Cantellius cardenae spec. nov. (Cirripedia: Pyrgomatinae) from *Acropora (Isopora) brueggemanni* (Brook, 1893) (Anthozoa: Acroporidae), a case of host specificity in a generalist genus

Y. Achituv & B.W. Hoeksema

Achituv, Y. & B.W. Hoeksema. *Cantellius cardenae* spec. nov. (Cirripedia: Pyrgomatinae) from *Acropora (Isopora) brueggemanni* (Brook, 1893) (Anthozoa: Acroporidae), a case of host specificity in a generalist genus.
Zool. Med. Leiden 77 (1), 29.viii.2003: 1-8, figs 1-4, table 1.— ISSN 0024-0672.
Yair Achituv, Faculty of Life Sciences, Bar-Ilan University, Ramat Gan 52900, Israel (e-mail: achity@mail.biu.ac.il).
Bert W. Hoeksema, National Museum of Natural History, P.O. Box 9517. 2300 RA Leiden, The Netherlands (e-mail: hoeksema@naturalis.nnm.nl).

Key words: barnacle; corals; association; Cirripedia; Pyrgomatidae; Scleractinia; Acroporidae.
A new species of coral inhabiting barnacle *Cantellius cardenae* spec. nov. (Crustacea, Cirripedia: Pyrgomatinae) is described. This barnacle was found on the staghorn coral *Acropora (Isopora) brueggemanni* (Scleractinia: Acroporidae). It is characterized by having transversally elongated scuta and narrow terga with a spur length more than half of the total tergal length. This species belongs to the *secundus* group of *Cantellius*, which includes barnacles with transversally elongated scuta, and which are limited to the Acroporidae. The distribution of *C. cardenae* supports the hypothesis that structurally specialized pyrgomatines occupy a more limited variety of hosts than do morphologicaly generalized ones.

Introduction

The family Pyrgomatidae consist of barnacles largely limited to stony corals, (Scleractinia: Anthozoa), but some species occur on Milleporidae and Stylasteridae (Hydrozoa), and one occurs on a sponge (Porifera). It includes modified barnacles with conical or flat walls and cup shaped or columnar bases embedded in the skeleton of the coral host. According to Ross & Newman (in press) there are 11 nominal genera in this family, the most generalized being *Cantellius* Ross & Newman, 1973, with 21 nominal species known from a variety of coral hosts. Some of the species are widely distributed while few are restricted to a single host species. In the present paper we describe a new *Cantellius* found on *Acropora (Isopora) brueggemanni* (Brook, 1893), *Cantellius cardenae* spec. nov.

This barnacle is mainly found on the lower side of branches facing the substratum (fig. 1). The host specificity of this species of *Cantellius* is compared to that of others. It is concluded that, within this structurally generalized genus, this species, restricted to *Acropra (Isopora) brueggemanni*, represents a part in an evolutionary line that has lead to greater host specificity.

Material and methods

Shells and opercular valves of this barnacle were removed from skeletons of *Acropora brueggemanni* in the coelenterate collection of the National Museum of Natural history, Leiden, The Netherlands (RMNH). A sample of *A. brueggemanni* from South

Sulawesi, Indonesia, hosting barnacles, was preserved in alcohol and dissected for the description of soft parts. Additional samples were obtained from the collection of the Museum of Tropical Queensland, Australia (MTQ).

The wall plates and opercular valves were removed from the coral, immersed for about two hours in household bleach, rinsed in tap water followed by distilled water, and then dried on a small hot plate at 90°C. The specimens were examined under the dissecting microscope, adhering chitin was removed using needles and fine forceps. Dried samples were mounted on brass stubs, coated with gold, and examined with a JEOL scanning electron microscope at 25 kV. Images were copied and stored using Autobeam software. The procedure of preparation of soft parts is according to Newman et al. (1969).

