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Excavation, habitation and transportation of massive corals by the crab *Actumnus setifer* (Crustacea: Brachyura: Pilumnidae) in Moreton Bay, Queensland

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ABSTRACT

Previously unreported coral-carrying, and coral-burrowing, behaviour is described and illustrated for *Actumnus setifer* from Moreton Bay, Queensland, Australia. *A. setifer* typically inhabits excavated burrows in living or dead massive coral clumps that weigh as much as one kilogram or more. Records of this behaviour in other species are discussed. Taxonomy is briefly reviewed and full synonymy and distribution records presented. Morphological modifications that allow such behaviour may be important in generically revising the genus *Actumnus*. The sheltered coral reefs of Moreton Bay provide an ideal environment for this crab-coral association to flourish. ❑ *symbiosis, mutualism, Actumnus, behaviour, coral reef, taxonomy*.

An interesting commensal association between crabs of the genus *Actumnus* and a variety of corals, whereby the crab excavates a burrow in the base of the coral clump and moves the coral from place to place, has been reported several times. Ward (1942) first noted this behaviour for *Actumnus antelmei* Ward, 1942, inhabiting dead corals at Mauritius, while also mentioning that he had seen a similar species behaving in the same way at Lindeman Island, on the Great Barrier Reef, using living colonies of *Leptastrea bottae*, and on reefs off Papua. Later, Lamberts & Garth (1977) reported *A. antelmei* and *A. digitalis* (Rathbun, 1907) inhabiting 12 species of both living and dead corals at Tutuila, American Samoa. Marsh (1990) also reported an unidentified Xanthoid crab found in a species of *Cyphastrea* coral at Shark Bay, Western Australia, that in all likelihood would also have been an *Actumnus* species.

Actumnus setifer (de Haan, 1835) has a widespread Indo-West Pacific distribution, and a bathymetric range generally < 50 m (Sakai 1976). Although it is commonly associated with coral reef environments it has not been previously recorded as inhabiting a moveable coral shelter. Its habitat has been previously noted as holes made in soft stones (Lanchester 1900), rock or coral crevices, amongst algae and in holes in sponges (Sakai 1976). We here describe and illus-

trate previously unreported coral-burrowing and coral-carrying behaviour of *A. setifer* observed in Moreton Bay, Australia.

Moreton Bay lies at latitude 27 25′ S. It is 150 km long (north to south) and about 15 km wide at the northern end where it opens to the South Pacific Ocean. It is enclosed on its eastern margin by large islands of Pleistocene and Holocene dune sands. The southern bay is congested with low deltaic mangrove islands, and high islands of similar lithology to the adjacent mainland occur in the central Bay. In the more open, northern parts of Moreton Bay, coral reefs have developed adjacent to the mainland and several of the islands. Many areas of these reefs have degraded during the late Holocene period, probably as a result of diminished tidal flushing, the changed position of the Brisbane River mouth, and a slight fall in relative sea level (Lovell 1989; Stephens 1992; Johnson & Neil 1998) and, more recently, due to increased sediment concentrations in the Brisbane River due to land use change (Neil 1998). Reefal environments of Moreton Bay have also been exploited for lime-making for more than a century (Allingham & Neil 1995).

TAXONOMY

Family Pilumnidae Samouelle, 1819

Actumnus Dana, 1851

Actumnus Dana, 1851: 128. Type species: *Actumnus tomentosus* Dana, 1852, by subsequent designation of Rathbun (1922); gender masculine [= *Actumnus setifer* (De Haan, 1835)].

Remarks. The genus currently includes 28 species (see Ng *et al.* 2008).

Actumnus setifer (de Haan, 1833)
(Figs 1, 3)

Cancer (*Xantho*) *setifer* de Haan, 1833: pl. 3, fig. 3; Yamaguchi, 1993: 580.

Cancer (*Pilumnus*) *setifer* — de Haan, 1835: 50.

Actumnus tomentosus Dana, 1852: 243; 1855: pl. 14, fig. 2a–c; Milne-Edwards A., 1865: 285; 1873: 194; Haswell, 1882: 73; Alcock, 1898: 202; Borradaile, 1902: 249; Nobili, 1906b: 132; Grant & McCulloch, 1906: 17; Klunzinger, 1913: 271; Rathbun, 1924: 20.

Actumnus setifer — Milne-Edwards, A., 1865: 287, pl. 15, fig. 5; Richters, 1880: 148; Miers, 1884: 225; de Man, 1887a: 47; Walker, 1887: 110; de Man, 1887b: 262; Pocock, 1890: 74; Henderson, 1893: 364; Ortmann, 1893: 474; 1894: 52; Alcock, 1898: 202; Calman, 1900: 19; Lanchester, 1900: 742; 1902: 541; Borradaile, 1902: 249; de Man, 1902: 639; Nobili, 1906a: 285; Grant & McCulloch, 1906: 17; Rathbun, 1910: 357; 1911: 230; 1914: 660; 1923: 126; Klunzinger, 1913: 272; Balss, 1922: 119; 1924: 20; 1933: 38; Yokoya, 1933: 187; Sakai, 1934: 309; 1935: 70; 1936: 173, pl. 52, fig. 1; 1936: 67; 1939: 528, pl. 65, fig. 1; 1965: 156, pl. 76, fig. 6; 1976: 496, pl. 177, fig. 2; Shen, 1940: 72, 87; Stephensen, 1945: 143; Miyake, 1961: 173; Takeda & Miyake, 1969: 115, fig. 9d–f; Campbell & Stephenson, 1970: 285, fig. 46; Takeda & Nunomura, 1976: 76; Yamaguchi *et al.*, 1976: 38; Takeda, 1977: 86; 1989: 166; 1997: 246; Miyake, 1983: 133, pl. 45, fig. 1; Dai & Yang, 1991: 369, fig. 179(1), pl. 49(7); Yamaguchi & Baba, 1993: 454, fig. 170; Wada, 1995: 402, pl. 112, fig. 1; Muraoka, 1998: 45.

Actumnus setifer var. *tomentosus* — Laurie, 1906: 408; 1915: 458.

Actumnus setifer var. *setifer* — Laurie, 1906: 409.

?*Actumnus setifer* — Barnard, 1947: 365; 1950: 271, fig. 50.

