

GODZILLIUS FUCHSI, A NEW SPECIES OF REMIPEDIA (GODZILLIIDAE) FROM ABACO ISLAND, BAHAMAS

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ABSTRACT

We describe a new species of *Godzillius*, a remipede belonging to Godzilliidae, discovered from Dan's Cave and Ralph's Sink, two inland anchialine blue holes on Abaco Island, Bahamas. *Godzillius fuchsi* n. sp. is the second species assigned to this genus. Collected adult specimens have a relatively robust body, with lengths measuring 34 mm and up to 28 trunk segments. The new species is distinguished from *G. robustus* in particular by the varying construction of the terminal claw complex on the cephalic limbs; having seven large teeth on the maxillae; and six large teeth separated by seven smaller teeth on the maxillipeds. The status of *G. fuchsi* as a distinct species was validated using pairwise distance calculations of COI sequences and that of previously published Bayesian analyses from selected remipede taxa, including *G. robustus*. Dan's Cave and Ralph's Sink are in very close proximity and likely are hydrologically connected. *Godzillius fuchsi* is the fifth remipede to be recorded from Dan's Cave.

KEY WORDS: anchialine caves, Bahamas, blue holes, Godzilliidae, molecular taxonomy, Remipedia

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INTRODUCTION

Scientific cave divers have discovered a second species of the remipede genus *Godzillius* Schram, Yager, and Emerson, 1986, from Little Bahama Bank. Five specimens of *Godzillius fuchsi* n. sp. were found inhabiting two inland blue holes on Abaco Island. Morphologically similar, but unidentified, remipede specimens of the genus *Godzillius* have also been found on Abaco Island and the Exuma Cays, extending the geographical range of *Godzillius* to now include both of the major underlying limestone banks of the Bahamas.

The Bahamas Archipelago is comprised of over 125,000 km² of submerged shallow water banks or platforms (Meyerhoff and Hatten, 1974) separated by deep-water channels. The northwestern province includes two major platforms, Little Bahama Bank and Great Bahama Bank, while the southeastern province contains numerous smaller banks (Mullins and Hine, 1989; Carew and Mylroie, 1995; Sealey, 1995). Submerged banks are composed of limestone of shallow-water origin, depositing continuously since the Cretaceous. The Bahamas, like many other carbonate islands, have a characteristic geohydrology, controlled by rainfall and infiltration of saltwater due to the porosity of the surrounding rock. Beneath the islands, freshwater meets and mixes with submerged marine water, forming a halocline. This boundary layer has aggressive dissolutional properties, aiding in the formation and expansion of karstic features such as blue holes. The anchialine blue holes found on Abaco Island are deep (100+ m) and contain extensive

vertical and horizontal passages, giving insight towards the geologic development and glacial eustatic events on the island.

Neiber et al. (2011) identified "*Godzillius* n. sp. A" from Ralph's Sink to be a distinct lineage, sister to *G. robustus* Schram, Yager, and Emerson, 1986, from Cottage Pond, Turks and Caicos; we describe "*Godzillius* n. sp. A" herein. This is the fifth remipede to be described from Dan's Cave and Ralph's Sink including *Godzilliognomus frondosus* Yager, 1989, *Pleomothra fragilis* Koenemann, Ziegler, and Iliffe, 2008, *Cryptocorynetes elmorei* Hazerli, Koenemann, and Iliffe, 2010, and *Speleonectes benjamini* Yager, 1987. These two inland blue holes are separated from one another by terminal collapses, so far blocking passageways sizable enough for divers to penetrate. Neiber et al. (2011) report that at least five additional unidentified specimens from varying genera, including *Godzillius*, *Godzilliognomus* Yager, 1989, and *Speleonectes* Yager, 1981, have been collected from these two blue holes. Preliminary examination has identified these remipede individuals to known genera, but molecular and taxonomic delineation is pending. Several of these specimens may be new records of known species or even new cryptic species.

This discovery of a second species of *Godzillius* marks the seventh occurrence of sympatric speciation in remipedes known from inland blue holes throughout the Bahamas (Fig. 1). Three blue holes located on Abaco Island (Dan's Cave, Ralph's Sink, and Sawmill Sink) and blue holes from Grand Bahama (Sagittarius Cave), Exuma

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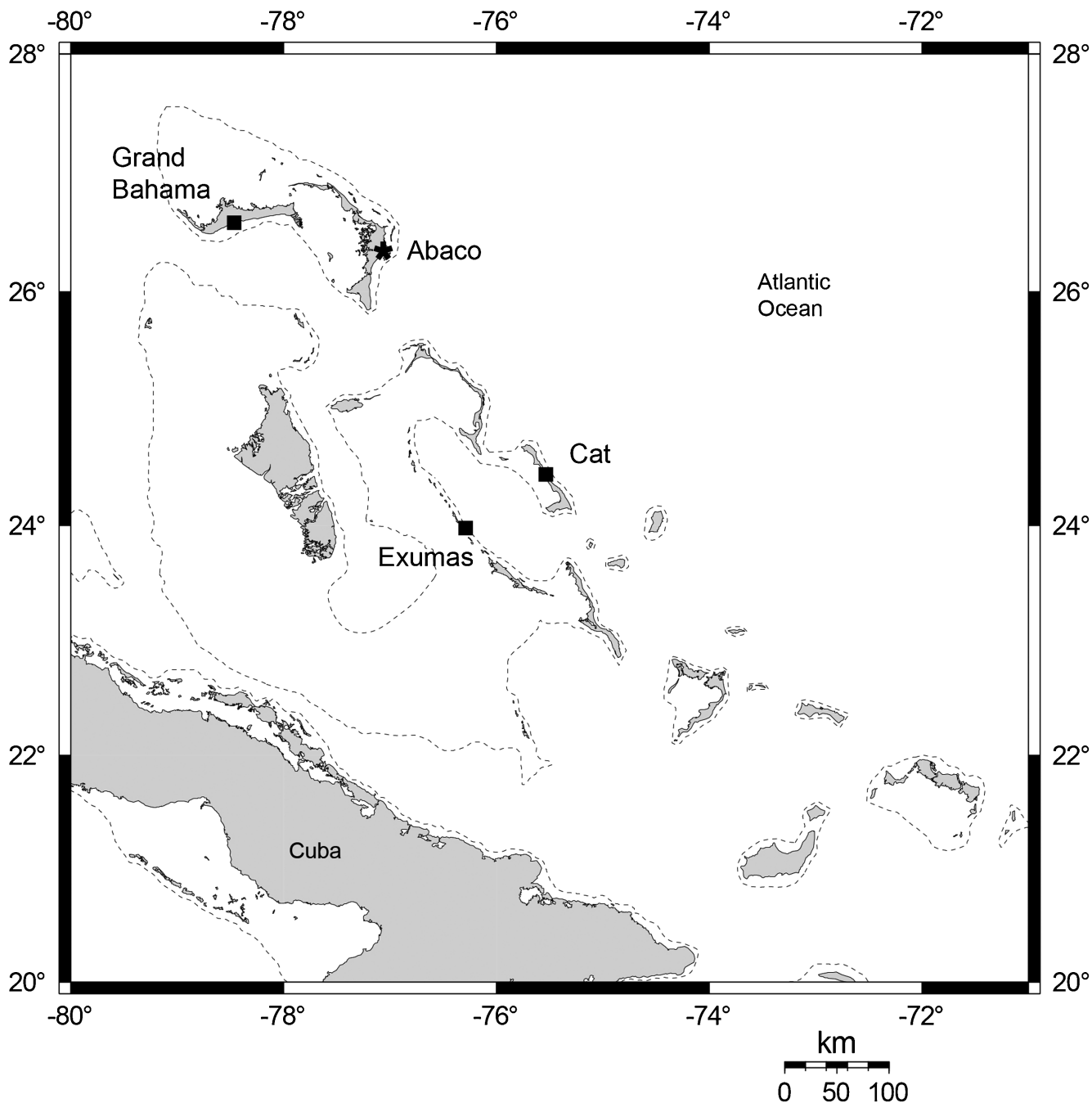