Family Pyrgomatidae Gray, 1825
Subfamily Pyrgomatinae Gray, 1825
Genus *Cantellius* Ross & Newman, 1973

Cantellius cardenae spec. nov.
(figs 1-4)

Material.— Holotype, RMNH C2591, shell and opercular, mounted on SEM stub, taken from *Acropora brueggemanni* sample RMNH Coel. 15542 (Indonesia, SW Sulawesi, Langkai north side, 05°01'S 119°05'E, 100 m offshore at 5 m depth, 9.vi.1980, coll. H. Moll). Paratypes, RMNH C2592, shells and opercular valves from same coral sample. Additional material: 1). RMNH C2593, shell and opercular valves taken from *A. brueggemanni* (RMNH Coel. 20977, Indonesia, SW Sulawesi, SW Salayer, SW of Bahuluang I., 06°29.5'S 120°25'E; 11.x.1984; Snellius II expedition sta. 4.210). 2). A branch of *A. brueggemanni* containing barnacles (Indonesia, SW Sulawesi, Kudingareng Keke I., NW side, 05°06'S 119°17'E, reef slope 5-10 m depth, preserved in 70% ethanol; coll. C.C. Wallace and B.W. Hoeksema (material lost in mail after study). These barnacles were used for the description of the soft parts of *Cantellius cardenae.* 3). MTQ-W13675 barnacles from an *A. brueggemanni* specimen (MTQ-G52865, Papua New Guinea, Kimbe Bay, Ema Reef, 05°12'S 150°09'E; 10 m depth, coll. C.C. Wallace, J. Wolstenholme 11.iv.1997). 4) MTQ-W 13676 barnacle from an *A. brueggemanni* specimen (MTQ G-32821, Philippines, Bolinao; coll. C.C. Wallace).

Diagnosis.— Wall of four plates with about 22 internal and 30 external ribs; scutum and tergum not fused, scutum transversally elongated (wider than high); tergum slender with broad, shallow external spur furrow; spur length more than half the length of entire plate.

Description.— Shell: Flat, nearly round, not projecting above the coral surface. Rostro-carinal diameter up to 3 mm; wall made of four parietes separated by two pairs of sometimes indistinct radii, covered by coral, more than 20 internal and 30 external primary radial ribs radiating from central aperture, some secondary ribs reach half way between wall circumference and aperture (fig. 2A). Tubes between sheath and parietes largely filled. Orifice oval; 1/5 of rostro-carinal diameter. Sheath with concentric growth ridges extending more than half way down its internal surface (fig. 2B). Lateral margins of radial septa denticulate. Carina wider than rostrum.

Basis white, (fig. 2C) solid, thin, moderately deep, cup shaped, depth reaching 4 mm depending on age. Longitudinal ridges separated by narrower grooves; each ridge with a single row of elevated bumps (fig. 2D).

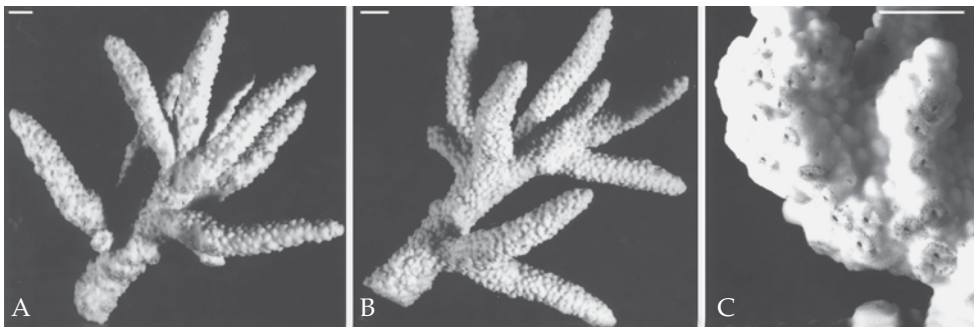

Fig. 1. *Acropora brueggemanni* A, sample MTQ-G 52865, from Indonesia, lower side of coral showing *Cantellius cardenae*; B, upper side of same coral branch, note the difference in barnacle density on the different sides of same coral; C, sample MTQ- G 48391, from Papua New Guinea, lower side of coral showing high density of *Cantellius cardenae*. Scale bars: 1 cm.