Material Examined. QM-W28544, male (24.0 x 17.0 mm), 2 females (18.3 x 13.2; 21.3 x 14.8 m), Wellington Point, Moreton Bay, SE Qld, 27°28′0" S, 153°14′0" E, low intertidal, P. Davie, I. Fellegara, 30 Jul 2008, under and in dead coral colonies of *Favia speciosa*. QM-W16680, ovig. female (17.5 x 12.2 mm), King Reef, off Kurrimine Beach, NE Qld, 17°45′0" S, 146°9′0" E, trawled, K. Lamprell, 29.07.1983. QM-W21176, female (11.8 x 9.0 mm), Long Is, Vansittart Bay, Kimberley Coast, WA, 13°58′ 9" S, 126°19′ 6" E, J.W. Short, 24.11.1995. W27453, 3 males (22.0 x 16.8, 22.4 x 17.1, 22.6 x 17.4 mm), Mirs Bay, New Territories, Hong Kong, 22°55′0" N, 114°40′ 0"E, agassiz trawl, P. Davie, 26.04.1989.

Diagnosis. Deep-bodied crab; dorsal surface convex, regions clearly defined; carapace covered with short-cropped tomentum; frontal lobes markedly deflexed; anterolateral margins convex, with three pointed teeth behind exorbital angle, more or less obscured by tomentum; posterolateral borders markedly excavated, forming concavity into which last pair of ambulatory legs fold. Chelipeds markedly unequal; covered with dense short tomentum; carpus and propodus covered with irregular beaded granules projecting through tomentum. Ambulatory legs relatively short and stout; anterior and posterior borders thickly fringed with setae.

Distribution. Type locality Japan. Widespread from South Africa to Japan and French Polynesia. AUSTRALIA — Albany Passage (Haswell, 1882), Thursday I., Port Denison, Percy Islands and

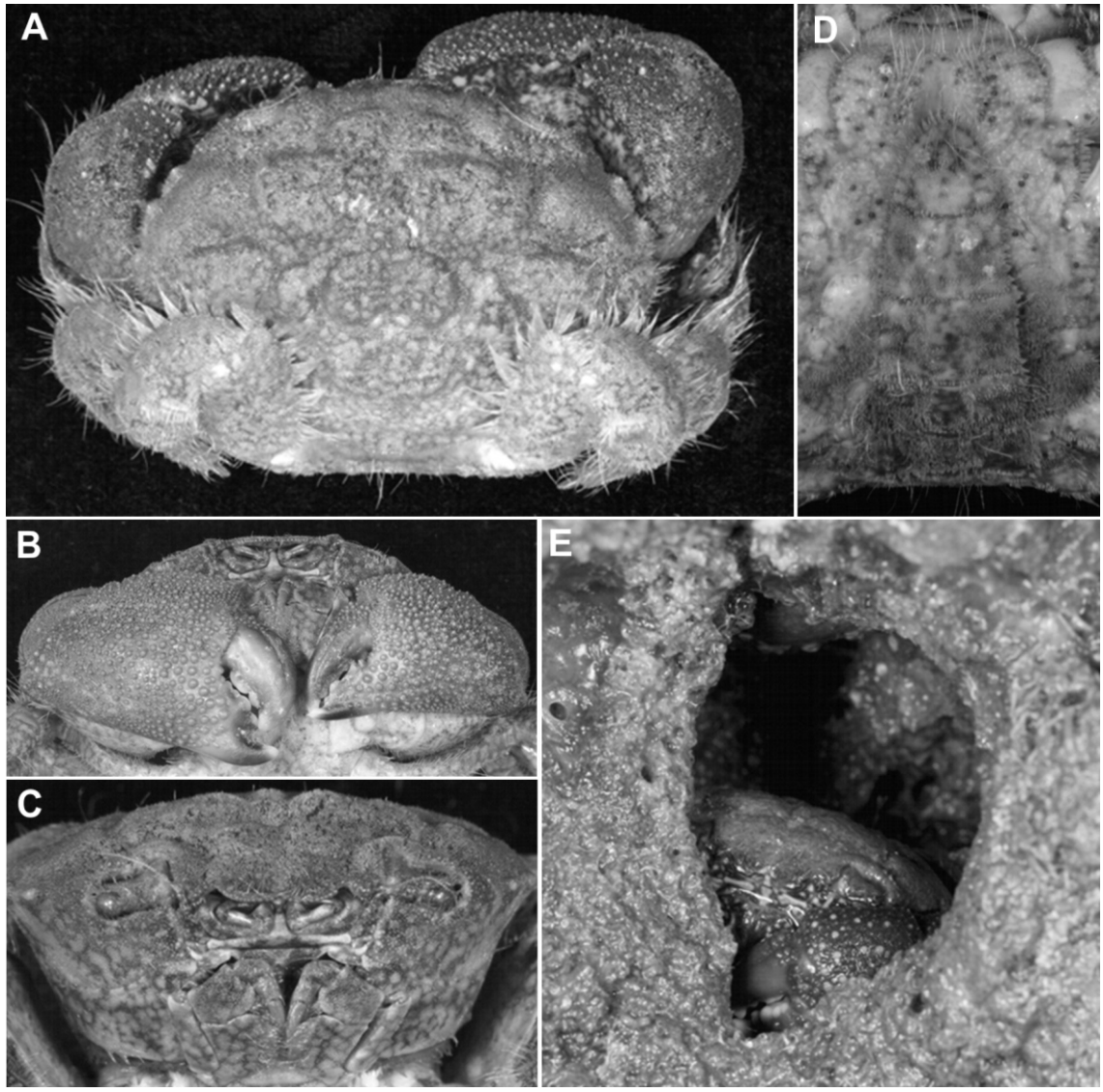

FIG. 1. *Actumnus setifer* male (24.0 x 17.0 mm) from Wellington Point, Moreton Bay (QM-W28544). **A**, dorsal view with legs folded against body in typical fashion; **B**, frontal view of claws; **C**, view of frontal margin, orbits and pterygostome; **D**, male abdomen and sternum; **E**, peering out from inside coral hole.