Fig. 1. Bahamas Archipelago; dashed outlines representing the 100 m contour edge of the submerged limestone banks. Type locality of *Godzillius fuchsi* n. sp. indicated by (★). Filled in squares (■; in addition to Abaco Island) represent islands of the Bahamas, where sympatric speciation amongst remipedes occurs in a single blue hole.

Cays (Basil Minns, Oven Rock Cave), and Cat Island (Big Fountain) all exhibit similar patterns of sympatry of remipedes. Localities outside the Bahamas of sympatric speciation in remipedes include the Yucatán, Mexico, and Lanzarote, Spain, suggesting that sympatry is the rule rather than the exception in Remipedia (Neiber et al., 2011).

MATERIALS AND METHODS

Specimens were collected during a biodiversity inventory assessment of anchialine caves in the Bahamas. Remipedes described here were collected

in March 2006 and December 2010, from Dan's Cave and Ralph's Sink (both inland blue holes) on Abaco Island, Bahamas. Five specimens of an apparent new species of *Godzillius* were collected for taxonomic and molecular comparison.

All specimens were fixed in the field with 70–96% ethanol or phosphate buffered saline solution (PBS). Specimens used for morphological examination were transferred into glycerine and dissected. Drawings were prepared using a Zeiss Stereomicroscope and drawing tube. For a clear representation of three-dimensional structures, solid lines were used to outline articulated structures, dotted lines to indicate covered structures, and dashed lines for the reconstruction of structures that were damaged during dissection or fixation. Because the holotype and paratypes 3 and 4 had their heads removed

in the field, the number of trunk segments and the exact body lengths are approximated since loss of a segment is unknown.

COI sequences used for Bayesian analysis by Neiber et al. (2011) were downloaded from GenBank for calculation of pairwise distances. Pairwise distances (PD) of COI sequences for *G. fuchsi* (JF3321537) were estimated against sequences of select representatives of the Godzilliidae Schram, Yager, and Emerson, 1986, including *Godzillius robustus* (JF332152), *Godzilliognomus frondosus* (FJ527839), and *Godzilliognomus schrami* (Iliffe, Otten, and Koenemann, 2010) (FF332154). Sequences were visualized, trimmed, and aligned by amino acids using Mesquite V.2.71 (Maddison and Maddison, 2009). jModelTest (Guindon and Gascuel, 2003; Posada, 2008) was employed to select the appropriate model of evolution for COI. Pairwise distances (see discussion) were calculated and corrected in Paup* 4.0a123 (Swofford, 2002) using the general time reversible model, with proportional of invariable sites (GTR + I) according to the results of the Akaike Information criterion (AIC) (Akaike, 1974).

SYSTEMATICS

Godzillius Schram, Yager, and Emerson, 1986

Type Genus.—*Godzillius* Schram, Yager, and Emerson, 1986.

Diagnosis.—Cephalic shield subtrapezoidal, wider posteriorly than anteriorly; convex posterior corners. Pleurotergites with hooked corners; sternal bars isomorphic and sublinear. Basal protrusion covering male gonopores on segment 14. Frontal filament with blade like terminus; setae absent. Antennule with varying length plumose setae on all segments. Antennae with long plumose setae, protopod with few short setae only; exopod ovalous. Endite 3 of maxillule underdeveloped, endite 4 club-like; lacertus wider than broad, long talon-like terminal claw. Maxilla and maxilliped subchelate, lacertus with convex margins, longer than wide; narrow and elongate concave brachium. Lacertus and brachium densely setose. Teeth of terminal claws in hook-like arrangement.

Remarks.—Adult specimens very large compared to that of individuals from other genera. Large cephalic limbs are a diagnostic character, having broad boxy lacerti in all limbs and slender subchelate brachia adorned with setae in maxillae and maxillipeds.

Godzillius fuchsi n. sp.
(Figs. 2-5)

Type Locality.—Dan's Cave (26°14'N, 77°11'W), Abaco Island, Bahamas; paratype 1 from Ralph's Sink (26°15'N, 77°11'W), paratypes 2-4 from Dan's Cave; also on Abaco Island.

Material Examined.—Holotype (ZMB 28052; our ID: AB 2011-C) 34 mm, 28 trunk segments; collected by Thomas M. Iliffe, 01 December 2010; type location. Paratype 1 (ZMB 28052; our ID: 06-AB RS-1) 34 mm, 27 trunk segments; collected by Thomas M. Iliffe, 13 March 2006; Ralph's Sink. Paratype 2 (our ID: BH 337) 27 mm, 28 trunk segments, collected by Jill Yager, collection date unknown. Paratype 3 (ZMB 28052; our ID: AB 2011-T) 32 mm, 27 trunk segments; collected by Thomas M. Iliffe, 01 December 2010; type location. Paratype 4 (our ID: AB 2011-U) 33.5 mm, 28 trunk segments; collected by Thomas M. Iliffe, 01 December 2010; type location. Immediately

after collection, the heads and antennules of the holotype and paratypes 3 and 4 were separated for neuroanatomical studies. The existence of a new species was unknown at this time. Paratype 1 was bisected at the mid trunk region, from where 5 trunk limbs were removed for DNA extraction. The holotype and paratypes 1 and 3 are deposited at Museum für Naturkunde Berlin (ZMB). Paratype 2 was dissected for the morphological description; paratypes 2 and 4 remain in the research collection of Stefan Koenemann at Montessori Education House, Hannover.

