Biology of a high-density population of *Stichopus herrmanni* at One Tree Reef, Great Barrier Reef, Australia

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Abstract

The population biology of *Stichopus herrmanni* on a back reef habitat at One Tree Reef, southern Great Barrier Reef, Australia was investigated. A density of 736 animals per hectare was recorded, and is one of the highest known for this species. Individuals were found in 67% of all transects. The population's size-frequency distribution approximated a normal distribution with a mean length of 344 mm. There was no evidence of small or juvenile specimens. The mean distance between individuals was 221 cm. Reproductive success is likely to be enhanced by the high density, large size and short distance between individuals. This population will be monitored to provide baseline data on the population biology of *S. herrmanni* from an unfished reef as a potential reference site for the Great Barrier Reef fishery of this species.

Introduction

Australian waters have historically been fishing grounds for sea cucumbers (MacKnight 1976; Uthicke 2004). There are presently a number of beche-de-mer fisheries operating in Australian waters, including the East Coast Queensland Fishery (located along the Great Barrier Reef), the Northern Territory Fishery, Torres Strait Fishery, Western Australia Fishery and a developmental fishery in Moreton Bay, South Queensland (Kinch et al. 2008a). In addition, there is an area in Australian waters off of Broome where Indonesian fishermen harvest reef resources (includes Ashmore Reef, South and North Scott Reef) (Skewes et al. 1999). The East Coast Queensland fishery along the Great Barrier Reef (GBR) has been operating since 1997 (Kinch et al. 2008a). From 1997–2001 this fishery focussed on teatfish (*Holoturia whitmaei, H. fuscogilva*) and to some extent sandfish (*H. scabra*) (QDPIF 2007). In recent years, this fishery has concentrated on blackfish and burrowing blackfish (*Actinopyga spinea*, *A. miliaris*), harvesting *Actinopyga spinea* in waters deeper than 30 m (QDPIF 2007). This fishery also focuses on shallow-water species in the curryfish group (*Stichopus herrmanni*, *S. ocellatus*, *S. vastus*). The Queensland fishery is managed by a rotational zoning system (Lowden 2005). Stocks of *S. herrmanni* are particularly conspicuous in the shallow waters of the southern GBR in the Bunker Capricorn Group where they inhabit shallow back reef areas and lagoons. *S. herrmanni* is also included in other beche-de-mer fisheries, such as in the western Indian Ocean (Conand 2008), and in many Pacific Islands (Kinch et al 2008a). It is also part of a domestic market in some areas (Lambeth 2000).

Current beche-de-mer management and fishing practices throughout the Indo-Pacific region are resulting in overfishing (Bell et al. 2008; Friedman et al. 2008). This makes it imperative to adopt an adaptive and precautionary management approach to the development of new fisheries. There is also a need to understand how removing commercial sea cucumbers, often the largest benthic species in coral reef communities, affects ecosystem resilience (Wolkenhauer et al. 2009). Tropical holothurians serve an important role in nutrient recycling, which improves benthic productivity (Uthicke 1999; Uthicke and Klummp 1998). With these aspects in mind, the relatively recent focus on the curryfish species group in eastern Australia provides the impetus to establish rigorous local and benchmarked knowledge of the biology of this species in the region, a current gap in the published literature. This information is necessary in order to inform management decisions regarding the fishery.

S. herrmanni is currently listed as a low to medium value beche-de-mer species (Lambeth 2000; Choo 2008; Conand 2008). Processing the body wall of this and other species in the curryfish group can be difficult because it tends to fall apart during boiling, thereby reducing its commercial value (Lambeth 2000). This is due to the mutable properties of the body wall. In the East Coast Queensland Fishery, processing and

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marketing of curryfish as frozen ready-to-eat product avoids this problem, thus enhancing the value of the product (QDPIF 2007). The trend of switching to frozen product at the expense of the traditional dried product is expected to continue from the Queensland fishery (QDPIF 2007).

The lagoon system at One Tree Reef supports a diverse and abundant assemblage of sea cucumber species. This reef has been a "no-take" scientific research zone for decades. The local and long-term high abundance of *S. herrmanni* at One Tree Reef provides an opportunity to investigate the population biology of this species from an unfished reef. A similar approach has been adopted for black teatfish surveys in no-take and special sanctuary zones in the far northern GBR Marine Park (Byrne et al. 2004; Uthicke et al. 2004). This study will contribute to the generation of a time series dataset for populations of *S. herrmanni* excluded from harvesting. This provides an important baseline data for the GBR fishery and also for comparison with other populations of *S. herrmanni*, especially in areas subject to harvesting.

