Discovery and description of *Stichopus herrmanni* juvenile nursery sites on Heron Reef, Great Barrier Reef

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Abstract

The population biology of the curryfish, *Stichopus herrmanni*, was investigated at Heron Island in the Capricorn Bunker Group of the southern Great Barrier Reef (GBR), Australia. Heron Reef is of particular interest because it is a protected no-take area within the GBR Marine Park and is adjacent to areas where this species is fished. We report the discovery of a juvenile nursery site for *S. herrmanni*, which to date are still poorly understood. An area of ~3,200 m^2 across the leeward side of Heron Reef was found to support a density of 0.017 ind. m^{-2} of *S. herrmanni.* Sexually immature adults (<220 mm) constituted 49% of a population of 53 individuals, and 2 individuals were juveniles (≤100 mm). The mean length of *S. herrmanni* at site 1 was 190 mm (±7.5 mm) while individuals at site 2 had a mean length of 294 mm (±13.3 mm). The fact that individuals were larger at site 2 suggests ontogenetic migration of this species. This is an important documentation of juvenile *S. herrmanni* habitat, which should be considered in fisheries management strategies to better understand and protect this delicate life stage and avoid serious depletion of this important commercial species from the reef.

Introduction

The fishery operating within the Great Barrier Reef Marine Park (GBRMP), the East Coast Bêche-De-Mer Fishery (ECBDMF), exploits medium value beche-de-mer species, including the curryfish, *Stichopus herrmanni*, which sells on the Hong Kong market for around USD 197 ± 47 kg^{-1} (Purcell 2014). From 2007 to 2011 the total harvest of *S. herrmanni* increased at an average annual rate of 200% (Eriksson et al. 2013; Eriksson and Byrne 2015). The *S. herrmanni* fishery is now presenting an average annual catch of approximately 34,000 individuals, roughly equivalent to 17.2 t (landed weight) (Skewes et al. 2014). At this rapidly increasing level of harvest, it is vital to develop a better understanding of the biology and ecology of this species to provide useful guidelines for fisheries management.

Sea cucumbers play a fundamental role in the recycling of nutrients, helping to break down detritus and other organic matter after which bacteria continue the degradation process (Uthicke 1999; Mangion et al. 2004; Purcell et al. 2013). Furthermore, sea cucumbers have an important ecological role through their released nitrogenous waste compounds, which promote the growth of seagrass and microalgal communities (Uthicke 2001; Wolkenhauer et al. 2010). Their faecal casts also increase local seawater total alkalinity, and this is suggested to promote coral calcification processes and potentially provide a buffer against the negative effects of ocean acidification (Schneider et al. 2011, 2013; Friedman et al. 2011). In light of these discoveries it is clear that the depletion of sea cucumbers, such as *S. herrmanni*, from reef areas could seriously impact coral reef ecosystem resilience (Schneider et al. 2011).

Our study was conducted at Heron Reef, southern GBR, which is a no-take zone exposed to minimal anthropogenic and fishery disturbances. The collection of biota, including sea cucumbers, has been highly regulated since 1843. The reef is located close to reefs where the ECBDMF operates in the Capricorn Bunker Group. This island group supports a conspicuous population of *S. herrmanni* and is a major target region for this fishery (Eriksson et al. 2010, 2013; Skewes et al. 2014; DAFF 2014).

Heron Reef provides an opportunity to investigate the conservation and fishery biology of *S. herrmanni*. We encountered a population of juvenile *S. herrmanni* on the leeward margin of Heron Reef, allowing us to assess the characteristics of a potential recruitment site for this commercially important species. Other studies document similar juvenile habitat in the Capricornia Bunker Group at nearby One Tree Island (Eriksson et al. 2010, 2013; Eriksson and Byrne 2015). On One Tree Reef the smallest *S. herrmanni* encountered was 110 mm long, and this was located in shallow coral/crustose coralline algal habitat (Eriksson et al. 2010, 2013). We document the smallest individuals of *S. herrmanni* reported in situ in the southern GBR (Shiell 2004). Conand (1993) reports a juvenile *S. herrmanni* of 90 mm in length in New Caledonia.