Etymology.—The new species is named in honor of our sponsor, Olivier Fuchs of the Barony of Buncle and Preston, Berwickshire, Scotland, whose financial support contributes to furthering remipede research.

Diagnosis.—*Godzillius fuchsi* is a robust, large species (Fig. 2). Body length up to 34 mm in length, largest specimen with 28 trunk segments. Terminal claw complex, hook-like, differs between maxilla and maxilliped. Maxillary claw with 7 large isomorphic teeth; maxillipedal claw with 6 large isomorphic teeth and 7 additional small isomorphic teeth at apex.

Description.—Based on holotype and paratypes. Body large and robust with a maximum length of 34 mm and 28 trunk segments (Fig. 2).

Cephalic shield (Fig. 3A): Subtrapezoidal, wider posteriorly than anteriorly; convex posterior corners. Cephalic shield twice as long as maximum width. First segment reduced; overlapped by cephalic shield. Pleurotergites four times longer than broad, with posterobilateral hooked corners. Sternal bars isomorphic and sublinear.

Trunk limbs (Fig. 3B, E, G): Swimming limbs reduced in anterior (Fig. 3B) and posterior trunk regions (Fig. 3G); all with similar plumose (Fig. 3C) and serrate (Fig. 3D) setation. Trunk limbs immediately before anal somite strongly reduced. Anal somite longer than wide (Fig. 3G). Caudal rami half as long as anal somite; short setae on lateral margins and several longer setae on apical and mediodistal margins.

Female gonopores basal of seventh pair of trunk limbs. A subtriangular protrusion basal of segment 14 covers small male gonopores. Swimming limbs of first trunk segment with three plumose setae on left posterior margin of protopod, proximal to segment 1 of exopod (Fig. 3B); endopod slightly shorter than exopod; exopod twice as wide as endopod. Mid-torso swimming limbs with exopods laterally widened (Fig. 3E); exopod relatively equal in length to endopod; segment 2 of exopod widest, segment 3 ovoid; segments 1 and 2 of exopod bear up to 14 long serrate setae on distolateral margins; distal corners of segment 2 and 3 of endopod with six rows of serrate setae.

Frontal filaments (Fig. 3F): Long and slender. Small medial extension 1/4 length of the non-segmented main filament.

Antennules (Fig. 4A1-A3): Peduncle bulbous, 2 segments. Peduncular aesthetascs (~30) arranged in rows on proximal segment. Distal segment of peduncle short; forked at emergence of dorsal branch and ventral flagellum. Dorsal branch consists of 11 segments, 1/6 of total body length; segment 11 shortest (Fig. 4A1-A2); except proximal segment,

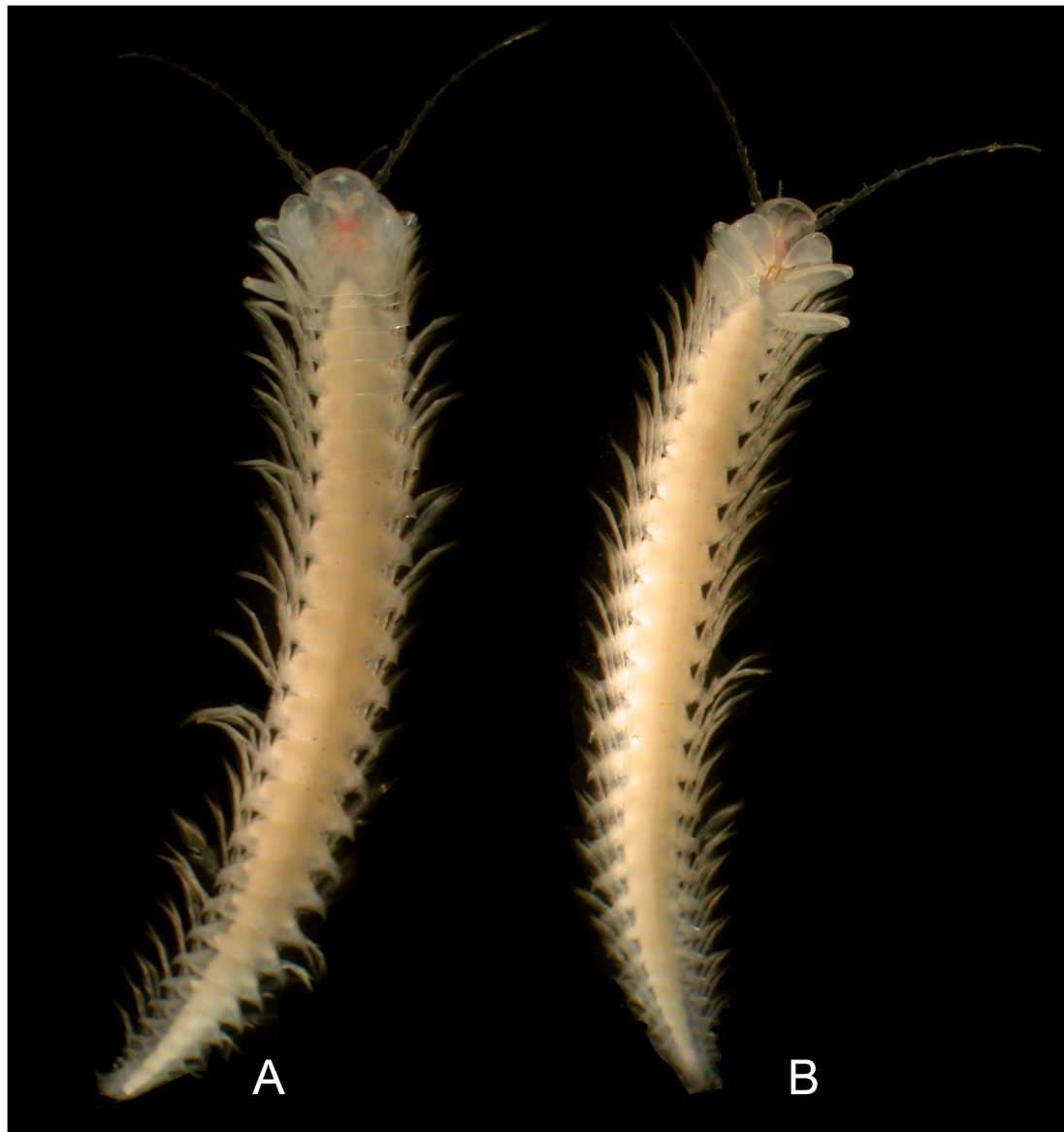


Fig. 2. *Godzillius fuchsi* from Abaco Island, Bahamas. A, paratype 2, 27 mm; dorsal view of living individual; B, ventral view of living individual. (Photo by B. C. Gonzalez.) This figure is published in colour in the online edition of this journal, which can be accessed via <http://booksandjournals.brillonline.com/content/1937240X>.

all segments adorned with 2-3 branched aesthetascs distally or proximally. Ventral flagellum very short, with 2 segments; segment 2 twice as long as segment 1; segment 1 lacks aesthetascs; segment 2 with 3-4 long aesthetascs and row of fine setae on lateral edge; tuft of forked aesthetascs on terminal end of segment 2 (Fig. 4A3).

