leader: Hatchery manager

   Assistance: DCS

   Outputs: Establishment of new populations

   List of Equipment: Materials required for chemical and physical analyses. Funding for hatchery staff (one full-time manager; one full-time technician).

F. ESTIMATED DATE OF DOWN LISTING

It is anticipated that it will take three years to evaluate the demography of the population, provide habitat protection to the species, and investigate the feasibility of hatching egg masses and rearing juveniles under controlled conditions. Increasing the extent of occupancy to suitable sites and monitoring larval recruitment to natural populations is estimated to be a long-term project of 10 years. It is only once that implemented actions are evaluated and demonstrate active reproduction of populations in a minimum of 75% of historical sites (or eight adequate sites) and sufficient recruitment for a self-sustainable population that down listing will be considered. This will first be considered 15 years from the date of implementation. Routine evaluation of the progress made in implementation of actions outlined in Section E and summarised in Part III are due to be conducted every five years; at this time, re-assessment of actions required will be made.

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		**Evaluation of current population status**	**24 months**	
	1	Assess density of breeders	9 months	DCS/Hatchery
	2	Assess size class distribution	12 months	DCS/Hatchery
	3	Verify genetic status	12 months	DCS
	4	Assess feeding, nursery grounds and movement	12 months	DCS/BBP/ Hatchery
	5	Legislate critical habitat protection	12 months	DCS
	6	Predation impact	24 months	DCS
2		**Captive breeding programme**	**3 years**	
	7	Determining viability of egg masses, larval, post-larval development	2 years	Hatchery
	8	Environmental requirements for growth	3 years	Hatchery
2		**Evaluation of spawning season and recruitment**	**2 years**	
	9	Monitoring of egg masses	10 months	DCS/Hatchery
	10	Qualitative and quantitative analyses of conch larvae	12 months	DCS/Hatchery
	11	Monitoring of juveniles to nursery grounds	2 years	DCS
2		**Increasing extent of occupancy**	**10 years**	
	12	Site selection	1 year	Hatchery
	13	Translocation of adults	1 year	DCS/Hatchery
	14	Translocation of egg masses	2 years	DCS/Hatchery
	15	Transfer of hatchery-reared juveniles	5 years	DCS/ Hatchery
	16	Monitoring programme for juvenile assessment	5 years	DCS/ Hatchery

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Old Queen Conch