Sir C. Hardy's Is, Qld (Miers, 1884), Thursday I. (Ortmann, 1894), Torres Strait (Calman, 1900), Masthead I. (Grant & McCulloch, 1906), Shark Bay, WA (Miers, 1884, Balss, 1933), Monte Bello Is (Rathbun, 1914), Cape Jaubert (Rathbun, 1924), north-west of Cape Jervis and Kangaroo Island, SA (Rathbun, 1923), Moreton Bay (Campbell & Stephenson, 1970). ELSEWHERE — New Caledonia (A. Milne-Edwards, 1873, Takeda & Nunomura, 1976); Vanuatu (Miers, 1884); Fiji (Miers, 1884); Samoa (Ortmann, 1893, Alcock, 1898); Tahiti (A. Milne-Edwards, 1865); Tahiti or Samoa (Dana, 1852); Red Sea (Klunzinger, 1913, Laurie, 1915); Zanzibar (Nobili, 1906); ? South Africa (Barnard, 1947); Seychelles (Rathbun, 1911); Mauritius (Richters, 1880); Persian Gulf (Alcock, 1898, Nobili, 1906, Stephensen, 1945); India (Alcock, 1898); Sri Lanka (Alcock, 1898, Laurie,

1906); Maldives (Borradaile, 1902); Burma (Alcock, 1898), Gulf of Martaban (Henderson, 1893); Andaman Islands (Alcock, 1898); Mergui Archipelago (de Man, 1887a, Alcock, 1898); Japan (de Haan, 1833; Ortmann, 1893; Calman, 1900, Sakai, 1965; Balss, 1922; Yokoya, 1933; Sakai, 1935; Sakai, 1939; Miyake, 1961; Takeda & Miyake, 1969; Sakai, 1976; Yamaguchi et al., 1976; Takeda, 1977; Miyake, 1983; Takeda, 1989; Takeda, 1997); China (Alcock, 1898; Shen, 1936, 1940; Dai & Yang, 1991); Macclesfield Bank (Pocock, 1890); Gulf of Thailand (Rathbun, 1910); Singapore (Walker, 1887); Malay Peninsula (Lanchester, 1902); Philippines (Miers, 1884); Indonesia (de Man, 1887b; de Man, 1902).

Bathymetric range. Low tide pools to 200 m.

Remarks. This species was first reported from Moreton Bay by Campbell & Stephenson (1970), though their specimen was collected from a dredge and no coral association was recorded. The present specimens were compared with those from other localities in northern Australia, and from Hong Kong (see Material Examined). All Australian specimens conform closely with the Asian crabs, and there is no doubt of their correct identity. Indeed this species has been reported many times from a wide range of localities and only the identity of a specimen from South Africa reported by Barnard (1950) is currently in question — according to Sakai (1965), this specimen differs in the formation of the front, and in the armature of the anterolateral borders.

Actumnus contains 28 currently recognised species (see Ng *et al.* 2008), however there is some suggestion that the genus is not monophyletic as presently conceived (Takeda & Miyake 1969; P. Davie pers. observ.). Clark & Ng (2004) have also documented the complete larval development of *Actumnus setifer.* This species has only three zoeal stages instead of the more common four, and the zoeas differ from those of the only other species of *Actumnus* for which larvae are known, *A. squamosus*, in several carapace and abdominal features. Clark & Ng consider the differences important enough to indicate that the two species are not congeneric.

Actumnus is in need of a thorough taxonomic revision, and as part of this, it will be important to take into account the morphological and behavioural apomorphies that have evolved in several species in relation to their association with coral. While this association has only been documented for three species thus far, *viz. A. antelmei*, *A. digitalis* and *A. setifer*, it can be expected that other species with similar morphology will also prove to inhabit corals. In particular, characters such as the short stout legs with the last pair folding into the deeply excavated posterolateral margins, and the powerful claw morphology that allows these crabs to abrade holes in the coral bases, must be of generic significance. In this context it seems likely that species such as *Actumnus elegans* De Man, 1888, *A. granotuberosus* Garth & Kim, 1983, *A. intermedius* Balss, 1922, *A. margarodes* MacGilchrist, 1905, and *A. similis* Takeda & Miyake, 1969, amongst others, will need to be transferred into one or more new genera.

BEHAVIOUR & ECOLOGY

PRESENCE OF *A. SETIFER* IN MORETON BAY

Prior to this study, Campbell & Stephenson (1970) reported a single specimen of *A. setifer* in a dredge sample from south of Peel Island. Our observations of *A. setifer* in Moreton Bay were made at Mud, Green, Coochiemudlo, Peel, Bird and Goat Islands, at Dunwich and Myora on North Stradbroke Island, and at Wellington Point and Scarborough on the mainland side of the Bay (Fig. 2). All of these sites represent coral reefs except for Dunwich and Myora, where there are extant coral communities, and Scarborough where no live corals were observed.

Searches were made using viewing buckets, manta tows, snorkelling, wading and observations from a boat in < 1 m water depth.

A. setifer was most commonly found in colonies of *Favia speciosa*, the most common coral species in Moreton Bay, but also occurred in other massive corals (*Favia*, *Favites*, *Goniopora* and *Cyphastrea* sp.), both living and dead. *F. speciosa* has not previously been reported as having such a relationship with crabs. Coral use by *A. setifer* appeared to be roughly proportional to the coral species' relative abundance, although this relationship was not quantified. Other coral morphologies are found in Moreton Bay (eg. branching, tabulate, foliose, encrusting), however *Actumnus* crabs were never observed utilising