Methods

The survey was undertaken at One Tree Reef (23°30'S, 152°05'E) in the Capricorn Bunker Group of the southern GBR. This is a platform reef with a lagoon enclosed by a continuous reef. The resident population of *S. herrmanni* was surveyed from 4–8 May 2009 at "Shark Alley", a back reef area just southwest of One Tree Island. Depending on the tide, the depth at this site ranged from 0.5–4.0 m. Shark Alley is subject to wave action over the reef flat at high tide. However, at low tide, the back reef area has low energy areas that are high in nutrients as seen by the prominent cover of benthic microalgae over fine sediment.

The population of *S. herrmanni* was surveyed using 40 m x 1 m transects and employing the protocol of the Reef Fisheries Observatory (Secretariat of the Pacific Community) used elsewhere in the Pacific Islands region (Kim Friedman pers. comm.). This approach allows for a thorough investigation of an area with high replication due to the short time required to process each transect. Transects (n = 36) were laid out in back reef areas along the reef edge. The data were used to estimate a per hectare (ha^{-1}) density.

As an indication of aggregation, nearest neighbour measurements (i.e. animal-to-animal proximity) were randomly collected for *S. herrmanni* individuals that were encountered during snorkelling in Shark Alley. Data were collected for the sizes of two neighbours and their distance from one another, thus providing a rough estimate of proximity within sampled populations. The length of the animals encountered in the nearest neighbour survey was measured to establish a length-frequency distribution for *S. herrmanni* at One Tree Reef.

Results

The mean density of *S. herrmanni* along the back reef site was 736 animals ha^{-1} (SE = 172, n = 36). This species was found in 67% of transects (n = 36) and was most common in areas close to main reef feature or reef outcrops (Fig 1a, b). *S. herrmanni* were located on sand, rubble and nestled among live coral. The length-frequency distribution resembled

Figure 1. *Stichopus herrmanni* is common near and on reef features in Shark Alley at One Tree Reef, Great Barrier Reef, Australia.

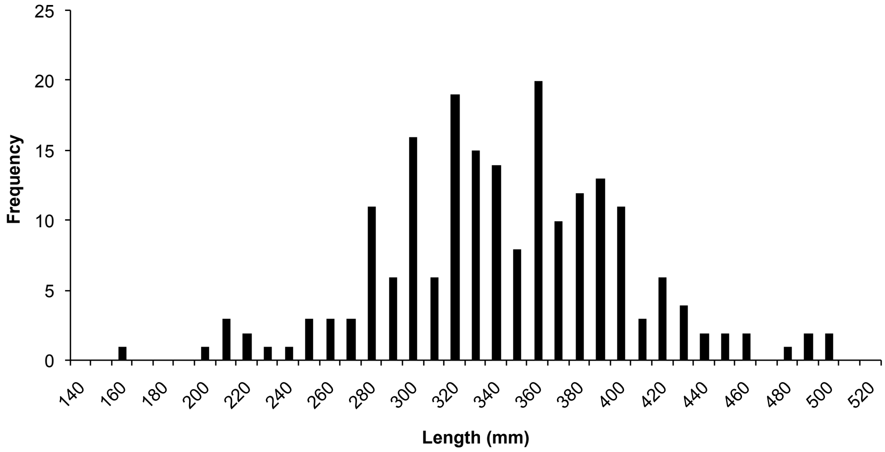

Figure 2. Length–frequency diagram for *S. herrmanni* at One Tree Reef. n = 203.

a normal distribution (Fig. 2) with a mean length of 344 mm (SD = 58 mm, n = 203, range 160–500 mm). Small adults and juveniles were not observed. The mean distance between *S. herrmanni* individuals was 221 cm (SE = 50 cm, n = 82, range = 0–3570 cm).

Discussion

One Tree Reef supports a diverse and abundant assemblage of aspidochirotid sea cucumbers. This may be because of the high nutrient retention of this reef system due to its structure, which limits lagoon circulation and loss of nutrient rich water (Larkum et al. 1988). In a recent translocation study, lagoon sands were shown to support remarkable growth with an annual length increase of up to 100% in *Holothuria atra* (Lee et al. 2008).

