Length-weight relationship, movement rates, and in situ spawning observations of *Holothuria scabra* (sandfish) in Fiji

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Abstract

This study investigated the length-weight relationship and movement rates of the sea cucumber *Holothuria scabra*, and reports on two *in situ H. scabra* spawning events at a site with relatively healthy stocks in Vanua Levu, Fiji. A length-weight equation was established − weight = 0.1878 × length$^{2.5807}$ − which explained 90% of the variance for *H. scabra* of length 5–24 cm. *H. scabra* moved at a rate of 40 cm h^{-1} ± 3.40 SE and appeared active for 10 h day^{-1}, displayed a home-ranging behaviour, and therefore are considered mobile within a limited range. Spawning occurred during October and December, coincided with spring tides, and was only observed around enclosures that were stocked with high densities (ca. 350 g m^{-2}) of *H. scabra*. The animals aggregated around high-density enclosures prior to spawning, suggesting that spawning is density dependent. Observations during spawning indicate the length at first maturity is ca. 15 cm.

Introduction

Holothuria scabra is a deposit-feeding species of sea cucumber found in low-energy environments behind fringing reefs or within protected bays and shores of the tropics (Hamel et al. 2001). Despite being an important species in the domestic Fijian and international beche-de-mer market (Hair 2011; Purcell 2014), there are key information gaps that are relevant to the management of Fiji's *H. scabra* fishery. Beche-de-mer is sold by weight, and the relationship between dollar value and mass of *H. scabra* is exponential (Purcell 2014). As such, estimates of mass from length, and therefore the potential value of an animal prior to harvest, are important to understand. Fijian communities have strong cultural and historical rights over customary fishing grounds (*qoliqoli*) and have used a range of traditional management methods such as *tabu* (i.e. periodically harvested closures) areas (Jupiter et al. 2014). Given the area, the level of resource management and management practices can differ considerably from one *qoliqoli* to the next, and the movement of valuable resources such as *H. scabra* can be a cause for conflict between communities. Hence, there is a strong need to understand movement rates and patterns of *H. scabra*, particularly for communities using *tabu* areas or restocking as a way of replenishing stocks (Bell et al. 2008). Fishery closures during spawning seasons are commonplace (Overzee and Rijnsdorp 2014; Jupiter et al. 2017); however, the basic information required for this management approach – timing of the spawning season – for *H. scabra* in Fiji remains unknown. The research presented aimed to: (a) determine the length-weight relationship based on a simple 'field-friendly' methodology in order to allow estimates of biomass; and (b) calculate movement rates of *H. scabra*. Two *in situ* spawning events are described, with their associated environmental conditions. These provide an estimate of the spawning season of *H. scabra* in Fiji.

Materials and methods

This study was part of a larger one investigating the impact of *H. scabra* removal on reef sediment function on Vanua Levu, Fiji (Lee et al. 2017). At the study site, 12 enclosures of 9 m^2 each were constructed and stocked with different densities of *H. scabra* depending on treatment (n = 4 enclosures per treatment). High-density treatment enclosures were stocked with approximately 15 *H. scabra* (ca. 350 g m^{-2}), 'natural' density enclosures contained approximately 3 *H. scabra* (ca. 60 g m^{-2}), and exclusion enclosures contained no *H. scabra*. Enclosures used in the Lee et al. (2017) study were positioned in the centre of the Natuvu reef flat, while the current study surveyed *H. scabra* from the entire reef flat.

Length-weight relationship

A total of 689 *H. scabra*, ranging in lengths from 5–24 cm, were collected on the extensive reef flat in front of Natuvu village, Wailevu East District, Vanua Levu, Fiji (16°44.940'S, 179°9.280'E) between August 2015 and February 2016, and again in December

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2016. The animals were collected during belt transects and surveys of two deeper pools – covering a total area of ca. 5400 m^2 and ca. 22,170 m^2, respectively – were carried out by foot or snorkel where appropriate.

