# The future of bêche-de-mer and trochus fisheries and aquaculture in Australia.

Final report to the Fisheries Resources Research Fund

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# Executive summary

Sea cucumbers are found throughout the world's oceans, however only a few tropical species are sought for their commercial value for production of the final processed product, bêche-de-mer. Growing demand for bêche-de-mer has resulted in increased fishing effort and catches in many countries. Collapses in sea cucumber fisheries have been reported in countries where inadequate management regulations have been implemented.

Currently, Australian sea cucumber fisheries are limited to tropical regions where species high in commercial value, such as black teatfish, white teatfish and sandfish, are fished preferentially. The major markets are Hong Kong, Singapore and Taiwan. Of the sea cucumber species sandfish fetch the highest price in the South East Asian markets (US $34-45/kg).

*Trochus niloticus* has been harvested for centuries for subsistence purposes, but it is only since the early 20th century that trochus has been harvested commercially for use in the manufacture of buttons. Intensive commercial harvesting has resulted in trochus stocks on many reefs in the Indo-Pacific, including some reefs in tropical Australia becoming over-exploited.

Trochus shell importing countries include France, Germany, Italy, Spain, Japan, UK and USA. The value of trochus has often declined when cheaper alternatives, such as plastic buttons, become available on the market. The trochus fishery in Australia is currently considered to be an economically marginal fishery in terms of economic return, returning about $4/kg however, for Aboriginal communities in the Kimberley, Western Australia and Torres Strait Islander communities fishing for trochus provides an important source of income for some community participants who have very limited opportunities for financial independence.

Over-exploitation of sea cucumbers and trochus has spurred research into the mass production of juveniles in hatcheries and reseeding techniques. *Holothuria scabra* is the only tropical species of sea cucumber that can currently be mass-produced in hatcheries and has proven to be the easiest of the commercial species to culture, however, to date there has only been one successful spawning in Australia. Trochus have already been successfully cultured in Australia.

Restocking has been considered as an alternative management option to fast-track the restoration of depleted stocks in some fisheries. Restocking is practised successfully on a temperate sea cucumber, *Stichopus japonicus* in Japan but there has been limited research into the growth and survival of reseeded juvenile tropical sea cucumbers and what research has been conducted has been confined to sandfish.

There have been numerous attempts at reseeding trochus. These trials have had mixed success.

The challenge for management authorities of sea cucumber and trochus fisheries is to find and implement management strategies that will create sustainable fisheries that maintain the fish stocks while ensuring a reasonable livelihood for those involved, now and into the future. Further information on sea cucumber and trochus biology and ecology are needed to enable fisheries managers to set sustainable fisheries regulations in the longer term.

Finding a means of obtaining timely, accurate and reliable catch and effort data, devising and implementing education and extension programs and alternative compliance methods are also high priorities for effective management.

Research into restocking has to date generally been poorly designed and long-term monitoring has been rare, making any conclusions about the usefulness of restocking difficult. Before restocking or stock enhancement becomes a viable management option major challenges such as; scaling-up current hatchery technology to produce sufficient numbers of juveniles, developing effective strategies for releasing cultured juveniles into the wild and identifying them will need to be addressed. The economic viability of restocking also needs to be assessed. For example, the cost involved with setting up a hatchery facility combined with declining demand and price received for trochus may make reseeding of trochus presently cost prohibitive.

Translocation of trochus and sea cucumber broodstock and triggering of asexual reproduction in sea cucumber species that have this capacity should be further investigated and evaluated to see if these are potential alternative means of reseeding or enhancing stocks of these animals in Australia.

# Introduction

Sea cucumbers are members of the class Holothuroidea in the phylum Echinodermata. They are sometimes referred to as holothurians (Preston 1997) or bêche-de-mer. Bêche-de-mer, also called trepang, is actually the highly valued dried body wall of the sea cucumber. Processing methods for sea cucumber include gutting, boiling, smoke–drying and sun-drying (Anon 2002).

The term sea cucumber, bêche-de-mer and trepang are used interchangeably in legislation and past research, therefore for the purpose of this report the term bêche-de-mer can be assumed to mean sea cucumber unless specified otherwise.

Sea cucumbers are found throughout the world's oceans. Over 1000 species of holothurians have been taxonomically described but only a small portion of these are commercially important (Williams *et al.* 2000). Among coastal species, the holothurians of the order Aspidochirotida, which contain the commercial species, tend to predominate in tropical waters, while Dendrochirotida species, which are generally of little commercial interest, are more commonly found in temperate waters (Conand 1989).

International bêche-de-mer trade began in the waters of India, Indonesia and the Philippines over 1,000 years ago, and expanded to Oceania in the last half of the 20$^{th}$ century (Conand and Sloan 1989).

Economic liberalisation and growing affluence of mainland China has led to a significant increase in demand for bêche-de-mer in the past 15 years. Steadily rising prices being received for bêche-de-mer has resulted in increased production in many countries and has frequently been followed by the fishery collapsing (Preston 1997).

A marked increase in landings and holothurian exports combined with limited fisheries data, a small amount of biological information and population parameters for commercially important species and the existence of few management measures in developing countries are all contributing factors to the decline of sea cucumber populations (Conand and Byrne 1993).

The nature of sea cucumbers and the simple, low technology methods used to fish and process them also make them an ideal commodity for rural areas in developing tropical countries. The raw resource is often plentiful in these areas and cold storage and other facilities needed for trade of other marine products may not be readily available. In some countries the fishing of sea cucumbers plays a major role in providing income-earning opportunities to communities where other earning opportunities may be limited (Preston 1997).

In Australia sea cucumber fisheries occur in State and Commonwealth waters off Northern Territory, Western Australia and Queensland (including Torres Strait). About a dozen species are commercially harvested however most of the effort is focused on the high value species sandfish (*Holothuria scabra*), black teatfish (*H. nobilis*) and white teatfish (*H. fuscogilva*). (Hunter *et al.* 2002). Recent research has shown that Torres Strait sandfish (Skewes *et al.* 1998) and Queensland east coast black teatfish (Uthicke and Benzie 2001) have been over-exploited.

*Trochus niloticus* is commonly known as the topshell or trochus shell. It is a member of the family Trochidae, a large family of marine gastropod mollusc containing several hundred species (Nash 1993). It is a conical shaped shell that inhabits shallow tropical reefs and can attain sizes of over 120mm (measured across the base) (Department of Fisheries 2001).

Trochus shell has been used for centuries by Indigenous peoples of the Pacific to make ornaments and jewellery. In the Western world the main use of trochus has been in the manufacture of buttons from the thick layer of mother-of-pearl (nacre) obtained from the trochus shell (Nash 1993).

Commercial trochus harvest began in the Pacific and driven by global demand, followed a similar course in most countries. Trochus fishing around the world suffered because of the introduction of synthetic buttons and virtually ceased in the mid-1950s. This was followed by a recovery in the 1970s brought about by increased price (Nash 1993), however in recent years the demand for trochus and therefore market price has once again declined.

Trochus occupy a well-defined habitat (the intertidal and shallow subtidal zones on the seaward margin of the reef) and, despite their cryptic behaviour they are easily located by experienced fishers (Nash 1993). Like sea cucumber fishing, trochus fishing does not require sophisticated fishing and processing equipment and in many situations they can be harvested by gleaning reefs at low tide.

Trochus stocks have been fished very intensively during the periods when demand for trochus shell and therefore price were high, so much so that trochus stocks on many reefs in the Indo-Pacific, including Australia have been over-exploited (Department of Fisheries 2001).

Trochus are found and fished in two tropical regions of Australia, the Great Barrier Reef and Torres Strait Islands off the coast of Queensland and in Western Australia on the coral reefs of the Buccaneer and Bonaparte Archipelagos in the Kimberley and at Rowley Shoals, Scott, Seringapatam and Ashmore Reefs and Cartier and Browse Islands (Department of Fisheries 2001).

The over-exploitation of these animals has spurred much research into the mass production of juveniles in hatcheries and restocking techniques, which aim to provide methods for stock enhancement.

This report provides a summary of the history and current status of bêche-de-mer and trochus fisheries in Australia and overseas, their markets, and management regulations in place in these fisheries. It also examines management challenges for the fisheries and alternative sustainable harvest methodologies as well as reviewing the technology utilized overseas for bêche-de-mer and trochus aquaculture, research into reseeding of these animals and the potential for reseeding of these animals in Australia.

# Part 1. Bêche-de-mer and trochus fisheries in Australia

## History of Bêche-de-mer fishing in Australia

Bêche-de-mer fisheries and trade are more than 1000 years old and originated in China and India (James and James 1994). Bêche-de-mer, also known as sea cucumber and trepang has been fished in northern Australia since the $18^{th}$ century. The trade of bêche-de-mer in Australia dates back at least to 1700, when Macassans[1] from South Celebes[2] fished in Northern Australia. The fishery began to decline in 1881 when the South Australian government (which initially controlled the Northern Territory) began taxing Macassan boats fishing in Australian waters. By 1907 the South Australian government ceased issuing licences to the Macassans (Cannon and Silver 1986). This is believed to have been due to a local industry run by whites, but employing Aboriginals having been established (Williams *et al.* 2000).

A lower level of exploitation continued in Northern Territory until about 1945 (Fallu 1997) however sea cucumbers were fished mainly in the Torres Strait region. During 1916-1917 fishing season 124 boats were registered solely for the collection of bêche-de-mer with 558 tonnes of sea cucumber, mainly black and white teatfish being exported from Thursday Island (Williams *et al.* 2000).

The fishery continued to expand until 1928. After this the exports from Australia declined until the 1940's, probably due to declining stock numbers caused by over fishing or due to a tax increase on fishery products by the South Australian Government (Uthicke and Klumpp 1996). By the Second World War the fishery had contracted into insignificance as the demand for product had dropped significantly and prices were too low for profitable fishing. After the Second World War till the early 1980's there were virtually no exports of bêche-de-mer from Australia.

In the late 1980's – early 1990's interest in the bêche-de-mer fisheries in Australia again increased due to an enhanced demand in China and in Chinese communities around the world. As a result prices were seen to increase causing harvesting of bêche-de-mer to once again intensify (Williams *et al.* 2000). The late 1980's saw Northern Territory, Torres Strait and Queensland introduce new measures to manage bêche-de-mer harvest (Breen 2001). In the early 1990's the interest in fishing for bêche-de-mer in Western Australia increased. This probably reflected the increase in demand for bêche-de-mer from the growing affluence of China at this time (Breen 2001).

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[1] Fishermen and traders from the Celebes.

[2] An island province of Indonesia known as Sulawasi

# Current Status of Australia's Commercial Bêche-de-mer Fisheries

Bêche-de-mer fisheries in Australia are limited to the tropical regions where species high in commercial value such as black teatfish *(Holothuria nobilis)*, white teatfish (*H. fuscogilva)* and sandfish *(H. scabra)* tend to be fished preferentially.

## Queensland East Coast

Information contained in this section is derived from the following source unless referenced otherwise:
Breen, S. (2001) Queensland East Coast Bêche-de-mer Fishery Statement of Management Arrangements. Queensland Fisheries Service, Queensland.

Fishing for bêche-de-mer in northern Queensland has a long history. Total annual landings of bêche-de-mer from 1895 to 1948 have been reported as ranging from 5.1 to 542 tonnes of sun-dried product. With an average conversion factor of 10 (bêche-de-mer have an average water content of 90%) this represents a range of 51 to 5420 tonnes wet weight (Queensland Fisheries Service 2001).

The Queensland East Coast Bêche-de-mer Fishery is managed by the Queensland Department of Primary Industries' Queensland Fisheries Service (QFS) under the *Fisheries Act 1994* (the Act) and its subordinate legislation *Fisheries Regulation 1995* (the Regulations). Prior to April 1999, the Queensland Fisheries Management Authority managed the Torres Strait Bêche-de-mer Fishery under Queensland law. This fishery is now under the jurisdiction of the Torres Strait Protected Zone Joint Authority (PZJA). However, QFS and the Australian Fisheries Management Authority (AFMA) carry out day-to-day management including licensing and enforcement.

Harvest of bêche-de-mer from Gulf of Carpentaria waters is also managed by the QFS. Bêche-de-mer is considered a developmental fishery in this area and is managed by permit. This fishery is the subject of its own Declaration of Controlled Specimens under the *Wildlife Protection (Regulation of Exports and Imports) Act 1982* now under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The main focus of the bêche-de-mer fishery on Australia's east coast is in reef waters to 30m depth between Townsville in north Queensland (19°30'S) to the Torres Strait (10°00'S). However, commercial fishing is authorised from Hervey Bay to the tip of Cape York (R. Lowden, Seafresh Australia P/L, April 2002, pers. comm.). Sandfish harvest has occurred in the Tin Can Bay/Hervey Bay area, but the take of sandfish from these areas is now prohibited. Table 1 describes the major commercial species of bêche-de-mer in Queensland.

**Table 1:** Major commercial species of bêche-de-mer in Queensland.

| Common name | Species name | Primary target area |
|---|---|---|
| Sandfish | *Holothuria scabra* | Tin Can Bay / Hervey Bay – Inshore waters (Take of sandfish from these areas closed) |
| Lollyfish | *H. atra* | Reef |
| Black teatfish | *H. nobilis* | Reef-top (Take of black teatfish closed since 1999) |
| White teatfish | *H. fuscogilva* | Deep reef areas / inter reef |
| Deep water redfish | *H. echninites* | Reef |
| Blackfish | *H. miliaris* | Reef |
| Surf redfish | *H. mauritiana* | Reef |
| Elephant's trunk | *H. axiologa* | Reef |
| Prickly redfish | *Thelenota ananas* | Reef |

There is no information on recreational fishing levels of bêche-de-mer in Queensland but it can be assumed to be very low.

Total bêche-de-mer harvest in the East Coast Bêche-de-mer fishery peaked in 1993/94 at around 350 tonnes, with 27 authorised operators in the fishery (Tyrer 1997). Following a collapse of black teatfish stocks, the former Queensland Fisheries Management Authority reduced the quota available of black teatfish to zero in 1999. Following concerns that white teatfish may subsequently be targeted and overfished, a white teatfish quota was introduced. Since that time, the quota (which operates on financial year basis) has been reviewed annually. A total allowable catch (TAC) of zero tonnes for black teatfish remains, while currently the quota of white teatfish is 127 tonnes. Table 2 summarises the bêche-de-mer catch for the East Coast Bêche-de-mer Fishery between 1993/94-2000/2001.

**Table 2:** Bêche-de-mer catch for the East Coast Bêche-de-mer Fishery between1993/94-2000/2001.

| Year | Tonnes |
|---|---|
| 1993/94 | 359 |
| 1994/95 | 357.915 |
| 1995/96 | 201 |
| 1996/97 | 175 |
| 1997/98 | 211 |
| 1998/99 | 196 |
| 1999/2000 | 225 |
| 2000/2001 | 257 |

(Data obtained directly from Queensland Fisheries Service)

Prior to its closure in 1999, the primary species harvested on the east coast was black teatfish, which made up approximately 65% of the total catch. Now the primary target species are white teatfish and prickly redfish. The far northern section of the Great Barrier Reef and the Cairns area are targeted for the reef species such as white teatfish. The quota for white teatfish is generally met in a season. At present Cairns is the main port of landing in the fishery.

The major management strategies in place in the East Coast Bêche-de-mer Fishery are those that limit the harvest of bêche-de-mer by output control. These are as follows:

- Total Allowable Catch (TAC) of 380 tonnes;
- Individual quotas allocated to 18 authority holders in 15, 25 and 50 tonne units; and
- Minimum legal sizes (15cm applies to all species).

Fishing effort is managed by:

- limiting the number of authorisations in the fishery to 18;
- limiting collection methods to either diving or collecting fish by hand;
- limiting the number of crew authorised to fish under an authority to 10;
- limiting the use of dinghies attached to a primary fishing boat to four with a maximum size of 7 metres;
- a prohibition on collecting sandfish in Tin Can and Hervey Bays.

A detailed validated logbook program also operates in the fishery. Both fishers and buyers are required to submit trip reports in a timely manner. Further, a telephone prior reporting system, which provides the Queensland Boating and Fisheries Patrol officers an opportunity to inspect landed product, validates quota. Vessel Monitoring System (VMS) has been compulsory for all boats operating in the fishery since 2000.

Queensland Fisheries Service believes that the risk of over-exploitation in the Queensland East Coast Bêche-de-mer Fishery is largely mitigated by the protection of reefs through the Great Barrier Reef Marine Park zoning arrangements (at least 22% of the Great Barrier Reef is closed to fishing), and the related surveillance and enforcement, the natural fishing habits of authority holders, and the fisheries management regulations in place.

**Proposed bêche-de-mer fishing areas**

Applications for developmental fishing permits to harvest bêche-de-mer in Moreton Bay and on Boot and Ashmore reefs, which lie to the east of Torres Strait, have been received by Queensland Fisheries Service (QFS). Both have been made available to interested parties to provide comment and recommendations to QFS on whether these new fisheries might be developed and if so the most appropriate manner in which to implement the developmental phase in accordance with Ecological Sustainable Development (ESD). Consultation is still occurring for both applications (P. Gaffney, QFS, September 2002, pers. comm.).

## Northern Territory

Information contained in this section is derived from the following source:
Kelly, M. (2001) Trepang Fisheries Status Report 2000. Department of Primary Industry & Fisheries, Darwin, Australia.

A commercial fishery of around 300 tonnes (whole weight) per annum for the collection of bêche-de-mer operates in the Northern Territory. Fisheries in the Northern Territory are controlled under the *Fisheries Act 1993* and the *Fisheries Regulations 1993.*

A total of six licences to collect and export species of the class Holothuroidae have been granted. Licences became transferable during 1993 to further encourage development and investment in the fishery and the same company now owns all six licences. Fishing is restricted to two designated zones, eastern and western, and size limits are imposed. Collection can only be undertaken by hand and the number of people in the water collecting under each licence is limited. The use of scuba and hookah gear was approved to allow fishermen to use safety cages because of the risk of crocodile attack. No maximum harvest quantities are set at this stage however, daily logbooks and regular reports are required. Although other high value commercial species are found in Northern Territory waters the sandfish is the only species reportedly taken in NT.

Table 2 summarises the estimated bêche-de-mer catch, effort and catch per unit effort (CPUE) between 1996-2000. Catch per unit effort for 2000 rose from that of 1999. Kelly (2000) reported that this increase coincided with licensees fishing new areas, so may not indicate an increase in abundance of bêche-de-mer.