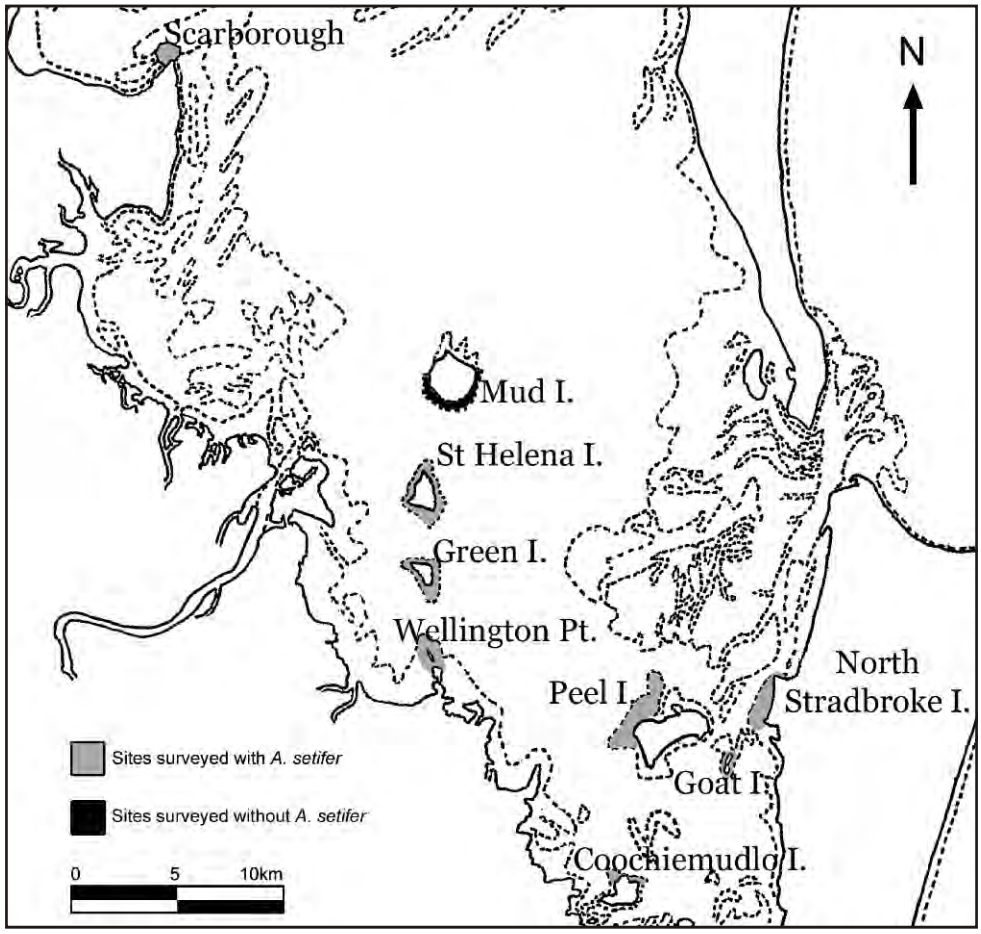

FIG. 2. Localities where coral-carrying *Actumnus setifer* have been observed in Moreton Bay.

coral colonies with morphologies other than massive.

A. setifer was predominantly found in areas of Moreton Bay proximal to living and dead coral reefs. The substrate in these areas was a sparse cover of massive corals and/or coral debris on patches of sandy or muddy sediments. These areas are consistent with the ecotone habitat of *Actumnus* crabs at Tutuila (Lamberts & Garth 1977). Areas of the Mud Island reef flat which were searched did not support the *A. setifer* coral association, while all other reefal areas searched did. Coral dredging of the Mud Island reef flat has created a substrate of loose rubble and steep slopes (Allingham & Neil 1995). This substrate would inhibit the movement of corals carried by crabs and also inhibit feeding by the crabs, thereby excluding the *A. setifer* coral association from such sites.

BEHAVIOUR

Actumnus setifer observed in a salt water aquarium showed patterns of behaviour similar to those of the *Actumnus* crabs observed by Lamberts & Garth (1977). If the colony was overturned, the crab would roll it back so that the entrance to the burrow faced the substrate (see sequence of photographs in Fig. 3). Movement of the colonies was in small jerks, as the crab gripped the coral colony with the last pair of legs and pushed against the substrate with its chelipeds.

The burrows of *A. antelmei* and *A. digitalis* are excavated by the crab using the trabeculated manus of its chelipeds as a rasp (Ward 1942;

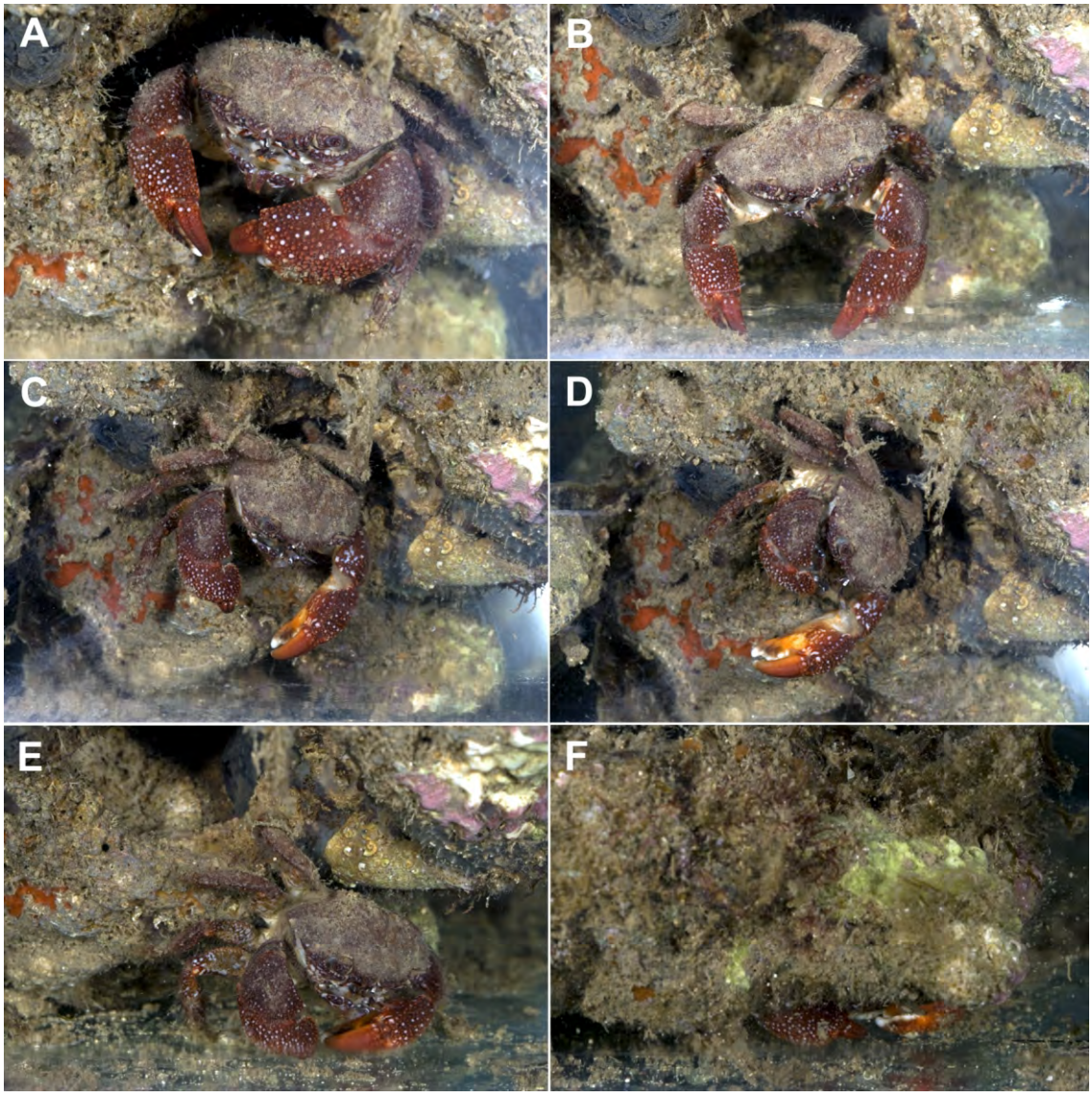

FIG. 3A–F. Sequence of pictures showing *Actumnus setifer* repositioning an upturned coral colony.

