A New Coronuloid Barnacle Subfamily, Genus and Species from Cheloniid Sea Turtles

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Abstract

During a survey of the commensal barnacles of nesting and foraging sea turtles from the coastal waters of Florida and Georgia, USA, an undescribed species of platylepadid coronuloid barnacle was encountered, embedded within the carapace and plastron regions of host turtles. This new genus and species is described herein as *Calyptolepas bjorndalae* gen. et sp. nov. and is compared with other members of the family Platylepadidae. While similar in some respects to members of currently recognized platylepadid subfamilies, particularly *Cylindrolepas darwiniana* Pilsbry (Cylindrolepadinae Ross and Frick) and *Platylepas decorata* Darwin (Platylepadidae Newman and Ross), this new species bears an amalgamation of characters from these two subfamilies that require it to be placed into a new subfamily, Calyptolepadinae subfam. nov., also described herein.

Keywords

Caretta caretta, *Chelonia mydas*, sea turtles, epibiont, barnacle, new genus and species, Coronuloidea

Introduction

Sea turtles host a variety of plants and animals—collectively known as "epibionts"—that adhere to most external surfaces of host turtles, particularly the carapace region and skin (Frick et al. 1998, 2010). While many sea turtle epibionts also occur in the surrounding environment as free-living forms, some species are obligate commensals (Frick et al. 2002). For instance, some barnacles of the superfamily Coronuloidea exist solely on marine turtles (Frick and Zardus 2010), and obligate associations between turtles and extant coronuloid barnacle species reportedly date back to at least 15 million years ago (e.g., *Chelonibia testudinaria* [L.]; Ross 1963).

The nature of associations between chelonophilic barnacles and their hosts is generally considered to be symbiotic, particularly as various forms of commensalism. Other crustacean epibionts of sea turtles, such as crabs and certain amphipods, share a mutualistic or facultative association, or both, with their respective host turtles (Frick et al. 2002; Frick, Williams, Bolten et al. 2004; Frick, Williams, Markestyn et al. 2004). Some epibiotic crustaceans, particularly porcelain crabs, appear to be phoronts of sea turtles; phoresis represents a nonobligatory form of commensalism whereby the phoront (typically a motile organism) is mechanically transported from one area to another by a larger host (Khan and Frick 1997; Frick et al. 2002). Turtle barnacles are largely represented by relatively benign barnacle–host relationships that can only be described as a rudimentary form of commensalism, whereby the barnacle uses the host turtle as a filter-feeding platform (Ross and Newman 1967; Seilacher 2005).

Of the coronuloids documented from cheloniid sea turtles, the most commonly reported species are the superficial *Chelonibia testudinaria*

and the partially embedding *Platylepas hexastylos* (Fabricius). Both species serve as pioneering epibionts whose gregarious attachment creates a complex network of gaps and sinuses that allow for the subsequent colonization of a variety of other epibiotic forms, including motile epibionts such as crabs, amphipods, gastropods and tanaids (Frick et al. 1998, 2002; Frick, Williams, Markestyn et al. 2004). Yet other coronuloids—those that nearly or fully embed themselves within the host integument—are more often overlooked, probably as a result of their cryptic station (e.g., *Stomatolepas elegans* [Costa] and *Cylindrolepas darwiniana* Pilsbry) or their unique position within the gullet of the host turtle (e.g., *Stomatolepas praegustator* Pilsbry) (Frick and Zardus 2010; Frick et al. 2010).

The sea turtles from the southeastern United States represent one of the most thoroughly studied marine turtle populations in the world (Caldwell 1959; Bjorndal 1982; Carr et al. 1982). Similarly, the epibiotic communities from turtles in this region are also well known and have been examined in numerous studies (see Frick et al. 1998; Pfaller et al. 2008; Reich et al. 2009). However, despite the breadth of information available on the biology of sea turtles from the southeastern United States, little is known of the occurrence and distribution of coronuloids that fully embed into the integument of turtles in this region. During such a survey of loggerhead (*Caretta caretta* [L.]) and green (*Chelonia mydas* [L.]) turtles from Georgia and Florida, USA, an undescribed platylepadid coronuloid barnacle was encountered, nearly to fully embedded within the bony carapace and plastron regions of host turtles. We have determined that this represents not only a new species but also a new genus and subfamily, and it is described below.

