



SHORT REPORT

Echinoderms piggybacking on sea cucumbers: Benign effects on sediment turnover and movement of hosts

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Abstract

Sea cucumbers (Holothuroidea) are known to host ectocommensal animals but echinoderm epibionts have never been reported nor their effects on hosts appraised quantitatively. At one location in New Caledonia, we found a high number of ophiuroids (*Ophiothela* cf. *danae*) and synaptid sea cucumbers (*Synaptula media* and *Synaptula* sp.) living on the bumpy external body wall of sea cucumbers, *Stichopus hermanni*. Rates of midday sediment defecation (mean: 23 g h⁻¹) and short-term displacements (mean: 60 cm h⁻¹) by the hosts were not significantly affected by the number of echinoderm commensals they carried. The frequent relationships at the location suggest that such facultative commensalism between echinoderms could be more common than previously understood. Appreciable numbers of scaleworms, crabs and shrimps on the sea cucumbers show that sea cucumbers can act as hosts to echinoderms and other epibiotic taxa, bolstering the notion that they play important ecological roles in reef ecosystems.

Key words: Brittle star, coral reef, holothurian, invertebrate, Ophiuroidea, symbiosis

Introduction

Commensal associations in which one organism rides on the body of a mobile host are common in the sea and may offer commensal animals a variety of benefits including protection, access to food and displacement (Mercier & Hamel 2005; Fourgon et al. 2007; Parmentier & Michel 2013). Echinoderms have often been reported as hosts or as epibionts. Ectocommensalism, or ‘epibiontism’, by a range of taxa has been widely reported on host echinoids (sea urchins and sand dollars) (e.g. Doti et al. 2008; Campos et al. 2009; Hardy et al. 2011) and crinoids (feather stars) (e.g. Deheyn et al. 2006). Holothuroids (sea cucumbers) also act as hosts for some commensal organisms, commonly entocommensals living within the sea cucumbers’ body. Perhaps the most notable entocommensal is the pearl fish, which unenviably retreats into the anus of their host (Parmentier & Vandewalle 2005; Parmentier et al. 2006).

Holothuroids can also host ectocommensals, such as the opisthobranch sea slug *Plakobranthus ocellatus* van Hasselt, 1824, which piggybacks on the sea cucumber *Holothuria* (*Halodeima*) *atra* Jaeger, 1833, apparently exploiting the host’s chemical defences against predators at night. Through adaptation to toxicity, the Harlequin crab (*Lissocarcinus orbicularis* Dana, 1852) identifies its host through the cytotoxic molecules secreted as a defence mechanism by the host sea cucumber (Caulier et al. 2013). Certain species of crabs, shrimps and scaleworms can also live on the body of various sea cucumber species (Britayev & Zamishliak 1996; Lyskin & Britaev 2005). Scaleworms such as *Gastrolepidia clavigera* Schmarda, 1861 may harm the hosts by feeding on their tissues but they also consume ectoparasites (Britaev & Lyskin 2002). Indeed, some trauma or cost to the host can occur within the theoretical boundaries of commensalism (Parmentier & Michel 2013). Examination of such effects helps to define the symbioses