The density of *S. herrmanni* at One Tree Island back reef areas (i.e. 736 individuals ha^{-1}), was very high, and is likely to represent some of the highest densities reported for this species. We recognize that density comparisons are affected by differences in sampling method, replication and spatial effort. In the northern GBR, Hammond et al. (1985) reported densities of 10 animals ha^{-1} (extrapolated from 0.4 animals 400 m^{-2}). In the northwest Australia area (Scott, Ashmore and Seringapatam reefs) and Torres Strait, densities of 0–14 individuals ha^{-1} and 0–21 individuals ha^{-1}, respectively, have been reported (Skewes et al 1999, 2004). Densities at One Tree Reef are also much higher than those found in Papua New Guinea (0.1–31 individuals ha^{-1} as reported by Kinch et al. 2008b). *S. herrmanni* is noted to be common in the southern GBR (Roelofs 2004), but it is not known if the extraordinary high density is similar in other areas in the region; therefore, further surveys of neighbouring reefs are required.

The conspicuous population of *S. herrmanni* has been present in the back reef site at One Tree Reef for at least 20 years (Byrne pers. observ.). At this site, this species occupies sand at the base of coral reefs and small patch reefs in the lagoon. The presence of *S. herrmanni* along reef edge strata is noted for the Torres Strait (Skewes et al. 2004) but elsewhere it is more common in soft sediment and seagrass habitats (Desurmont 2003). At One Tree Reef, *S. herrmanni* were often found nestled among corals and may be an important nutrient resource through ammonia production (Uthicke and Klumpp 1998). However, it is not known why *S. herrmanni* is so abundant in this area of One Tree Lagoon. Further investigation of local sediment nutrient dynamics may be informative. In other regions of One Tree Lagoon *S. herrmanni*, while conspicuous, is less dense in sandy substrates that are some distance from coral (Eriksson and Byrne pers. observ.). Data are needed to determine distribution patterns. Continuous surveys of this back reef population and the larger lagoon area will provide time-series data on population metrics. Our current understanding of population dynamics of unfished and commercial populations of *S. herrmanni* and other species is a major impediment for designing sustainable harvesting strategies. It is not known how stocks respond following harvesting. Empirical data on population biology for tropical sea cucumbers are key for management, not only in the GBR fishery, but also throughout the tropics where sea cucumber resources are harvested.

With respect to the fisheries biology of *S. herrmanni*, the stable and dense population at the surveyed site provide an excellent opportunity for future research into population dynamics, distribution, spawning and Allee effects. We aim to collect seasonal information regarding stock density and aggregation. *S. herrmanni* spawns in the summer at One Tree Reef (Eriksson and Byrne pers. observ.). The planktonic larval duration of tropical aspidochirotida sea cucumbers is generally 14–21 days (Ramofafia et al. 2003). This survey was performed in May, but juveniles or small sub-adults were not observed. The smallest animals observed were 160 mm. The size at sexual maturity for *S. herrmanni* is estimated to be 220 mm (Conand 1993), suggesting that the majority of the surveyed population is mature. For the Queensland fishery, size at first maturity is 140 mm with harvest size limits proposed to be 200 mm (Roelofs 2004). If this were applied to the surveyed population at One Tree Reef, virtually the entire population would meet the harvest criterion. In comparison the minimum size listed for the Torres Strait *S. herrmanni* fishery is 270 mm (Lloyd and Prescott 2004).

Most beche-de-mer species have different recruitment habitat, juvenile nursery areas, and adult habitat. We do not have data on the location of these sites. It is likely that juveniles were hidden in reef structures, and would only be found by destructive measures. No juveniles were found during nighttime surveys (Eriksson, pers. observ.), demonstrating that even for a conspicuous species such as *S. herrmanni* in a protected reef at One Tree Reef, its is difficult to observe and establish recruitment processes and life history parameters of these organisms. Addressing this knowledge gap is key to informing future management decisions regarding beche-de-mer species.

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References

Bell J.D., Purcell S.W. and Nash W.J. 2008. Restoring small-scale fisheries for tropical sea cucumbers. Ocean and Coastal Management 51:589–593.

Byrne M., Cisternas P., Hoggett A., O'Hara T. and Uthicke S. 2004. Diversity of echinoderms at Raine Island, Great Barrier Reef. p. 159–164. In: Heinzeller T. and Nebelsick J.H. (eds). Echinoderms: München. Taylor and Francis Group, London.

Choo P.S. 2008. Fisheries, trade and utilization of sea cucumbers in Malaysia. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper 463. FAO, Rome.

Conand C. 1993. Reproductive biology of the holothurians from the major communities of the New Caledonian Lagoon. Marine Biology 116:439–450.

Conand C. 2008. Population status, fisheries and trade of sea cucumbers in Africa and the Indian Ocean. p. 143–193. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. FAO, Rome.