Opercular valves: Scutum (figs 2E-F) translucent, triangular, less than twice as long as high. Externally growth ridges separated by a row of small depressions, occludent margin slightly toothed, teeth formed by every other growth ridge; basal margin sinusoidal, adductor ridge very prominent, equal to or slightly projecting beyond basal margin. Conspicuous rostral tooth at the basi-occludent angle, articular ridge weakly developed, pit for lateral depressor muscle noticeable (fig. 2F).

Tergum (figs 2G-H) translucent, marked with growth lines, narrow, height, including spur, nearly four times its width, spur length more then half of total tergal length, articular ridge straight, weakly developed (fig. 2H).

Trophi (fig. 3): Labrum (fig. 3D) with two to four small teeth on each side of deep notch. Palps (fig. 3D) ovate, attached along the sides of the labrum. Mandible (fig. 3A) with cutting edge of three teeth and an irregular molariform lower angel, basal margins with widely spaced long setae, short setae covering lateral face. First maxilla: (fig. 3B) straight, two stout long apical spines and a row of strong spines of different length along cutting edge, two lower spines stout, basal margins with long spaced setae. Second maxilla (fig. 3C) divided into two lobes.

Cirri (fig. 4): number of articles of cirri is given in table 1, data given in table is of counts of two randomly chosen barnacles. Cirrus I (fig. 4A), with unequal rami , posterior ramus about half the length of anterior, terminal article of posterior ramus with serrate and pinnate setae, proximal articles with pinnate setae; anterior ramus somewhat antenniform with pinnate setae. Cirrus II (fig. 4B) shortest of the cirri, posterior ramus a little longer than anterior ramus, terminal articles with serrate setae, proximal articles with pinnate setae. Cirrus III (fig. 4C) with anterior ramus slightly longer than posterior, terminal article of posterior ramus with serrate and pinnate setae, anterior ramus only pinnate setae. Rami of cirri IV to VI slender and long (fig. 4D), many are broken, essentially equal in length but the numbers of articles differ, there are also small differences in number of articles between the right and the left side. Two to three pairs of setae of different length arranged along anterior margins of each article, the distal pair being longest. Penis long, annulated throughout its length, with only few setae, tip provided with a group of setae.