The lengths and weights of *H. scabra* were recorded following similar methods used by Seeto (1994) and Al-Rashdi et al. (2007). *H. scabra* individuals were removed from the water and allowed to initially contract and expel water, which happened almost immediately following handling (<3 s). The animal's length was recorded from anus to mouth by placing a ruler along its ventral surface. All measurements were recorded to the nearest centimetre. Sea cucumbers were then placed into containers filled with water from the site. Water in the containers was continuously exchanged to reduce stress on the animals. All *H. scabra* of the same length were kept together in containers (Figure 1). Following each collection, the animals were taken ashore and weighed on a digital scale (± 0.02 g) to the nearest gram. Time from initial capture to weighing took no longer than 1 hour. Individuals were allowed to contract and expel water before being weighed, as described above. Following weighing, all sea cucumbers were released back into the site.

Movement rate

The movement rates of 28 *H. scabra* (lengths 8–16 cm, mean length = 13 cm ± 0.22 SE; mean mass = 145 g ± 6.27 SE) were studied over two weeks in January 2016. The study was conducted during day and night, flood and ebb tides, and within three habitats: sand, *Halodule* seagrass beds, and *Syringodium* seagrass beds. Markers (made using 4.0 mm diameter wire) were driven vertically into the sediment at a standardised distance (ca. 1 cm) behind the caudal end of the animal. If the animal appeared disturbed (e.g. contracted its body, stopped feeding or moving) then another one was chosen. Approximately every hour the animal was spotted again by following its trail of sediment pellets, and another marker was placed; after three hours the third and final marker was placed. Time was recorded each time a marker was placed. The animal's length and weight were recorded. Distance travelled by *H. scabra* was measured as straight distance between each marker, rounded to the nearest centimetre.

Results and discussion

Length-weight relationship

The length and weight of *H. scabra* (n = 689, 13 cm ± 0.15 SE, 168 g ± 4.91 SE) were recorded; a power regression () in Microsoft Excel 2010 explained 90% of variance ($r^2 = 0.90$) (Figure 2).

Figure 1. *H. scabra* of the same length (measured to the nearest cm) were placed in the same containers prior to weighing (Photo: Steven Lee).

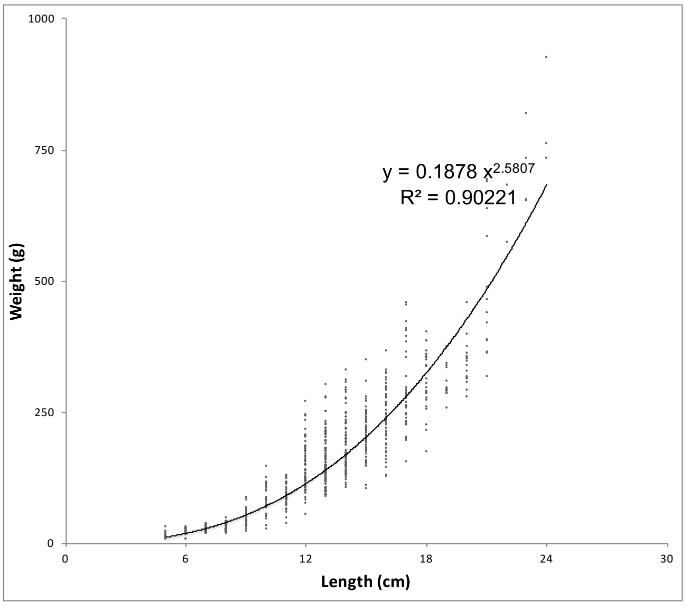

Figure 2. Length-weight relationship of *H. scabra* (n = 689). Power regression (Microsoft Excel 2010), $weight = 0.1878\ length^{2.5807}$, $r^2 = 0.90$.

The calculated length-weight equation was limited to *H. scabra* between lengths of 5–24 cm, as there was a lack of data outside this size range. Two studies of *H. scabra*, the first in Toliara (Madagascar) and the second in Mahout Bay (Oman), using a similar method, produced a length-weight equation that explained 97% and 80% of variation, respectively (Lavitra 2008; Al-Rashdi et al. 2007). The dataset produced by Al-Rashdi et al. (2007) had considerably more data for lengths ≥24 cm, but lacked data for lengths ≤10 cm. The length-weight equation produced by Al-Rashdi et al. (2007) was $weight = 0.0033\ length^{2.178}$. The dataset produced by Lavitra (2008) comprised animals between a length of 6 and 24 cm, and the equation produced was $weight = 0.111\ length^{2.685}$. Lavitra (2008) provided a separate equation for juveniles (1–6 cm length), which explained 93% of variance; $weight = 0.070\ length^{2.992}$.