Lamberts & Garth 1977). This also seems to be true of *A. setifer*. Typical burrow morphology in a *Favia speciosa* colony consists of an entrance and feeding chamber on the underside of the colony (Figs 1E, 3, 4), a vertical shaft which opens to a habitation chamber, and small apertures to the upper (growth) surface of the coral colony. As many as 8–12 apertures may occur on a single colony 15–20 cm in diameter. Of 12 *A. setifer* inhabited colonies measured at Green, Bird and Goat Islands wet weights ranged from 142g to 1106g, averaging 458g.

Crabs spent their time either at rest within the coral colony, feeding, or moving the colony. While at rest, crabs appeared to spend most of their time adjacent to the small apertures in the upper surface of the colony. This position is likely to facilitate respiration and detection of food. Feeding was usually undertaken in the large entrance chamber in the undersurface of

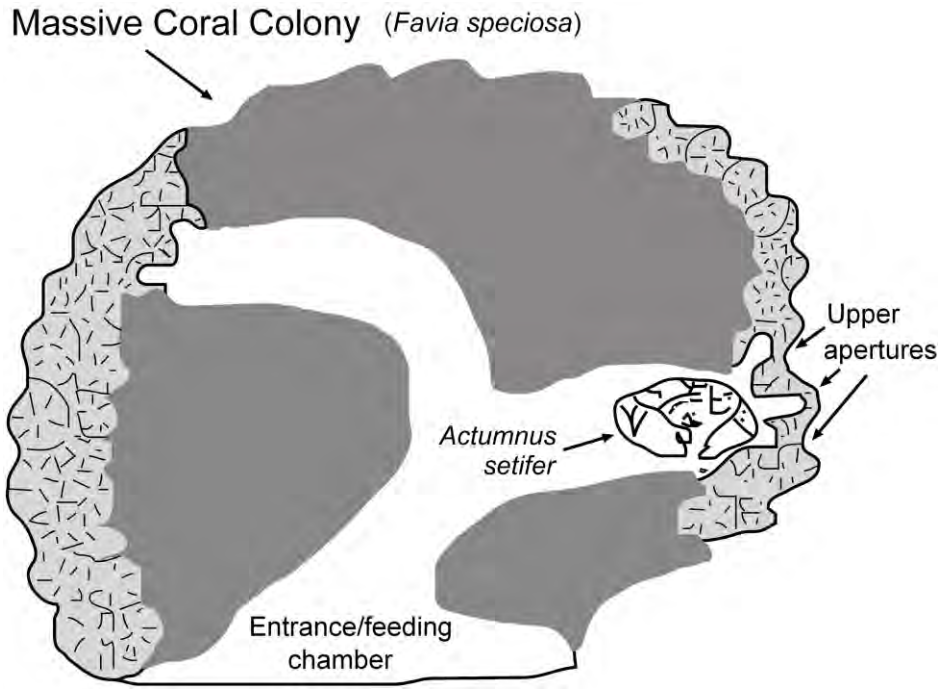

FIG. 4. Typical *Actumnus setifer* burrow morphology in a *Favia speciosa* colony.

the colony. Food was acquired by moving the colony over the top of the food, or occasionally by moving to the exterior of the colony and dragging the food item into the chamber. Even when obtaining food or righting the colony, crabs would seldom release their grip on the coral colony. This behaviour is identical for both sexes, and it would be interesting to know if female crabs release the first zoeae through the apertures in the upper surface, or whether they lift the colony clear of the substrate to facilitate more effective spawning.

SYMBIOSIS/MUTUALISM

While Lamberts & Garth (1977) and Marsh (1990) have referred to this type of coral-crab symbiosis as commensalism, we hesitate to use this term. Perhaps it is more a 'transportation mutualism' *sensu* Grutter & Irving (2007), similar to that of the Great Barrier Reef sipunculid *Aspidosi muelleri* that lives in a spiral cavity in solitary corals (Rice 1976). The sipunculid is protected under the coral which it moves around while it feeds, and the coral is kept upright on the substratum and transported to new feeding areas. This is essentially what Lamberts & Garth (1977) suggested for the *Actumnus*/coral association. There is little formal evidence that transported corals have increased survival rates or growth benefits compared to attached corals, however one crab was observed to free itself, and the coral it lived in, from being completely buried in mud (I. Fellegara pers. observ.). Detrimental effects due to the presence of the crab have also been observed on a number of coral colonies. The formation of apertures requires the removal of some of the polyps and movement of the colony may result in tissue abrasion. Clearly this association is deserving of more study. As Grutter & Irving (2007) point out, 'positive interactions can play a fundamental role in maintaining the abundance and distribution of many marine species, as well as in structuring entire communities'.

CONCLUSION

Despite its widespread distribution throughout the Indo-West Pacific region and the general similarity of this distribution to that of hermatypic corals, *A. setifer* has not previously been reported as burrowing into, or carrying, coral

colonies. Similarly, although *F. speciosa* is also a widely distributed coral, overlapping in distribution with *A. setifer* throughout much of its range, no burrowing or carrying of this species by *Actumnus* crabs has been reported. An explanation for this lack of reporting may be that *Actumnus setifer* is locally less common in other areas, and because it is so well hidden within the coral clump, it has previously escaped attention. It may also simply be that because many small reef crabs, particularly those in the Pilumnidae and Xanthidae, occupy holes and crevices in rocks and coral, simply as places to hide, that the presence of *A. setifer* also in such shelters has been ignored as nothing unusual.

The central part of Moreton Bay appears to provide the perfect environment for this coral/crab association because of its low wave energy, numerous areas of sheltered coral patches dominated by small colonies of *Favia*, and the intervening areas of fine sediments with relatively little coarse coral debris. The *A. setifer/F. speciosa* association was found at every reef site which was searched with the exception of the dredged reef flat of Mud Island. The crabs absence at this site is attributed to the coral dredging method which left a residual deposit of mobile, coarse coral rubble covering the dredged substrate, thereby creating an unfavourable environment for these coral-carrying crabs.