Antennae (Fig. 4B): Proximal segment of protopod with 7 plumose setae on distomedial side; medial border of distal segment with 10 plumose setae. Exopod ovoid, bearing about 64 setae. Endopod composed of 3 segments, covered with marginal setae; rowed setation of unequal length on segment 3 of endopod, posterior margin with single row of 16 setae. All setae plumose.

Labrum (Fig. 4C): Anterior region cuspidate with apex pointed anteriorly; posterior portion of labrum overlaid by anterior invagination. Posterior margin concave medially;

bearing dense fields of fine setae. Both lateral margins of posterior region with clusters of short setae.

Mandibles and molar processes well developed with fine setae (Fig. 4D-F). Right incisor process composed of 3 triangular denticles with jagged margins (Fig. 4E1); right lacinia mobilis with 3 uneven, flat teeth at an oblique (Fig. 4E2). Left incisor process with 3 large triangular teeth, separated by deep grooves; tooth 4 small, no separation from tooth 3, innervates below base of tooth 3 (Fig. 4F1); five equal-sized, irregular shaped teeth on left lacinia mobilis; outermost tooth projecting outward with rounded margins (Fig. 4F2).

Maxillules broad and robust (Fig. 5A-B). Segment 1 with 2 long endites; terminal margin of endite 1 with 10 sclerotized spine-like setae in a row. Endite 2 asymmetrical, oval-shaped; 22 moderately long curved setae on apical margin;

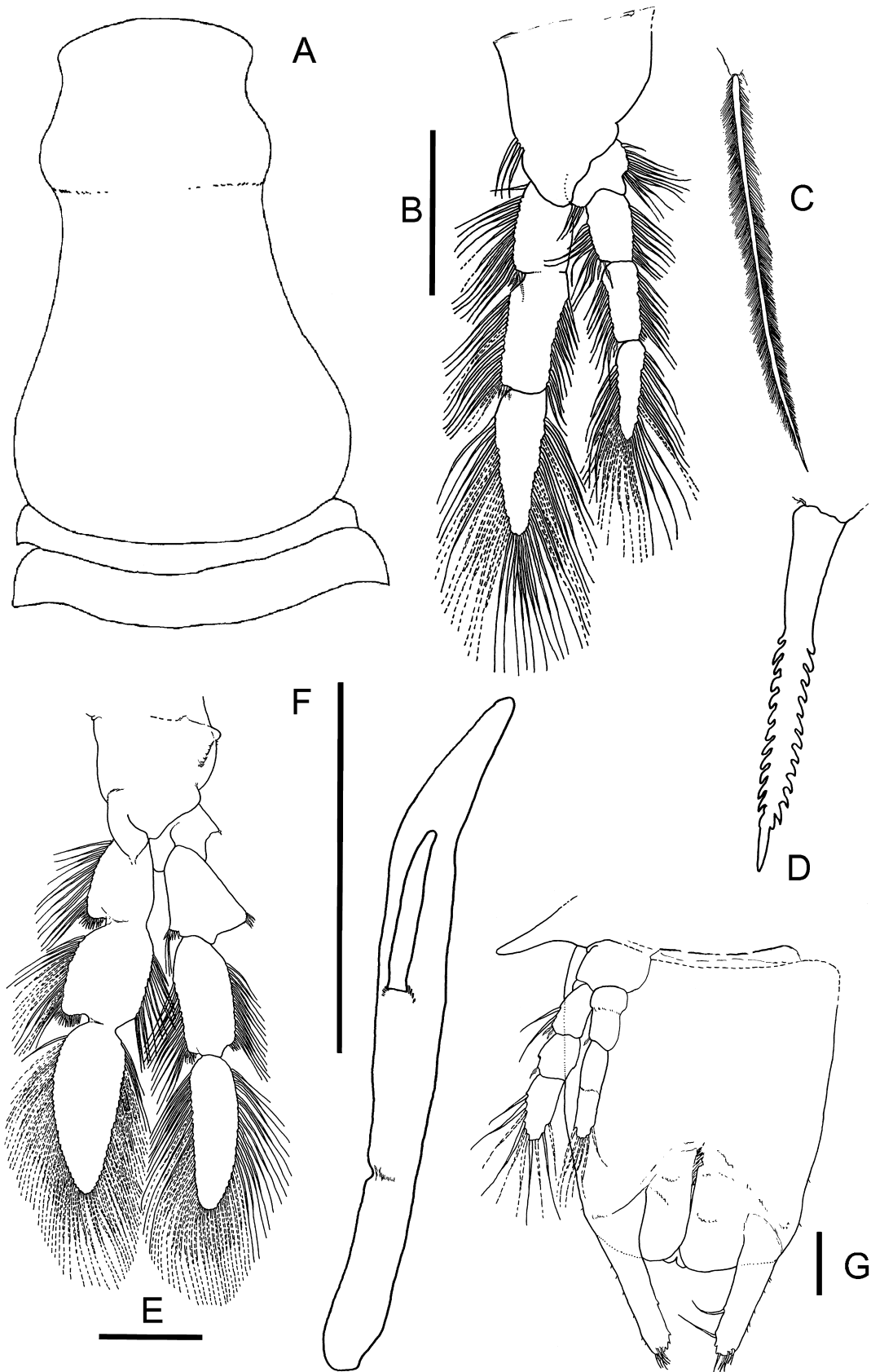


Fig. 3. *Godzillius fuchsi*. A, holotype 34 mm; B-G, paratype 2, 27 mm; A, dorsal view of head shield with trunk segments 1-2 (sketch after photography); B, first trunk limb, scale bar = 1 mm; C, plumose seta of first trunk limb, magnified; D, short, serrate seta of first trunk limb, magnified; E, fourteenth trunk limb, scale bar = 0.2 mm; F, frontal filament, scale bar = 0.5 mm; G, anal segment and caudal rami with trunk limb of last segment, scale bar = 0.5 mm.