Materials and Methods

Descriptions and observations are presented in systematic form below. All specimens are deposited in the Division of Invertebrate Zoology at Yale University's Peabody Museum of Natural History (YPM IZ). The following abbreviations are used to denote the individual plates of the barnacle shell: C, carina; CL1, carino-lateral-1 plate; CL2, carino-lateral-2 plate; R, rostrum; RCD, rostro-carinal diameter; RL, rostro-lateral plate.

Superfamily Coronuloidea Leach, 1817
Family Platylepadidae Newman and Ross, 1976
[nov. translation Ross and Frick (2007b)]

Diagnosis. Wall with six plates, deciduous; parietes commonly with pronounced medial tooth or sulcus; wall elaborations, when present, emanating from both sides of suture concomitant with diametric growth; opercular plates wider than high; embedded in tissues of sea turtles and other marine animals.

Remarks. The family Platylepadidae currently comprises four subfamilies (Ross and Frick 2007b): Platylepadinae, Cylindrolepadinae, Stomatolepadinae Ross and Frick and Chelolepadinae Ross and Frick. The new species described below does not conform to any available subfamily definition with the Platylepadidae. As a result, the new subfamily Calyptolepadinae is erected and described below to accommodate *Calyptolepas bjorndalae* gen. et sp. nov. Of the members of the platylepadid subfamilies listed above, *C. bjorndalae* shares characters—particularly with respect to the ornamentation of the plates—also seen in *Cylindrolepas darwiniana* (Cylindrolepadinae) and *Platylepas decorata* (Platylepadinae). Frick and Zardus (2010) noted similarities in ontogenetic development and ornamentation between *C. darwiniana* and *P. decorata*, and the same similarities, including ontogenetic development, apply to *C. bjorndalae* as well. All three species are fragile, bowl-like or vaselike forms when young, with ornamentation noticeably absent from the lateral surfaces of the plates but concentrated along the margins of the radii instead. These three species eventually develop thick monolamellar plates ornamented by few or numerous vertical columns of globose projections or beads. Often these vertical columns are composed of paired beads (see Darwin 1854, *P. decorata*).

These three species, however, differ in a few major characters that facilitate placing them into separate subfamilies. For instance, like other platylepadines, *Platylepas decorata* develops a massive or markedly large internal median tooth with a corresponding external sulcus, although this sulcus in some older specimens is occasionally filled. Regardless, neither *Cylindrolepas darwiniana* nor *Calyptolepas bjorndalae* produces such a massive internal median tooth. Additionally, the shell of *P. decorata* is ringlike, and the median tooth of each plate extends well beyond the basal margin of the shell. The shells of *C. bjorndalae* and *C. darwiniana* are taller and more cylindrical than those of *P. decorata*, and the basal edge of the internal median tooth of the two former species is often flush with the basal margin of the overall plate that it is produced from. The ornamented vertical columns on the external surfaces of the plates of these three species form longitudinal sulci. In *P. decorata* these are more or less evenly spaced and nearly straight. The longitudinal sulci of *Cylindrolepas darwiniana* are relatively shallow and somewhat sinuous. These features in *C. bjorndalae* are very deep—forming inflated lateral folds or pleats—and they are not evenly spaced. The longitudinal sulci of *C. bjorndalae* are often sinuous and not nearly as perfectly straight as in *P. decorata*. In addition to the differences listed above, *C. bjorndalae* differs from *C. darwiniana* in that the shell of *C. darwiniana* is asymmetrical, because one of the CL2 plates in *C. darwiniana* is always inflated and pushes the rostrum aside and away from

the front of the shell (Frick and Zardus 2010). The inflated CL2 plate of *C. darwiniana* also produces a lopsided profile, in which the front of the shell is markedly taller than the rear (carinal end) of the shell. The shell of *C. bjorndalae* sp. nov. is symmetrical in both apical view and in profile.