Desurmont A. 2003. Papua New Guinea sea cucumber and beche-de-mer identification cards. SPC Beche-de-mer Information Bulletin 18:8–14.

Friedman K., Purcell S., Bell J. and Hair C. 2008. Sea cucumber fisheries: A manager's toolbox. ACIAR Monograph No.135. 32 p.

Hammond L.S., Birtles R.A. and Reichelt R.E. 1985. Holothuroid assemblages on coral reefs across the central section of the Great Barrier Reef. Proceedings from the Fifth Coral Reef Congress, Tahiti, Vol 2.

Kinch J., Purcell S., Uthicke S. and Friedman K. 2008a. Population status, fisheries and trade of sea cucumbers in the western Central Pacific. p. 7–55. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper, No. 516. FAO, Rome.

Kinch J., Purcell S., Uthicke S. and Friedman F. 2008b. Papua New Guinea: A hotspot for sea cucumber fisheries in the western Central Pacific. p. 57–77. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). 2008. Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. FAO,Rome. 317 p.

Lambeth L. 2000. The subsistence use of *Stichopus variegatus* in the Pacific Islands. SPC Beche-de-mer Information Bulletin 13:18–21.

Larkum A.W.D., Kennedy I.R. and Muller W. 1998 Nitrogen fixation on a coral reef. Marine Biology 98:143–155.

Lee J., Byrne M. and Uthicke S. 2008. The influence of population density of fission and growth of *Holothuria atra* in natural mesocosms. Journal of Experimental Marine Biology and Ecology 365:126–135.

Lowden R. 2005. Management of Queensland sea cucumber stocks by rotational zoning. SPC Beche-de-mer Information Bulletin 22:47.

Loyd C. and Prescott J. 2004. Torres Strait beche-de-mer fishery – Draft assessment report.

McKnight, C. 1976. The voyage to Marege: Macassan trepangers in northern Australia. Melbourne, Melbourne University Press.

QDPIF. 2007. Annual status report east coast beche-de-mer fishery, April 2007. Queensland Department of Primary Industries and Fisheries, Queensland Government.

Ramafofia C., Byrne M. and Batteglene S. 2003. Development of three commercial sea cucumber *Holothuria scabra, H. fuscogilva* and *Actinopyga mauritiana*: Larval structure and growth. Marine Freshwater Research 54:1–11.

Roelofs A. 2004. Ecological assessment of the Queensland's east coast beche-de-mer fishery. A report to the Australian Government Department of Environment and Heritage on the ecologically sustainable management of a highly selective dive fishery. Queensland Government Department of Primary Industries.

Skewes T.D., Dennis D.M., Jacobs D.R., Gordon S.R., Taranto T.J., Haywood M., Pitcher C.R., Smith G.P., Milton D. and Poiner I.R. 1999. Survey and stock size estimates of the shallow reef (0–15 m deep) and shoal area (15–50 m deep) marine resources and habitat mapping within the Timor Sea MoU74 Box. Volume 1: Stock estimates and stock status. CSIRO Marine Research.

Skewes T., Dennis D., Koutsoukos A., Haywood M., Wassenberg T. and Austin M. 2004. Stock survey and sustainable harvest for Torres Strait beche-de-mer. Australian Fisheries Management Authority Torres Strait Research Program Final Report. AFMA Project Number: R01/1345.

Uthicke S. 1999. Sediment bioturbation and impact of feeding activity of *Holothuria* (*Halodeima*) *atra* and *Stichopus chloronotus*, two sediment feeding holothurians, at Lizard Island, Great Barrier Reef. Bulletin of Marine Science 64(1):129–141.

Uthicke S. 2004. Overfishing of holothurians: Lessons from the Great Barrier Reef. p. 163–171. In: Lovatelli A. Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper 463. FAO, Rome.

Uthicke S. and Klumpp D.W. 1998. Microphytobenthos community production at a near-shore coral reef: Seasonal variation and response to ammonium recycled by holothurians. Marine Ecology Progress Series 169:1–11.

Uthicke S., Welch D. and Benzie J.A.H. 2004. Slow growth and recovery in overfished holothurians on the Great Barrier Reef: Evidence from DNA fingerprints and repeated large-scale surveys. Conservation Biology 18:1395–1404.

Wolkenhauer S-M., Uthicke S., Burridge C., Skewes T. and Pitcher R. 2009. The ecological role of Holothuria scabra (Echinodermata: Holothuoroidea) within subtropical seagrass beds. Journal of the Marine Biological Association of the United Kingdom 1–9.