**Table 3:** Estimated Bêche-de-mer Catch, Effort and CPUE: 1996-2000

| | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| **Catch** ***(Kgs Wet Weight)*** | 83,386 | 94,811 | 96,710 | 227,757 | 245,976 |
| **Effort** ***(Diver Days)*** | 851 | 958 | 1,758 | 1,232 | 953 |
| **CPUE** ***(Kgs/Diver Day)*** | 98 | 99 | 55 | 184 | 258 |

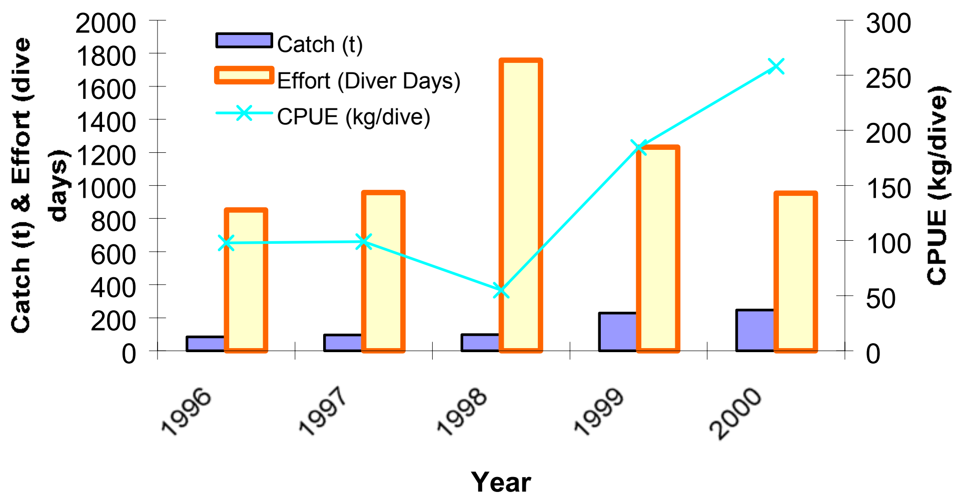


**Figure 1:** Catch and Effort for the NT Trepang Fishery, 1996 – 2000

The level of recreational take of bêche-de-mer is not known, but is probably insignificant. The local Asian community may take limited amounts for personal consumption. There are no records of fishing tour operators reporting bêche-de-mer in their catch.

Aboriginal rights to utilise bêche-de-mer in a traditional manner are provided for by Section 53 of the *Fisheries Act*. The level of utilisation by this sector is currently unknown and current evidence is that bêche-de-mer is not used as a traditional food source.

A number of communities in Arnhem Land have historical links with previous commercial exploitation of the resource by both the Macassans and Australians. Several Aboriginal communities have shown interest in acquiring licences to fish bêche-de-mer commercially, but a major constraint has been the lack of finance to purchase licences, suitable vessels and processing facilities.

## Western Australia

Information contained in this section is derived from the following source:
Fisheries Western Australia (2001). Preliminary Summary of Catch and Effort from the 2000 Western Australian Bêche-de-mer Fishery.

Fisheries in Western Australia are managed in accordance with the provisions of the *Fisheries Resources Management Act 1994* and the *Fish Resources Management Regulations 1995* that are administered by Fisheries Western Australia. Prior to 1994 there was little harvest of bêche-de-mer. However, increased demand from Asian countries in 1995 and 1996 stimulated fishermen to harvest bêche-de-mer from Western Australian waters.

The bulk of the bêche-de-mer catch is taken north from Exmouth Gulf to the Northern Territory border, but catches are also taken from the Shark Bay area and the south coast of Western Australia. There are 6 commercial permits to harvest bêche-de-mer.

The majority of the fishing effort is divided between the northern sector of the fishery (the Kimberley) and the Pilbara sector close to Port Hedland.

The bêche-de-mer catch in Western Australia is dominated by sandfish *(H. scabra).* Fishing takes place in shallow water mangrove lagoons and estuaries. The silty, low visibility conditions in which these stocks are sought provide protection for the species, as visibility of the water is generally limited.

The fishery is spread over an extremely large area, there are only 6 commercial permits, and due to the high tidal range of the northwest of Western Australia, strong currents and poor visibility, stocks can only be accessed during neap tides.

A summary of catch and catch rates for the fishery is shown in Figure 2. The graph shows how the total catch increased markedly from 1995 to 1997 (93 to 382t). However, since 1997 catches have decreased to 83 t (live weight) for the 2000 season. CPUE peaked in 1996 (1,128 kg/day) then declined steadily to below 600 kg/day in 1998-9. There was a slight recovery in CPUE in 2000 to 628 kg/day.

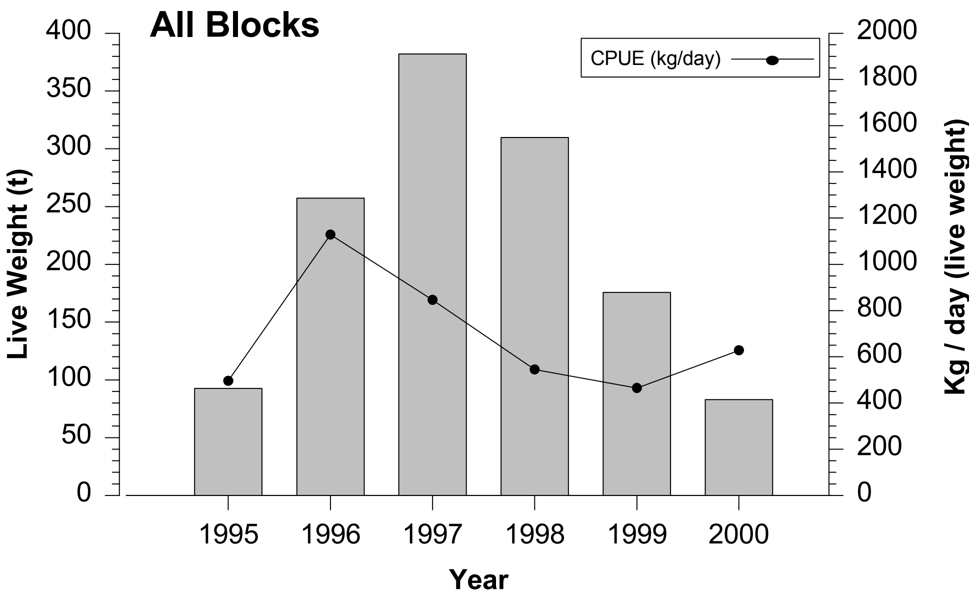


**Figure 2:** Production (tonnes/live weight) and catch rate (kg/day) from the Western Australian bêche-de-mer fishery.

The level of commercial exploitation of bêche-de-mer in Western Australian waters has historically been, and continues to be, controlled by a series of input and output controls. These controls include:

- prohibition of fishing for bêche-de-mer without a Western Australian fishing boat licence;
- prohibition of fishing for bêche-de-mer by means of underwater diving and/or breathing apparatus without an endorsement on the fishing boat licence and commercial fishing licence;
- limitation on the number of specific bêche-de-mer endorsements issued to 6;
- restriction on the method of harvest to hand collection only;

- restriction on the number of crew members to 6, with no more than 4 permitted to dive at any one time;
- prohibition on the take of bêche-de-mer in particular areas;
- minimum size at which particular species of bêche-de-mer may be harvested (as listed below in Table 3); and
- prohibited fishing areas.

**Table 4:** Minimum size limits for bêche-de-mer in the Western Australian Bêche-de-mer Fishery.

| Species | Common Name | Length (cm) |
|---|---|---|
| *Holothuria scabra* | Sandfish | 16 |
| *H. fuscogilva* | White teatfish | 32 |
| *H. nobilis* | Black teatfish | 26 |
| *H. atra* | Lolly fish | 15 |
| *Thelenota ananas* | Prickly redfish | 30 |
| *Actinopyga echninites* | Deep water redfish | 12 |

Renewal or extension of permits is dependent upon (but not limited to) a minimum catch of four tonnes (wet weight) in the previous season. All licences are transferable.

Daily logbooks have been introduced into the fishery in 2002, which will enable the closer assessment of the sustainability of the fishery and bêche-de-mer stocks.

## Commonwealth – Torres Strait & Coral Sea

### Torres Strait

Information contained in this section is derived from the following source:
Torres Strait Protected Zone Joint Authority. (2000). Torres Strait Protected Zone Joint Authority Annual Report 1999-2000. Australian Fisheries Management Authority, Canberra.

The Torres Strait Bêche-de-mer Fishery is under the jurisdiction of the Protected Zone Joint Authority (PZJA) and comprises of tidal waters within the Torres Strait Protected Zone, and the outside but near area declared under the *Torres Strait Fisheries Act 1984*.

Participation in this fishery is limited to Torres Strait traditional inhabitants with the exception of one long-term non-islander who was active in the fishery prior to the introduction of licence limitation in the fishery in April 1995. Traditional fishers who wish to harvest bêche-de-mer commercially are required to hold a Traditional Inhabitant Fishing Boat Licence endorsed accordingly. These licences are not limited at this time. In the case of the non-traditional fisher, a Torres Strait Boat Licence is required. A total of 148 traditional vessels are presently licensed for the fishery.

Bêche-de-mer stocks in the Torres Strait are managed primarily through the use of the following measures:

- TAC of 0 tonnes for *Holothuria scabra* sandfish (closed since 1998);
- competitive TAC of 260 tonnes for *H. nobilis, H. fuscogilva* (teatfishes);
- competitive TAC of 260 tonnes for *Thelenota ananas* (prickly redfish);
- competitive TAC of 80 tonnes for all other species of bêche-de-mer;
- minimum size limits on each species (see Table 4);
- limited to hand collection only;
- ban on the use of underwater breathing apparatus;
- no new non-islander fishery participants;
- limitation of boat length to 7 m; and
- cap on the number of buying vessels.

**Table 5:** Minimum size limits for bêche-de-mer in Torres Strait Protected Zone

| Species | Minimum size |
|---|---|
| Lollyfish | 15cm |
| Black teatfish | 25cm |
| White teatfish | 32cm |
| Elephant's trunk | 24cm |
| Prickly redfish | 30cm |
| Deepwater redfish | 12cm |

Traditionally sandfish was the primary species in the Torres Strait, however pressure on the stocks has resulted in the total fishery closure for this species in 1998 and buyers and fishers have needed to target other species. Surf redfish, black teatfish and white teatfish amongst other species are also harvested in large numbers in the Torres Strait. Table 5 summarises the bêche-de-mer harvest for 1995 & 1997-1999.

**Table 6:** Bêche-de-mer harvest for 1995 & 1997-1999

| Year | Surf redfish (tonnes) | Black and white teatfish (tonnes) | Others (tonnes) | Total (tonnes) |
|---|---|---|---|---|
| 1995 | | | 29 | 1200-1400* |
| 1997 | 57 | 29 | 15 | 115 |
| 1998 | 80 | 20 | 12 | 115 |
| 1999 | 15 | 23 | 29 | 50 |

*Industry estimate of total catch, all but ~50 t being sandfish. Official figures revealed total harvest to be around 1000 tonnes.

Kung (2002) reported that the catch rate for teatfish declined from 245 kg/day/authority in 1996/97 to 9 kg/day/authority in 2000/01. This decline in catch rate would suggest a declining resource of black teatfish on a fishery wide basis (Kung 2002).

Catch rates for surf redfish have declined from 281 kg/day/authority in 1996/97 to 44 kg/day/authority in 2000/01, again suggesting overexploitation of this resource (Kung 2002). In contrast the catch rates of all other species combined showed an increase. This can be explained by the shift in effort to lower value species following the depletion of higher value species such as the teatfish and surf redfish (Kung 2002). Both black teatfish and surf redfish are now regarded as over-exploited (Skewes *et al.* 2002).

**Coral Sea**

The Coral Sea Bêche-de-mer Fishery is controlled under the *Fisheries Management Act 1991* and the *Fisheries Administration Act 1991,* which are administered by the Australian Fisheries Management Authority (AFMA) based in Canberra.

To date very little is known about the status of bêche-de-mer in the Coral Sea Fishery (CSF). The main targeted bêche-de-mer stocks in the fishery are the white teatfish *(Holothuria fuscogilva*), black teatfish *(H. nobilis*), prickly redfish *(Thelenota ananas*), surf redfish *(Actinopyga mauritiana*), lollyfish *(H. atra*) and amberfish *(T. anax*).

Since 1993, AFMA has issued several permits to take bêche-de-mer in the CSF. As of July 2002, there are two permits for the sea cucumber sector of the CSF. However, an application for review has been lodged with the Administrative Appeals Tribunal that relates to an earlier AFMA decision not to regrant access to this sector to a third operator (M.Clarke, AFMA, July 2002, pers. comm.).

AFMA implemented precautionary management arrangements for the sea cucumber collectors in 2000 pending the outcome of current research projects. These arrangements included:

- an effective logbook, catch disposal record and other measures intended to improve catch monitoring and data collection;
- the requirement to carry and use a Vessel Monitoring System which will verify logbook location data and prevent mis-declaration of catches from depleted black teatfish stocks in the adjacent Queensland East Coast Fishery;
- a limit of 75t landed weight per year total catch of sea cucumber per Fishing Permit (for most high value species the ratio of landed weight in kg to pieces is approximately 1:1, but the ratio is lower for some of the species that are not currently being targeted); and
- the introduction of species-specific catch limits within the total catch limit for the five high value species taken in the Coral Sea Fishery.

A Research Project, funded by the AFMA Research Fund, has just concluded. This report provides a preliminary assessment of stock status for target species of sea cucumber in the CFS. AFMA has recently consulted with the current concession holders in the CFS about management responses to this report. These include a reduction in the catch limit for two high value species, black teatfish and white teatfish (M.Clarke, AFMA, July 2002, pers. comm.).

All CSF permits are transferable. At the completion of each fishing season the permit holder is required to provide AFMA with an annual report covering all aspects of the fishing operation, including fishing area, detailed catch and marketing arrangements. In accordance with interim management arrangements for all sectors of the CSF, no further access will be considered until longer-term management arrangements for those sectors are formalised.

# History of Trochus Fishing in Australia

Trochus shell has been used for centuries by Indigenous peoples of the Pacific to make ornaments and jewellery. In the Western world the main use of trochus has been in the manufacture of buttons. It has however also been utilised to make necklaces, rings and hairclips, as a hardener in varnish, in floor tiles (Nash 1986[a]) and wood-inlays in some furniture (Nash *et al.* 1995).

Although trochus has been fished by Aboriginal people for subsistence purposes in Australia for centuries, it is only since 1912, when trial shipments were sent from Torres Strait reefs to Japan, the United Kingdom and Europe, that it was commercially harvested (Nash 1989). Commercial fishing first began in the Torres Strait but by 1917 the annual catch was nearly 970 tonnes and boats had moved out of Torres Strait and down the east coast of Cape York Peninsula. In 1927 commercial quantities of trochus shell were found on the southern end of the Great Barrier Reef (GBR) and from then on the entire GBR was exploited for trochus (Nash 1989). Most trochus boats were crewed by Torres Strait Islanders (Nash 1986[b]). A small trochus fishery, which was largely incidental to pearl shell fishing, also existed in Western Australia prior to 1939 (Sutherland 1996).

As the exported trochus shell was used primarily in the manufacture of buttons the advent of plastics and its use in the manufacture of buttons lead to the collapse of the fishery in the mid-1950s (D'Silva 2001). The trochus resources in King Sound, Western Australia which have cultural significance to the Bardi Aboriginal community and provide a major source of individual income and economic return for this community group, was also affected by the fishery's collapse (Ostle 1997).

Australia's trochus fisheries did experience resurgence in the late 1970s- early 1980s when the fashion houses of Europe and later Taiwan and other East-Asian countries, once again adopted the use of natural buttons on their high-quality shirts (Nash 1989), however in recent years the demand for trochus and therefore market price has once again declined to a point where it is considered to be a marginal fishery in terms of economic returns (R.Lowden, Seafresh Australia P/L, April 2002, pers. comm.).

# Current Status of Australia's Commercial Trochus Fisheries

The commercial trochus fishery is based on the collection of one species of trochus, *Trochus niloticus.*

## Queensland

Information contained in this section is derived from the following source unless referenced otherwise:
Ryan, K. (1999) Review of the Stock Monitoring Program for the East Coast Trochus Fishery. Queensland Fisheries Management Authority, Queensland.

The East Coast Trochus Fishery (ECTF) is managed under the *Fisheries Act 1994* and *Fisheries Regulation 1995*. The area of the fishery operates in tidal waters between Cape York and Gladstone. Exclusion zones (Green Zones) have been established by the Great Barrier Reef Marine Park Authority (GBRMPA), effectively excluding fishing activity from areas previously harvested for trochus. Mackay is the main port for the fishery.

There are six authority holders, each with a designated annual quota. The Total Allowable Catch (TAC) of the fishery is 250 tonnes. Available annual catch data for 1996-1999 shows that the annual catch of trochus from this fishery has continually been significantly under this TAC as seen in Table 6. Regulations apply to the licence holders in that licences are transferable, a maximum of four tender vessels not greater than 7 m in length are allowed and they must complete logbooks.

Minimum and maximum size regulations of 80 and 125mm respectively apply to the fishery. Trochus may be taken by hand or hand-held non-mechanical implements or by underwater breathing apparatus**.** The authority holder or a person approved by the Queensland Fisheries Service (QFS) must be present when trochus are taken.

**Table 7:** Annual catches for 1996-1999 for the East Coast Trochus Fishery

| Season | Fishing days | Catch (tonnes) | GVP ($) |
|---|---|---|---|
| 1996 | 220 | 126.1 | 765,300.5 |
| 1997 | 339 | 223.7 | 1.4 million |
| 1998 | 203 | 148.4 | 900,626.5 |
| 1999 | 240 | 191.2 | 1.2 million |

(Data obtained directly from Queensland Fisheries Service)

## Western Australia

Information contained in this section is derived from the following source:
Personal communication with B.Fraser, Executive Officer, Aboriginal Fishing Strategy, Fisheries Western Australia, May 2002.

The trochus fishery in Western Australia is managed under a policy designed specifically for Aboriginal communities. There are currently two Aboriginal communities involved in the fishery. Only one (Bardi Aborigines Association at One Arm Point) of which has significant history in the fishery. The fishery is located in the Buccaneer Archipelago region in the Kimberley. No other areas of Western Australia are known to possess commercial quantities of trochus.

Management arrangements for the fishery are developed in a co-management approach between Fisheries Western Australia and Aboriginal communities. This is essential as the fishery operates from a remote Aboriginal community and there is very limited compliance available from Fisheries Western Australia for trochus. Essentially, agreement is reached on the appropriate management arrangements and then compliance responsibility is given to the community council, which controls who can participate in the fishery.