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Aside from early planktonic larval life stages of marine invertebrates where mortality is around 99% (Gosselin and Qian 1997), little is known about the juvenile life stages, which are considered to be extremely vulnerable (Battaglene et al. 1999; Shiell 2004; Hu et al. 2010). Success at the juvenile stage is fundamental for establishing adult populations, which are necessary for fisheries. It is imperative that we develop a better understanding of the population structure of sea cucumbers to provide information for fisheries management strategies. Understanding the biology and ecology of recruitment and early juvenile stages is particularly important.

Methods

Observations were made across Heron Reef in a series of surveys over several days during April 2015. After identifying a specific habitat where small *S. herrmanni* were present, two sites were chosen along the leeward reef edge for further study (Fig. 1). This habitat is characterised by dense intertidal reef and thick crustose coralline algae shelves (Fig. 2). There are obvious spur-and-groove systems along the reef edge, with narrow gullies of sandy habitat between reef structures (Fig. 2).

The population structure of *S. herrmanni* was investigated using a targeted transect technique across the sand cay. Transects (40 × 2 m; n = 20 per site) were laid out randomly across sandy substrate, sometimes intercepting reef habitat, and employing the protocol of the Reef Fisheries Observatory (Secretariat of the Pacific Community) (Eriksson et

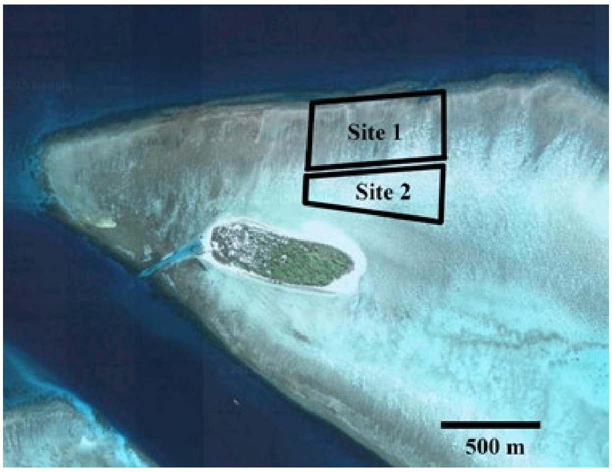

Figure 1. Satellite image showing Heron Island and sites 1 and 2, along the leeward reef edge, where the juvenile *Stichopus herrmanni* nursery was found. (Image: Kennedy Wolfe)