The remaining platylepadine species (*Platylepas* spp.) differ from *P. decorata*, and as a result from *Calyptolepas bjorndalae*, in that they produce relatively thin shells lacking globose lateral ornamentations with sheaths that are hollowed-out from behind. Platylepadines excepting *P. decorata* bear septate basal margins with primary, secondary and tertiary septa that extend onto the internal surface of each plate (Ross and Newman 1967). These septations run upward and terminate near the base of the sheath or within the hollowed out portion behind the sheath. The internal surfaces adjacent to the sheath and the basal margin of the shell in *C. bjorndalae*, *Cylindrolepas darwiniana* and *P. decorata* are smooth. The characters defining the remaining platylepadid subfamilies (stomatolepadines and chelolepadines) do not appear within the platylepadines, cylindrolepadines or calyptolepadines. The stomatolepadines are characterized by small, fragile, bowl-shaped or boat-shaped shells with well-developed sutural elaborations that are simple or antlerlike. The chelolepadines are characterized by cylindrical or tubelike shells without midribs or basal teeth. Chelolepadines also produce sutural eminencies that are formed by pairs of abutting flanges. Thus, the three subfamilies compared above (cylindrolepadines, calyptolepadines and platylepadines) need no further delineation from the chelolepadines or the stomatolepadines.

Distribution. Cosmopolitan; attached to sirenians, sea turtles and sea snakes.

Subfamily Calyptolepadinae
Frick, Zardus and Lazo-Wasem, subfam. nov.

Diagnosis. Wall monolamellar with strongly developed internal median tooth with accessory lateral teeth on either side; sheath nearly smooth and filled from behind. Plates bearing a few to numerous large, external folds or pleats, ornamented by a series of vertical columns consisting of globose projections or beads. Lateral folds or pleats form deep longitudinal sulci on the external surfaces of the plates, giving the shell a stellate appearance when viewed from above.

Description. The shell is eight-plated (R-RL-CL2-CL1-C) in juveniles but superficially six-plated (R-CL2-CL1-C) in adults, embedded in bony tissues and skin of sea turtles. Plates monolamellar with pronounced or large median tooth and corresponding external sulcus; external sulcus largely or entirely closed. Wall elaborations emanating from both sides of radii (sutures) concomitant with diametric growth. Ornamentations and elaborations of shell consisting of small, medium-sized or massive lateral folds or projections extending downward, outward, or both from prominent *en chevron* radii. Projections also on external lateral surfaces of plates, consisting of series of nearly evenly spaced, irregularly spaced or paired globose projections or "beads," appearing as vertical "columns" extending down each plate. Ornamented columns terminating at basal margin; terminus often corresponding with accessory teeth along the basal margin. Opercular plates wider than high. Basis is membranous.

Type genus. *Calyptolepas* gen. nov.

Remarks. In adults the presence of the tripartite compound rostrum is evident only when the shell is soaked in a 50% bleach solution for approximately 3 hours and pressure is applied to the center of the rostrum, whereby the rostro-lateral plates can be forcibly disarticulated from the rostrum (Figure 1B). Similarly, Darwin (1854) noted that "by slight violence" the rostro-lateral plates can be disarticulated from the rostrum in *Chelonibia testudinaria*. However, unlike *C. testudinaria*, only in newly settled or young *Calyptolepas bjorndalae* specimens (<1 mm RCD) is the incipient compound rostrum visible. Specimens greater than 1 mm RCD bear well-calcified external and internal surfaces that commonly obliterate the presence of external or visible sutures that indicate the rostrum to rostro-lateral junctions.

Etymology. From the Greek *Calypto-*, "hidden," and *-lepas*, "barnacle"; gender feminine.

Distribution. Currently Florida and Georgia, USA (western North Atlantic Ocean).

Genus *Calyptolepas*
Frick, Zardus and Lazo-Wasem, gen. nov.

Diagnosis. Currently as for subfamily (monogenic).

Description. Eight-plated juvenile and superficially six-plated adult calyptolepadine; regularly or irregularly spaced folds or lobes projecting laterally, giving stellate appearance. Basal growth creating appearance of in-folding in shell plates, producing a large, conspicuous, internal median tooth with several large, alternating basal teeth incorporated into it, secondarily filled with calcareous material during secondary growth. External sulcus producing internal median tooth closed.

Calyptolepas bjorndalae
Frick, Zardus and Lazo-Wasem, sp. nov.