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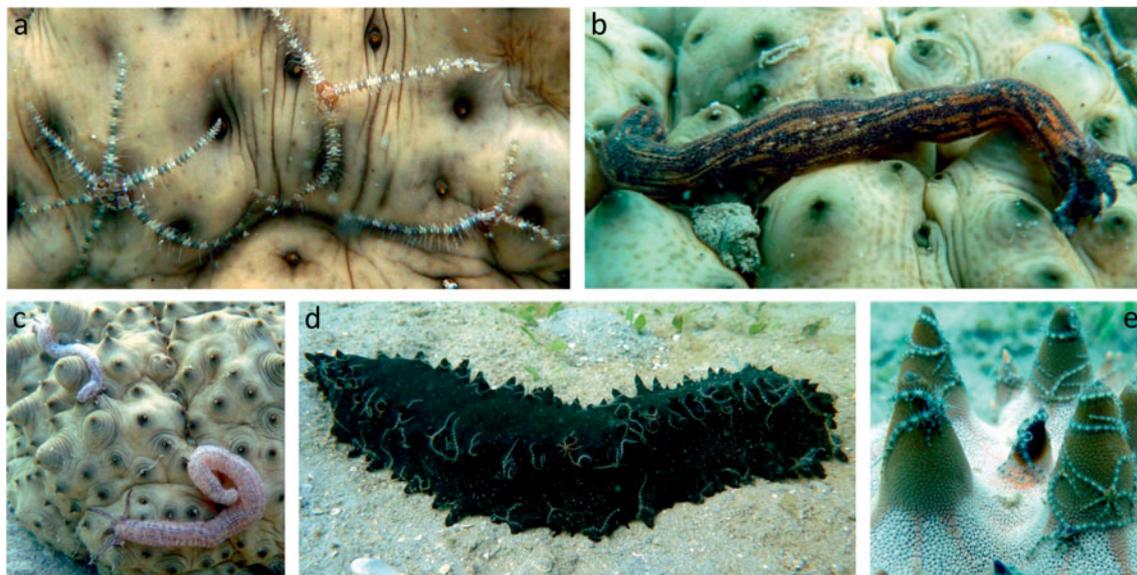


Figure 1. (a) Several *Ophiothela* cf. *danae* on the body of *Stichopus hermanni*, (b) *Synaptula* sp. on the body of *S. hermanni*, (c) anterior end of *S. hermanni* showing two *Synaptula media* attached, (d) *Ophiothela* cf. *danae* on *Stichopus chloronotus*, (e) *Ophiothela* cf. *danae* on spines of *Protoreaster nodosus*.

and may shed light on the underlying ecological or evolutionary mechanisms of the relationships.

Echinoderm ectocommensals on holothuroids have never been reported. We observed brittle stars (Ophiuroidea: *Ophiothela* cf. *danae* Verrill, 1869) (Figure 1a) and two species of synaptid sea cucumbers (Holothuroidea: *Synaptula media* Cherbonnier & Féral, 1984, and *Synaptula* sp.) (Figures 1b,c) piggybacking on numerous individuals of the large sea cucumber *Stichopus hermanni* Semper, 1868, at

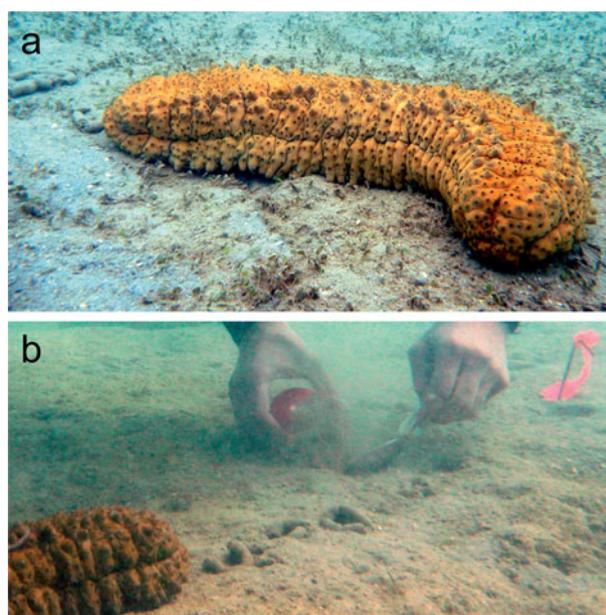


Figure 2. (a) An adult *Stichopus hermanni* with faecal casts to the left, (b) collecting faecal casts behind a *Stichopus hermanni*, with marker in background.