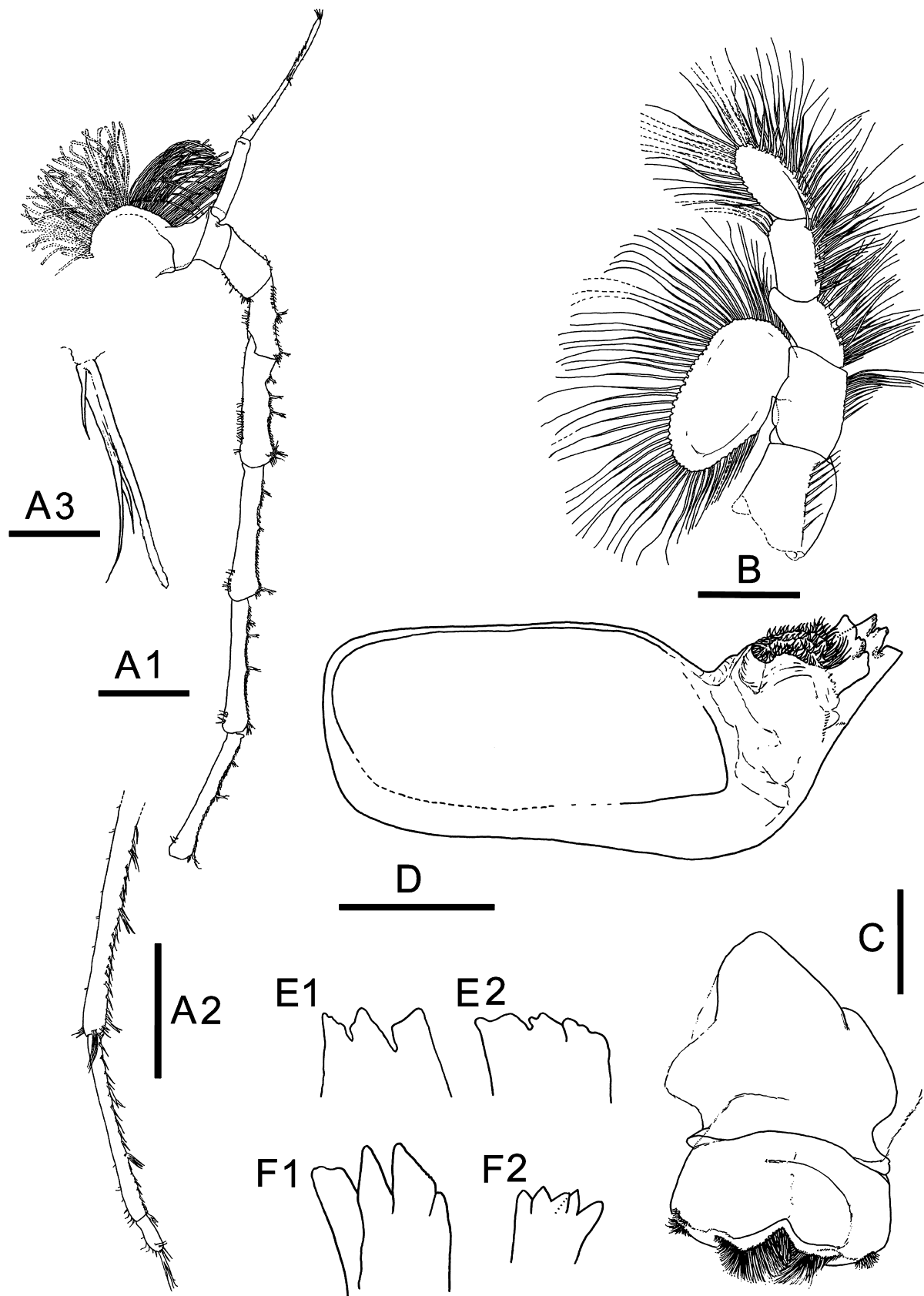


Fig. 4. *Godzillius fuchsi*. A1-A2, holotype, 34 mm. A3, B-F, paratype 2, 27 mm; A1, antennule, scale bar = 1 mm; A2, segments 9-11 of antennule, scale bar = 0.5 mm; A3, magnification of aesthetasc, scale bar = 1 mm; B, antenna, scale bar = 0.5 mm; C, labrum, scale bar = 0.5 mm; D, right mandible, scale bar = 0.5 mm; E1, incisor process (right); E2, lacinia mobilis (right); F1, incisor process (left); F2, lacinia mobilis (left).