Material examined. *Holotype*:YPM IZ 042061; from the carapace of a nesting green turtle (tag nos. X4260/X4261), Kennedy Space Center; collected by Mario Mota, University of Florida (UF), 24 August 1996. *Paratypes*: All collected by M. Mota, from green turtles: YPM IZ 042062 (1 specimen), same data as holotype; YPM IZ 042077 (2 specimens), host turtle tag nos. UF N9206/N9207, collected from carapace at Kennedy Space Centeron 6 August 1996; YPM IZ 042078 (1 specimen), host turtle tag nos. UF BP5542/N5500, collected from plastron at a sabellariid worm reef in the Indian River Lagoon on 29 June 1995; YPM IZ 042079 (1.05 mm RCD specimen), same locality data as previous specimen but collected from host turtle carapace, tag nos. UF BP5541/N5499; YPM IZ 042080 (4 specimens) and YPM IZ 048385 (1 young specimen), host turtle tag nos. UF N4609/X4287, collected from carapace at Kennedy Space Centeron 18 June 1994.

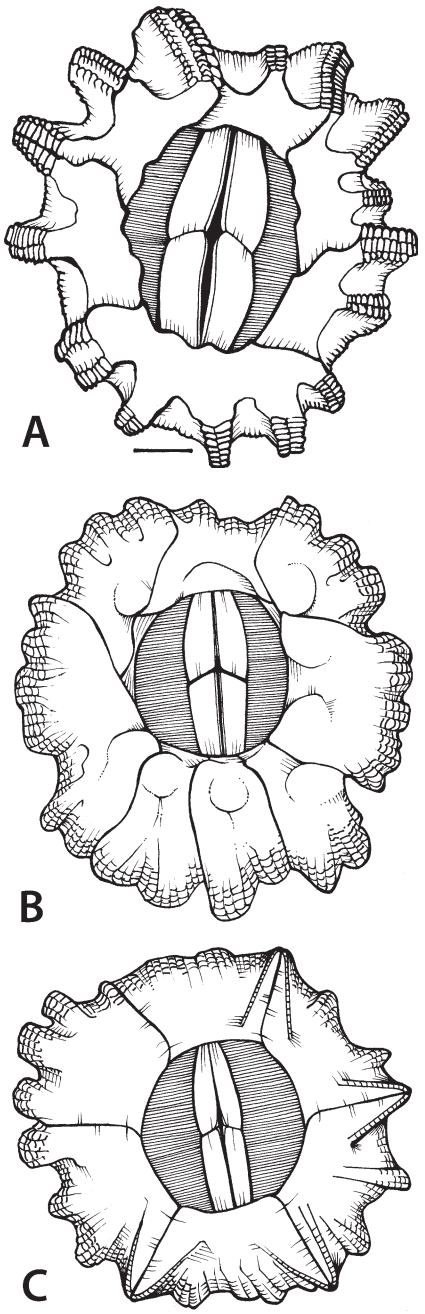

Figure 1. A schematic illustration of morphological variation in *Calyptolepas bjorndalae* (apical view). **A.** Specimen removed from upper surface of second marginal scute on an adult loggerhead turtle carapace. **B.** Specimen removed from upper surface of a supramarginal scute of an adult green turtle carapace (soaked in bleach until plates of the tripartite compound rostrum were visible). **C.** Specimen removed from underside of a supramarginal scute from a subadult loggerhead carapace. Scale bar 1 mm.

Diagnosis. Currently as for the subfamily.

Description. Shell stellate when viewed from above, nearly twice as long as high, some morphological variation exists—likely as a result of attachment location on the turtle (see Figure 1). Basal aperture same size as or larger than orifice. Basis is membranous. Body cavity cylindrical, smooth or delicately transversely striated sheath extending two-thirds to nearly entire length of plate. Sheath filled from behind, uniting with shell wall to produce relatively thick, monolamellar plate. Internal surface of shell below sheath extending to basal margin smooth (Figures 2 and 3). Typically, one to four, sometimes five or six, vertical, lateral folds on each plate (Figures 4–6), including median fold forming internal midrib prop terminating in slightly inflected, basal marginal "tooth." Basal margin of shell, including margin of midrib prop, most often crenulated or bearing globular projections or "beads." Lateral folds, in addition to median fold, terminating in accessory lateral teeth similar in form to median basal tooth but most often smaller. Occasionally calcium deposition between basal marginal teeth, obscuring their presence (see Figures 2 and 3). Lateral folding of plate wall occasionally evident internally as vertical striations running entire length of sheath, particularly where the median fold is located. Sheath nearly to perfectly smooth in most specimens. Top of median fold often indicated along apices of plates by large depression (Figure 7). Similar sites also present at apices of sutures adjoining plates. Radii wide or narrow, depending on space available for outward growth, forming distinct chevrons projecting downward and outward, occasionally laterally, giving shell stellate appearance when viewed from above. External surfaces of radii or sutures, representing center of each chevron, smooth or decorated with transverse folds or transverse rows of spherules. Risen edges of radii comprising sutural chevrons septate or, more commonly, covered by globose projections or "beads." Scuta and terga subrectangular, contacting each other but not articulating (Figure 8). Terga almost two-thirds size of scuta. Rostral end of scutum rounded slightly, tapered; tergal end squared, same size as the scutal end, which it abuts. Specimens examined for this study were initially preserved and stored in formalin and then dried. Attempts to adequately rehydrate these parts were unsuccessful. Thus description of the soft parts of this new species is lacking until more material becomes available.