New Caledonia (Figure 2). Sea cucumbers are known to play important roles in reef ecosystems by recycling nutrients (Uthicke 2001) and cleaning vast quantities of surface sediments (Massin 1982; Uthicke 1999). The digestion process appears to dissolve some carbonate sands, potentially buffering corals and other reef organisms from ocean acidification (Schneider et al. 2011, 2013). *Stichopus hermanni* is a large Indo-Pacific sea cucumber that lives in a range of shallow reef habitats (Conand 1989, 1993). This species is diurnally active and can be abundant in habitats protected from fishing (Conand 1993; Eriksson et al. 2012). However, *S. hermanni* is one of many species recently listed by the IUCN as vulnerable to extinction due to widespread over-exploitation (Purcell et al. 2014). In addition to describing the commensal associations, we aimed to assess whether the commensals deleteriously affected the hosts. Infestations of these epibionts could conceivably perturb the hosts, causing them to move and feed less. Therefore, we tested whether rates of diurnal defecation (as a proxy for feeding activity) and movement were affected by the extent of ectocommensalism by ophiuroids and holothuroids.

Materials and methods

This study was carried out during April–May 2013 at the sheltered inshore bay of Baie des Citrons, New Caledonia. The same procedures of field work were carried out at site A (22°17'55"S, 166°26'12"E) on 30 April 2013 and at site B (22°17'49"S, 166°26'11"E)

on 2 May 2013. The two sites were 215 m apart and followed parallel, 100 m long rows of marker buoys. Midday water temperature was 24 °C. Light intensity, measured by a Testo™ 540 light meter, was ~55,000 lux at 11:30 and ~70,000 lux at 14:30.

We firstly located 10 adult *Stichopus herrmanni* during 07:00–08:00 at 3–8 m depth and placed marked stakes just behind the anus of the animals without disturbing them. Sand defecated from the animals appears mostly as pellets or trails of faecal casts (Figure 2). We flattened the faecal casts near animals just before the first monitoring period. Individuals have unique fine-scale colouration patterns and wart-like papillae, so the anterior end of each individual was photographed as a means of later validating that repeated measurements were made on the same individuals. We returned to the same animals between 09:33 and 10:43 (time from marking averaged 2.5 h) and collected all (morning) faecal casts that had been left by the animals. Faecal casts were scooped gently into plastic vials with the aid of a spoon (Figure 2b) and sealed underwater. We then measured the displacement of each sea cucumber from its marker to ± 1 cm with a measuring tape. Depth of each replicate was measured to the nearest 10 cm using an electronic depth gauge and later standardized to zero tidal datum. We recorded the time and repositioned the markers again just behind the anus of each animal. We repeated the same procedure during 12:08–13:45 (time from marking averaged 2.8 h) to obtain a second (midday) sample of faecal casts and measurements of displacement distance. Afterwards, each animal was re-photographed then placed into sealed plastic bags and brought to the surface. During a 5 min draining period, the animals and water from the bags were closely examined and all epibionts were identified to coarse taxonomic resolution and counted. For each *S. herrmanni*, we then measured body length and width (ventral surface) to ± 0.5 cm and weighed them to ± 10 g on an electronic balance. Photographs were later checked to validate consistency of individuals ascribed to replicates. Faecal samples in vials were rinsed twice with fresh water with 12 h settling intervals. The samples were dried thoroughly and weighed to ± 1 g.

Sediment defecation (g) and displacements of the host *S. herrmanni* were standardized to rates by dividing by the number of minutes for the time period of each replicate. We had just two time periods, so repeated measures analyses to test the effects of commensals on the hosts would not have been very appropriate. Instead, we first performed two-tailed paired *t*-tests to analyse differences in sediment defecation and displacements from morning to

midday periods at the two sites separately. Because the host animals displaced somewhat greater distances and defecated much more at midday, we performed two Generalized Linear Model (GLM) analyses for the midday data to examine the effects of echinoderm commensals on the hosts. Those analyses compared midday sediment defecation and displacements ($\ln+1$ transformed) of the host sea cucumbers between sites (fixed factor) and across three covariates: the number of echinoderm ecto-commensals, depth and body size of individual hosts. Homogeneity of variances were confirmed using Levene's test (P values = 0.19 and 0.94).