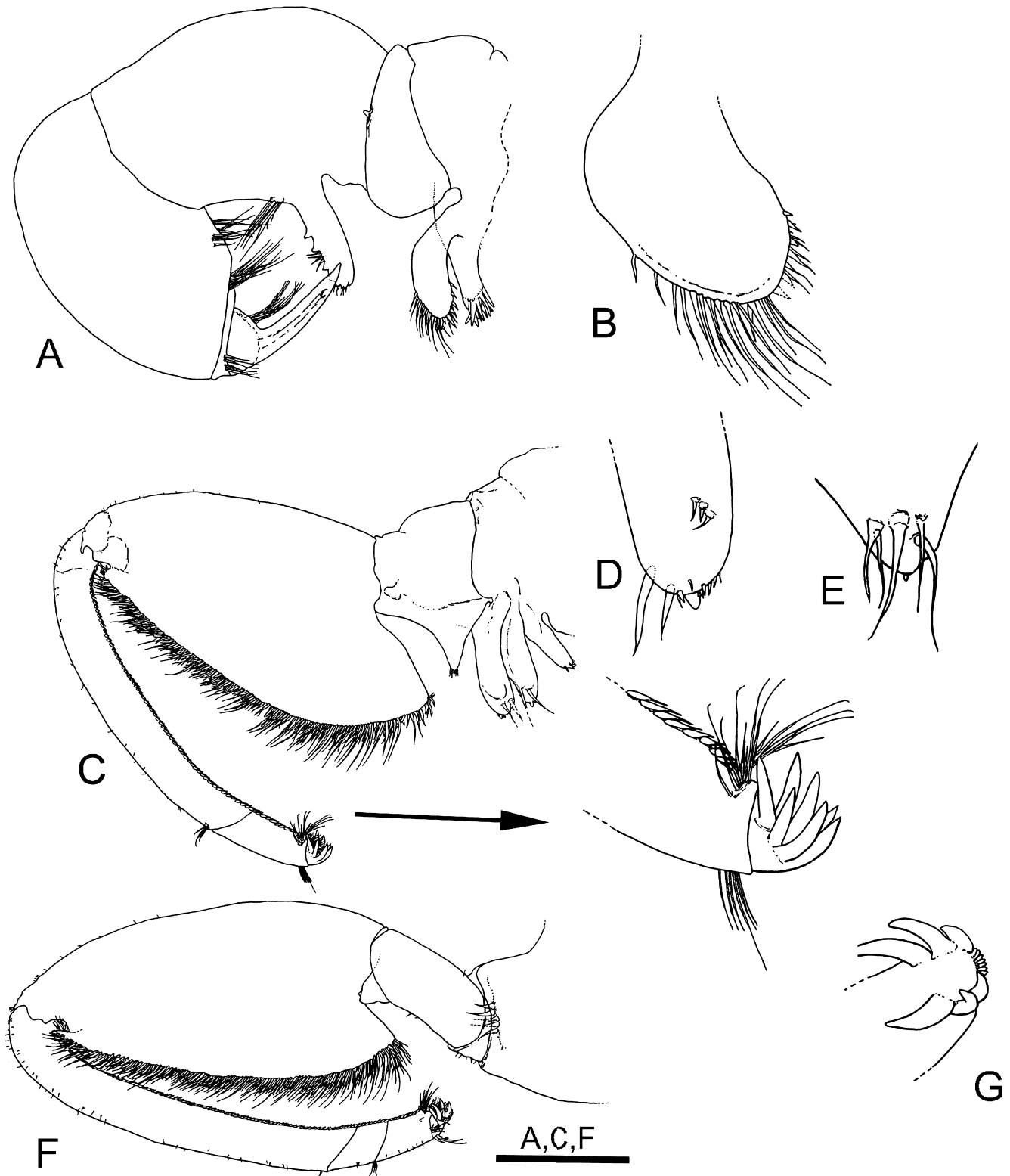


Fig. 5. *Godzillius fuchsi*. A-G, paratype 2, 27 mm; A, maxillule; B, endite of second segment of maxillule. C-E, maxilla, with arrow pointing at enlarged terminal claw; D, enlarged endite 3 of first segment; E, enlarged endite of second segment. F-G, maxilliped; G, enlarged claw of maxilliped. Scale bar (A, C, F) = 1 mm.

row of short, broadly curved setae adjacent (Fig. 5B). Endite of third segment strongly reduced. Lacertus longer than wide, with long, digitiform endite and a cluster of long setae

on medial margin; endite bearing short setae centrally and apically between tooth-like projections along lateral margin and apex. Segment 5 longer than lacertus, but less wide,

bearing two clusters of setae on medial and distomedial margin. Very short and narrow segment 6; row of setae on distolateral margin. Terminal claw long and talon-like; cluster of 16 long, simple setae on medial surface; large pore at apex of claw with subdermal membrane-lined duct.

Maxillae subchelate, slightly longer and more slender than maxillules (Fig. 5C-E). Segment 1 with 3 digitiform endites, sparsely setose (Fig. 5D). Single endite of segment 2 pointed, funnel-shaped, with cluster of short, apical setae (Fig. 5E). Lacertus very broad; medial margin extends proximally; adorned with dense rows of unequally long setae. Brachium very narrow, with fused segments exhibiting a fine suture distally; length of brachium including claw shorter than medial margin of lacertus, forming a concave arc that aligns with convexity of lacertus; medial surface of brachium densely covered with short, leaf-like, spiky setae; lateral surface with 3 short setae at distal margin. Terminal claw with 7 broad, free-standing teeth; blade-shaped teeth in hook-like arrangement around margins of a fleshy pad; assortment of setae present on pad.

Maxillipeds similar in form and size to maxillae (Fig. 5F-G). Arrangement of proximal segments indistinct, endites lacking. Lacertus slightly longer and narrower than that of maxilla. Brachium longer than medial margin of lacertus, with two sutures distally. Terminal claw equipped with 6 large, isomorphic teeth, but unlike that of maxilla, with 7 short teeth located at apex (Fig. 5G).

Taxonomic Affinities.—*Godzillius fuchsi* is the second species described for the genus *Godzillius* and the sixth species assigned to Godzilliidae, formerly comprised of three monotypic genera including *Godzillius*, *Godzilliognomus*, and *Pleomothra* Yager, 1989. *Godzillius fuchsi* morphologically fits within Godzilliidae, characterized by uniquely shaped head shields and prehensile cephalic limbs (Schram et al., 1986). The ventral flagellum of the antennule is reduced and significantly shorter than the dorsal branch. The maxillae and maxillipeds are subchelate with long, robust lacerti, densely covered with modified setae, slim brachia with partially fused segments and isomorphic sternites. Specific variability in size and shape of these limbs can be seen between the genera in Godzilliidae, including *G. robustus*, *Gn. frondosus* and *P. fragilis*. *Godzillius fuchsi* is distinguished from *G. robustus* by a number of morphological characters sufficient enough to necessitate a new species designation. Major differences between *G. robustus* and *G. fuchsi* relate to the construction of the cephalic limbs. For example, *G. robustus* has 6 long teeth separated by 4 smaller teeth for a total of 10 teeth on both claws of the maxillae and maxilliped. The 4 smaller teeth in *G. robustus* do show a slight reduction in overall length from that of the outermost 6, where the innermost teeth being the smallest. *Godzillius fuchsi* has fewer teeth on both maxillary and maxillipedal claws. The claws of the maxillae have seven isomorphic teeth; the maxilliped has six isomorphic teeth bilaterally arranged on the terminal claw complex with seven small teeth in-between. Differences in teeth construction between the maxillae and maxillipeds were not identified or described in the original description or drawings of *G. robustus* by Schram et al. (1986). Another difference between the two species occurs in the length of the ratio between maxillary

and maxillipedal lacerti and brachia; compared to *G. fuchsi*, the brachia of both limbs are distinctly longer in *G. robustus*. The new species of *Godzillius* can also be distinguished from *G. robustus* by the form and shape of the frontal filaments; *G. robustus* has a main filament with three segments, whereas *G. fuchsi* has only one segment. Additional differences can be found between the setal arrangements of the labrum (less setose in *G. robustus*), the morphology of the mandibular incisor processes and laciniae mobiles (less asymmetrical in *G. robustus*), and between form and setal types of the first and second endites of the maxillules.

DISCUSSION

Issues of Relationships

Godzillius fuchsi is the second remipede recorded to have unequal claw structures on maxillae and maxillipeds. The only species previously known to have this adaptation belongs to Micropacteridae (*Micropacter yagerae* Koenemann, Iliffe, van der Ham, 2007a), having a horseshoe-shaped terminal claw of the maxilliped, while the claw of the maxilla has long fingers, i.e., has long, acuminate teeth (Fig. 6) (Koenemann et al., 2007a). Adaptive feeding strategies could explain the unequal claw morphology on maxilliped and maxilla within these families. Based on the varying claw designs of species in both families, Godzilliidae and Micropacteridae, one could postulate that these two families may have closer affinities than previously assumed (Koenemann et al., 2007a); however, no COI comparisons can be furnished as COI data is currently lacking from *M. yagerae* (Neiber et al., 2011).