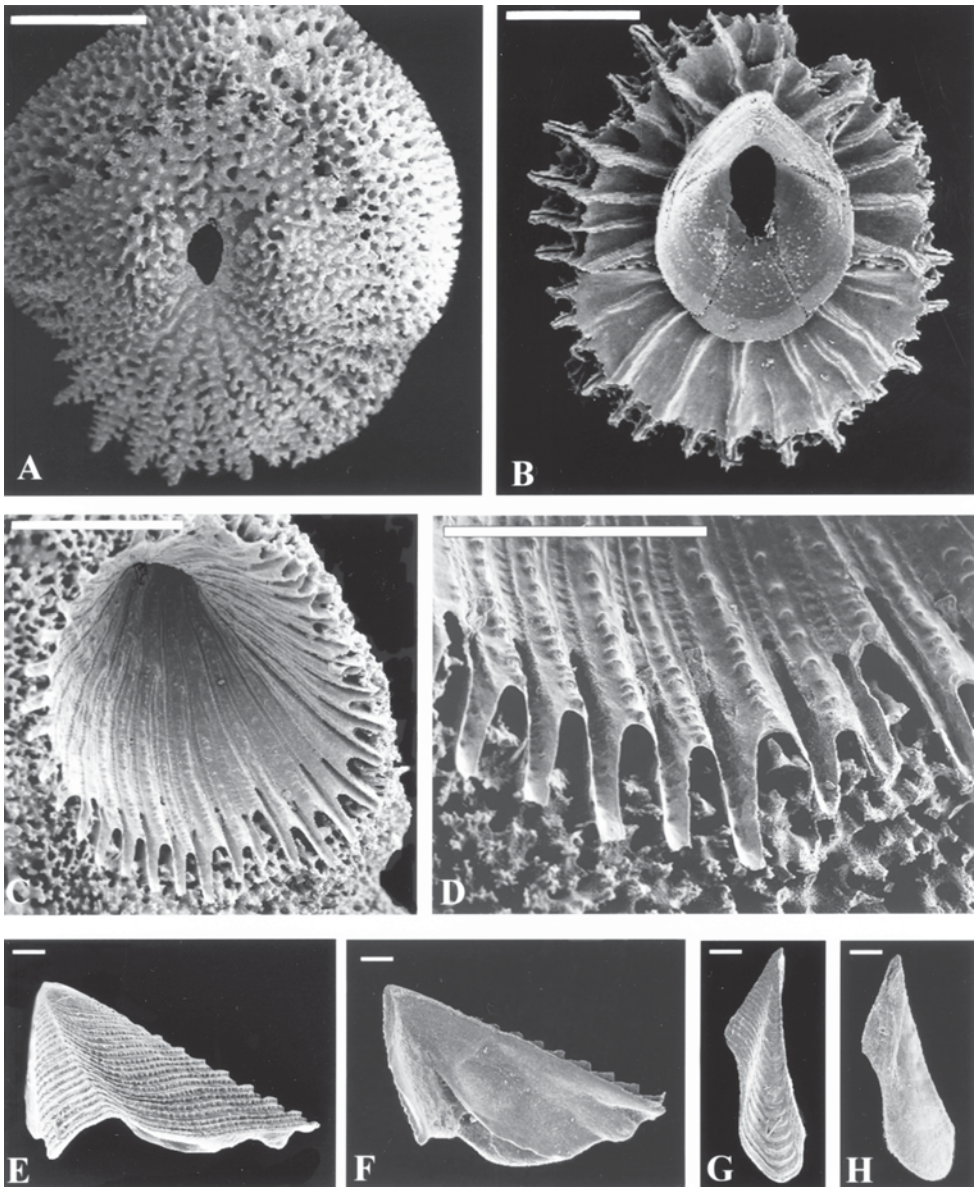

Fig. 2. *Cantellius cardenae,* SEM micrographs of shell and opercular valves, from *Acropora brueggemanni*, Sulawesi, Indonesia. A-B, outer and inner views of shell (paratype RMNH C2592); C, inner view of basis (sample lost); D, margin of basis (sample lost); E-H, outer and inner views of left and right scuta of holotype (RMNH C2591). Scale bars: A-D: 1 mm; E-H: 200 μm.

Etymology.— Named in honour of Dr Carden C. Wallace, Museum of Tropical Queensland, Townsville, in appreciation of her studies of *Acropora,* the host coral of *Cantelius cardenae.*