Movement rate

As the animals were active for ca. 10 h day^{-1}, movement rate for *H. scabra* was in the range of 2–8 m day^{-1} (mean = 4 m day^{-1} ± 0.34 SE), thus an individual could potentially travel up to 120 m $month^{-1}$. Although movement was measured as straight distance, observed movement patterns appeared to be more random – similar to findings by Mercier et al. (2000). Observations of *H. scabra* with distinct natural markings (e.g. scarring) over the course of six months revealed a 'home ranging' behaviour (moving about a restricted area – roughly 100 m radius in this study) similar to that of *Bohadschia argus* and *Thelenota ananas* (Purcell et al. 2016). Therefore, *H. scabra* are relatively mobile, but appear to have a limited range. Movement patterns of sea cucumbers may be linked to the distribution of food, as some species of sea cucumbers exhibit patch selectivity (Uthicke and Karez 1999).

In the case of *H. scabra*, movement may also be driven by the availability of soft-bottom sediment in which to shelter through burying (Mercier et al. 1999). Given the 'home ranging' behaviour of *H. scabra*, the animal was assumed buried when not seen above the substratum. Given their limited range, the main method by which *H. scabra* would spread into other areas may be during their planktonic larval stage (Hamel et al. 2001). The migration of these mobile invertebrates into neighbouring *qoliqolis* is of concern for communities that rely on these high-value organisms for their livelihood (Natuvu village headman, pers. comm.), particularly in small *qoliqolis*. Results of the current study suggest *qoliqoli* and *tabu* areas may be able to contain stocks of *H. scabra* with little loss to neighbouring *qoliqolis*. Spatial planning of networks of *tabu* areas for sea cucumbers and fishery management plans should therefore pay special attention to the dispersal of larvae and the safeguarding of brood stock.

In situ spawning observation

H. scabra (≥20 individuals) were observed spawning around 14:00 and 17:00 on 28 October 2015 and 15 December 2015, respectively. These events coincided with spring tides and the full and new moon, respectively. Spawning appeared to be synchronised and only occurred within and around enclosures stocked with high densities of *H. scabra* (n = ca. 16 *H. scabra* $enclosure^{-1}$) and where the water depth was ca. 1 m. Only individuals ≥15 cm in length were observed spawning.

These findings are consistent with previous observations at the same study site in November 2009 (Hai 2011). The peak spawning period in the Solomon Islands occurs during similar conditions; i.e. the dry season (August–November) coinciding with the full moon, and during the afternoon or early evening (Battaglene et al. 2002). The findings of the current study suggest that *H. scabra* in Fiji spawns from October–December, with multiple spawning events occurring around the full and new moon. Aggregate behaviour prior to and during spawning only took place in and around enclosures stocked with high densities of *H. scabra,* and no spawning occurred in and around enclosures stocked with natural densities (60 g m^{-2}) of *H. scabra*, suggesting density-dependent spawning that is possibly linked to chemical cues (Lovatelli et al. 2004). Accordingly, reduced densities of *H. scabra* may inhibit the ability of this species to spawn or significantly reduce the chances of successful spawning (fertilised gametes), further inhibiting chances of population recovery and increasing the risk of an Allee effect (Bell et al. 2008). As only *H. scabra* ≥15 cm were observed spawning in these aggregations, length at maturity for *H. scabra* in Fiji is assumed to be at least 15 cm.

Acknowledgements

We thank the German Federal Ministry of Education and Research (BMBF, grant number 01LN1303A) and the Rufford Foundation for providing financial support. The Leibniz Centre for Tropical Marine Research (ZMT), Wildlife Conservation Society, University of Bremen, and University of the South Pacific are thanked for supporting field and laboratory work. Vinaka vakalevu to the people of Natuvu village for allowing this study within their traditional fishing ground.

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