Results and discussion

Sea cucumbers play a role as epibiont hosts

At sites A and B, the host *Stichopus herrmanni* had body lengths of 37 cm \pm 5 cm s.d. and 38 cm \pm 4 cm and weights of 1792 g \pm 256 g and 1824 g \pm 344 g, respectively, indicative of adults (Conand 1989). We found a large but variable number of ophiuroid and holothuroid epibionts on the host sea cucumbers (Figure 3). Across both sites, the average numbers of other epibionts per host were 0.2 crabs, 0.4 gastropods (probably parasitic), 0.6 shrimps and 0.6

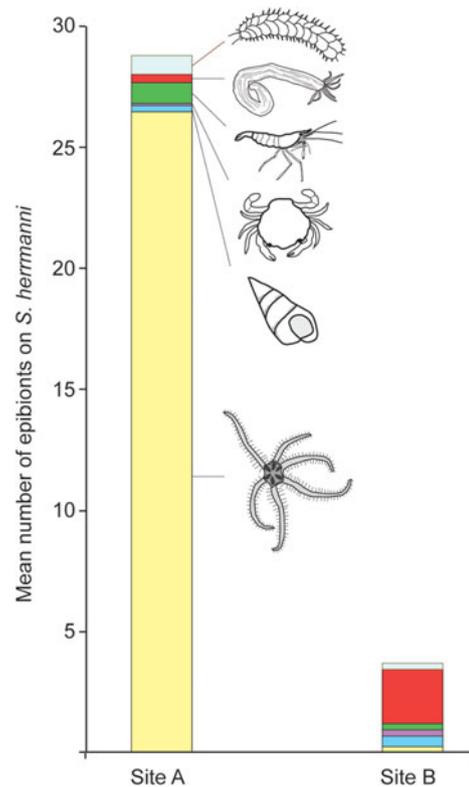


Figure 3. Stacked bar graphs of mean numbers of epibiont animals on host sea cucumbers (*Stichopus herrmanni*). Drawings from top to bottom correspond to scaleworms, synaptid holothuroids, shrimps, crabs, gastropods and ophiuroids.

polychaete scaleworms (Figure 3). The present study demonstrates that sea cucumbers are hosts to a diverse range of commensal organisms including echinoderms, thereby performing important ecological roles and enhancing reef biodiversity.

Echinoderms are often reported as hosts in commensal relationships (e.g. Deheyn et al. 2006; Campos et al. 2009) but comparatively few studies have reported echinoderms as epibionts on mobile hosts. One exception is the curious life-history of certain ophiuroids in the genus *Ophiomastix*, which 'babysit' epibiotic juveniles of their congeners (Fourgon et al. 2007). Our observations of commensal ophiuroids on the holothuroids *S. herrmanni* and *S. chloronotus* Brandt, 1835 (Figure 1d), and several individuals of the asteroid *Proto-reaster nodosus* Linnaeus, 1758 (Figure 1e), suggest that a wide range of echinoderms can at times act as 'piggyback' or 'babysitter' hosts to other echinoderms. Lyskin and Britaev (2005) found crabs and scaleworms to be common commensals of sea cucumbers in Vietnam, and evidence of intraspecific antagonism between the commensals, but they did not report any echinoderm commensals. In our study, crabs and scaleworms occurred on the ventral surface of the hosts, whereas the ophiuroids were prolific on the hosts' dorsal and lateral surfaces where they were conspicuous and exposed to fish predators. Perhaps the associations correspond to 'inquilism' (benefit of refuge), whereby saponin chemicals exuded from the host sea cucumbers offer the epibionts a defence against predators and might also attract them to the host (Caulier et al. 2013).

The symbioses may serve as 'phoretisms' (see Parmentier & Michel 2013) to facilitate displacements of the epibionts from one reef patch to another. Sea urchins are known to transport various epibiotic taxa, and it appears that certain urchins (Cidaroida) improve the dispersal of epibionts (Hardy et al. 2011). At our study sites, patches of coral habitat were isolated by expanses of silty sand, which is probably a vulnerable substrate for small epibionts. The host *S. herrmanni* lives adjacent to reefs and is known to commonly nestle into the coral structures (Conand 1993; Eriksson et al. 2012) and we observed some individuals wedged in coral and rocks in the morning. On such occasions, commensals might move from reef structures onto the hosts, and vice versa.