There is no TAC for the fishery. Management arrangements include a maximum size limit of 100mm, a minimum size limit of 75mm and a six-month seasonal closure. All trochus must be picked from exposed reef (i.e.: no diving is permitted). All shell must be sold through one central point.

Figure 3 shows the catch of trochus between 1985 and 2001. From this it can be observed that there has always been a large fluctuation in the catches of trochus. From discussions with fishers and other available information it appears that catches are linked directly to social issues within the community. For example, in some years where low catches have been reported there were housing projects in the community that resulted in more work for community members and less effort in the trochus fishery.

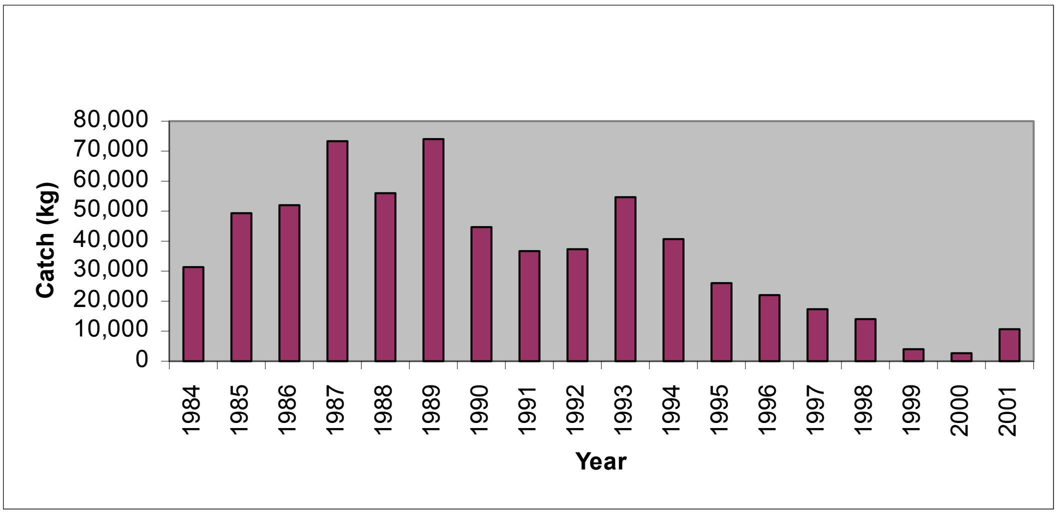


**Figure 3:** Catch for the Bardi Trochus Fishery 1984 - 2001

Since 1995, when world trochus prices dropped significantly the catch has been decreasing. Recent low catches in the fishery have related to management measures specifically designed to reduce effort in the fishery. In 1998 seasonal closure was introduced to the fishery as a precautionary response to traditional owners' concerns that trochus stocks were declining. In addition, issues relating to native title and agreements between traditional owners resulted in one half of the fishery being closed for two years (1999 and 2000). This area was re-opened in 2001.

The low market price for trochus is also affecting the catch rates in the fishery with pickers receiving 20% less than they did in 2001. In 2001 the catch of trochus was capped at 11 tonnes by Bardi administration as a result of marketing difficulties (and low prices). The trochus season in 2002 commenced in March with approximately 6 tonnes being collected by May. The current price pickers are receiving for trochus is only $4.00 per kilo.

Although the commercial value of the fishery can be estimated by the catches and prices received for the product it does not accurately indicate the real value of the fishery to the local participants, who have a cultural link to the fishery and very limited opportunities for financial independence.

## Commonwealth – Torres Strait and Coral Sea

### Torres Strait

Information contained in this section is derived from the following source:
Torres Strait Protected Zone Joint Authority. (2000). Torres Strait Protected Zone Joint Authority Annual Report 1999-2000. Australian Fisheries Management Authority, Canberra.

The Torres Strait Trochus Fishery is a small, single-species commercial and subsistence fishery. It is however an important source of income for some Islanders, particularly women and children. Due to a recent decline in overseas market demands for shell in button manufacturing the level of participation in the fishery is relatively low.

Participation in the Torres Strait Trochus Fishery is limited to traditional inhabitants only and there are 47 licensed dinghies in the fishery. The taking of trochus is restricted to hand collection or by hand-held non-mechanical implements. The use of underwater breathing apparatus is also permitted. A minimum size limit of 80mm and maximum size of 125mm applies to all fishing (except traditional). The total allowable catch for the TSPZ is 150 tonnes of trochus.

The status of trochus stock in the TSPZ is uncertain at present. Records held by the major mothership transporting trochus shell out of Torres Strait in 1999 indicated an approximate catch in the order of 24 tonnes. Log returns from individual islands indicated the commercial catch in 1998 as 1.8 tonnes and 1997 catch at 17 tonnes, with a value of approximately $0.1 million (~$5.80/ kg). The total catch for 1996 was 9.35 tonnes. All catches are well below the TAC of 150 tonnes.

### Coral Sea

There are only three permits allowing hand collection of lobster and trochus in the Coral Sea Fishery. As of July 2002, this access is a stand-alone permit allowing the hand collection of trochus and lobster with or without the use of diving equipment. A maximum of seven persons and two tender boats may be used for these operations, and performance criteria (20 days) apply. Very little data has been collected for this sector and its viability has not been demonstrated (M.Clarke, AFMA, July 2002, pers. comm.).

## Illegal fishing of bêche-de-mer and trochus in Australian waters

There are reports that PNG fishers illegally poach sea cucumbers in Australian waters near Warrior Reef in Torres Strait. Illegal fishing by PNG fishers is believed to have been occurring in this area since 1991, including both day and night poaching, and it continued through the closure of the fishery in 1993. Increased patrols in the area by Australian authorities resulted in the apprehension of 163 fishers during 1992 but few were prosecuted (Lokani 1996).

Indonesian fishermen, using traditional methods and sail-powered vessels, are permitted in an area of the Australian Fishing Zone authorised under a Memorandum of Understanding between the Australian and Indonesian Governments. Generally, this area includes the outer areas of Ashmore Reef, Cartier Island, Browse Island and Scott Reef, in the far north-western waters of Australia. A number of illegal fishing activities, including illegal fishing of bêche-de-mer have been detected in these waters (Fisheries Western Australia 2000).

Indonesian fishermen have also been caught illegally poaching trochus in the Kimberley, Western Australia. In 1995 Indonesian poachers were caught in the fishery with approximately 7 tonne of trochus. The total catch from poachers is unknown (B. Fraser, Fisheries Western Australia, May 2002, pers. comm.).

## The Environment Protection and Biodiversity Conservation Act 1999

Commonwealth legislative power in the environment is primarily delivered through the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The objects of the EPBC Act include protection of the environment, promotion of ESD and the conservation of biodiversity. It introduces an assessment and approval process for activities that are likely to have a significant impact on matters of national environmental significance. Some of these include nationally threatened species and ecological communities, the marine environment, and internationally protected migratory species.

Through a subsequent amendment in 2001, the provisions of the *Wildlife Protection (Regulation of Exports and Imports) Act 1982* (WP(REI) Act) were incorporated with the EPBC Act, coming into effect on 11 January 2002. This means that the EPBC Act now gives effect to Australia's obligations as a signatory to the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) as well as Australia's longstanding regulation of trade in native Australian wildlife.

The key feature of the EPBC Act for fisheries is that all Commonwealth-managed fisheries not previously assessed under the *Environment Protection (Impact of Proposals) Act 1974* will be required to undergo strategic environmental assessment. Also since the incorporation of the provisions of the WP(REI) Act, any export fishery will need undergo a similar assessment to the strategic environmental assessments required for Commonwealth fisheries. These features mean that all bêche-de-mer and trochus fisheries in Australia will need to be assessed.

To assist meeting the fisheries strategic assessment and export approval requirements of the EPBC Act, the Minister for the Environment and Heritage has released guidelines for environmental assessment of commercial fisheries (the *Guidelines for the Ecologically Sustainable Management of Fisheries*). The guidelines address the ecological sustainability of target and non-target species, their ecosystems and the management regimes to which the relevant fisheries are subject.

Environment Australia will now assess the ecological sustainability of the management arrangements for a fishery before exports from it are permitted. An exemption from export controls will be provided for marine species harvested in accordance with management arrangements assessed as ecologically sustainable. If a species is found to be subject to the export controls of the Act, an export permit or authority—restricted by conditions determined by the Minister for the Environment and Heritage—will be required before export of the species would be permitted. The amendments to export controls come into full effect in December 2003. In the interim, species that were exempt from export control under the WP(REI) Act will continue to be exempt while assessments are undertaken. The exception is a number of holothurians (that is, bêche-de-mer/sea cucumbers) that were previously exempt from export controls. Confusion with respect to taxonomy created serious inconsistencies, so all holothurians now come under the export controls of the EPBC Act (i.e. export fisheries will require permits, or have to have achieved exemption by demonstrating sustainability against the criteria).

# Bêche-de-mer and trochus fisheries in other countries

## Bêche-de-mer

Sea cucumber fisheries operate throughout the world. During the first half of the 20th century about 15 countries were thought to be producing a total of between 1,000 and 3,000 t annually (Conand 1989), primarily to supply Asian markets.  Production in the late 1970's and early 1980's ranged between 10,000 ad 15,000 t annually, with Philippines and Indonesia being the largest producers. From 1992 to 1997 the total annual catch of sea cucumber fluctuated around 90,000 metric tons live weight (Hamel and Mercier 1997). Production areas other than Australia are or have been Philippines, Indonesia, south and east Africa, islands of the Indian Ocean, India, Sri Lanka, Thailand, Malaysia, China, Taiwan, Korea, Japan and the Pacific Islands (Preston 1993).

Tropical fisheries tend to be multi-specific, whereas temperate fisheries are mono-specific. The species of highest commercial value in the tropical waters of the western Pacific and Indian Oceans are *Holothuria fuscogilva* (white teatfish), *H. nobilis* (black teatfish) and *H. scabra* (sandfish). Temperate fisheries are divided into western Pacific regions (*Stichopus japonicus*) and Eastern Pacific (*Parastichopus californicus*), with a small fishery developing in recent years (1994) in the Atlantic for a shallow nearshore species, *Cucumaria frondosa* (Anon 2002).

Since 1985 world production has increased due to an increase in demand from the People's Republic of China for a less expensive lower grade product. This has resulted in a change in the holothurian species being exploited, from first-category species such as *H. nobilis* and *H. fuscogilva* to species such as *Actinopyga miliaris* (blackfish) (Conand and Byrne 1993).

Historically bêche-de-mer fisheries have been characterized by long cycles of heavy exploitation followed by periods of rest during which the resource is able to recover. Generally these cycles are a mixture of fluctuations in worldwide demand and supply caused by wars, economic recession and other events beyond the control of the producer countries (Preston 1993). Over-exploitation is poorly documented for most areas of holothurian fishing and often indirect information such as declining catch rates with increased fishing effort or changes of target species towards lower value species have to be interpreted as signs of decline (Uthicke and Klumpp 1996).

Declines in resource abundance have been reported from collection areas in India, Thailand, Papua New Guinea, the Galapagos, New Caledonia, Philippines and several other collection locations. Overexploitation has been particularly notable in *H. scabra* and stocks in Fiji and PNG and other areas have collapsed as result of intense fishing pressure. This localized resource depletion has usually resulted in a forced closure of the fishery or in harvesters moving to other areas. However, like the sandfish population in Torres Strait it is now well recognised that populations take many years to show even slight recovery once their density is reduced below a critical mass, even after fishery closure (Preston 1993).

In Samoa, Tonga, Cook Islands and Palau only the intestines are collected for local consumption. These fisheries are likely to be sustainable as the animals are thrown back into the sea once the intestine is removed where they regenerate their organs (Anon 2002).

Most fisheries managers believe that a sustainable fishery is to be preferred over one that follows this “boom-and-bust cycle. However in most developing countries little official control and compliance is exercised in the artisanal sea cucumber fisheries (Conand and Byrne 1993).

Other countries have established management regulations to varying degrees and with varying levels of success. Often these regulations are implemented too late because stocks are already severely depleted. Some of the management measures that have been implemented in an attempt to prevent overexploitation include permit systems, quotas, seasonal harvest, rotational harvest, ban on take via SCUBA and minimum harvest sizes. In many countries, certain sites are closed to harvest due to overexploitation and the take of certain species is prohibited. Table 7 attempts to summarise the management regulations in place in countries involved in the export of sea cucumbers.

The bêche-de-mer trade has also had significant environmental consequences in some parts of the world. One of the most obvious environmental impacts is the deforestation of coastal areas. Some islands of Fiji for example were completely stripped of usable firewood early in the $19^{th}$ century as 10 tonnes of firewood were harvested to smoke 1 tonne of bêche-de-mer (Preston 1993). The destruction of mangroves for bêche-de-mer smoking is still a matter of concern in some countries, although this practice no longer occurs in Australia.

Sea cucumbers also play an important role in the ecosystem. They are responsible for the extensive shifting and mixing of substrate and recycling of detrital matter. Sea cucumbers consume and recycle sediment and organic matter into smaller particles, turning over the top layer of sediment and oxygenating the sediment. This process prevents the build up of decaying organic waste and may help to control populations of pests and pathogens. In some areas the removal of sea cucumbers from an ecosystem has resulted in the sea floor hardening, effectively eliminating habitat for some other benthic organisms (Anon 2002).

Mercier *et al.* (1999) however reported that the way sea cucumbers enrich or deplete a substrate of its organic contents might depend on the time of day. General organic depletion of rich substrates was observed in this study, but poor substrates with around 1% organic matter content appeared to be alternatively enriched or depleted by the presence of foraging juveniles. Moriarty *et al.* (1985) showed in cage experiments that the feeding activities of sea cucumbers may reduce bacterial and microalgal production in coral reef sediments and Uthicke (1994) reported that microalgal biomass might be reduced by sea cucumbers grazing at high intensities.

CSIRO Marine Research Division in Cleveland, Queensland are currently hosting a PhD student to further investigate the interaction between *H.scabra* and the environment (T. Skewes, CSIRO, September 2002, pers. comm.).

**Table 8:** Summary of existing regulations for countries involved in the export of bêche-de-mer.

| Country | Quotas | Licences/limited entry | Habitat/area closures | Closed season | Minimum sizes | Gear restrictions | Prohibition on fishing | Comments | Species targeted | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Galapagos | X | | X | 2 month season | | | | New management plan introduced 1999 | *Stichopus fuscus* | Martinez (2001) |
| Solomon Islands | | | Biennial year long moratorium on harvest in Ontong Java[a] | | | | Ban on sandfish in 1997 but locals still collect them[b] | Population in severe decline[b] | 22 species[b] | [a]Adams (1993)<br>[b]Anon (2002) |
| Fiji | | Harvest restricted to Fijian natives | | | X | X | 1995 exports prohibited | Stocks depleted. Consumed locally | *H. scabra, A. miliaris* | Anon (2002) |
| Vanuatu | | | | | | | | Export limit 40 tonnes | | Anon (2002) |
| India | | | | | Ban on export of bêche-de-mer shorter than 7.6cm[a] | | | Sea cucumber collection banned in Andaman and Nicobar Islands- CPUE and specimen size declined in Gulf of Manner and Pal Bay[b] | *H. scabra, H. spinifera, B. marmorata, A echinites, A. miliaris, H. nobilis, T. ananas, H. atra, A. mauritiana, S. chloronotus*[b] | [a]James and James (1994)<br>[b]Anon (2002) |
| USA | | | | | | | | Management plans in Maine, Washington, California, Alaska and Florida and in federal waters of US Caribbean and South Atlantic. Research, monitoring in place; west coast fishery appears sustainable | *S. californicus, S. parvimensis, C. .frondosa* (Maine) | Anon (2002) |

| Country | Quotas | Licences/limited entry | Habitat/area closures | Closed season | Minimum sizes | Gear restrictions | Prohibition on fishing | Comments | Species targeted | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Japan | | | | During spawning time | | | | The catch of *S.japonicus* has decreased annually by 5-10% from over 10,000 mt (wet weight) in 1978 to 7133 mt in 1987. | *S. japonicus* | Anon (2002)<br>Uthicke and Klumpp (1996) |
| Mexico | <1000 t quota proposed (1996) | 14 licence limit proposed (1996) | | Restricted to 7 months of the year | X | | | Fishery began 1991, *Stichopus fuscus* declared endangered in 1994. | *Stichopus fuscus* | Castro (1995) |
| Canada | 223mt | 84 licences | 25% of coast fished only | Open 3 weeks of year when muscle is greatest (maximise yield) | | | | New fishery started in Quebec in 1999 –1 licence in 1999, 3 issued 2000 and 5 issued in 2001. | *Cumcumana frondosa*<br>*Parastichopus californicus* (Giant red or California sea cucumber) | Anon (2002) |
| Philippines | | | | | | | | Exports increased from 250mt in 1977 and 1189mt in 1984 to 2123mt in 1996. | 25 species collected including *Holothuria scabra, H. nobilis, H. fuscogilva*, *H. atra, Bohadschia marmorata and Actinopyga lecanora*. | Anon (2002) |
| Malaysia | | | | | | | | No countrywide regulations for the holothurian fishery. Imports may exceed exports. | *Stichopus variegates* | Anon (2002) |

| Country | Quotas | Licences/limited entry | Habitat/area closures | Closed season | Minimum sizes | Gear restrictions | Prohibition on fishing | Comments | Species targeted | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Madagascar | | | | | | | | Exports increased from 56 t in 1986 to over 500 t in 1991 – declining exports, quality and size or cucumbers indicate resource over-exploited (1998). | *B. vitiensis, H. scabra* and other species | Anon (2002) |
| Mozambique | | | X | | | | | High fluctuations in exports may be due to irregular reporting or over-exploitation | *H. scabra, H. nobilis, H. fuscogilva, H. atra, Actinopyga extinites, A. mauritiana* | Anon (2002) |
| Maldives | | | | | | | | Recommendations for management were made by Adams (1993), unaware if these have been implemented or not. | *T. ananas* (prickly redfish), *M. nobilis* (white teatfish), *H. atra* (lollyfish), *B. marmorata* (brown sandfish) | Adams (1993) |
| Tonga | | X 10 licences[a] | | | X<br>for some species[a] | Ban on use or scuba and hookah gear[a] | | Traditional use: commercial fishery began in mid 1980s.[b]<br>10 year ban on take implemented in 1999.[b] | Greenfish, elephant fish, sandfish, surf redfish, stonefish, black and white teatfish, curry fish, prickly red, brown sandfish, blackfish, lollyfish, black sandfish + other species[b] | [a]Ministry of Fisheries (1996)<br>[b]Anon (2002) |
| Indonesia | | | | | | | | No known management measures specific for sea cucumber | 10 species | Anon (2002) |

| Country | Quotas | Licences/limited entry | Habitat/area closures | Closed season | Minimum sizes | Gear restrictions | Prohibition on fishing | Comments | Species targeted | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| New Caledonia | | | | | | | | Fishery currently mainly indigenous and artisanal fishers.[a] | *A. milians, H. scabra, H. scabra versicolor*[b] | [a] Purcell *et al.* (2002)<br>[b]Anon (2002) |
| Tuvalu | | | | | | | | Fishery not regulated, but there are recommendations to ban SCUBA and hookah gear. | *H. nobilis, H.. fuscogilva, H. fuscopunctata, T. ananas* & 4 other species | Anon (2002) |
| Papua New Guinea | X 140 mt | | | | | | Sandfish ban | 1000 t sandfish (H. scabra) exported 1995, population collapse. Consumed locally | *H. scabra, A. mauritiana, H. nobilis, H. fuscogilva* + 13 other species | Anon (2002) |
| Palau | 15 t quota | | | | | | | Small export fishery | *A. mautitiana, B. argus* and *H. scabra* | Anon (2002) |
| Micronesia | | | | | | | | Minimal subsistence use | | Anon (2002) |
| Cook Islands | | | | | | | | Small export market, mostly subsistence use | *A. mauritiana* | Anon (2002) |
| Thailand | | | | | | | | No management or regulation, decreased abundance in fished areas | *H. scabra, H. leucospilota, H. atra, B. marmorata, B. argus, S. chloronotus, S. variegates, S. chloronatus* | Anon (2002) |
| Tanzania | | | | | | | | Fishery is unregulated | *H. atra* is prized species | Anon (2002) |

| Country | Quotas | Licences/limited entry | Habitat/area closures | Closed season | Minimum sizes | Gear restrictions | Prohibition on fishing | Comments | Species targeted | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Venezuela | | 4 boats received 1 year licences, each to harvest 200 kg. | | | | | | Sporadic legal commercial fishing and frequent closures | *Isostichopus badionatus, H. mexicana* | Anon (2002) |
| Ecuador | | | | | | | | Fishery began 1989.<br>Stocks depleted; fishery moved to Galapagos | *S. fuscus* | Anon (2002) |
| New Zealand | 15 t | | | | | | | Experimental fishery started 1990 | *Stichopus mollis* | Anon (2002) |

## Trochus

Trochus has been harvested for centuries for subsistence reasons, however it has only been since early 20th century that trochus has been harvested commercially (Nash 1993). Commercial trochus harvest began in the Pacific and driven by global demand, followed a similar course in most countries. Like Australia, trochus fishing around the world suffered because of the introduction of synthetic buttons and virtually ceased in the mid-1950's. This was followed by a recovery in the 1970's brought about by increased price (Nash 1993).