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LITERATURE CITED

Alcock, A.W. 1898. Materials for a carcinological fauna of India. No. 3. The Brachyura Cyclometopa. Part 1. The Family Xanthidae. *Journal of the Asiatic Society of Bengal, Calcutta* **67** (2)(1): 67–233.

Allingham, D.P. & Neil, D.T. 1995. The supratidal deposits and effects of coral dredging on Mud Island, Moreton Bay, southeast Queensland. *Zeitschrift für Geomorphologie* **39**: 273–292.

Balss, H. 1922. Östasiatische Decapoden. IV. Die Brachyrhynchen (Cancridea). *Archiv für Naturgeschichte* **88A**(11): 94–166, figs 1–2, pls 1–2.

1933. Beiträge zur Kenntnis der Gattung *Pilumnus* (Crustacea, Dekapoda) und verwandter Gattungen. *Capita Zoologica* **4**(3): 1–47, figs 1–7, pls 1–7.

Barnard, K.H. 1947. Descriptions of new species of South African Decapod Crustacea, with notes on synonymy and new records. *Annals and Magazine of Natural History, London* (11) **13**(102): 361–392.

1950. Descriptive catalogue of South African Decapod Crustacea (Crabs and Shrimps). *Annals of the South African Museum* **38**: 1–837, figs 1–154.

Borradaile, L.A. 1902. Marine Crustaceans. III. The Xanthidae and some other crabs. *In*, Gardiner, J.S. (Ed.), *The Fauna and Geography of the Maldive and Laccadive Archipelagoes, being the Account of the Work carried on and the Collections made by an Expedition during the years 1899–1900.* Vol. **1**(3): 237–271, figs 41–60.

Calman, W.T. 1900. On a collection of Brachyura from Torres Straits. *Transactions of the Linnean Society of London (Zoology)* (2) **8**(1): 1–50, pls 1–3.

Campbell, B.M. & Stephenson, W. 1970. The sublittoral Brachyura (Crustacea: Decapoda) of Moreton Bay. *Memoirs of the Queensland Museum* **15**(4): 235–302, figs 1–49, pl. 22.

Clark, P.F. & Ng, P. K.L. 2004. The larval development of *Actumnus setifer* (de Haan, 1835) (Brachyura: Xanthoidea: Pilumnidae) described from laboratory reared material. *Crustacean Research* **33**: 27-50.

Dai, A. & Yang, S. 1991. *Crabs of the China Seas.* English edition (China Ocean Press, Beijing and Springer-Verlag, Berlin). (Translation from Chinese original 1986). Pp. i–iv, 1–608, figs 1–295, pls 1–74.

Dana, J.D. 1851. On the Classification of the Cancroidea. *Am. J. Sci. Arts* **12**(34): 121–131.

1852. Crustacea. *United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U.S.N.* **13**(1): i–viii, 1–685, pl. 8.

1855. Crustacea. *United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842 under the command of Charles Wilkes, U.S.N.* **14**(Atlas): 1–27, pls 1–96.

Grant, F.E. & McCulloch, A.R. 1906. On a collection of Crustacea from the Port Curtis District, Queensland. *Proceedings of the Linnean Society of New South Wales* **31**(1): 1–53, figs 1–3, pls 1–4.

Grutter, A.S. & Irving, A. D. 2007. Positive interactions in marine communities. Pp. 110–137. *In*, Connell, S.D. & Gillanders, B.M. (Eds), *Marine Ecology*. (Oxford University Press, Oxford).

Haan, H. M. De 1833–1849. Crustacea. *In*, *P. F. von Siebold, Fauna Japonica, sive Descriptio animalium, quae in itinere per Japoniam, jussu et auspiciis*

superiorum, qui summum in India Batavia imperium tenent, suscepto, annis 1823–1830 collegit, notis, observationibus a adumbrationibus illustravit. Lugduni Batavorum, fasc. 1–8: I–xxi+vii–xvii+ix–xvi+1–243, pls. 1–55, A–Q, circ., pl. 2. (For publication dates see Sherborn & Jentink, 1895; Holthuis, 1953; Holthuis & Sakai, 1970).

Haswell, W.A. 1882. *Catalogue of the Australian stalk- and sessile-eyed Crustacea*. (Australian Museum: Sydney). Pp. i–xxiv, 1–324 + 2 p. addenda, figs 1–8, pls 1–4.

Henderson, J.R. 1893. A contribution to Indian Carcinology. *Transactions of the Linnean Society of London, (series 2, Zoology)* **5**(1): 325–458, pls 36–40.

Johnson, P.R. & Neil, D.T., 1998. The corals of Moreton Bay: living with extremes. Pp. 503–524. *In,* Tibbetts, I.R. Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment.* (University of Queensland, School of Marine Science: St Lucia, Brisbane).

Klunzinger, C.B. 1913. Die Rundkrabben (Cyclometopa) des Roten Meeres. *Abhandlungen der kaiserlich Leop.-Carol. Deutschen Akademie der Naturforscher Halle* **99**(2): 97–402, figs 1–4, pls 5–11.

Lamberts, A.E. & Garth, J.S. 1977. Coral-crab commensalism in Xanthids. *Pacific Science* **31**(3): 245–247.

Lanchester, W.F. 1900. On a collection of Crustaceans made at Singapore and Malacca. Part I. Crustacea Brachyura. *Proceedings of the Zoological Society of London* **48**(1): 719–770, pls 44–47.

1902. On the Crustacea collected during the *Skeat Expedition* to the Malay Peninsula, together with a note on the genus *Actaeopsis*. Part I. Brachyura, Stomatopoda and Macrura. *Proceedings of the Zoological Society of London* **1901**(2): 534–574, pls 33–34.

Laurie, R.D. 1906. Report on the Brachyura collected by Professor Herdman, at Ceylon, in 1902. *In*, Herdman, W.A., *Report to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Manaar with supplementary reports upon the Marine Biology of Ceylon by other Naturalists*, part 5, suppl. Rep. **40**: 349–432, figs 1–12, pls 1–2.