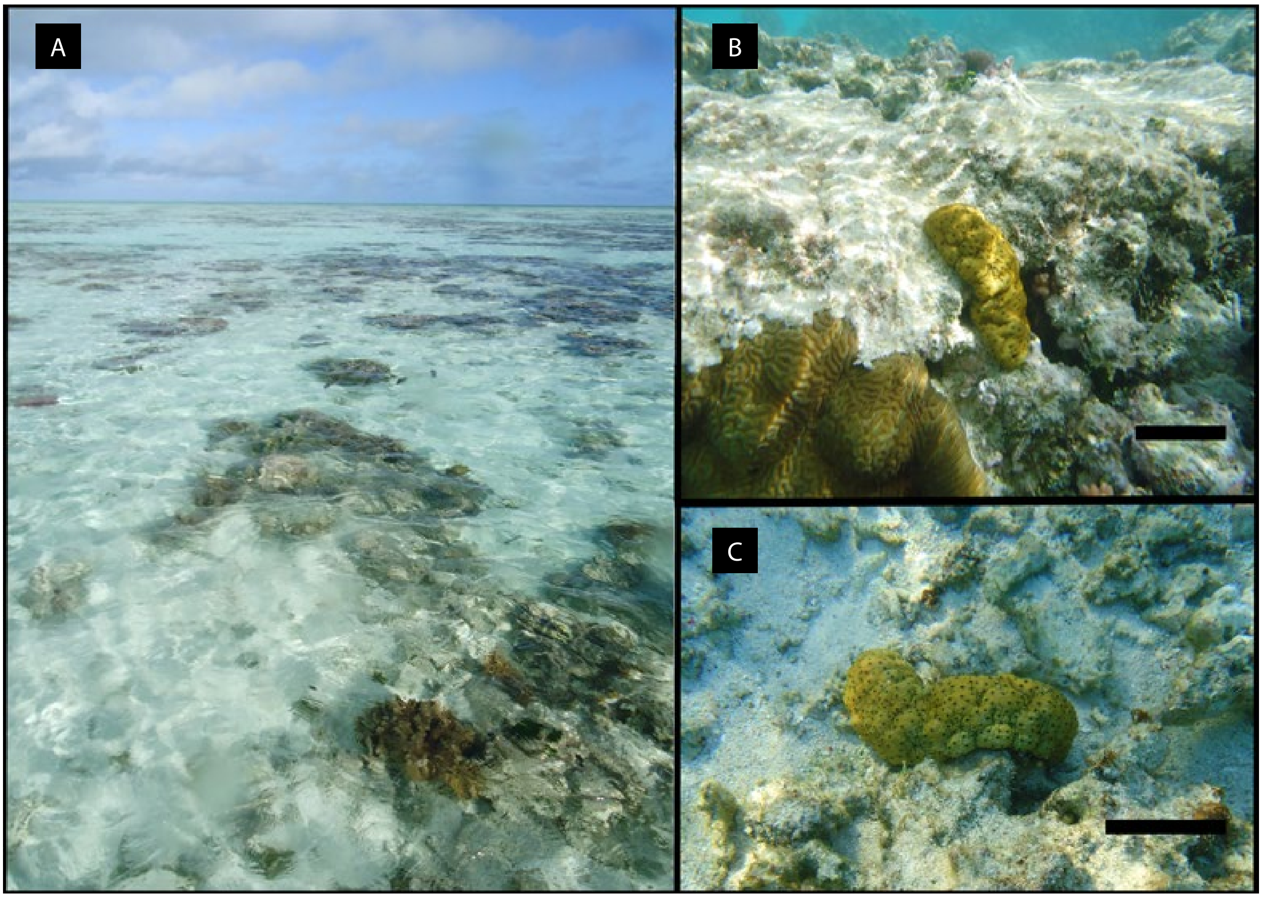

Figure 2. Habitat typical of site 1, where juvenile *Stichopus herrmanni* were found. A: Patches of reef around sandy channels; B and C: juvenile *S. herrmanni* in the reef network (scale bars = 4 cm). (Images: Kennedy Wolfe and Luca Palazzo)

al. 2010). All *S. herrmanni* inside each transect were counted, and the length and width of each individual were measured. Measurements were made using a flexible tape measure without touching or disturbing the individual, so as not to make it contract or change shape.

Results

A total of 53 *S. herrmanni* were found over an area of ~3,200 $m^{2,}$ a density of 0.017 ind. m^{-2}. The density of *S. herrmanni* found at site 1 was 0.0175 ind. m^{-2} and at site 2 the density was 0.016 ind. m^{-2}. Over this area, considering sexually immature *S. herrmanni* are <220 mm in length (Eriksson et al. 2010), subadults represented 75% of the total population at site 1 and 20% at site 2. Individuals at site 1 had a mean length of 190 mm (SE 7.5 mm; n = 28; range 100–260 mm) while at site 2 they had a mean length of 294 mm (SE 13.3 mm; n = 25; range 190–400 mm) (Fig. 3). Two individuals were 100 mm in length at site 1 (Fig. 3).

Discussion

The lagoon system of Heron Reef supports a wide and stable population of *S. herrmanni*, similar to that recorded for nearby One Tree Island (~15 km to the east) (Eriksson et al. 2010, 2013). The discovery of juvenile nursery habitats has added more value to these lagoonal systems for the conservation of this vulnerable species in the Capricorn Bunker Islands. The data generated here indicate the need for more expansive research on *S. herrmanni* in the region to assist informed management for the beche-de-mer fishery that operates in the Capricorn Bunker Group.

The density of *S. herrmanni* at Heron Island was lower than that found by Eriksson et al. (2010) on One Tree Island, but is still high compared to the literature (Kinch et al. 2008a, 2008b; Skewes et al. 2014). It is important to keep in mind that the density for this species seems to be significantly influenced by site (Eriksson et al. 2010, 2013). The population at Heron Reef presented a conspicuous number of juveniles (100 mm) and immature adults (<220 mm; Eriksson et al. 2013), in contrast to the smallest individuals observed on One Tree Reef (110 mm).

A population of juveniles is a rare observation for beche-de-mer species (Shiell 2004). Our surveys did not cover a very extensive area (3,200 m^2), and further surveys are needed for a better understanding of the extent of the recruitment/nursery habitat of *S. herrmanni* on Heron Reef, and for a deeper understanding of the juvenile life stage of *S. herrmanni*. More data are needed to determine the characteristics of juvenile nurseries for this beche-de-mer species, from physical and chemical perspectives. Since both juveniles and adults are present in the study area, Heron Reef provides an excellent opportunity for future research on the population structure and reproduction (e.g. spawning, Allee effects) of *S. herrmanni*.