Phylogenetic analysis based on morphology was assessed by Koenemann et al. (2007b) when the addition of several new taxa revealed critical inconsistencies at and below the family level. Koenemann et al. (2007b) used 26 morphological characters with emphasis on the prehensile cephalic limbs (important diagnostic feature) to evaluate the taxonomic affinities within Remipedia and to determine the position of Micropacteridae. Godzilliidae was the only taxon emerging as having a stable position across all analyses. Removal of Micropacteridae maintained Speleonectidae Yager, 1981, as monophyletic, yet with poorly supported positions of several species within. Looking at strictly comparative morphological points of view, inclusion of Micropacteridae is critical to understanding its placement amongst Nectiopoda Schram, 1986. Koenemann et al. (2007b) showed that inclusion of Micropacteridae in analyses with alternative treatment of five autapomorphic character states resulted in clades comprising Godzilliidae and Micropacteridae as sister groups (Koenemann et al., 2007b). Given the morphological similarities of the unequal claw morphologies between these two species (*M. yagerae* and *G. fuchsi*), reevaluation of the phylogeny of extant nectiopodans is needed. To date, *Micropacter* does not align morphologically to any of the other two families, justifying the need for its own separate familial status. Additional molecular analysis is needed to evaluate the phylogenetic relationships more accurately.

Results of a Bayesian analysis of COI sequences (Neiber et al., 2011) show a well-supported clade of *Godzillius* and *Godzilliognomus*. The genetic distance between the new species described herein and *G. robustus* was calculated

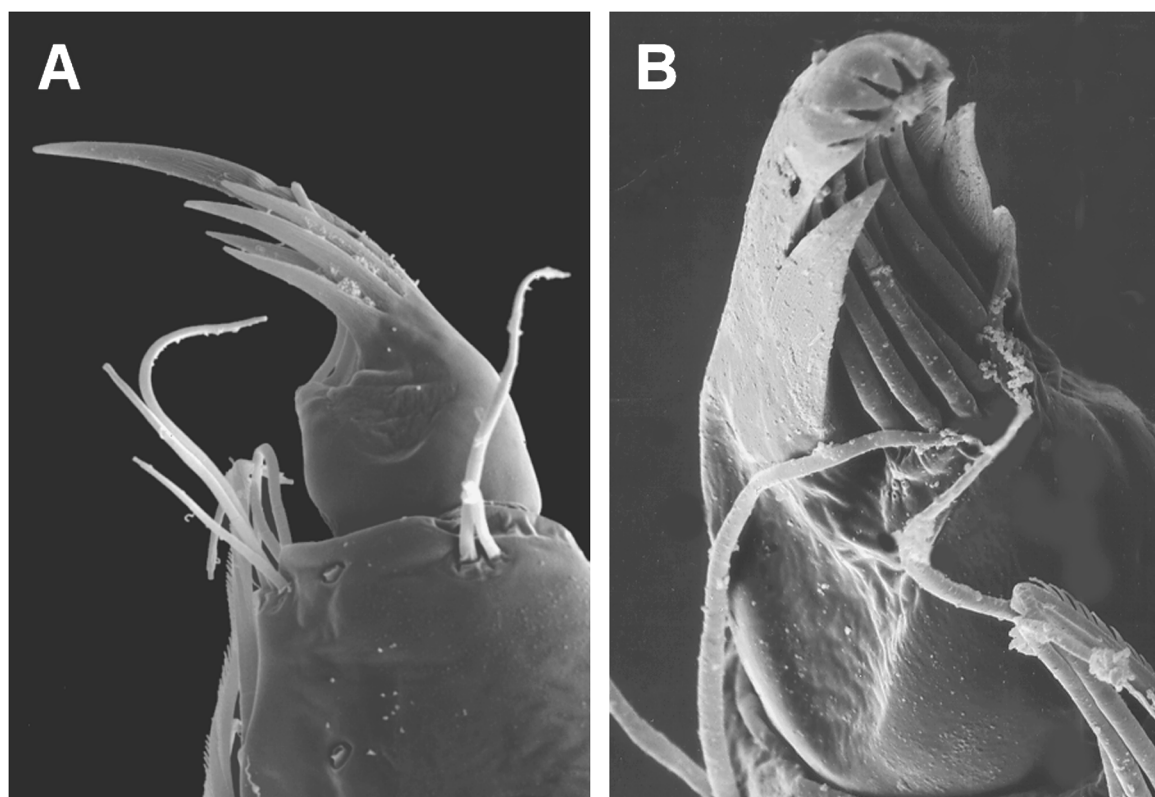


Fig. 6. Terminal claws of *Micropacter yagerae*. A, maxilla with claw composed of free teeth in hook-like arrangement; B, maxillipedal claw with fused arc of small teeth. (Modified from Koenemann et al., 2007a.)

by using a GTR + I model on their COI sequence data. Corrected PD of COI sequences between *G. fuchsi* and that of *G. robustus* is 18.3% (12.8% uncorrected PD), indicating two distinct species. Hence, COI evidence supports the generic assignment of *G. fuchsi*.

Godzillius robustus, the first described species of *Godzillius* occurs on the islands of Turks and Caicos, 700 km southeast from Abaco Island. *Godzillius* had previously not been reported outside of Turks and Caicos until investigations of additional Bahamian islands yielded specimens resembling *G. robustus* on Exuma Cays and Abaco Island. Geographical distribution of Remipedia within the Bahamas Archipelago suggests that multiple invasions and dispersals within crevicular habitats has occurred, allowing wide ranges and sympatry between the islands (Koenemann et al., 2009). These karstic islands are host to a variety of suitable anchialine habitats that undoubtedly plays a role in the unique distribution, evidenced with the discovery of remipedes throughout the Bahamas in various anchialine habitats including inland blue holes, fracture caves, ocean blue holes, and sub-seafloor caves. Subterranean environments are long viewed as being energy limited (Dickson, 1975), yet anchialine environments in the Bahamas have been found to host a variety of indigenous bacterial communities supporting the food web (Gonzalez et al., 2011), which may provide the means for heightened sympatry and diversity of remipedes throughout the Bahamas and within individual anchialine systems. With the discovery of *G. fuchsi* from Abaco Island, and the possible expansion of the known range of *G. robustus*, the

processes that might control the dispersal and competitive exclusion in Remipedia remain ever more mysterious.

Ecological Remarks of Type Locality

Dan's Cave is located in a pine forest 35 km south of Marsh Harbour. The cave entrance is a partially roofed-over sinkhole with a vertical drop of 5 m to water level. A small crescent-shaped entrance pool fills the dissolutional undercutting of the upper rock face. Dense shrubs surround the entrance pool, contributing organic debris along the underwater slope of the cavern. Surface water is very clear and emerald blue in color. Dan's Cave has several kilometers of extensive horizontal passageways in multiple directions, with depths exceeding 50 meters.