The Pacific Islands region is the most important trochus-producing region in the world. In the 1990's the Pacific Islands produced about 59 per cent of the global trochus harvest (some 2,300 metric tonnes) (ICECON 1997). The export of this shell for button-making and other uses is an important source of income for rural and outer island dwellers in the region (Preston 1995).

Table 8 estimates the worldwide annual commercial trochus production as it was in the 1990's. It is interesting to note that Australia at this time harvested more trochus than any other single country, and Indonesia came in as the second largest producing country, despite having a ban on the harvesting or export of trochus.

**Table 9:** World trochus production in the 1990's (ICECON 1997)

| Area | Tonnes |
|---|---|
| Pacific Islands | 2,300 |
| Indonesia | 475 |
| Philippines | 200 |
| Okinawa | 200 |
| Australia | 500 |
| Minor Areas | 225 |
| **Total** | **3,900** |

In many parts of the world where trochus are fished it is a casual artisanal fishery, with trochus being collected when money is needed. The general trend in world trochus fisheries appears to be that the intensity of fishing is greatest in those places that there has been large investment in the trochus industry, or where there are few alternative means of income. For example, in countries where button blank factories have been established such as Vanuatu, Fiji and Solomon Islands a minimum production of shell is required to achieve a profit. There is concern that the amount of trochus needed to achieve profitability is actually greater than the sustainable catch of the reefs. Low world demand and thus low prices of products like copra, cocoa and coffee has also resulted in more intensified fishing of trochus as there is no longer an alternative source of income available (Nash 1993).

*Trochus niloticus* is native to the Western Pacific but it has also has been translocated to at least 70 new settings during the last 70+ years (Eldredge 1994). An example of a translocation success story is the Aitutaki fishery in the Cook Islands. Clarke and Ianelli (1995) reported that between 6,500 tonnes and 12,000t of trochus were harvested between 1945 –1995 due to successful transplanting programmes.

While trochus reseeding appears to have been a fishery development success and trochus are one of the most well-studied inshore fisheries resources in the Pacific (Clarke and Ianelli 1995), the status of trochus fisheries in some countries is not well known or understood because of inadequate or non-existent catch statistics (Nash 1993). There are concerns about the current state of trochus stock health in Micronesia (Clarke and Ianelli 1995), the Solomon Islands (Foale 2000) and New Caledonia (Elaix-Bonnin 2000).

Management regulations implemented by countries involved in the commercial export of trochus vary considerably but at the very least consist of a minimum size limit. A number of countries are involved in transplanting or reseeding of stock and this will be discussed further in Section 6 of this report. Table 9 summarises the management regulations implemented by countries involved in the commercial harvest of trochus.

**Table 10:** Management regulations implemented by countries involved in the commercial harvest of trochus.

| Country | Min size (cm) | Max size (cm) | TAC | Seasons | ITQ | Sanctuaries | Moratorium | Rolling closures | Transplants | Reseeding | Harvest method limitation | Live inspection | Dead inspection | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cook Island (Aitutaki) | 8 | 11 | + | + | (T) | + | + | | + | | | + | | Nash (1993) |
| Fiji | 8.2 | | | | | + | | | | | | | | Nash (1993) |
| French Polynesia | 8 | 11 | + | + | + | + | | + | + | | + | | | Nash (1993) |
| Federated States of Micronesia<br>Chuuk<br>Kosrae<br>Pohnpei<br>Yap | <br>7.6<br>6<br>7.6<br>7.6 | <br>?<br>10.2<br>10.2<br>10.2 | | +<br>+<br>+<br>+ | | ++<br>+ | +<br>+<br>+ | | +<br>+<br>+<br>+ | + | +<br>+<br>+ | +<br>+<br>+ | + | Nash (1993). Modification from Clarke and Ianelli (1995) |
| Indonesia | | | | | | | + | | | | | | | Nash (1993) |
| Japan (Okinawa) | 6 | | | | | | | | | + | | | | Nash (1993) |
| New Caledonia | 9 | 12 | | | | + | | + | | + | + | | | Nash (1993) |
| Palau | 7.6 | | | + | | + | + | | | + | | | | Nash (1993) |
| PNG | 6.2 | | | | | | | | | | | | + | Nash (1993) |
| Solomon Islands | 8 | | | | | | | | | | | | + | Foale (2000) |

| Country | Min size (cm) | Max size (cm) | TAC | Seasons | ITQ | Sanctuaries | Moratorium | Rolling closures | Transplants | Reseeding | Harvest method limitation | Live inspection | Dead inspection | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Commonwe-alth of Northern Mariana Islands | 7.6 | | | + | | + | + | | | | | | | Clarke and Ianelli (1995) |
| Republic of Marshall Islands | 7.6 | | | + | | | + | | | | | | | Clarke and Ianelli (1995) |

Notes: TAC: total allowable catch; ITQ: individual transferable quotas; (N): IQs are not transferable; (T): IQs are transferable

# Markets

## Bêche-de-mer markets

In the late 19th century the major importer of bêche-de-mer was China, with about 1,000 tonnes annually (Conand and Sloan 1989). Today the major markets are Hong Kong, Singapore and Taiwan. Since 1986 Hong Kong has been the largest of these markets importing more than 6,000 t and re-exporting 3,500 t of sea cucumber annually (Jaquemet and Conand 1999).

Most bêche-de-mer produced in tropical countries is exported to Hong Kong or Singapore. In each of these markets a good deal of repackaging and re-export takes place to China, Chinese communities world-wide and South-east Asia. These two centres procure product from and export to different destinations, with Singapore trading mainly to the west and Hong Kong having major links to neighbouring countries and those in the south (van Eys and Philipson 1989). The function of importers/exporters is not limited only to the physical movement of product but also to upgrading and value-adding activities such as grading, cleaning, drying and packaging (Preston 1993). Preston (1993) reported that the transhipment of products between these markets makes it very difficult to interpret trade statistics.

Trade into and out of the various markets is influenced by consumer preferences, tariffs and traditional trading practises. The demand in Hong Kong, Singapore and Taiwan by local consumers is for a high-quality product mainly consumed at restaurants or on special occasions. Exports to China however and some other markets contain large volumes of low-quality, lower-cost species. Preferential tariff rates existing among ASEAN (Association of South-East Asian Nations) member countries encourage Malaysia, Brunei and Thailand to import bêche-de-mer through Singapore rather than directly from the producing countries (Preston 1997).

The bêche-de-mer production boom, which took place in the late 1980's – early 1990's, was a result of increasing prices being received for product, resulting from an increase in demand. In particular a marked increase has been noted in the price of traditionally low-valued species, which is attributed to a rise in demand in mainland China for cheaper bêche-de-mer types. This has led to a significant change in the composition of exports (Preston 1993). Data presented by McElroy (1990) showed that during the previous decade, increases in bêche-de-mer production in Fiji and Solomon Islands were accompanied by a decrease in the average value per kg of product. This is attributed to the increased proportion of lower-value species in the catch.

In 1988 prices for bêche-de-mer, particularly lower-grade species were seen to decline, which led to a levelling off of production in some countries. Prices for high value species have however remained high or have increased in price, resulting in most countries production still being higher than pre-1986 levels. Therefore there is still concern over the long-term sustainability of most fisheries particularly in fisheries where adequate management controls are absence (Preston 1993).

Bêche-de-mer is traded by species and within the species categories by grade, which is generally determined principally by size. The type and grade greatly influence the price that the product receives. Table 10 shows a comparison of prices for various bêche-de-mer types in 1990, 1996 and present. Where there is a range of prices recorded it represents the typical values for the lowest and highest grades for that particular species at that time.

**Table 11:** Reference prices (US $/kg) for bêche-de-mer in the South East Asian markets

| **Product** | **Hong Kong and Singapore Mid-1990 (McElroy 1990)** | **Singapore 1996 (Ferdouse 1997)** | **Singapore and SE Asia April 2002 (INFOFISH 2002*)** |
|---|---|---|---|
| White teatfish (*Holothuria fuscogilva)* | 14-24 | 25-30 | 13-23 |
| Black teatfish *(H. nobilis)* | 11-12 | 20-25 | 12-18 |
| Sandfish *(H. Scabra)* | 5-15 | 30-45 | 34-45 |
| Prickly redfish *(Thelenota ananas*) | 12 | 10 | 12 |
| Greenfish *(Stichopus cholonotus)* | 8 | 12-15 | 13 |
| Surf redfish (*Actinopyga mauritiana)* | 7-8 | 12-15 | 10 |
| Curryfish *(Stichopus variegatus)* | 6-7 | 15-20 | 8-14 |
| Stonefish *(A. lecanora)* | 4-6 | 15-18 | 14 |
| Elephant's trunk fish *(H. fuscopunctata)* | 3 | | 2 |
| Lollyfish *(H. atra)* | 2-4 | | 1.5 |
| Tiger fish *(Bohadschia argus)* | 4 | 5-7 | 3 |
| Brown sandfish *(B. vitiensis)* | 2-3 | 5-7 | 3 |

*Source: INFOFISH Trade News No. 5/2002.

According to INFOFISH statistics dried Australian sandfish on the Singapore wholesale market from August 2001 to April 2002 ranged from US$45 to $US58/kg (approx. AU$83 to AU$107/kg - exchange rate 1 AU$ = 0.54$US) (INFOFISH 2002). During this nine month period Australian sandfish meat fetched prices between AU$9 and AU$46 more per kg than product from Indonesia or the South Pacific.

The visceral organs (entrails) such as the fermented intestines (Konowata) and dried gonad (Kuchiko), of commercially important sea cucumber species also have a market in Japan, Korea and China. There is also a market for sea cucumbers for use in traditional Chinese medicines. Clinical trials have revealed that sea cucumbers contain chondroiton and glucosamine, which are important cartilage building blocks, as well as other bioactive substances that have anti-inflammatory properties (Mindell 1998) and in recent years sea cucumbers have been used in the manufacture of arthritis medicines (Anon, 2002). The meat is believed to contain beneficial chemicals that possess antibacterial and antifungal properties (Hamel and Mercier 1997) and it is even considered to be an aphrodisiac in China (Uthicke and Klumpp 1996).

### Trochus markets

Importers of trochus shell include France, Germany, Italy, Spain, Japan, UK and USA where trochus shell is used mainly in the manufacture of buttons. Japan has historically dominated trochus button manufacturing however, many of the major shell manufacturers in Japan have relocated to manufacturing branches in lower wage countries such as Thailand, Philippines and China. Five or six companies also manufacture trochus buttons in Korea and many of the South Pacific trochus processing operations are affiliated to Korean firms. Most Pacific Island trochus processing operations produce only button blanks for Korea and Japan, as they are unable to produce the quality of buttons demanded by Asian and European buyers (ICECON 1997).

In 1997 the ICECON (1997) reported to the World Bank that the European trochus button industry was centred in northern Italy while the largest button manufacturer in Europe was located in Spain. At least one button manufacturer was operating at this time in both the United Kingdom and the United States (ICECON 1997). While there has been a decline in raw product exports, the export of button blanks made from trochus and other near-shore marine resources has steadily climbed. This has been mainly due to an increase in the number of countries processing trochus shell in their country of origin (TRAFFIC 1995).

High prices were offered for trochus after the World Wars at a time when stocks were abundant (Gluckman and Lindholm 1982). This makes it difficult to determine if high catches were as a result of high abundances or high economic value. The value of trochus has been seen to decline when cheaper alternatives become available on the market (Ryan 1999). In the 1950s trochus fisheries declined as a result of the development of plastic buttons. In the 1970s trochus prices once again rose as a result of resurgence in the demand by the fashion houses of Europe for natural mother-of-pearl buttons. Future demand for trochus will probably be affected by the use of substitute materials and increased environmental concerns over the harvest of living animals for the production of buttons. A study by Conraths and Schroeder (1995 as cited in ICECON 1997) on the trochus trade in Italy found that at least one designer had stopped using trochus buttons due to environmental concerns. Several other leading fashion designers in Unites States also indicated some environmental sensitivity in the industry (ICECON 1997). This will most likely increase as consumer concerns for the environment increase thus potentially having a negative effect on demand.

Over the last decade trochus prices in Australia have also been seen to fluctuate. Authority holders in the East Coast Trochus Fishery indicated that in 1990 the value of trochus was $7.50 to $8.30 per kg, with a maximum value of $8.90. In 1991 the value of trochus declined to $3.75 to $4 per kg, and in 1997 was $6.50 (Ryan 1999). In 2002 pickers are reportedly receiving only $4 per kg (B. Fraser, Fisheries Western

Australia, May 2002, pers. comm.). Authority holders suggested a value of between $5.80 and $6.40 per kg would meet the costs required to fish trochus reef while maintaining adequate profit (Ryan, 1999). The trochus fishery is currently considered to be a marginal fishery in terms of economic returns (R. Lowden, Seafresh Australia P/L, April 2002, pers. comm.).

Recent interest has also been expressed on the processing and export of trochus meat, which is known to fetch a high price in Japan (~ $14/kg) (S. Gaddes, QFS, July 2002, pers. comm.). The sustainability and economics of this needs to be questioned however as to the huge amount of trochus that would need to be collected to yield only a small amount of meat. R. Lowden (Seafresh Australia P/L, April 2002, pers. comm.) estimated that almost 1000t of trochus would be needed to yield 1000kg (1 tonne) of meat.

# Part 2. The potential for establishing and maintaining modern bêche-de-mer and trochus fisheries in Australia.

## Lessons learnt from other countries

In almost all countries where trochus and bêche-de-mer have been harvested there has been overfishing of stocks. The advent of strong financial gain (high return relative to effort put in) has lead to high levels of pressure on stocks that would not experience the same level of pressure in a purely subsistence economy (Foale 2000).

Overseas experiences have shown that the developmental phase of trochus and bêche-de-mer fisheries are often short with high fishing pressure. In fisheries where there is no suitable management action to regulate this high fishing pressure there are soon reports of overfishing (Nash 1993). For example, in the Galapagos Islands bêche-de-mer stocks were reported overfished in early 1995 even though the fishery only started in 1994 (Stone 1995 as cited in Uthicke and Klumpp 1996). It has also been witnessed that once the density of a population falls below a critical level that it can take many years to see any recovery in the population, even after fishery closures are put in place (Preston 1993; Uthicke and Klumpp 1996). It is therefore imperative that conservative management regimes are implemented in the early development stages of the fisheries.

Australian fisheries managers and policy-makers must be wary of these experiences when creating management regimes for Australia's bêche-de-mer and trochus fisheries. Although both the health of trochus and bêche-de-mer stocks and their ability to recover versus the social and economic requirements of stakeholders in the fishery need to be considered when creating management regimes, to secure the ongoing health of the resource the precautionary approach should be adopted. While the current management strategies in place in Australia's bêche-de-mer and trochus fisheries are cautious in their approach, for certain bêche-de-mer populations they have been implemented too late. For instance the sandfish population on Warrior Reef in the Torres Strait was closed in the mid-1990's due to over-fishing. Subsequent population surveys have revealed that the sandfish population on Warrior Reef has shown very little recovery since its closure. The heavily depleted nature of the population was also confirmed by estimates of the standing stock, which suggested that there were no more than 100 tonnes of adult animals remaining on Warrior Reef (Skewes *et al*. 2000).

It is also evident from the experiences of other countries that no matter what conservation regulations are put in place, if the regulations are not adhered to the stocks are likely to decline leading to fishermen being forced out of the fishery or stringent regulations being introduced in an attempt to protect the resource (Nash 1986[a]). The implementation of education and extension programs can serve the purpose of informing fishermen why these management regulations have been enforced and hopefully lead them to understand that the regulations are not only for the protection of stock and the environment but also to ensure their own livelihood now and into the future.

In addition to this, in areas of the world where traditional values govern community life, the importance of community consultation has been witnessed. For example, in the Vanuatu trochus fishery the depletion of the trochus resource led to the implementation of a minimum size limit of 9cm for trochus shell and a fine for non-compliance. Despite the fine, the regulation was continually violated. Amos (1995) believes that this was due to the management regime being implemented without consultation, adequate education and extension.