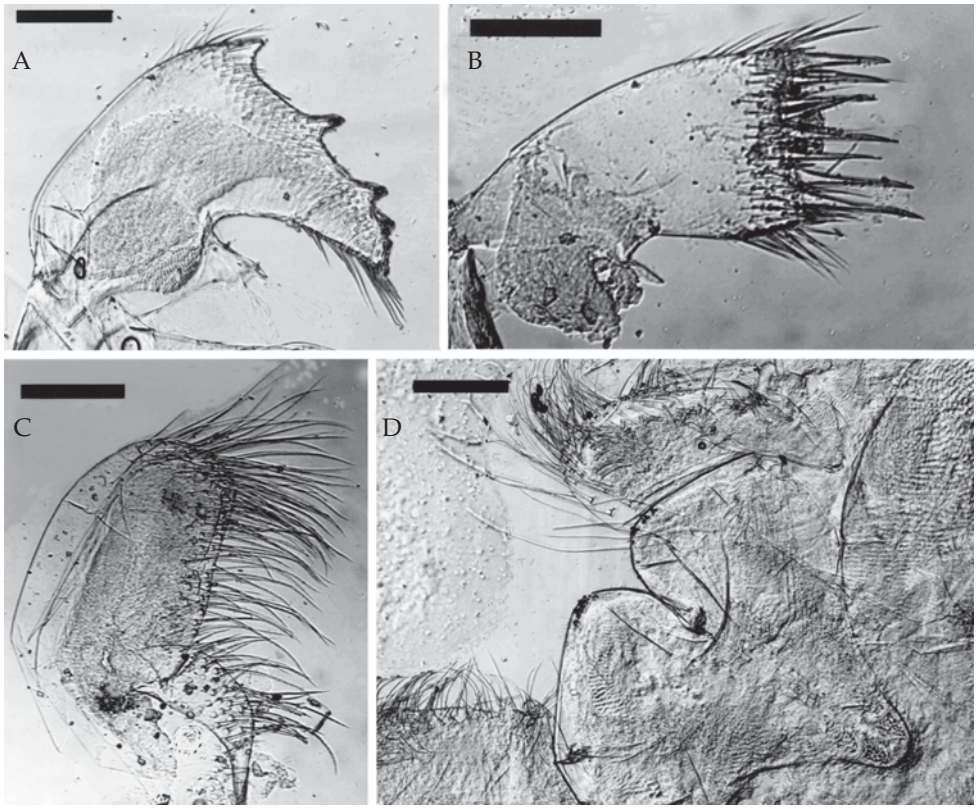

Fig. 3. Photomicrographs of trophi of *Cantellius cardenae* from Sulawesi, Indonesia. A, mandible; B, first maxilla; C, second maxilla; D, labrum and mandibular palps. Scale bar: 100 μm

Discussion

Comparison with other species of *Cantellius* reveals that it is most similar to *C. acutum* (Hiro, 1938) described from *Acropora formosa* (Dana, 1846). Our material can be distinguished from *C. acutum* by a more pronounced indentation in the basal margin of the scutum, in the vicinity of the lateral depressor muscle scar, resulting in an abrupt change in the direction of the external growth lines running from the apex to the base, and in the deeper, more pronounced spur furrow of the tergum.

The angle between the carinal margins of the tergum and the axis between the carino-basal and scuto-basal corners is more obtuse in *C. cardenae* than in *C. acutum*.

The width of the terga of *C. acutum* is about half its length while in *C. cardenae* the length is nearly four times its width. These differences support its designation as a new species.

We found that the number of articles of the cirri is highly variable. It is not due to size differences, since the rostro-carinal diameter of all specimens was about 2.5 mm. In coral-inhabiting barnacles, with initially growth is in the diameter of the shell plates, for most of its life it is mostly in depth of the embedded basis that has to keep

Fig. 4. Photomicrographs of cirri of *Cantellius cardenae* from Sulawesi, Indonesia. A, cirrus I; B, cirrus II; C, cirrus III; D, cirrus VI; E, setation on articles of cirrus VI. Scale bars: A-C, E : 100 μm, D 250 μm.

up with the growth of the coral. Thus the diameter of the barnacle does not necessarily represent the real age or size. Another possibility is that the low counts of articles are a result of regeneration of the cirri recovering from predation, as suggested by the presence of many broken cirri in our sample.

Galkin (1986) and Anderson (1992) discussed the phylogenetic relationship of *Cantellius*. Galkin (1986) divided *Cantellius* into three groups, the most generalized being the *tredecimus* group, which shows the most plesiomorphic characters, and the *arcuatum* and *secundus* groups, which include the more specialized members of the genus, including

Table 1: Cirral counts of two randomly chosen specimens *Cantellius cardenae* from a branch of *Acropora (Isopora) brueggemanni* from Kudingareng Keke I., SW Sulawesi, Indonesia, number of articles of anterior and posterior rami. + indicating a broken ramus.

Cirrus	I	II	III	IV	V	VI
Specimen 1 (A-	7-4	4-6	8-4	8-9	8-8	13-11
Specimen 2 (A-	12-7	5+-13	14+-13	18+-24	18-24	20-15+

those with transversally elongated scuta. Based on the musculature of the opercular valves and cirral activity, Anderson (1992) distinguished three slightly different lines of divergence within *Cantellius*, i.e. the *pallidus, septimus* and *secundus* branches. At the basis of the phylogenetic tree of *Cantellius* he placed *C. euspinulusum* (Broch, 1931) and *C. sumbawae* (Hoek, 1913). Anderson's *septimus* and *secundus* groups are included within Galkin's *secundus* group, apart of *C. madreporum* (Borradaile, 1903), which Galkin (1986) assigned to the *arcuatum* group while Anderson included it in the *pallidus* group. *Cantellius cardenae* belongs to the *secondus* group of Galkin (1986). Both authors do not discuss the connection between the host coral and the divergence of the barnacles.