1915. Reports on the Marine Biology of the Sudanese Red Sea, from Collections made by Cyril Crossland, M.Z., B.Sc., F.Z.S., XXI. On the Brachyura. *The Journal of the Linnean Society, London (Zoology)* **31**(209): 407–475, figs 1–5, pls 42–45.

Lovell, E.R. 1989. Coral assemblages of Moreton Bay, Queensland, Australia, before and after a major flood. *Memoirs of the Queensland Museum* **27**: 535–550.

Man, J.G. de 1887a. Report on the Podophthalmous Crustacea of the Mergui Archipelago, collected for the Trustees of the Indian Museum, Calcutta, by Dr. John Anderson, F.R.S. Superintendent of the Museum. Part I. *Journal of the Linnean Society of London, (Zoology)* **22**(136): 1–64, pls 1–3.

1887b. Bericht über die von Herrn. Dr. J. Brock im indischen Archipel gesammelten Decapoden und Stomatopoden. *Archiv für Naturgeschichte, Berlin* **53**(1): 215–288, pls 7–10.

1902. Die von Herrn Professor Kükenthal im indischen Archipel gesammelten Dekapoden und Stomatopoden. *In*, W. Kükenthal, Ergebnisse einer zoologischen Forschungsreise in den Molukken und Borneo, in Aufträge der Senckenberg. Naturforsch. Gesellschaft ausgeführt von Dr. Willy Kükenthal. *Abhandlungen der Senckenbergischen naturforschenden Gesellschaft* **25**(3): 465–929, pls 19–27.

Marsh, L.M. 1990. Hermatypic corals of Shark Bay, Western Australia. Pp. 115–127. *In* Berry, P.B., Bradshaw, S.D. & Wilson, B.R. (Eds), *Research in Shark Bay — Report of the France-Australe Bicentenary Expedition Committee.* (Western Australian Museum: Perth). Pp. viii, 325.

Miers, E.J. 1884. Crustacea (Brachyura). *In*, *Report on the Zoological Collections made in the Indo-Pacific Ocean during the Voyage of H.M.S. Alert 1881–1882. Part I. The collections from Melanesia. Part II. The collections from the Western Indian Ocean. British Museum (Natural History), London* **8**(1): 178–322, pls 18–32.

Milne-Edwards, A. 1865. Études zoologiques sur les Crustacés récents de la famille des Cancériens. Cancérides, Pirimélides, Carpilides, Première Partie. *Nouvelles Archives du Muséum national d'Histoire naturelle, Paris* **1**: 177–308, pls 11–19.

1873. Recherches sur la faune carcinologique de la Nouvelle-Calédonie. Part II. Groupe des Cyclométopes Portuniens. *Nouvelles archives du Muséum national d'Histoire naturelle, Paris* **9**: 155–332, pls 4–18.

Miyake, S. 1961. A list of the decapod Crustacea of the Sea of Ariake, Kyushu. *Records of Oceanographic Works in Japan*, Spec. No. **5**: 165–178.

1983. *Japanese Crustacean Decapods and Stomatopods in Color. Vol. II. Brachyura (Crabs)*, (Hoikusha: Osaka). Pp. i–viii, 1–277, pls 1–64. (In Japanese; second edition in 1992).

Muraoka, K. 1998. Catalogue of the Brachyuran and Anomuran Crabs donated by Prof. Dr. Tune Sakai to the Kanagawa Prefectural Museum. *Catalogue of the Collection in the Kanagawa Prefectural Museum of Natural History* **11**: 5–67, pls 1–16.

Neil, D.T. 1998. Moreton Bay and its catchment: landscape and seascape, development and degradation. Pp. 3–54. *In*, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment.*

(The University of Queensland, School of Marine Science: Brisbane).

Nobili, M.G. 1906a. Faune carcinologique de la Mer Rouge. Décapodes et Stomatopodes. *Annales des Sciences naturelles, Zoologie* (9) **4**(1–3): 1–347, figs 1–12, pls 1–11.

1906b. Mission J. Bonnier et Ch. Pérez (Golfe Persique 1901). Crustacés Décapodes et Stomatopodes. *Bulletin scientifique de la France et de la Belgique* **40**: 13–159, figs 1–3, pls 2–7.

Ortmann, A.E. 1893. Die Decapoden-Krebse des Strassburger Museums, mit besonderer Berücksichtigung der von Herrn Dr. Döderlein bei Japan und bei den Liu-Kiu-Inseln gesammelten und zur zeit im Strassburger Museum aufbewahrten Formen. Theil VII. Abteilung Brachyura (Brachyura genuina Boas), II. Unterabteilung: Cancroidea, 2. Section: Cancrinea, 1. Gruppe: Cyclometopa. *Zoologische Jahrbücher, Abtheilung für Systematik, Geographie und Biologie der Thiere* **7**: 411–495, pl. 17.

1894. Crustaceen. *In*, R. Semon (Ed.), Zoologische Forschungsreisen in Australien und dem Malayischen Archipel ausgeführt in den Jahren 1891–93. V. *Denkschriften der medizinisch-naturwissenschaftlichen Gesellschaft, Jena* **8**: 1–80, pls 1–13.

Pocock, J. 1890. Report upon the Crustacea collected by P. W. Bassett-Smith, Esq., Surgeon R.N., during the survey of the Macclesfield and Tizard Banks, in the China Sea, by H.M.S. *Rambler*. *Annals and Magazine of Natural History* (6) **5**: 72–80.

Rathbun, M.J. 1910. The Brachyura. *In*, The Danish Expedition to Siam, 1899–1900. V. *Kongelige Danske Videnskabernes Selskabs Skrifter, Kjøbenhavn* (7) **5**(4): 301–367, figs 1–44, pls 1–2, 1 map.

1911. Marine Brachyura. *In*, The Percy Sladen Trust Expedition to the Indian Ocean in 1905, under the Leadership of Mr J. Stanley Gardiner. Vol. III, part II, No. XI. *Transactions of the Linnean Society of London, (Zool.)* (2) **14**(2): 191–261, figs 1–2, pls 15–20.

1914. Stalk-eyed Crustaceans collected at the Monte Bello Islands. *Proceedings of the Zoological Society of London* **1914**: 653–664, pls 1–2.

1922. Opinion 73. Five generic names in Crinoidea, eighty-six generic names in Crustacea, and eight generic names in Acarina, placed on the Official List of Generic Names. Opin. rend. Internat. Comm. Zool. Nomencl. *Smithsonian Miscellaneous Collection* **73**(1): 23–31.