## Factors affecting stocks and sustainability of bêche-de-mer and trochus fisheries in Australia

Bêche-de-mer and trochus fisheries display particular characteristics that make them susceptible to over-fishing including:

- Bêche-de-mer are sessile, benthic animals that are large, easily seen and easily collected;
- Trochus occupy a well-defined habitat (the intertidal and shallow sub-tidal zones on the seaward margin of the reef) and despite their cryptic behaviour they are easily located by experienced fishers (Nash 1993)
- Although fishing for bêche-de-mer and trochus is labour intensive it does not require sophisticated fishing and processing equipment and in many situations they can be harvested by gleaning reefs at low tide (Breen 2001);
- The harvest methods allow specimens to be identified and physically selected, as opposed to the other fishing methods where the fishing apparatus attempts to attract fish (Breen 2001);
- Fishing activities can potentially strip all animals out of an area (Breen 2001);
- Bêche-de-mer are patchily distributed (Breen 2001). Reducing population numbers further by fishing will impact on spawning stocks and may reduce the chances of successful recruitment occurring (explained in further detail below).

Unless there are precautionary enforceable restrictions applied to bêche-de-mer and trochus fishing operations, given these traits, it is unlikely that these fisheries will remain sustainable.

Possibly the most serious potential ecological effect that bêche-de-mer and trochus fishing can have on the stocks is reduction of spawning stocks and reduced natural recruitment (Breen 2001). Both bêche-de-mer and trochus are broadcast spawners and if spawning stocks are reduced below a critical point then successful recruitment may not occur due to the greater distance between males and females. Also if all legal sized animals are removed leaving insufficient animals above the size of sexual maturity then recruitment is also at risk. This risk would be minimised by implementing minimum size limits that are set using an appropriate method, which ensures adequate spawning stock remain for recruitment to occur. It may however be difficult to determine if reduced recruitment is due to overfishing or environmental causes. A useful approach to assess the source of reduced recruitment is a control/impact study combined with detailed monitoring, collection and analysis of high precision data on environmental parameters such as seagrass and coral cover, substrate biotic and abiotic characteristics (Williams *et al.* 2000).

The use of SCUBA and hookah gear has made it easier to collect deeper-water sea cucumbers and trochus that are too deep to be taken by free-diving and hand-collection. For bêche-de-mer there is evidence that there is a large interchange of genetic material between deep and shallow populations. The deep-water populations may therefore be a source of new recruits for the fished shallow populations of sea cucumber (Uthicke and Benzie 1998). Thus use of this type of equipment has the potential to significantly increase the likelihood of localised over-harvesting.

The trend that seems to occur in bêche-de-mer fisheries is that once higher value species have been fished out, fishing effort shifts onto less valuable species (serial depletion). If this trend continues without conservative management regulations being applied then only species of minimal value will be left.

Some of these medium-low value species such as lollyfish and greenfish are also known to reproduce asexually by transverse fission (Uthicke and Klumpp 1996), a process whereby the sea cucumber divides into two parts, each of which eventually regenerate to form fully developed sea cucumbers. This is an important means of population size maintenance in these species (Uthicke and Klumpp 1996; Uthicke 1997) and could potentially help to restock areas when higher value species have been reduced. It is therefore important that these species are not over-exploited as well.

While critical habitats are not well known for sea cucumbers there is definitely a strong relationship between sandfish and seagrass cover. Seagrass beds may also be an important nursery area for juveniles (Uthicke and Klumpp 1996). Therefore seagrass degradation could have a major effect on sandfish stocks. In Tin Can Bay, Queensland, for example, during the wet season of 1998/99, floods caused a large amount of freshwater to accumulate in the shallow waters of the Bay causing seagrass mortality, which may have lead to impacts on the sandfish population and contributed to its eventual closure (Breen 2001).

It has been reported in the Great Barrier Reef that some fishers have been collecting their entire quota of bêche-de-mer from the reefs nearest to human centres to save on costs. If this is true and several fishermen are following the same practice then it will result in localised depletion of the resource on these near reef areas. Nash (1985) also reported this trend for the trochus fishery. During the 1980s fishers moved from Cairns, because of stock declines following heavy fishing of the local area and reports of larger quantities of trochus in Mackay.

## Management challenges

The challenge for management authorities of bêche-de-mer and trochus fisheries is to find and implement management regulations that will keep the fisheries sustainable for the future and thus protect both the stocks and the livelihood of those involved in the fishery now and in the future.

At present we do not have all the information needed to manage bêche-de-mer fisheries in order to produce maximum or optimum sustainable yields. We do however have the basic biological information needed and research techniques available to at least develop management systems that will hopefully protect resources from the worst effects of overfishing and ensure it is sustainably harvested (Uthicke and Klumpp 1996). For example, information on size at first maturity and reproduction seasonality is known for most species and can be used to derive minimum size limits, seasonal closures etc. (Uthicke and Klumpp 1996). For those species where such biological parameters as spawning time and size at first maturity are not known then strict application of the precautionary principle should be utilised and the species should not be harvested.

Further information on the following aspects of bêche-de-mer and trochus biology and ecology are needed to enable fisheries managers to set sustainable fisheries regulations that are specific to their area:

- Life history parameters: Growth, mortality, size at maturity, reproductive seasonality, aggregations and burrowing behaviour (for bêche-de-mer). While some of these parameters are known for trochus and some species of bêche-de-mer the information has been obtained from limited locations. For such parameters as reproductive seasonality and size at maturity further information needs to be gathered from different regions to ascertain if there is change with latitude and location.
- Recruitment and juvenile ecology: Genetic studies to determine larval drift between reefs and populations as well as larval survival and settlement induction studies need to be undertaken. There is very limited information on these factors for both trochus and bêche-de-mer, which makes it very difficult to predict such factors as the minimum stock size needed to keep a population sustainable (Uthicke and Klumpp 1996). Factors that influence recruitment, such as water currents and the relationship of fished and unfished populations to these currents also need to be investigated for each fisheries region.
- Habitat requirements for juvenile and adult trochus and bêche-de-mer: Determining the habitat requirements of adult and juvenile bêche-de-mer and trochus would enable sanctuaries to be established in areas that possess optimal bêche-de-mer and trochus habitat and enable reseeding to be undertaken in areas that best meet the species habitat requirements, thus giving them a greater chance of survival.
- Role of bêche-de-mer in the overall ecology of the reef: Recent research carried out at AIMS has shown that black and white teatfish and sandfish play an important role in reef ecology and appear to increase the productivity of reef communities (AIMS 2002). This research should be extended to examine the

ecological importance of all commercially important holothurian species. Interaction between sea cucumber species and the impact that fishing one species may have on other species is also unknown.

- Environmental impacts of fishing for trochus and bêche-de-mer: The impacts of reef walking to hand gather trochus and bêche-de-mer should be assessed.

In addition to this it is vitally important that fisheries managers find a means of gathering reliable and accurate catch data for these fisheries. Without this it makes it extremely difficult to observe what is occurring in the fisheries over time. It also makes it difficult to undertake population modelling to gain an understanding of a population's response to fishing and management actions as this requires long time series' of abundance and catch data.

Compliance in bêche-de-mer and trochus fisheries in Australia is a difficult challenge as much of the fishing effort occurs in remote locations. Compliance is particularly difficult in Torres Strait due to the numerous boats spread over the vast fishing ground throughout Torres Strait, few compliance officers and the close proximity to PNG and Indonesia. While the implementation of such tools as VMS and telephone prior reporting systems in the East Coast BDM fishery is reported to have improved compliance and enforcement capabilities, such tools are most likely to be unfeasible for the Torres Strait fisheries due to it being a remote indigenous fishery, the cost of implementing such compliance measures to both management authorities and fishermen and there being many small independent operators.

An alternative compliance method for the Torres Strait may be to give the compliance responsibility back to the communities. If an agreement can be developed between fisheries managers and communities on appropriate management arrangements, compliance responsibility can be transferred to the community council. This will promote self-confidence among community members as well as promoting good working relationships between fisheries managers and communities. It will also go some way towards improving compliance in Torres Strait. This method has been adopted in the Kimberley Trochus Fishery (see Part 1 Section 4.3 for further details) and could be a model for the Torres Strait bêche-de-mer and trochus fisheries to follow.

Devising and implementing suitable education and extension programs could also help to contribute to increased compliance in the fisheries. Education programs can show that it is in the interest of all involved in the fishery (fishers, buyers, processors and fisheries managers) to adhere to the regulations that have been established.

For fisheries such as the Torres Strait bêche-de-mer and trochus fishery both modern and customary management systems should be taken into account in the management of the resource. Combining the two management systems can be straightforward as they both share the same objective, (sustaining the resource and therefore the livelihood of those fishing), even though methods of implementation may differ. However, the challenge is establishing a working relationship and building trust between Fisheries departments and resource users and owners.

# Sustainable harvest methodologies

## Collection of data

The importance of data collection is often underestimated and appears to have been ignored or under-valued in many of the world's bêche-de-mer and trochus fisheries. The first signs of overfishing can be detected by monitoring the abundance of stocks but also through declining catch rates, increased effort to recover the same catch and change of catch composition from high value to low value species. This information can be obtained through a properly implemented logbook program in which fishermen enter basic catch information (total catch and catch composition, time spent fishing, area fished etc.).

While logbooks can be a very valuable fisheries management tool if catch information is entered correctly they are of little or no value if the catch information is inaccurate or unreliable. At a Torres Strait Bêche-de-mer Workshop in May, 2002 it was identified that even though logbooks were in place in the bêche-de-mer fishery the data received from these logbooks was too inaccurate to adequately monitor and manage the fishery. Some independent methods of evaluation, such as regular surveys of stock abundance, are still required to ensure that the information being obtained is representing what is actually happening in the fishery. Fishermen also need to be educated to realise the value of completing logbooks accurately.

There also appeared to be some confusion at the Torres Strait Bêche-de-mer Workshop between identifying deepwater redfish and surf redfish. This sort of confusion when identifying catch would also contribute to inaccurate logbook entries and should be addressed.

As well as the weight of the catch being recorded in the logbook it would be beneficial to also record the number of animals in the catch. This would enable to average weight of bêche-de-mer being caught to be calculated and enable fisheries authorities to monitoring if the catch was consisting of an increasing amount of smaller specimens (another early sign of overfishing). This would however be a very time consuming process.

To enable the weight and size of bêche-de-mer catch to be recorded accurately it would be useful for the relationships between measurement of bêche-de-mer in different states (eg: wet, processed, dry) to be established and standardised so that data from different sources can be compared.

## Minimum size limits

The application of minimum size limits to protect immature individuals is believed to be one of the easiest and most effective means of protecting breeding stock numbers (Uthicke and Klumpp 1996). The minimum allowed catch size for each species should be based on the size at first maturity. Regulations should ensure that the animals have a chance to spawn at least once before they are harvested.

Uthicke and Klumpp (1996) proposed that the size limit be set to the length / weight of the species at first maturity plus 20% to overcome problems with weighing or measuring accuracy and to ensure that at least 50% of the juveniles were protected. As male and female trochus become sexually mature when they are between 5.5cm and 7cm basal diameter (Foale 2000) the minimum size restriction of 8cm for trochus in Queensland and Torres Strait should go some way to protecting sexually mature specimens however if Uthicke and Klumpp's (1996) suggestion is taken into consideration, the size limit of 7.5cm in Western Australian trochus fishery should potentially be increased. The size of first maturity for commercial sea cucumber varies between species but ranges from 12cm for *A.echinnites* to 30cm for *Thelenota ananas* (Conand 1989). The minimum size limit of 15cm for all commercially harvested species of bêche-de-mer in Queensland may need to be revised and adjusted to more accurately reflect the size of first maturity for each species. The minimum size limits currently set in the Torres Strait and Western Australian bêche-de-mer fisheries appear to have been set at the size of first maturity for most species and therefore it may also be beneficial to increase these by 20%.

## Total Allowable Catches

Total allowable catches (TAC) are used as a fisheries management tool in many parts of the world, however they are commonly based on apparently historical sustainable harvests. This has proven dangerous in many fisheries where there is little known about absolute abundance of stock and key biological parameters. This setting of TAC according to historically sustainable levels is how the TACs on the GBR and Torres Strait have been determined. The GBR fishery saw the black teatfish population collapse under this management strategy. Perhaps a more appropriate way of determining TACs may be to set it as a fixed proportion of the estimated biomass of legal-sized animals. This method of quota allocation has been used in the French Polynesia and Aitutaki Atoll trochus fisheries (Nash 1993) and aims to ensure that only a percentage of the legal-sized (reproductive sized) animals are removed from the reef rather than the TAC being set on the total population of trochus when the number of legal-sized trochus could be very small and could potentially be all collected in one season. Population abundance and composition must be assessed regularly and the TAC adjusted accordingly to reflect this.

A total allowable catch for a large area is not an adequate tool to manage bêche-de-mer or trochus fisheries because some reefs may be completely depleted of stocks while others may not be fished at all. So this does not occur it may be more beneficial for a TAC to be applied to individual reefs. This would hopefully spread the impact over all the reefs in an area so that each reef was only cropped rather than being stripped of its valuable species.

Assigning TACs to individual islands or communities, determined through a cooperative mixture of traditional and modern methods but then divided up to individuals or families under traditional methods represents an opportunity that may be suitable for implementation in the Torres Strait trochus and bêche-de-mer fisheries. This method of quota allocation may provide significant benefits with minimum costs. Overseas examples have shown that assigning TACs to individuals or family groups is preferred to assigning a TAC to an entire region (Nash 1993). Nash (1993) believes this is because it reduces any between-group competition to obtain a share of the quota and stops the "race" to catch a share of the quota. The individual holders of the quota can then fish their share at a time of their choosing.

## Zoning

One of the biggest problems with bêche-de-mer and trochus fisheries is that both reefs with high and low stocks are fished. The implementation of zoning, such as occurs in the GBR would allow for reefs with good adult numbers to be fished, while reefs with low adult numbers could be closed for 3 – 5 years as recovery reefs. These zones could be reviewed on the basis of stock status every few years and adjusted accordingly. In addition to this other reefs could be set aside as permanent protected reefs to ensure breeding stocks are sufficient. These protected reefs would also be valuable for scientific purposes, ie: impact studies to compare fished and non-fished areas. However, Uthicke and Benzie (2001) found that the division of reef into fished and unfished zones is only effective when the protected areas are large.

If population abundance can be increased within permanently protected areas it will enhance spawning output. As larval dispersion for some bêche-de-mer species is known to be significant this could potentially propagate fished areas via larval dispersion (Clarke and Ianelli 1995). For trochus, larval dispersion is limited due to the larval stage being no more than a few days. The effectiveness of sanctuaries therefore also depends on a knowledge and understanding of factors such as larval dispersal range, current strength and direction, and the proximity of fished stocks to protected areas to ensure sanctuaries are established in the optimal position to maximise success.

The success of permanent protected areas as fishery conservation tools also depends on them being established in suitable habitats and not being fished (Nash 1993). Heslinga *et al.* (1984), in his evaluation of the success of trochus sanctuaries in Palau found that there was only marginally higher trochus abundance in the sanctuaries than there was outside of them. Only one of the established sanctuaries was in an area deemed to be optimal trochus habitat. Illegal harvesting of trochus from Aitutaki Atoll trochus reserve in the Cook Islands was also seen to reduce the effectiveness the protected area as a conservation tool (Nash 1993).

Further research needs to be undertaken into recruitment patterns and connectivity of bêche-de-mer populations to ensure that the management strategies applied are suitable for each species. For example, studies by Uthicke and Benzie (2001) reported high levels of gene flow between populations of black teatfish on the Great Barrier Reef and in Torres Strait. Sandfish however was found to have distinct population differences between Hervey Bay, Upstart Bay and Torres Strait. These results suggest that different management strategies may be required for each species. The high gene flow in black teatfish suggests recruits can be received from a wide geographical area and stocks could be managed on a regional scale whereas sandfish cannot rely on recruitment from other regions and local refugia may need to be provided (Uthicke and Benzie 2001)

## Restricted harvest seasons

The establishment of restricted fishing seasons is also a widely utilised management method throughout the Pacific (Clarke and Ianelli 1995). Setting up seasonal closures that correspond with the peak spawning periods of species will potentially maximise the spawning output and hopefully result in increased recruitment. A 6-month seasonal closure is already implemented in the Western Australian trochus fishery between September and February to protect spawning trochus. Purcell (unpublished) believes that seasonal closures are more effective than rotational closures as they spread the level of fishing across all reefs that have adequate stock rather than encouraging periodic, high exploitation on particular reefs.

The time of spawning is known for most commercially valuable sea cucumber species, but this information is usually sampled only from one location for most species and these periods may change with latitude and location (Uthicke and Klumpp, 1996). The time of spawning for trochus is known to vary at different latitudes and locations (Nash, 1993). For bêche-de-mer, if the fishery could be closed for a few months around the peak gonadal index period of each species it could assist in the animals reaching their spawning potential and greatly assist recruitment. For species that have no distinct cycle Uthicke and Klumpp (1996) suggests that they may be fished all year round but with reduced fishing pressure to compensate for the potential loss of ripe individuals. Species with biannual cycles should have two closed seasons of at least one month around each spawning peak (Uthicke and Klumpp 1996). For species that show seasonally occurring asexual reproduction by fission the fishery could be closed to that species for the two months around the fission event (Uthicke and Klumpp 1996).

For trochus, imposing a closed season during their peak spawning would also provide protection for them during a period when they are most vulnerable. *T. niloticus* aggregate to spawn at the top of the reef and with an approximate lunar rhythm (Nash 1993). Trochus fishermen from the Great Barrier Reef, Torres Strait and Vanuatu have stated that trochus are found more easily and in greater abundance at new moon (Nash 1993). Fishermen recognise this pattern and target trochus at this time. As spawning individuals are the easiest to locate this could have a significant effect on recruitment.

### Fishing methods

As the use of SCUBA and hookah have enabled the harvest of sea cucumbers and trochus that were previously protected by depth, deep-water specimens can be protected by fishing restricted to snorkelling and free-diving. This would be difficult to implement in fisheries such as the East Coast Bêche-de-mer Fishery where the target species, white teatfish, lives in deeper water.

### Restocking

Options to enhance the biomass of fished stocks should be considered. This could include stock enhancement through release of hatchery-reared juveniles, sea ranching of juveniles and translocation of broodstock from areas with abundant populations to depleted reefs. Aquaculture of bêche-de-mer and trochus and their potential for restocking are discussed further in Section 5 and 6.