Remarks. As mentioned aboved for the Platylepadidae, *Calyptolepas bjorndalae* shares some striking similarities with the coronuloids *Platylepas decorata* Darwin and *Cylindrolepas darwiniana* Pilsbry, particularly in the vertical (columnar) rather than horizontal (rowed) augmentation of the closely situated external ornamentation. In addition, all three species bear a markedly thick shell where the sheath is filled from behind. There is also a distinct lack of septation extending from the basal margin onto the inner surfaces of the plates in all three species—a notable characteristic observed in all other extinct and extant members of the genus *Platylepas* (see Ross 1963). *Cylindrolepas* and *P. decorata*, like *Calyptolepas*, also begin life as fragile, vase-like forms, with distinct, wide *en chevron* radii lined by evident and exaggerated ornamentations (see Zardus and Balazs 2008; Figure 9??). It seems that from a morphological standpoint *Cylindrolepas* and *P. decorata* are closely allied to the Calyptolepadinae. It is possible, however, that these similarities are

Figure 2. *Calyptolepas bjorndalae* YPM IZ 042061 (holotype). Internal surface of rostrum. Scale bar 2 mm.

Figure 3. *Calyptolepas bjorndalae* YPM IZ 042061 (holotype). Internal surface of lateral plate. Scale bar 2 mm.

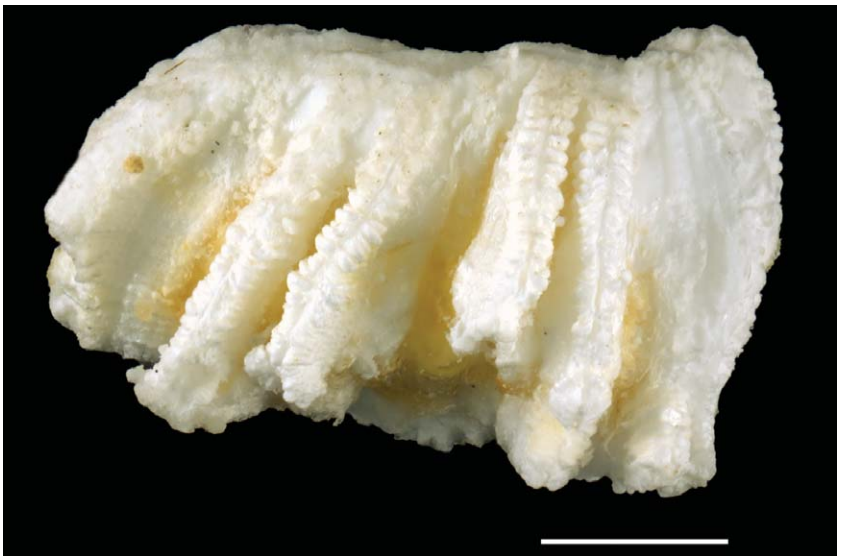

Figure 4. *Calyptolepas bjorndalae* YPM IZ 042061 (holotype). External surface of rostrum. Scale bar 2 mm.