Most *S. herrmanni* were found very close to reef structure and in sheltered sandy patches within the reef (Fig. 2). To date, habitats known to be suitable for larval settlement and metamorphosis to juvenile stage of holothurians are seagrass beds, intertidal reef, coralline algae and associated bacterial films (Shiell 2004; Hu et al. 2010; Skewes et al. 2014). We document juvenile/nursery habitat along the

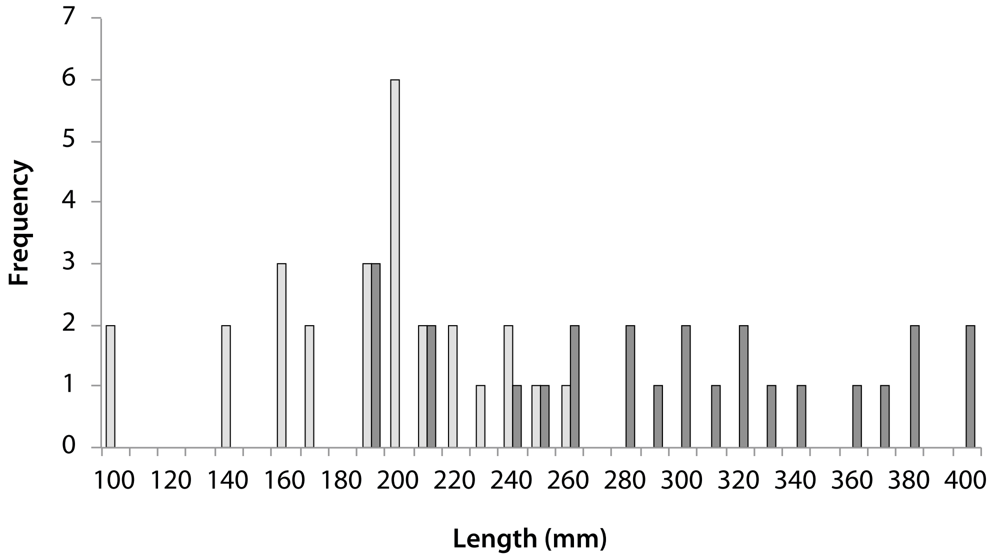

Figure 3. Length frequency diagram of *Stichopus herrmanni* specimens found at site 1 (light bars) and site 2 (dark bars) on Heron Reef (n = 53).

leeward side of Heron Reef, which is less exposed to the main wind and wave climate. We suggest that recruitment may occur once the larvae reach the outer leeward wall of Heron Reef, with juveniles developing along this margin and progressively moving inside Heron Lagoon to the deeper water as they grow; the deeper sediments are also more rich in nutrients (Larkum et al. 1988; Eriksson et al. 2010). All juveniles and a greater number of smaller individuals were found at site 1 compared to site 2, supporting the hypothesis of ontogenetic migration lagoonward (see also Eriksson et al. 2013).

Populations of beche-de-mer species often show very slow recovery following depletion by fishery removal. For example, the black teatfish, *Holothuria nobilis*, showed no recovery two years after fishery closure (Uthicke et al. 2004). This is suggested to be due to low recruitment and slow individual growth rates. Recovery of overfished sea cucumber populations on the GBR may take several decades (Uthicke et al. 2004). It is therefore important that fisheries identify recruitment habitats for protection and avoid collection from these locations.

There remains uncertainty around the population structure of commercially important beche-de-mer species. For example, there is still a lot of doubt on species longevity (Conand 1993; Friedman et al. 2011). For *S. herrmanni*, multiple cohorts across a broad size range were observed at One Tree Reef (Eriksson et al. 2013), leading to the suggestion that there is continuous replacement of individuals from recruitment and juvenile habitats to adult populations. Our findings support this. It is imperative that the fisheries operating within the Capricorn Bunker Group and elsewhere have a deeper understanding of the population structure and reproductive behaviour of commercially important species such as *S. herrmanni*. Surprisingly, there are no published data on the reproductive cycle for any of the populations of the major commercial species in the GBRMP. There is also a lack of published data on population recovery of reefs post-fishing. Regular population monitoring and fishery-independent data are essential to assess the sustainability of the fishery and the health of the reef itself.

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