1923. Report on the Crabs obtained by the F.I.S. *Endeavour* on the coasts of Queensland, New South Wales, Victoria, South Australia, and Tasmania. 3. *Biological Results of the Fishing Experiments carried on by the F.I.S. Endeavour 1909–14.* Vol. **5**(3): 95–156, figs 1–3, pls 16–42. (Australian Dept. Trade & Customs, Fisheries: Sydney).

1924. Brachyura, Albuneidae and Porcellanidae. *In*, Results of Dr. E. Mjöberg's Swedish Scientific Expeditions to Australia 1910–1913. 37. *Arkiv för Zoologi* **16**(23): 1–33, figs 1–7, pl. 1.

Rice, M. E. 1976. Sipunculans associated with coral communities. *Micronesica* **12**: 119–132.

Richters, F. 1880. Decapoda. *In*, *K. Möbius, Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, bearbeitet von K. Möbius, F. Richters und E. von Martens nach sammlungen, angelegt auf einer Reise nach Mauritius von K. Möbius*: 139–178, pls 15–18. (Berlin).

1934. Brachyura from the coast of Kyushu, Japan. *Science Reports of the Tokyo Bunrika Daigaku* (B) **1**(25): 281–330, figs 1–26, pls 17–18 (in colour).

1935. List of marine animals around Shimoda area. *Biological report of Shimoda Marine Biological Station, Tokyo University of Literature and Science* **1**: 23–85, 3 pls, 2 maps (In Japanese)

1936. *Crabs of Japan: 66 plates in Life Colours with descriptions*. (Sanseido: Tokyo) (1935): 1–239, figs 1–122, 27 pages of bibliography & index, frontispiece (in colour), pls 1–66 (colour). (In Japanese)

1939. *Studies on the crabs of Japan. IV. Brachygnatha, Brachyrhyncha.* (Yokendo Co.: Tokyo). Pp. 365–741, figs 1–129, pls 42–111, table 1.

1965. *The Crabs of Sagami Bay, collected by His Majesty the Emperor of Japan* (Maruzen Co.: Tokyo). Pp. i–xvi, 1–206 (English text), figs 1–27, pls 1–100: 1–92 (Japanese text): 1–26 (references and index in English): 27–32 (index in Japanese), 1 map.

1976. *Crabs of Japan and the Adjacent Seas.* 3 vols. Pp. i–xxix, 1–773 [English vol.]; 1–16, 251 pls [Plates vol.]; 1–461[Japanese vol.]. (Kodansha: Tokyo).

Shen, C.J. 1936. On a collection of Brachyuran Decapoda from Hainan Island, with description of three new species. *Chinese Journal of Zoology* **2**: 63–80, figs 1–4.

1940. On the collection of Crabs of South China. *Bulletin of the Fan Memorial Institute of Biology (Zool.), Peiping* **10**(2): 69–104.

Stephens, A.W. 1992. Geological evolution and earth resources of Moreton Bay. Pp. 3–23. *In*, Crimp, O. (Ed.), *Moreton Bay in the Balance*. (Australian Littoral Society/Australian Marine Science Consortium: Brisbane).

Stephensen, K. 1945. The Brachyura of the Iranian Gulf with an Appendix: The male pleopod of the Brachyura. *In, Danish Scientific Investigations in Iran*, Part 4: 57–237, figs 1–60. (E. Munksgaard: Copenhagen).

Takeda, M. 1977. Crabs from the shallow waters off Mage-jima Island, southwest Japan. *Bulletin of the National Science Museum, Tokyo, Series A (Zoology)* **3**(2): 73–89, figs 1–15.

1997. Deep-sea Decapod Crustacean Fauna of Suruga Bay, Central Japan. *National Science Museum Monographs* **12**: 229–255, pls 1–5.

1989. Shallow-water Crabs from the Oshima Passage between Amami-Oshima and Kakeroma--jima Islands, the Northern Ryukyu Islands. *Memoirs of the National Science Museum, Tokyo* **22**: 135–184, figs 1–17, pl. 4, table 1.

Takeda, M. & Miyake, S. 1969. Pilumnid crabs of the family Xanthidae from the West Pacific. II. Twenty-one species of four genera, with descriptions of four new species. *OHMU* **2**(7): 93–156, figs 1–18.

Takeda, M. & Nunomura, N. 1976. Crabs collected by the Melanesia Expedition of the Osaka Museum of Natural History, 1958. *Bulletin Osaka Museum of Natural History* **30**: 61–92, figs 1–3.

Wada, K. 1995. Brachyura. *In*, Nishimura, S., *Guide to Seashore Animals of Japan with Color Pictures and Keys*. Vol. 2: 379–418, pls 101–118. (In Japanese)

Walker, A.O. 1887. Notes on a Collection of Crustacea from Singapore. *Journal of the Linnean Society of London* **20**(118): 107–117, pls 6–9.

Ward, M. 1942. A new genus and eight new species of Brachyura from Mauritius and the Chagos Archipellago. *Mauritius Institute Bulletin* **2**: 39–48.

Yamaguchi, T. 1993. A list of Species described in the Crustacea Volume of Fauna Japonica as belonging to the Japanese Fauna. Pp. 571–598, figs 1–2. *In*, Yamaguchi, T. (Ed.), *Ph. von Siebold and Natural History of Japan. Crustacea*. (Carcinological Society of Japan: Tokyo).

Yamaguchi, T. & Baba, K. 1993. Crustacean specimens collected in Japan by Ph. F. Von Siebold and H. Bürger and held by the Nationaal Natuurhistorisch Museum in Leiden and Other Museums. Pp. 145–570, figs 1–200 D + II A–F + 3 fig. n.n. + III A–D. *In*, Yamaguchi, T. (Ed.), *Ph. von Siebold and Natural History of Japan. Crustacea*. (Carcinological Society of Japan: Tokyo).

Yamaguchi, T., Takeda, M. & Tokudome, K. 1976. A list of crabs collected in the vicinity of the Aitsu Marine Biological Station and a preliminary report on the cheliped asymmetry of the crabs. *Calanus* **5**: 31–46, figs., pl., 2 tabs.

Yokoya, Y. 1933. On the Distribution of Decapod Crustaceans inhabiting the Continental Shelf around Japan, chiefly based upon the Materials collected by S.S. Sôyô-Maru, during the years 1923–1930. *Journal of the College of Agriculture, Tokyo Imperial University* **12**(1): 1–226, figs 1–71, tabls 1–4.