Transverse fission has been artificially induced in black teatfish, surf redfish (Preston 1990) and sandfish (Lokani *et al*. 1995). Triggering transverse fission could potentially be another means of enhancing the biomass of bêche-de-mer species.

## Education

Education and information programs are vitally important to any attempt to build a new fishery or rebuild one. While the implementation of such management regimes as a minimum size limit, a sanctuary or compulsory logbooks may make sense to a fisheries biologist, the people that depend on the marine resource may not fully comprehend the biological concepts linking the implemented management regime and sustainable management. Education is the key to an appreciation of how each person relates to the environment and resources and what the person's obligations are. Without this understanding it is hard for those people that rely on the resource to realise the importance of the management regulations that have been put in place and fisheries managers will always be viewed as "the bad guys" putting up barriers to prevent people from making money. This makes it very difficult to secure the support of fishers for any management regulations and this is sometimes seen in reluctance to comply.

# Aquaculture

## Aquaculture of sea cucumber

The successful propagation and rearing of sea cucumbers was first reported in Japan in 1950 for *Stichopus japonicus*. By 1985 China had developed the technology and husbandry to routinely breed *S. japonicus* juveniles and was harvesting over 1000 tonnes of dried meat from aquaculture (Battaglene 1999). The seed of *H. scabra* was produced for the first time in India in 1988, when small quantities of juveniles were produced using the techniques developed in China for the production of *S. japonicus* (James *et al.* 1988). Despite the initial breeding successes commercial hatcheries for *H. scabra* did not develop in India but the techniques developed in India have since been used experimentally in Australia, Indonesia, Maldives and the Solomon Islands (Battaglene 1999).

*Holothuria atra* (Ramofafia *et al.* 1995), *H. nobilis* (Preston 1990) *Actinopyga echinities* (Chen and Chian 1990), *A. mauritiana* (Preston 1990) and *A. miliaris* (Battaglene 1999), *Stichopus horren* (Sarver 1995) and *Holothuria fuscogilva* (Battaglene 1999) are other species of tropical sea cucumber that have been the subject of culture attempts. These attempts have generally been met with poor results however *S .horren* (Sarver 1995) and *H. fuscogilva* (Battaglene 1999) have been successfully cultured through to settlement. *H. scabra* is the only tropical species that can currently be mass produced in hatcheries and has proven to be the easiest of the possible commercial sea cucumbers to culture therefore techniques discussed in this section refer to the culture of *H. scabra*. To date the only successful subtropical spawning of *H. scabra* has been reported by Morgan (2000).

### Broodstock

Hatchery production success for any species relies on the health of the broodstock and timing of collection on wild-caught stock in relation to their natural spawning cycle (Battaglene 1999; James 1999). Broodstock collection needs to be undertaken with minimal temperature and salinity fluctuation so as to avoid evisceration and premature spawning (Battaglene 1999). As many as 200 animals can be collected for spawning, but at a minimum 15 should be collected as the number of animals spawned for each hatchery run is an important genetic consideration, particularly if the cultured juveniles are to be released into the wild (Battaglene 1999). About 20-30 adults can be maintained in a 1-tonne tank with running seawater or water changed daily, with 15cm of sand and fresh algae added once a week (James *et al.* 1994; Battaglene 1999). Salinity should be between 30 and 40 ppt (Hamel *et al.* 2001). Tropical sea cucumbers can be difficult to hold in captivity. If proper nourishment is not given, the animals lose weight and the gonad reabsorbs (James 1999). Morgan (2000) reported reduced spawning and hatch rates of eggs of broodstock kept in captivity for more than one month.

In India and Indonesia *H. scabra* have been conditioned in captivity using a variety of products including soybean powder, rice bran, chicken manure, ground algae and prawn heads (James 1996 as cited in Battaglene 1999). Thermal stimulation has been reported as the best method to induce sea cucumbers to spawn (James 1999) however stimulation through the drying of broodstock and then spraying with a powerful jet of water (James *et al.* 1994) and the addition of powdered alga to broodstock tank water has also been used (Battaglene 1999). Only one or two males should be allowed to release sperm into the tank. The other males should be removed as soon as they start to spawn as high sperm densities can cause increased deformities in the larvae (Battaglene 1999; James 1999).

**Larval rearing**

Oocytes should be rapidly removed from the spawning tanks and washed several times to remove excess sperm that may pollute the water and cause deformed embryos (Battaglene 1999). Oocytes and larvae should be kept in suspension in water by slight aeration (Battaglene 1999) and the water of the rearing tank should be cleaned every 3-4 days by sieving the larvae on 80µm mesh. An optimum stocking density of larvae was established to be between 300-700 larvae $l^{-1}$ or 3 750 000 larvae in a 750l tank (James 1999).

Larvae need to be fed by adding 20 000-30 000 algal cells $ml^{-1}$. James *et al.* (1994) reported that best larval growth rates were obtained when fed the microalgae *Isochrysis galbana* for first 4-5 days and then a mixed culture chiefly consisting of *Chaetoceros* sp. James (1999) reported growth of 4-5mm/week when fed an extract of *Chaetoceros* sp. and *Tetraselmis chuii*.

Battaglene (1999) reported that mortality of larvae is greatest at first feeding and settlement. Cultured *H.scabra* settle on tank surfaces, mesh screens and fibreglass plates conditioned in seawater for 4-10 days so as they are covered in a bacterial film and fine coating of epiphytes that stimulate metamorphosis and settlement (Battaglene 1999). After settlement juveniles were fed with algal extracts and after 2 months fine algal powder was added to the food (James *et al.* 1994). *H. scabra* can be reared in concrete tanks at densities around 10 000 individuals per $m^2$. When juveniles reach 10-20mm in length they are transferred to fine sand substrata and fed powdered algae *Ulva lactuca* (James *et al.* 1994; Battaglene 1999). Figure 4 summarises the stages of sandfish culture. James *et al.* (1994), James (1999), Battaglene (1999) and Pitt (2001) provide more comprehensive descriptions on hatchery techniques and culture of sandfish.

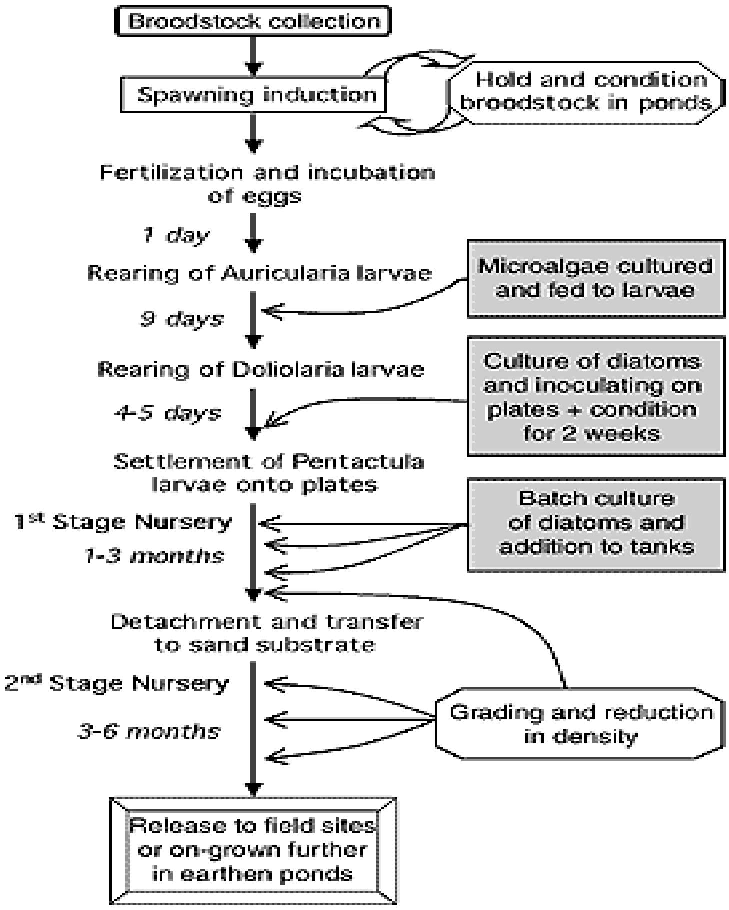


**Figure 4:** Flow chart of stages of sandfish hatchery culture (from Purcell *et al.* 2002).

**Juvenile growout**

Once juveniles have reached approximately 20mm in length they are transferred to growout farms. In Japan and China the hatchery-reared juveniles are sea ranched in their natural habitats for further growth and for enriching the natural populations. In India the seed produced in hatcheries is grown out in the sea in rectangular cages, velon screen cages, netlon cages and concrete rings (James 1999). Growout of sea cucumber in land-based tanks is not feasible at this time because of the inability to provide sufficient food once they reach a certain size (S. Purcell and W. Nash, SPC, April 2002, pers. comm.). Projects to assess the possibility of on growing sandfish in on-land shrimp ponds and polyculture with other species is planned for Vietnam, Madagascar and New Caledonia (Hamel *et al.* 2001). At Eastland Marine abalone farm in New Zealand techniques are being developed for growing adult *S. mollis* below abalone tanks (Morgan 2000). Morgan (2000) believes that it is probable that growth rates can be optimised in such as system while also providing an alternative to relying on naturally existing food sources in the ocean.

## Current sea cucumber hatchery production in Australia

Sandfish are the only tropical sea cucumber to be mass produced in the world at this stage and therefore are the most likely species for hatchery production for restocking, however the techniques developed in India have only been used experimentally in Indonesia, Maldives and the Solomon Islands with only one successful spawning of *H.scabra* in Australia (Morgan 2000).

While pilot research into sandfish culture has been carried out by CSIRO, Cleveland in Queensland and several sea cucumber hatcheries are being established in Cairns it is likely that it will still be several years before the techniques are refined for subtropical Australia and commercial application in Australia. S. Keys (CSIRO, August 2002, pers. comm.) outlined some of the problems that were encountered with propagating sea cucumbers as the following:

- Production in subtropical areas of Australia will be hindered as these areas are at the southern end of the sea cucumber's distribution and the window of opportunity for gravid individuals is greatly reduced.
- Broodstock nutrition is still not well understood and most broodstock held indoors lose weight and condition in captivity. Holding broodstock will therefore generally reduce the chances of successful spawning; and
- Survival throughout larval and juvenile rearing. Most larvae are very sensitive to chemicals, bacteria or viral infections. Supply of suitable space and feed for juvenile benthic algae grazers is also a problem.

A sea cucumber hatchery has also been established in Exmouth, Western Australia. It will be attempting to produce blackteat and is planning to undertake spawning trials in early 2003. The current aim of this hatchery is to produce sea cucumbers to grow out for the export market however stock enhancement may be considered in the future (G. Shiell, Oceanwest, September 2002, pers. comm.).

Aboriginal communities and other groups in Northern Territory have also expressed interest in sea cucumber farming. One venture is currently seeking funding to set up a sea cucumber hatchery, nursery and grow-out in Arnhem Land.

## Aquaculture of trochus

The first spawning and tank culture of *T. niloticus* was first carried out by Heslinga and Hillmann (1981). Since then numerous studies of induced spawning and hatchery production of juveniles have been published (Nash 1988, 1990; Amos 1991; Dobson and Lee 1996; Lee 1997) and trochus hatcheries have been established in Eastern Indonesia, Vanuatu, Tonga, Palau and Australia (Lee 1997). The techniques used to induce trochus to spawn and produce juveniles in a hatchery has been simplified considerably in recent years (Lee 1997).

**Broodstock**

Broodstock are collected from the wild and kept in tanks of seawater providing strong aeration at ambient temperature. Between 30 and 100 animals are needed to ensure successful spawning induction, as only a small number of them will be ready to spawn at any one time. Methods used to successfully induce adults to spawn have included using 'temperature shock' method (Lee 1997), UV irradiation (Kikutani and Patris 1991), and physically massaging the gonad with a jet of water (Dobson 1994). Thermal stimulation appears to induce spawning soon (ie: within one hour) after the temperature of the water is raised 2-3°C at sunset and maintained. This procedure may need to be repeated (Department of Fisheries 2001).

**Larval rearing**

Neutrally buoyant, fertilised eggs must be rapidly but gently removed from the holding tanks using a fine (100µm) mesh net. Several hundred thousand eggs should be transferred to each culture tank containing aerated seawater filtered to 5µm. As trochus larvae do not begin feeding until after they have settled there is no requirement to provide algae at this time. Tanks should be in partial shade so as to reduce UV light but also provide good growth conditions for benthic diatoms on which the juveniles will feed. Cultured benthic diatoms, such as *Navicula spp*. and *Nitzschia closterium*, should be introduced to the tanks up to a week prior to spawning and then fertilised with 20-50ppm 'Aquasol' or similar suitable commercial fertiliser. A thin layer of coral rubble should cover the bottom of each tank. This rubble acts as a substrate for the diatoms to grow on. The salinity in culture tanks should be maintained at 35ppt and the temperature at 30-33°C for optimum survival of larvae and juvenile growth (Department of Fisheries 2001). Crowe *et al.* (2002[a]) provides a comprehensive description of hatchery techniques and culture of trochus.

**Juvenile growout**

Juveniles can be cultured in tanks to adult size but this is uneconomical as stocking densities need to be lowered to avoid overcrowding. Lee (1997) estimated that the cost to culture juveniles to 1-3mm could be as low as 0.7 cents/juvenile, but increased to 29 -71 cents/juvenile if the animals are grown up to 6-10mm in land-based systems. Juveniles will eventually graze the diatoms in the tank too heavily, resulting in slowed growth rates and starvation.

This situation is unlikely to change unless an artificial food can be developed to feed hatchery juveniles (Crowe *et al.* 1997). Currently it is however more cost-effective to remove juveniles from tanks when they are still small and transfer them to reef sites where trochus can be stocked into sea cages for further growth and for restocking the environment to growout. Purcell (2001) reported hatchery-cultured juveniles of 12-

20mm being caged in Western Australia while Clarke and Komatsu (2001) reported juveniles of 30mm being stocked into sea cages. Purcell (2001) also reported placing 15 litres of coral rubble covered in epilithic algae into each of the cages as a productive food source for the juvenile algae once stocked into the cages.

### Current trochus hatchery production in Australia

In recent years, research has refined the culture techniques for trochus. Broodstock can now be readily induced to spawn throughout the year. Trochus have already been successfully cultured in Australia at the Northern Territory University, Darwin and juveniles will be produced on a commercial scale in the Multi-species Hatchery (MSH), which has been constructed for the Kimberley Aquaculture Aboriginal Corporation (KAAC) in Broome.

Spawning trials conducted this year at the MSH have had mixed results and the following have been identified as possible problems that may be affecting the hatchery operation:

- Low water temperature during the 'Winter' months. Water temperatures in the hatchery dropping below the water temperature of King Sound where the spawners were obtained from may have caused problems with spawning and caused mortalities.
- Possible high concentration of heavy metals. The MSH utilises treated marine bore-water and it may therefore have high levels of copper for example in the bore water.
- High counts of ciliate population in the water supply (Kimberley Aquaculture Aboriginal Corporation 2002). Ciliates could cause injury or death to larvae and young juvenile trochus.

The MSH is planning to use hatchery reared trochus for the purpose of stock enhancement by stocking 8 week old juveniles (approximately 3mm in diameter) into cages to produce more breeding stock that will further replenish the reef (Pearce 2002). An alternative or complementary approach is to transfer broodstock to reefs with depleted populations (Department of Fisheries 2001).

## Restocking & stock enhancement

Stock improvement is a two-step process of producing the animals or plants in hatcheries and then releasing (or stocking) them into the wild. The previous section dealt with the hatchery production of sea cucumbers and trochus. This section will deal with restocking and stock enhancement. Restocking or reseeding is the process whereby juveniles are produced in hatcheries and are then released to rebuild depleted wild stocks. The same technology that is used for restocking can also be used to increase harvests beyond historical harvest levels by releasing large quantities of cultured juveniles into restored wild populations. This would allow the production of the animal to approach the habitat's carrying capacity, a process termed stock enhancement (Battaglene and Bell 1999).

The main benefit of restocking is that it potentially provides a means of fast-tracking the restoration of stocks. Although methods for the mass production of juveniles have been developed (as discussed in the previous section) there are still some major challenges that need to be addressed before restocking or stock enhancement becomes a viable management option: How to scale-up current hatchery technology to produce the huge number of juveniles needed to have an impact on stock abundance; developing effective strategies for releasing cultured juveniles into the wild and how to identify them; and assessing the economic viability of restocking. The cost-effectiveness of this as a management tool will depend on the cost of producing and releasing juveniles, the percentage of juveniles that will survive and enter the fishery and the market price of the species at the time of harvest.

Figure 5 shows the critical steps during the process of stock enhancement using hatchery-reared juveniles to reseed.

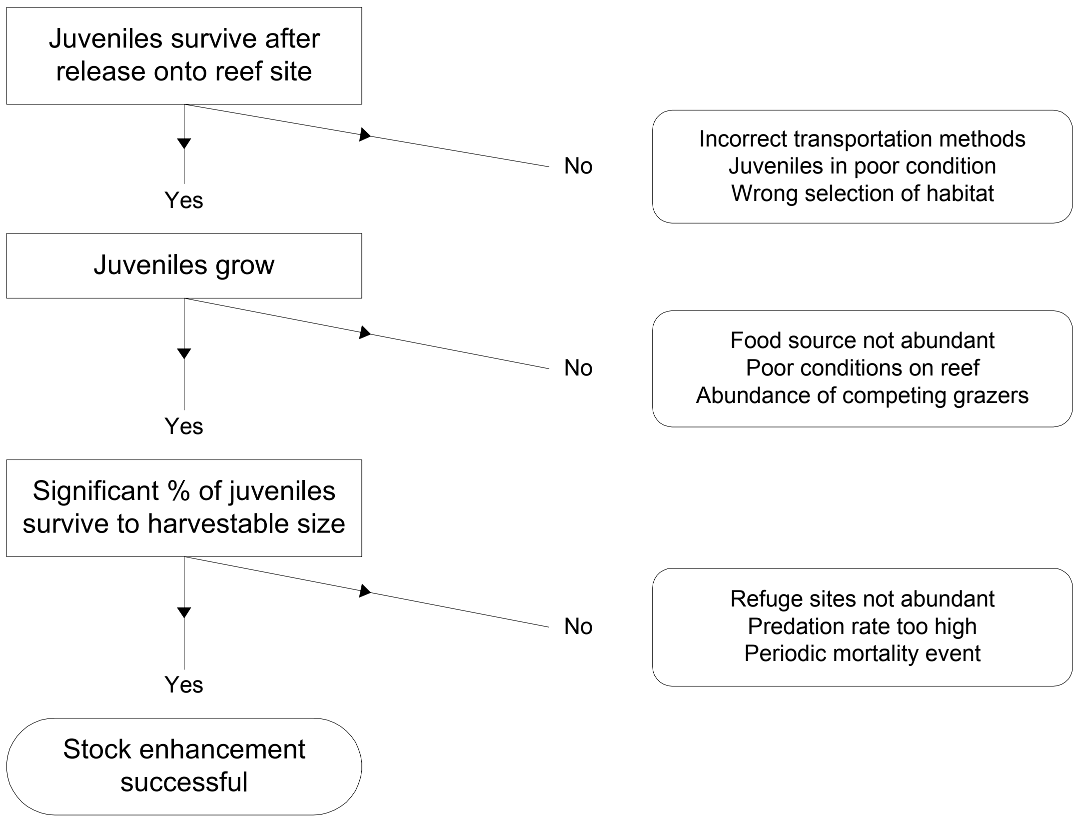


**Figure 5:** Juvenile seeding: Critical steps during the process of stock enhancement using hatchery-reared juveniles. Likely causes for failure are in boxes on the right (from Purcell and Lee 2001).