Ogawa et al. (1998) compiled a list of barnacles and their coral hosts, in which the *pallidus* group shows a wide range of hosts compared to members of the morphologically more specialized *secundus* group, which is restricted to the Acroporidae. *C. pallidus* was found in 37 species of corals, which is the largest number of corals inhabited by a single barnacle species. *C. euspinulosum* is known from nine corals species, while only two serve as hosts for *C. tredecimus* and *C. iwayama.* Based on its morphology as well as its limited host selection to *Acropora brueggemanni, Cantellius cardenae* should also be included in the *secundus* group.

The restriction of the *secundus* group to the Acroporidae supports the observation of Newman et al. (1976) that structurally generalized pyrgomatine genera occupy a greater variety of hosts than do specialists and that a high degree of morphological specialization is correlated with a fewer number of host corals. This principle can also be applied to the species of *Cantellius*. The *pallidus* group, which is morphologically the most generalized, has a wide range of hosts compared to members of the morphologically more specialized *secundus* group. Narrow host specificity may be the result of mutual evolution of barnacle and host. Cases of host-associated speciation seem to be the rule in epizoic marine invertebrates (Knowlton, 1993).

Acknowledgements

The visit of the first author to the National Museum of Natural History at Leiden was part of the scientific exchange program between Israel and the Netherlands and was partly supported by the Ministry of Science, Israel, and the Netherlands Organisation for International Cooperation in Higher Education (NUFFIC). The field research of B.W. Hoeksema at South Sulawesi was sponsored by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO grant W84-354). Thanks are due to Dr Maya Borel Best and Dr Charles H.J.M. Fransen of the National Museum of Natural History, Leiden, for their hospitality and assistance. Dr Carden C. Wallace and Mrs Barbara Done of the Museum of Tropical Queensland, Townsville,

helped us during the examination of material in the coral collection of the museum. Mr Zoltan Florian prepared the pictures of the corals with barnacles at MTQ. Mr Yaacov Langsam, Mrs Sylvia Markovitch and Mr Erez Feige of Bar Ilan University helped with the SEM work and the preparation of the plates.

References

Anderson, D.T., 1992. Structure, function and phylogeny of coral-inhabiting barnacles (Cirripedia, Balanoidea).— Zool. J. Linn. Soc. 106: 277-339.

Galkin, S.V., 1986. On taxonomic system of the genus *Cantellius* (Cirripedia, Pyrgomatidae).— Zool. Zh. 65: 1267-1272.

Hiro, F., 1938. Studies on the animals inhabiting reef corals II. Cirripeds of the genera *Creusia* and *Pyrgoma*.— Cont. Palao. Trop. Biol. Stn. 3: 391-416.

Knowlton, N., 1993. Sibling species in the sea.— Annu. Rev. Ecol. Sys. 24: 189-216.

Newman, W.A., P.A. Jumars & A. Ross, 1976. Diversity trends in coral-inhabiting barnacles (Cirripedia: Pyrgomatinae).— Micronesica 12: 69-82.

Newman, W.A., V.A. Zullo & T.H. Withers, 1969. Cirripedia. In: Moore R.C. (ed.) Treatise on Invertebrate Paleontology Part R. Arthropoda 4 (1) R206-R295.— Geol. Soc. Am. Univ. Kansas.

Ogawa, K. & K. Matsuzaki, 1992. An assay on host specificity, systematic taxonomy and evolution of the coral barnacles.— Bull. Biogeographical Soc. Jap. 47: 1-16.

Ogawa, K., R.M. Pillay & K. Matsuzaki, 1998. Coral-inhabiting barnacles. (Cirripedia: Pyrgomatidae) from Albion, west coast of Republic of Mauritius.— Bull. Biogeographical Soc. Japan 53: 1-21.

Ross, A. & W.A. Newman, 2002. Coral barnacles: Cenozoic decline and extinction in the Atlantic/East Pacific versus diversification in the Indo-West Pacific.— Proc. 9th Int. Coral Reef Symp., Bali: 179-184.

Received: 11.vii.2002
Accepted: 20.ix.2002
Edited: L.P. van Ofwegen