Observations of juvenile *Stichopus* sp. on a coral reef in Palau

Amelia Desbiens[1] and Kennedy Wolfe[1]*

Information on the supply-side ecology[2] of tropical sea cucumbers is poor because juveniles are rarely observed in nature, especially newly settled or early-stage juveniles (i.e. < 1 cm) (Conand 1988; Shiell 2004; Bourjon and Conand 2015). In the case of commercially important sea cucumber species, this hinders our ability to develop fisheries management strategies that adequately incorporate data on spawning windows (e.g. Balogh et al. 2019), larval recruitment, and juvenile nursey sites (e.g. Eriksson et al. 2010; Palazzo et al. 2016; Wolfe and Byrne 2017).

During field surveys of cryptic fauna inhabiting reef rubble in Palau, western Micronesia (Fig. 1), we found six, early-stage juvenile stichopodids. These surveys were part of a larger study aimed at characterising cryptofauna communities in degraded reef structures and quantifying their roles in coral reef trophodynamics. The rubble habitat was shallow (1–2 m depth) and on the back reef of a common research and dive site known as Lighthouse Reef (Fig. 1a). The back-reef habitat varied from large dead coral and rubble pieces (including coral bommies ~1 m) to rubble beds comprising smaller fragments (Fig. 1b), on which juvenile stichopodids were found. Two juveniles were found within our broader sampling protocol, while the remainder were found during haphazard searches in the same environment.

The juvenile stichopodids observed, presumably belong to the *Stichopus* genus. They ranged from 7 mm to 12 mm in length (Table 1), and were bright yellow. The trivium had three rows of podia and the bivium had a number of papillae with dark tips (Fig. 2a). Larger individuals were observed to have 10 ramified feeding tentacles at the anterior end (Fig. 2b), which were suppressed in the smallest individual (Table 1).

The first four juveniles found were kept in controlled aquarium conditions for subsequent weeks to monitor their growth. Natural rubble from the collection site was provided but no additional food was supplied. Within six days, the smallest individual (7 mm) had grown 1 mm and its tentacles became ramified. All other individuals (≥ 9 mm) had ramified tentacles when found, with the exception of the posterior end of a recently split individual (Table 1). Interestingly, Hu et al. (2010) documented 8 mm as the size threshold for ramification of the tentacles for (a likely different) *Stichopus* sp. reared in a laboratory. Growth rates were approximately 1 mm/week (Table 1). This is slower than that reported by Hu et al (2010) (1 mm/day), although notably, they provided enriched food throughout the juveniles' development.

We found one individual that exhibited traverse fission (i.e. splitting in half), with distinct and partially healed anterior