Commensalism was spatially variable

Ophiuroid commensals (approx. 1–2 cm total arm span) were far more common and variable in numbers at site A (27 ± 40 per host) than at site B

(0.2 ± 0.4 per host). Holothuroid commensals were more abundant on *S. herrmanni* at site B (2.2 ± 4.6 per host) than at site A (0.3 ± 0.5 per host), but a comparable proportion of the populations were host to at least one of these epibionts. With only two sites in this short study, little can be inferred about spatial variation in these relationships other than that it can be substantial over small spatial scales. Further studies will be needed to examine how such spatial variation may vary the role that the hosts play in different reef zones.

Effects on hosts were benign

We could imagine no benefit to the hosts, but the possibility of mutualism in these symbioses remains to be studied. Both the ophiuroid and synaptid holothuroids were quite small compared with the hosts and appear to be facultative commensals of sea cucumbers, because both can live on reef surfaces and other hosts. *Synaptula media*, the common commensal sea cucumber that we observed, is known to live on sponges and algae (Féral & Cherbonnier 1986). Indeed, we found an infestation of both species of synaptid sea cucumbers on the sponge *Ircinia irregularis* Poléjaeff, 1884. Similarly, the ophiuroid *Ophiothela* cf. *danae* is known to live on gorgonian corals and reef surfaces (Goh et al. 1999; Conand et al. 2013).

Our study provides the first evidence of a non-harmful commensal relationship between echinoderms and a holothuroid host. The mean rates of sediment defecation of the *Stichopus herrmanni* were modest in the morning at sites A ($6 \text{ g h}^{-1} \pm 5 \text{ g}$) and B ($5 \text{ g h}^{-1} \pm 6 \text{ g}$) compared with the midday period (both sites: $23 \text{ g h}^{-1} \pm 12 \text{ g h}^{-1}$ s.d.) (sites A and B, respectively: t -values 6.75 and 4.67, $P < 0.001$ and $P = 0.001$). Rates of displacement of the host *S. herrmanni* were slightly higher around midday (sites A and B: $0.5 \pm 0.2 \text{ m h}^{-1}$ and $0.7 \pm 0.6 \text{ m h}^{-1}$) than the morning period (sites A and B: $0.4 \pm 0.2 \text{ m h}^{-1}$ and $0.4 \pm 0.3 \text{ m h}^{-1}$), but the differences were non-significant (t -values 1.29 and 0.87, $P = 0.23$ and $P = 0.43$, respectively). The midday rates of sediment defecation by *S. herrmanni* were not significantly affected by the numbers of echinoderm commensals ($F_{1,15} = 0.15$, $P = 0.70$). The defecation rates were similar between sites ($F_{1,15} = 0.18$, $P = 0.68$) and did not differ across the narrow range of adult body weights of the hosts ($F_{1,15} = 0.51$, $P = 0.49$) or depth ($F_{1,15} = 2.06$, $P = 0.17$). Our estimations of sediment defecation rates are probably underestimated because a small portion of sediments, not contained within faecal casts, are spurted out of the anus and could not be collected viably. Similarly, the number of commensal

echinoderms appeared to have negligible effects on the midday rates of displacement of the hosts ($F_{1,15} = 0.01$, $P = 0.96$). Those displacements were comparable between sites ($F_{1,15} = 0.71$, $P = 0.41$) and did not differ significantly either across the range of host body weights ($F_{1,15} = 0.24$, $P = 0.63$) or depth ($F_{1,15} = 0.15$, $P = 0.71$). Therefore, the lack of effect on two primary ecological variables points to a truly commensal relationship between both the ophiuroid and holothuroid epibionts and their holothuroid hosts.

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