## Sea cucumber restocking and stock enhancement

Tropical sea cucumbers appear to have the necessary biological attributes to make it a potential candidate for restocking. They feed low on the food chain, are restricted to inshore habitats, are sedentary, have a simple feeding regime and well understood reproductive habits (Battaglene 1999). Sandfish have been found to be the tropical species of sea cucumber most suited to restocking (Purcell *et al.* 2002; Battaglene 1999). Not only that, but the fishery has several characteristics that make it a species regarded as "worth" restocking: it is of high value, is widely distributed and is over-exploited in most countries it is fished in (Battaglene 1999). Newly settled *H. scabra* can also be reared in tanks using simple technology, little or no added feeds and at a relatively low cost (Battaglene 1999). Battaglene (1999) reports that provided juveniles can be released successfully into the wild at sizes of <60mm and 20g so as to limit the amount of predation on released juveniles, there should be no major impediment to the production of juveniles for stock enhancement.

Restocking is practised successfully on a temperate sea cucumber species, *S. japonicus* in Japan. In 1994 over 2.5 million hatchery-reared juveniles were released (Battaglene 1999). There has only been one reported large release of tropical sea cucumber. This was performed in 2000 by a Solomon Islands research team, which released 2,600 juvenile hatchery-reared sandfish in the Western Province of Solomon Islands (Battaglene 2000). There has also been limited research into the growth and survival of released juvenile tropical sea cucumbers and what research has been conducted has been confined largely to sandfish.

Mercier *et al.* (2000) released hatchery-reared juveniles onto different substrates in the Solomon Islands where no sandfish had previously been found and periodically measured their growth and survival over two months. Sandfish showed good survival and growth rates of 10-15cm/month with sandfish released onto sand growing at the fastest rate.

Dance (2000 as cited in Pitt 2001) released batches of hatchery and nursery reared sandfish of 20-74mm onto coral-reef flats or mangrove-seagrass sites in Solomon Islands. On the coral-reef flat sites mean survival was only 37.5% one hour after release with total mortality within 48 hours. At the mangrove-seagrass area however 70% were found alive after three days. Growth and longer-term survival were not measured.

Research into the most effective ways to release hatchery-produced juvenile sandfish so as to maximise survival has recently began in New Caledonia (Purcell *et al.* 2002).

### Trochus restocking and stock enhancement

Unlike sea cucumbers there have been numerous attempts at releasing trochus for reseeding. These are summarised in Table 11 below. In all the studies there were significant reductions in the numbers of juveniles that were recaptured or survived in relation to the numbers released. In most of the studies this was attributed to juvenile mortalities due to predation or their migration from the sample area.

Survival rates after seeding for most of these studies were very low. Amos (1991) however released 1000 >20mm juveniles and 400 <20mm juveniles onto a reef area protected by rubble and/or cage and monitored them at 4, 7, 12, 27, 49 days and 13 months. Recovery rates as high as 28 per cent were measured 13 months after release (Nash 1993). Amos (1995) also recorded survival rates of 88% after 14 days and 32% after 200 days after releasing a mixture or large (12-35mm) and small (8-12mm) juveniles (1400 in total) into an area protected by rubble and/or plastic mesh.

Recent research by Clarke and Komatsu (2001) also reported good survival rates (76%-85%) of 40mm hatchery-reared trochus in the Solomon Islands 4 weeks after their release into substrata ranging from coral bench to mixed rubble/rocks. These results suggest 2 things: that high survival rates may be achieved if juveniles are transferred to suitable habitat in which they can shelter from predation and that the larger the trochus at release the better their chance of survival. Castell (1995) also found that larger juveniles (19-23 mm) survived better than smaller juveniles (4-12mm).

**Table 12:** Previous research into trochus reseeding. (Modified from Crowe *et al.* 1997)

| Study | Locality | Number released & size | Method of release | Monitoring | Survival | Cause of loss of trochus |
|---|---|---|---|---|---|---|
| Heslinga *et al.* (1983) | Palau | 32000<br>2-6 mm | Broadcast by diver | 2 months & 5 months | ?? | Migration of larger individuals |
| Kubo (1989, 1991) | Japan | 9000 & 8000 respectively<br>8-9mm & 17 mm respectively | Some free release, some attached to coral and some in enclosures | 15, 40-60 and 120-130 days | 13-75, 0-46 and 0-5% respectively. | Predation, storms |
| Hoffschirr *et al.* (1989)<br>Hoffschirr (1990) | New Caledonia | 2228 (March) + 3481 (June) =5409 (into 20 sites)<br>19mm | Released into rock piles | Initial 2228 sampled 2, 7 &<br>12 weeks.<br>All after 1 year | 2-week = 21-72%, 7-week incomplete, 12 week = 8.4%, 0.3% after 1 year. | Cyclone |
| Kikutani (1991) | Palau | 11244<br>7.1-34mm | Free-release into natural juvenile habitat | 2, 5, 10 & 40 days | Recovery rates decreased during the months of monitoring | Predation, migration |
| Amos (1991) | Vanuatu | 1000, 400<br>>20mm, <20mm<br>respectively | Protected by rubble &/or cage | 4, 7, 12, 27 and 49 days, 13 months | 87.5, 51, 44.25, 44.25%. 28% after 13 months (Nash, 1993). | Predation |
| Castell (1995) | Orpheus Island Nov 1993 – Feb 1994 | 943<br>13-44mm | Placed upright on sub-stratum | 3, 30, 111 days | 41, 26, 12.4% | Predation |
| | Orpheus Island<br>Oct 1994 | 430<br>4-8mm | Placed upright on sub-stratum | 1, 3 days | 61, 50% | Predation |
| | Orpheus Island<br>Dec 1994 | 460<br>4-8mm | Placed upright on sub-stratum | 1, 2 days | 56, 35% | Predation |

| Study | Locality | Number released & size | Method of release | Monitoring | Survival | Cause of loss of trochus |
|---|---|---|---|---|---|---|
| Castell (1995) cont. | Orpheus Island Feb-June 1994 | Several experiments 672 10-12, 19-20, 26-27mm | Tethered to steel rods with 0.5m lengths of cotton | Different experiments monitored for 2,4 & 8 days | Varied from 17% (12mm, 8days) to 90% (all sizes, 1 day) | No comment |
| | Vanuatu May 1994 | 600 30mm | Placed upright on substratum | 2, 40 days | 63, 6.7% | Predation |
| | Vanuatu May 1994 | 60 30mm | Tethered to steel rods with 0.5m lengths of cotton | 3 days | 81.5% | No comment |
| Amos (1995) | Vanuatu | 1400 large (12-35mm) small (8-12mm) | Protected by rubble &/or plastic mesh | Fortnightly for 200 days | 88% (14 days) 32% (200 days) | Predation |
| Clarke and Komatsu (2001) | Solomon Islands | 40mm | Release into substrata ranging from coral bench to mixed rubble/rock | Every second day after release for 4 weeks | 79-85% | Predation |
| Purcell (2001) | Western Australia – 2 sites | 75 trochus at each site 12-20mm | Released into cages with 15 litres of coral rubble in each. | 1, 3, 6 & 9 months from trial commencement | Good survival and growth rates. | |
| Crowe *et al*. (2002[b]) | Western Australia Indonesia Vanuatu | Different densities (2-8m$^2$ + Control) & sizes (6-12, 16-27mm) at replicated sites in each region | Placed upright on sub-stratum and into some cover (eg: crevices, under macroalgae etc.) where possible. | 1, 3, 6 & 12 months | Majority of juveniles release in Australia and Indonesia disappeared within a month of release and stocks were not enhanced in comparison to controls. Losses in Vanuatu also substantial but 4.4% of 10-27mm juveniles recaptured after 12 months. | Predation |

### Translocation

Broodstock translocation is another method, which can be utilised to assist in restocking or stock enhancement. Broodstock translocation involves transferring broodstock from one area with a high population of the species to reefs with depleted populations. It is then envisaged that these broodstock will spawn and recruitment of juveniles will occur. For most cases broodstock translocation is a cheaper and simpler method than the hatchery culture of juveniles (Purcell and Lee 2001). The success of stock enhancement by broodstock translocation relies on suitable environmental conditions for spawning, larval development and settlement and growth and survival of juveniles to adults (Purcell and Lee 2001). This requires conservative fishing regulations to be in place or cessation of fishing so that the transplanted broodstock are not removed and so that egg production and recruitment of a population can occur successfully.

Translocation of trochus broodstock has been practised extensively throughout the Pacific as a method of establishing breeding populations on reefs previously uninhabited by trochus with no noticeable adverse effects (Nash 1993). Broodstock were introduced to Aitutaki Atoll in the Cook Islands from Fiji in 1957. These were allowed to breed for 24 years unhindered by fishing and a first harvested of almost 200 tonnes of shell took place in 1981(Nash 1993; Nash *et al.* 1995). Trochus broodstock were also introduced to Tahiti in 1957 from Vanuatu. This introduction started a fishery that yielded more than 350 tonnes of harvestable trochus shell between 1971 and 1973 (Purcell and Lee 2001).

Nash (1993) reported that trochus fishermen on the Great Barrier Reef have transplanted trochus to productive reefs that have been depleted of stocks through overfishing, however measurements of the success of these transplants are lacking. Nash (1993) reported that this technique has not been used to replenish overfished stocks of trochus and is not a favoured management tool for stock enhancement of this species.

While these examples suggest that it may be an effective means of accelerating the recovery of a population or establishing a population, experimental trials would need to be conducted to establish if it is an effective method for other areas. There have also been concerns that translocations may cause problems by spreading unwanted organisms such as parasites and pathogens along with the trochus (Yamaguchi 1990). There are no records of bêche-de-mer broodstock being translocated. Figure 6 shows the critical steps during the process of stock enhancement using broodstock translocation.

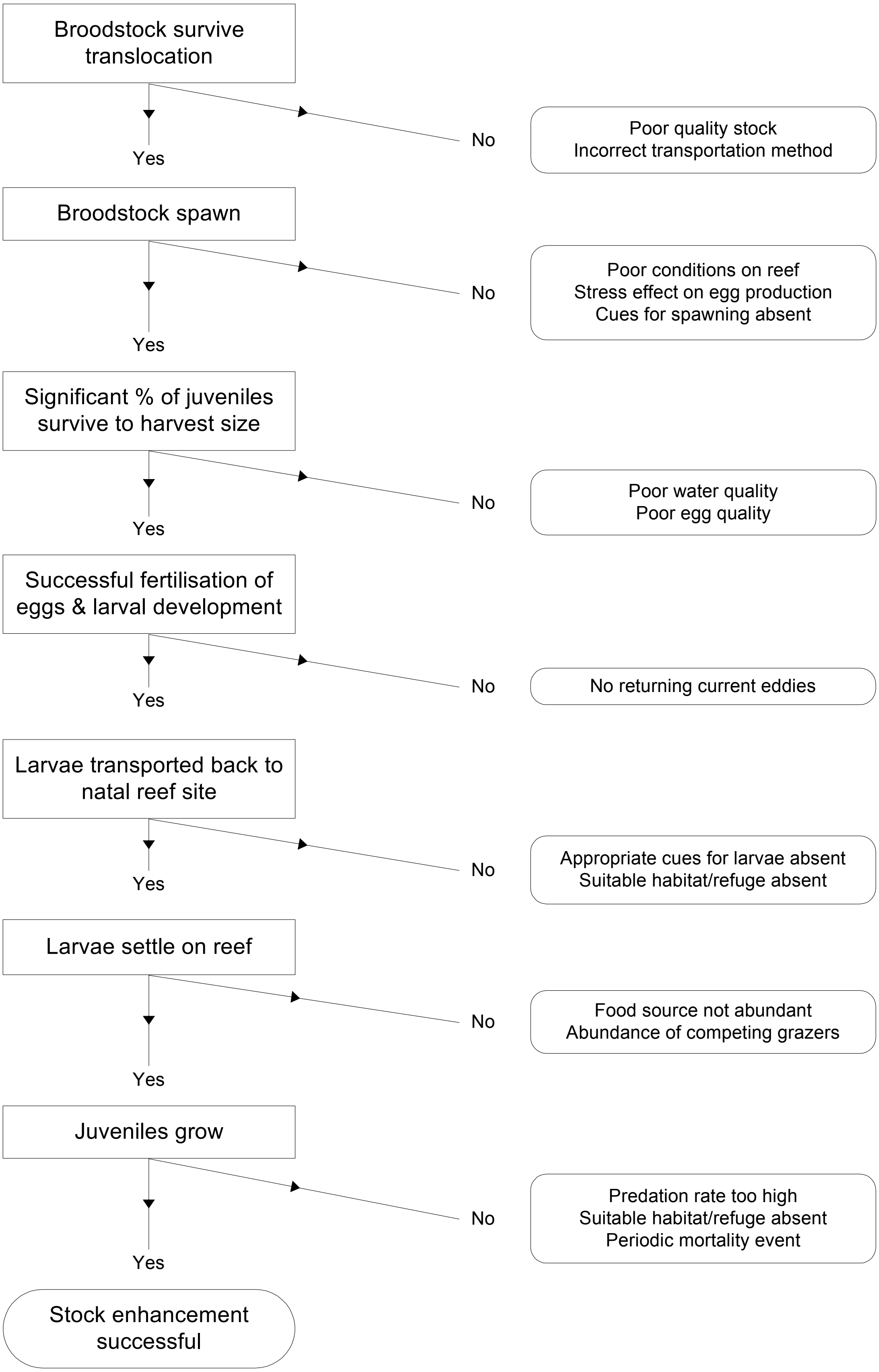


**Figure 6:** Broodstock translocation: critical steps during the process of stock enhancement. Likely causes for failure are in boxes on the right (from Purcell and Lee 2001).

## Potential for sea cucumber and trochus restocking in Australia

Northern Australia has a number of attributes that favour development of aquaculture and stock enhancement. These include:

- Its close proximity to major aquaculture and seafood markets of Asia;
- A great diversity of species associated with coral reefs that are high in demand for the aquaculture, seafood, aquarium and pharmaceutical markets in Asia (eg: sea cucumbers, pearl oysters, giant clams, angel fish, soft and hard corals, sponges);
- Australia's reputation for producing high quality, safe seafood and other fisheries products in a "clean and green" environment;
- Australia is relatively free of major aquatic diseases;
- Aboriginal and Torres Strait Islanders have a tradition of working with marine resources. Many coastal communities are aware of and understand the basic biology of many species.

Although there appear to be a number of advantages for development of aquaculture and stock enhancement in northern Australia there are also a number of constraints that need to be considered. These include:

- Transport problems – getting infrastructure to remote areas of northern Australia, including Torres Strait, and transport of product to market.
- Socio-economic factors – Many remote areas of Australia may lack the infrastructure, capital, skilled labour and training facilities required to implement a successful aquaculture facility, particularly hatcheries;
- Limited land and water sites available on which to establish aquaculture facilities. However, aboriginal landowners that have gained exclusive title to ancestral lands and the sea adjoining these lands provides an opportunity for indigenous communities to use coastal areas for aquaculture and perhaps enter into joint venture operations.
- Cyclones and storm activity – Can expect aquaculture installations to be damaged occasionally by large swells and winds
- Poaching – A product such as sandfish is a high value product. Poachers and illegal fishermen, particularly in areas where compliance is limited/difficult, may target growout and restocking areas.

Before restocking of sea cucumbers can be considered in Australia the production difficulties for sea cucumber need to be overcome. To date there has only been one successful sub-tropical spawning of sandfish (refer to Section 5.1). If restocking is to be utilised as a tool to replenish over-exploited stocks then it will be necessary for production techniques of other over-exploited species such as black teatfish to be developed. As well as this the current hatchery technology for trochus and, once developed, the hatchery technology for sea cucumbers will have to be scaled up to produce the huge numbers of juveniles needed to have an impact on stock abundance.

There are still many questions that need to be answered and research that needs to be undertaken, including determining how successful reseeding with hatchery reared juveniles will be over and above natural recruitment levels, and if reseeding with hatchery reared juveniles will be a cost-effective management tool. Information required to answer these questions include the following:

- The Biology and ecology of the species must be thoroughly understood
- Bio-economic modelling of the cost-effectiveness of restocking should be undertaken
- The stocking density & habitat suitability of the proposed restocking area should be assessed
- Some form of identifying released individuals needs to be developed (eg: tags or other visual identification or genetic monitoring) to allow identification and assessment of the effectiveness of reseeding.
- Juveniles to be placed into the marine environment should originate from broodstock collected from a nearby viable population. A large number of broodstock should also be used to ensure that there is genetic diversity in the juveniles produced.
- Hatchery reared juveniles need to be certified as disease and pest-free before release. Although the perceived risk with these animals is considered low, as there are no known serious diseases of sea cucumber or trochus reported in scientific literature, diseases caused by opportunistic organisms (such as bacterial or protozoal organisms) could occur if trochus and sea cucumber are cultured intensively without appropriate management practices.
- Where juveniles are to be stocked into cages to grow to a suitable size before release, the impacts from such structures or equipment on reef areas need to be minimised.
- What effect will the addition of hatchery-reared juveniles have on the ecosystem?
- What environments /habitats are suitable for restocking?
- Where should juveniles be released to maximise their survival?
- What is the carrying capacity of the system?
- What is the optimum density of the ecosystem?
- What age and size should juveniles be released to maximise survival but still be cost effective?
- What are the likely predators of the released juveniles?
- Will adding them to the system alter ecosystem dynamics?
- Can they be grown in good health and similar behaviour to their wild counterparts?