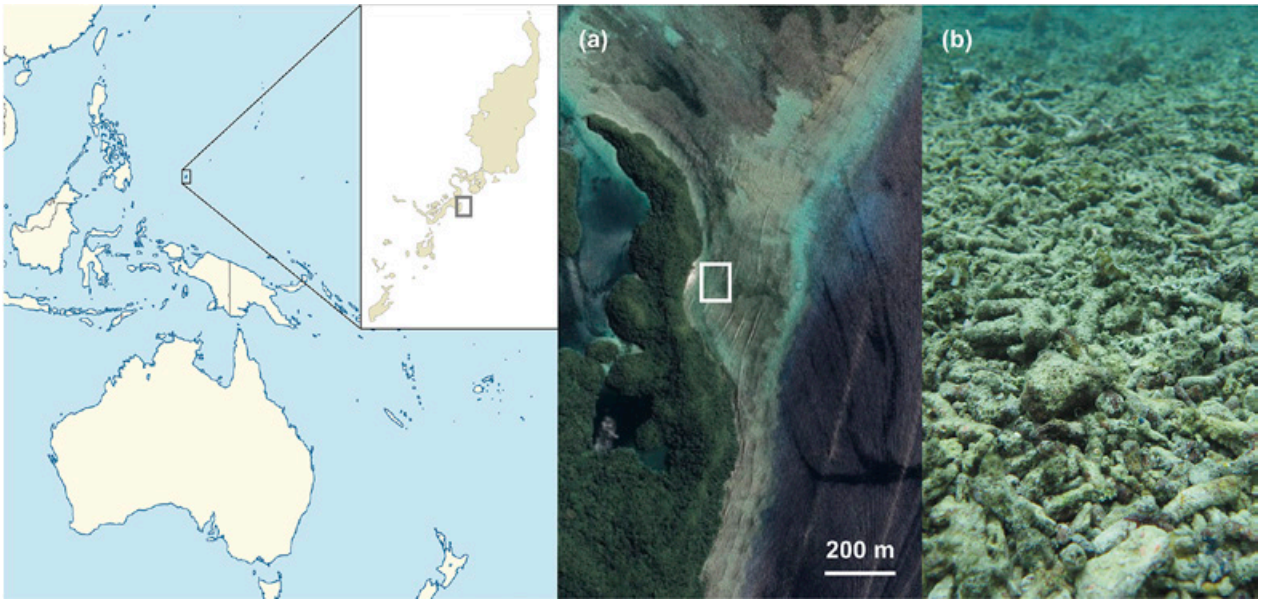

Figure 1. Palau, western Micronesia, indicating the location of Lighthouse Reef (7°16'06" N and 134°27'08" E) and the back-reef rubble site (a), and rubble habitat where juvenile stichopodids were found (b).

[1] Marine Spatial Ecology Lab, School of Biological Sciences and ARC Centre of Excellence for Coral Reef Studies, University of Queensland, St Lucia, QLD 4072, Australia

[2] "Supply-side" ecology looks at the mechanisms that control the settlement and recruitment of marine organisms, and the conditions under which recruitment variation affects the distribution and abundance of adults.

* Corresponding author: k.wolfe@uq.edu.au

Table 1. Information on juvenile *Stichopus* sp., including date found, initial and final size (mm), growth rate (mm/week) and the presence of ramified tentacles at the time of collection. Note: individual no. 4 had undergone fission, with separate measurements taken for the anterior (an) and posterior (po) segments.

ID no.	Date found	Days in aquaria	Initial size (mm)	Final size (mm)	Growth rate (mm/week)	Tentacles ramified
1	15-11-2019	25	7	12	1.40	No
2	18-11-2019	22	9	13	1.27	Yes
3	20-11-2019	20	12	16	1.40	Yes
4 (an)	28-11-2019	12	9	11.5	1.46	Yes
4 (po)	28-11-2019	12	5	8	1.75	No
5	06-12-2019	0	10	-	-	Yes
6	06-12-2019	0	11	-	-	Yes