Vertical water column profiles were obtained at the entrance of Dan's Cave during the March 2006 expedition using an YSI 600XLM multi-parameter water quality monitor carried outstretched by the lead cave diver from the surface to a maximum obtained depth (45 m) (Fig. 7). The entrance cavern contains freshwater (<0.5 ppt) to a depth of 12 m. A halocline between 12.5–17.5 m depth marked the transition to saltwater (32.4 ppt), where the salinity increased to 33.6 ppt at 45 m. The entrance pool is warmed by solar radiation (25.75°C); a general cooling trend occurs throughout the water below except for the interface of the two bodies of water at the halocline, where the temperature increases from 23.9°C to 24.1°C. Water temperatures continue to decrease below the halocline with several noticeable temperature gradients present. Dan's Cave like several other nearby anchia-

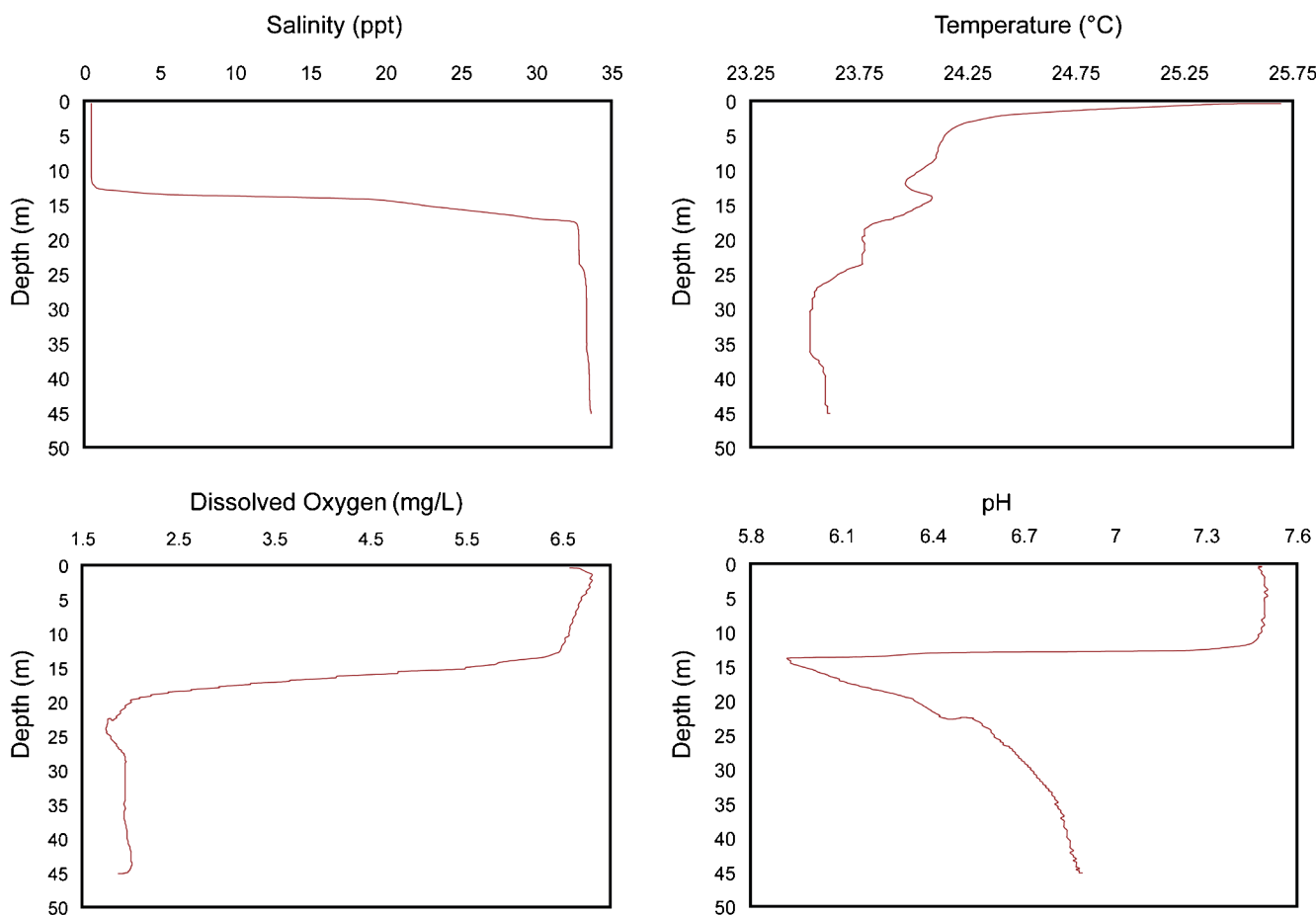


Fig. 7. Vertical profiles in Dan's Blue Hole. Salinity, temperature, dissolved oxygen, and pH measured using an YSI 600XLM multi-parameter water quality monitor. Individual measurements were taken at two-second intervals between the surface and maximum depth. This figure is published in colour in the online edition of this journal, which can be accessed via <http://booksandjournals.brillonline.com/content/1937240x>.

line blue holes observe a cooling trend at depth that may be due to deep-water circulation within the platform (Whitaker and Smart, 1997; Gonzalez et al., 2011). Dissolved oxygen decreased from 6.8 mg/l at the surface pool to 1.87 mg/l at depth. A secondary oxygen maximum occurred at 27.5 m which may be associated with lateral water flow. The pH drastically reduced from 7.5 in the surface pool to 5.9 at the top of the halocline. No visible sulfide layer was present, but bacterial mediated processes and degradation of surface pool organic matter contributes to the reduction of pH and similar results are present from nearby anchialine blue holes (Gonzalez et al., 2011). The pH recovers at maximum depth recorded to 6.89.

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Department of Fisheries Marine Resource collection permit (Thomas Iliffe). Logistical assistance for field work in Abaco was provided by Nancy Albury (Friends of the Environment, Abaco) and Brian Kakuk (Bahamas Underground, Abaco). In addition to B. C. Gonzalez, 2006 Abaco expedition team members included Renee Bishop, Lara Hinderstein, Mario Hoenemann, Thomas Iliffe, Brian Kakuk, Gregg Stanton, Tamara Thomsen and Ute Wollermann. The 2010 Abaco expedition members included Kenny Broad, Jill Heinerth, Thomas Iliffe, Brian Kakuk, Jennifer Macalady, Agnes Milowska, Tom Morris and Wes Skiles.

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