Restocking of populations with hatchery-reared animals also raises some interesting issues relating to ownership of the animals once released, especially if there is no way to determine the difference between hatchery and wildstock. Aquaculture interests may wish to close the reseeded areas so that the reseeded juveniles are protected from commercial harvest. This would mean that aquaculture interests would gain exclusive access to part of the fishery (including any wildstock in the area). As part of the fishery would be closed to commercial harvest this could also potentially lead to increased effort in the remaining areas of the fishery (B. Fraser, Fisheries Western Australia, May 2002, pers. comm.).

The ideal outcome of stock enhancement activities would be that the population eventually becomes self-sustaining, which means that it is imperative that reseeded hatchery reared juveniles are protected in some way. Therefore stock enhancement should be assessed for each fishery and as part of a collection of management techniques (Crowe *et al.* 2002[b]), such as the use of minimum size limits and closed areas, to ensure that reseeded hatchery individuals have the best possible chance of survival and have a chance to undergo at least one spawning event before being harvested. Fishers must be prepared to forego some catch until stocks are rebuilt and then continue to comply with the regulations designed to ensure good yields can be maintained each year.

If restocking is going to be done through the release of hatchery-reared sea cucumbers or trochus there are also many factors that need to be considered about setting up a hatchery to produce the juveniles required. Setting up an aquaculture facility can be very expensive, requires careful site selection and needs access to a reliable power and sufficient and acceptable water supply amongst other things. There are also many socio-legal and economic considerations and obtaining the correct licenses and permits can also be a lengthy and expensive process.

Due to the costs associated with setting up a hatchery facility and due to the declining demand for trochus shell and therefore declining trochus prices, reseeding of trochus may presently be cost prohibitive. Declining prices for trochus may also result in decreasing fishing pressure on stocks as it becomes less appealing and less profitable to fish for trochus. Trochus stocks may therefore start to regenerate through natural recruitment as long as populations have not been depleted below the critical point to enable successful recruitment to occur.

As the demand and price of sandfish around the world is still high and as new markets develop for other products produced from this animal, if production difficulties can be overcome and optimum methods and sizes for reseeding can be determined, then sandfish reseeding could potentially be a viable option. As stated by Williams *et al.* (2000) a restocking project in Australia could potentially extend also to Papua New Guinea reefs, which are similarly, if not more depleted than some of Australia's reefs. This may also reduce illegal fishing by PNG fishers on Australian reefs.

While predicted profits may or may not warrant commercial reseeding of trochus or sea cucumbers, there may be sociological benefits to communities, particularly indigenous communities which fish these species, as well as benefits to the environment (eg: enhanced fish stocks). This may in the long run be justification enough to adopt reseeding as a management tool. However there is a great deal of research and assessment that still needs to be undertaken before this can be decided.

In the following section the Torres Strait Bêche-de-mer Fishery is used as a case study to show how potential areas for reseeding and hatchery sites for other bêche-de-mer and trochus fisheries in Australia could be identified before undergoing more thorough site selection analysis.

## Torres Strait Bêche-de-mer Fishery case study

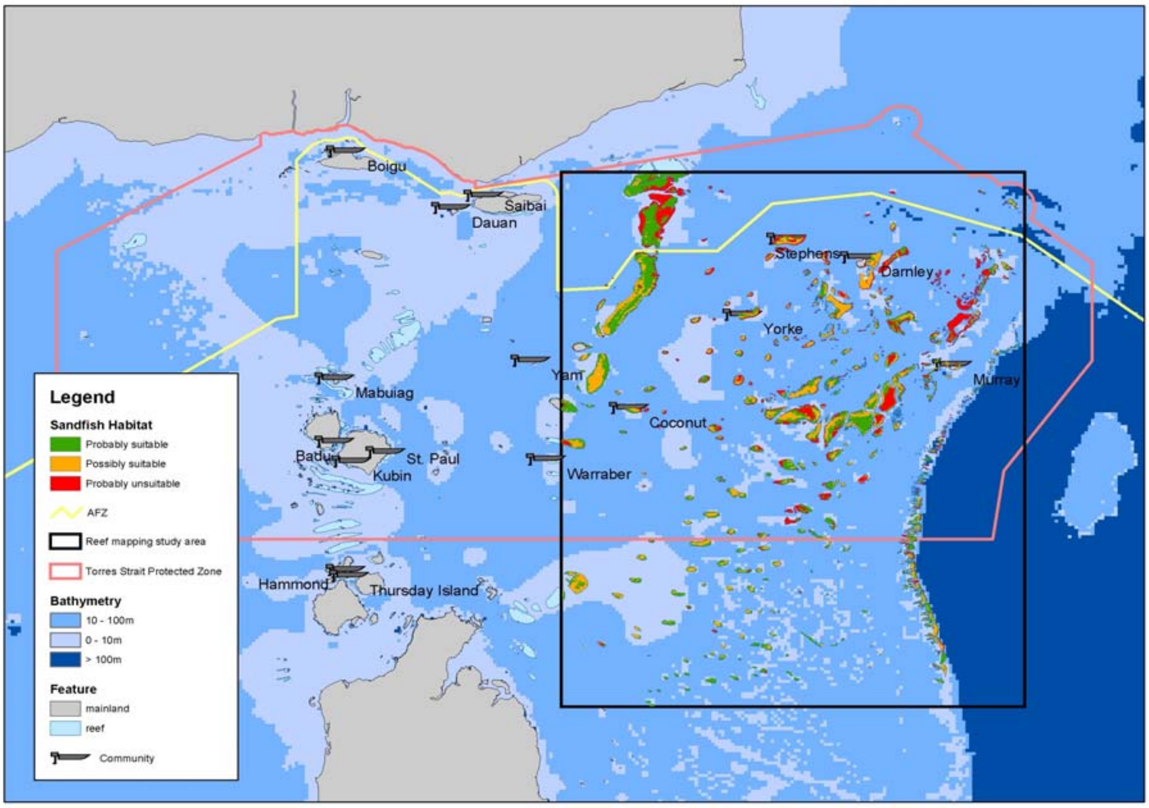


**Figure 7:** Habitat preference map for sandfish *(H. scabra)*

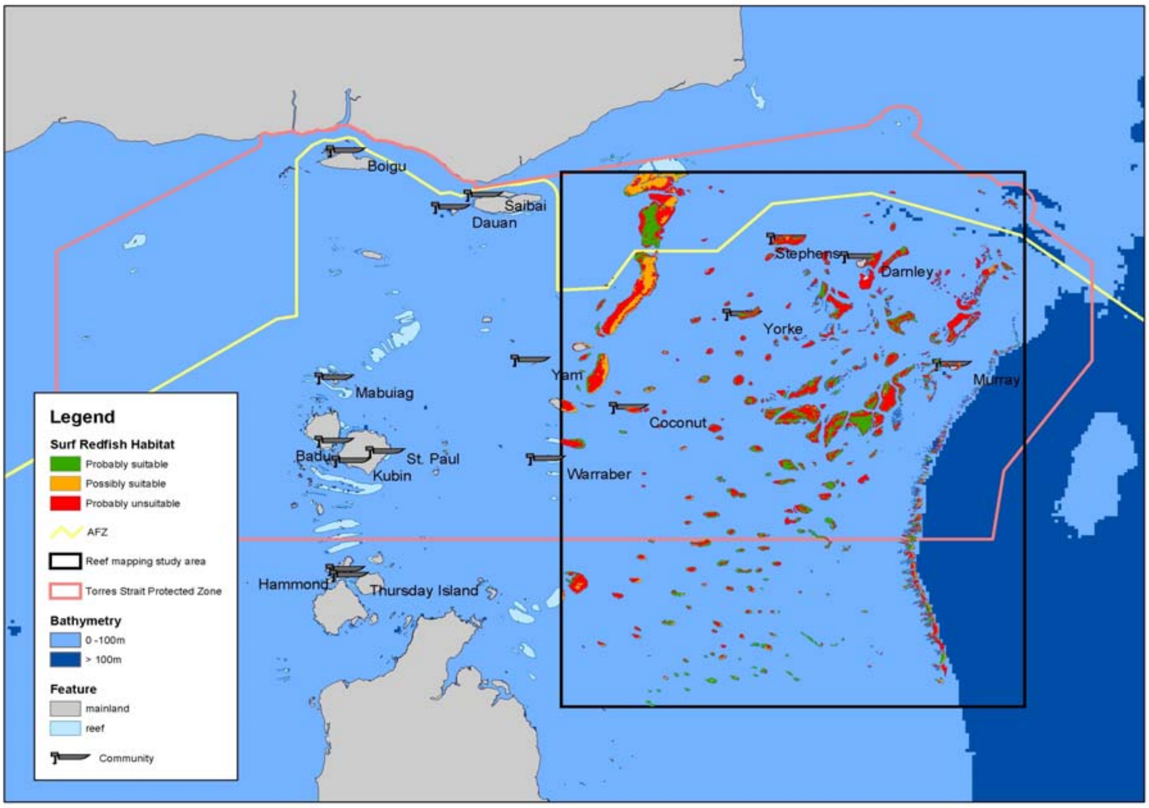


**Figure 8:** Habitat preference map for surf redfish *(A .mauritiania)*

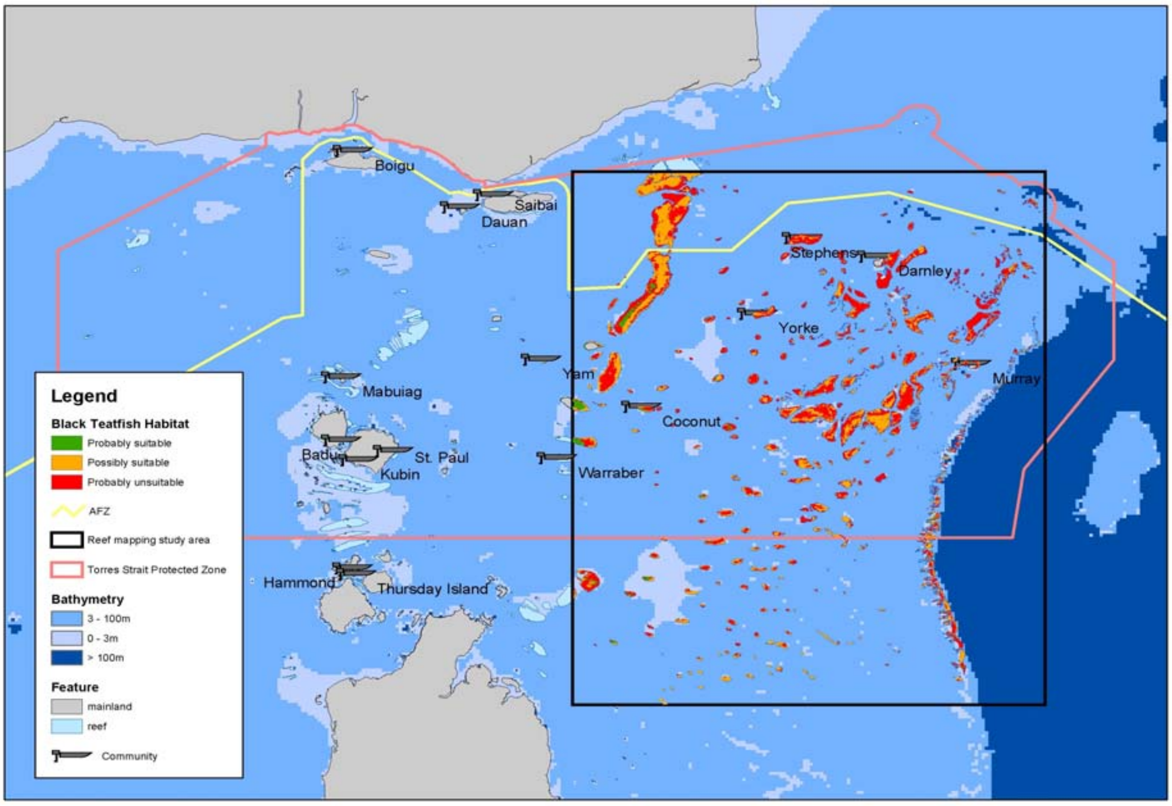


**Figure 9:** Habitat preference map for black teatfish *(H. nobilis)*

When considering reseeding with hatchery-reared juveniles as a management tool for a fishery, priority should be given to those areas that are fished or have been fished in the past and to species that are over-exploited. The area chosen should also meet the habitat requirement of the species to be reseeded so as to maximise the chances of the reseeded juveniles surviving.

Using available habitat data for east Torres Strait and available species habitat preference information for the three species regarded as over-exploited in the Torres Strait Bêche-de-mer Fishery (summarised in Table 13), maps have been developed to highlight probably suitable habitat areas (green), possibly suitable habitat areas (orange) and probably unsuitable habitat areas (red) for sandfish, surf redfish and black teatfish.

While the best available information has been used to develop these maps, they are to demonstrate a potential tool for identifying prospective areas for reseeding and hatchery sites only. Before such a tool can be relied on and used in bêche-de-mer and trochus fisheries around Australia more accurate and complete habitat data and species habitat preference information needs to be obtained.

Figure 7 indicates that the main areas of suitable habitat for sandfish are on the reefs to the north-east of Yam Island (Warrior Reef) and the south-west of Murray Island. Figure 8 indicates that the main areas of suitable habitat for surf redfish are to the south-west of Murray Island and reef area close to Yam Island. The reef areas around Yam Island also appear to possess suitable habitat for black teatfish (Figure 9).

**Table 13:** Preferred habitat substratum for sandfish, black teatfish and surf redfish.

| Common name | Scientific name | Preferred habitat substratum | Depth | Reference |
|---|---|---|---|---|
| Sandfish | *H.scabra* | Intertidal areas, silty sediment off mangrove areas and seagrass beds, inner reef flats | 0-10m | Uthicke and Klumpp 1996 |
| Black teatfish | *H.nobilis* | Reef flats and on clean sand | Shallow water up to 3m | Uthicke and Klumpp 1996 |
| Surf redfish | *A.mauritiania* | Fringing reef and outer reef where waves break, hard substratum | 0-2m | Uthicke and Klumpp 1996 |

It is quite possible that all the reef areas indicated as probably suitable habitats (green) for sandfish (Figure 7), surf redfish (Figure 8) or black teatfish (Figure 9) had significant populations of these species before they began to be exploited through fishing, and that some of these areas are no longer fished as the populations have been depleted to such a level that they are not worth targeting. If this were found to be the case some of these areas could potentially be zoned as no-take zones to enable remaining populations to rejuvenate, or in those cases where existing stocks are critically small or locally extinct they could be reseeded with hatchery-reared juveniles or translocated broodstock. If this were possible, other nearby reef areas may also benefit via larval dispersion from sanctuary areas.

For this to be adequately determined accurate catch data, including the location of the catch, would have to be collected and analysed to determine if there are areas with suitable habitat that are not being fished, and the extent to which larval dispersion could contribute to adjacent fished areas.

The location of a hatchery in relation to reefs chosen for reseeding also requires careful consideration. The hatchery needs to be located close enough to the chosen reseeding site that juveniles can be transported to the reef area easily and in good condition but also so that it is not cost-inhibitive to monitor the site and provide some form of security to ensure that reseeded individuals are not being removed by illegal fishermen. No matter where reseeding is carried out reseeded individuals will have to be protected and some catch foregone until stocks have had a chance to rejuvenate, therefore being able to monitor the site adequately will be very important to the success of the reseeding program. In addition to this the hatchery will have to be established at a location that has adequate and reliable electricity, adequate infrastructure to support a hatchery facility, all weather access, and access to reliable transport.

For example, looking at Figure 7-9 there are several reef areas including Warrior Reef, in relatively close proximity to Yam Island, which possess suitable habitat for sandfish, surf redfish and black teatfish. If it were possible to produce these species in a hatchery for the purpose of reseeding, and Yam Island was assessed as having the essential criteria needed to operate a hatchery, it may be a suitable location to base a hatchery to reseed nearby fished reef areas.

The sandfish fishery is already closed in Torres Strait and has been since 1998. Therefore if it were possible to establish a reseeding program for sandfish in this area, enforcement should be relatively easy as the restriction of not taking sandfish is already in place. It may be harder however to monitor illegal fishermen coming from PNG, thus showing the importance of having the community close to the reseeding site so communities can undertake a certain amount of their own monitoring.

## Conclusions and further research

The challenge for management authorities of bêche-de-mer and trochus fisheries is to find and implement management regulations that will keep the fisheries sustainable for the future and thus protect both the stocks and the livelihood of those involved in the fishery now and in the future.

While current management strategies in place in Australia's bêche-de-mer and trochus fisheries are cautious in their approach, future bêche-de-mer and trochus research needs to focus on life history parameters, recruitment and juvenile ecology, habitat requirements for juveniles and adults and genetic variation and isolation of populations over geographic ranges. Survey and field monitoring methods also need to be optimised and the ecological impacts of fishing these animals, particularly bêche-de-mer determined for all species.

Further research and surveys should ensure that some form of control/impact assessment is incorporated into further experimental designs plus detailed monitoring of high precision abundance information and environmental, biotic and abiotic characteristics such as seagrass, coral cover and substrate.

Fisheries managers should concentrate on finding a means of gathering timely, reliable and accurate catch data as this is vitally important in enabling the fishery to be monitored accurately over time and for population monitoring. Alternative compliance methods should also be considered and education and extension programs devised and implemented.

While reseeding and stock enhancement may be considered attractive options for the management of fisheries it requires further careful evaluation before large-scale implementation. Carefully designed pilot and research programs that incorporate fully replicated control and reseeded sites and long term monitoring of stock survival from release to harvestable size are required to assess the applicability of this technique to any given fishery region. Suitable methods and size of release for bêche-de-mer and trochus need to be determined to optimise survival after they are reseeded. Genetic, environmental and health issues of releasing hatchery-reared stock into wild populations would have to be addressed along with appropriate tagging systems to evaluate commercial catch arising from stock releases. Finally the cost-effectiveness of using reseeding as a fisheries management option for bêche-de-mer and trochus fisheries in comparison with or in conjunction with other management alternatives would need to be assessed.

Even if research showed reseeding and stock enhancement to be a viable option, the production difficulties for producing bêche-de-mer reliably in captivity in Australia will still need to be overcome. Although trochus have been bred successfully in captivity in Australia, production still needs to be scaled-up to produce the huge number of juveniles needed to have an impact on stock abundance once released and even then the price currently being received for trochus may make reseeding cost prohibitive.

Translocation of broodstock and the triggering of asexual reproduction in bêche-de-mer species that have this capacity should also be further investigated and evaluated to determine if these are potential alternative means of restocking these animals. The inability to provide sufficient and suitable food for the on-growing of trochus and bêche-de-mer juveniles means that aquaculture of these species through to harvestable size is currently not feasible.

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