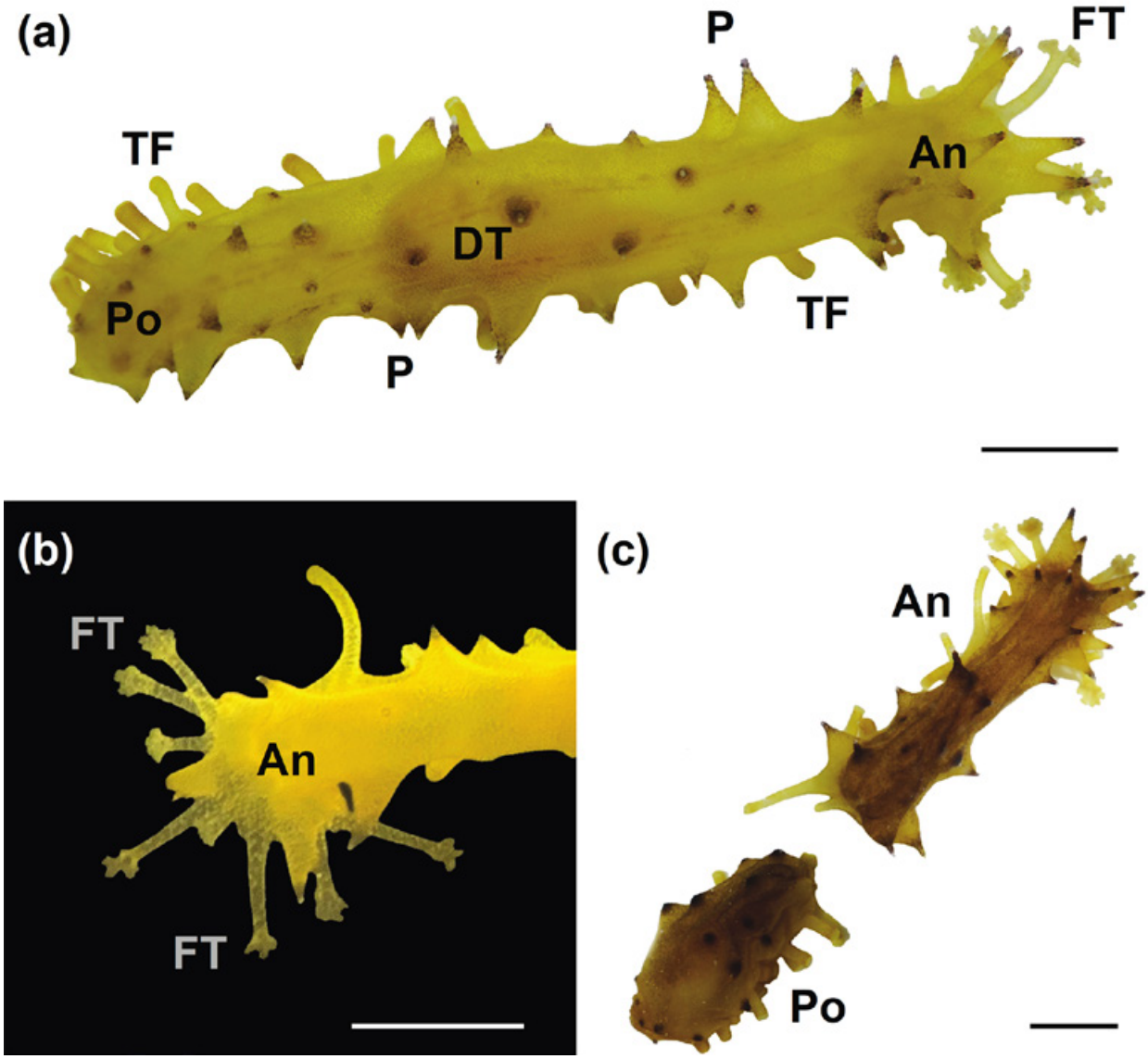

Figure 2. Images depicting: a) a juvenile *Stichopus* sp. found in reef rubble habitat in Palau, including b) the anterior end with ramified feeding tentacles, and c) the individual that had undergone fission. Letters indicate: TF = tube feet; P = papillae, FT = feeding tentacles; DT = digestive tract; An = anterior end, and Po = posterior end (scale bars = 2 mm).

and posterior parts (Fig. 2c). It remains unknown when this fission occurred but both halves were found on the same piece of rubble *in situ*. The cause of fission also remains unknown, but was possibly due to attempted predation or physical abrasion. Both halves persisted in aquaria with regeneration of ramified tentacles identified on the posterior segment approximately one week after discovery. This is consistent with previous observations of successful posterior-end regeneration in *Stichopus* spp., although persistence of the anterior segment, as observed here, is less common (Reichenbach and Holloway 1995; Dolmatov 2014). This may reflect the tendency for smaller (and younger) *Stichopus* individuals to show higher survivorship and shorter regeneration times relative to later life stages (Reichenbach et al. 1996).

To our knowledge, these are the smallest reported *Stichopus* spp. juveniles found in nature. There are several previous reports of juvenile *S. herrmanni* ≥ 9 cm (nearing the subadult stage) on the Great Barrier Reef, and in New Caledonia and the Indian Ocean (see Conand 1993; Shiell 2004; James 2005; Eriksson et al. 2010; Palazzo et al. 2016; Wolfe and Byrne 2017). Bourjon and Conand (2015) found one, 2.5-cm-sized *Stichopus* juvenile *in situ* in La Réunion, which was likely a different species to that found here. Our observations confirm predictions that rubble and similar consolidated reef matrices are important recruitment habitats for tropical sea cucumbers (Eriksson et al. 2013; Wolfe and Byrne 2017).

Observations around the shallow back-reef rubble site suggest that adult *Stichopus* spp. were rare, with infrequent observations of *Holothuria atra* and *Bohadschia argus*. Observations along the deeper reef slope (5–8 m depth) of Lighthouse Reef (Fig. 1a) suggest that *Thelenota anax* and *Holothuria atra* were the two most abundant holothuroids at this site, with less frequent observations of *S. herrmanni*, *T. ananas*, *H. edulis*, *H. scabra*, *H. whitmaei*, *B. argus* and *Pearsonothuria graeffei* (1–2 individuals per species during one 60-minute dive). Despite the sparsity of *Stichopus* spp. at this site, they are fairly common at other sites in Palau, particularly in the northwestern reef regions. Links between adult, larval and juvenile populations have yet to be characterised for most tropical sea cucumbers, and this remains a critical consideration for future research, particularly regarding commercially important aspidochirotoids such as *Stichopus*.

References

Balogh R., Wolfe K. and Byrne M. 2019. Gonad development and spawning of the vulnerable commercial sea cucumber, *Stichopus herrmanni*, in the southern Great Barrier Reef. Journal of the Marine Biological Association of the United Kingdom 99:487–495.

Bourjon P. and Conand C. 2015. Juvenile holothurian observed at La Réunion (Indian Ocean). SPC Beche-de-mer Information Bulletin 30:41–45.

Conand C. 1988. Comparison between estimations of growth and mortality of two Stichopodid holothurians: *Thelenota ananas* and *Stichopus chloronotus* (Echinodermata: Holothuroidea). p. 661–665. In Proceedings of the Sixth International Coral Reef Symposium, Australia volume2.

Conand C. 1993. Ecology and reproductive biology of *Stichopus variegatus* an Indo-Pacific coral reef sea cucumber (Echinodermata: Holothuroidea). Bulletin of Marine Science 52:970–981.

Dolmatov I.Y. 2014. Asexual reproduction in holothurians. The Scientific World Journal 2014. DOI: 10.1155/2014/527234

Eriksson H., Fabricius-Dyg J., Lichtenberg M., Perez-Landa V. and Byrne M. 2010. Biology of a high-density population of *Stichopus herrmanni* at One Tree Reef, Great Barrier Reef, Australia. SPC Beche-de-mer Information Bulletin 30:41–45.

Eriksson H., Thorne B.V. and Byrne M. 2013. Population metrics in protected commercial sea cucumber populations (curryfish: *Stichopus herrmanni*) on One Tree Reef, Great Barrier Reef. Marine Ecology Progress Series 473:225–234.

Hu C., Xu Y., Wen J., Zhang L., Fan S. and Su T. 2010. Larval development and juvenile growth of the sea cucumber *Stichopus* sp. (Curryfish). Aquaculture 300:73–79.

James D.B. 2005. Information on juvenile holothurians. SPC Beche-de-mer Information Bulletin 21:26.

Palazzo L., Wolfe K. and Byrne M. 2016. Discovery and description of *Stichopus herrmanni* juvenile nursery sites on Heron Reef, Great Barrier Reef. SPC Beche-de-mer Information Bulletin 36:36–40.

Reichenbach N. and Holloway S. 1995. Potential for asexual propagation of several commercially important species of tropical sea cucumber (Echinodermata). Journal of the World Aquaculture Society 26:272–278.

Reichenbach N., Nishar Y. and Saeed A. 1996. Species and size related trends in asexual propagation of commercially important species of tropical sea cucumbers (Holothuroidea). Journal of the World Aquaculture Society 27:475–482.

Shiell G. 2004. Field observations of juvenile sea cucumbers. SPC Beche-de-mer Information Bulletin 20:6–11.

Wolfe K. and Byrne M. 2017. Population biology and recruitment of the vulnerable sea cucumber, *Stichopus herrmanni*, on a protected reef. Marine Ecology 38:e12397.