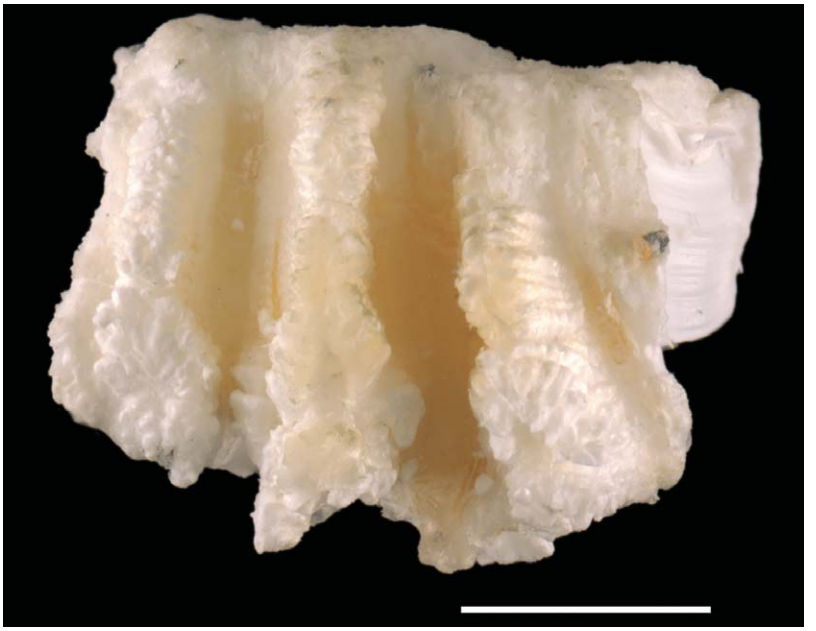

Figure 5. *Calyptolepas bjorndalae* YPM IZ 042061 (holotype). External surface of lateral plate. Scale bar 2 mm.

due to convergent evolution (see Ross and Frick 2007a). Despite the eight-platedness of juvenile *C. bjorndalae*, a character found within the genus *Chelonibia* Leach—the presence of a prominent median tooth or midrib prop—clearly places this new species within the Platylepadidae (see Ross and Newman 1967 for relationships). *C. bjorndalae* is a relatively large coronuloid, as compared with the variety of small platylepadids that occur as commensals of sea turtles. The largest specimen collected thus far measured 18.0 mm RCD and was 10.0 mm in height. Of the 11 specimens encountered in this study, including the specimen listed above, RCD ranged from 0.05 mm to 18.0 mm (average 10.7 mm) and height ranged from more than 0.05 mm to 10.0 mm (average 7.1 mm).

The external ornamentation and the many folds of the parietes and the midrib prop obviously serve to anchor this species into the host tissue. The parietal lobes are, however, not

FIGURE 6. *Calyptolepas bjorndalae* YPM IZ 042061 (holotype). External surface of carina. Scale bar 2 mm.

prominent in small (0.05 mm RCD) specimens. At this stage of development the forming midrib props are rather simple. These simple props, combined with downward growth, the folding and beading on the external surfaces of the parietes and a dentate basal margin, seem to anchor minute specimens. The external ornamentation of the plates of *Calyptolepas bjorndalae*, with respect to the texture created over the broader exterior surfaces, has been similarly described and simplified to "beads," "rows of beads," or beading by Darwin (1854) (for *Platylepas decorata*). These globose-to-crenulated rows and columns of spherules are also used by *Cylindrolepas darwiniana* to facilitate or supplement anchoring into the host turtle. Note that "folding" in the plates is the result of serial calcium deposition at the basis of the shell and not from an actual process of folding. Moreover, structures like the midrib props of the parietes aid in anchoring the shell by pressing against host tissue and allowing for diametric shell growth (as opposed to anchoring structures that simply grasp and "hold" onto host tissue). Because the basis of *C. bjorndalae* is larger than the orifice, and the exterior margins of the barnacle shell are often covered in host tissue, diametric growth in itself becomes an anchoring mechanism.

Calyptolepas bjorndalae lives fully embedded within the bone and associated tissues of the plastron and carapace regions of green and loggerhead turtles in Georgia and Florida, USA. It is likely that this cryptic species will also be found on turtles throughout the Gulf of Mexico and the greater Caribbean. Long-term studies on the carapace barnacles of sea turtles in Georgia have failed to detect *C. bjorndalae* (Frick et al. 1998, 2000, 2002), although a careful examination of barnacles from the skin and anterior margin of the carapace (where the skin

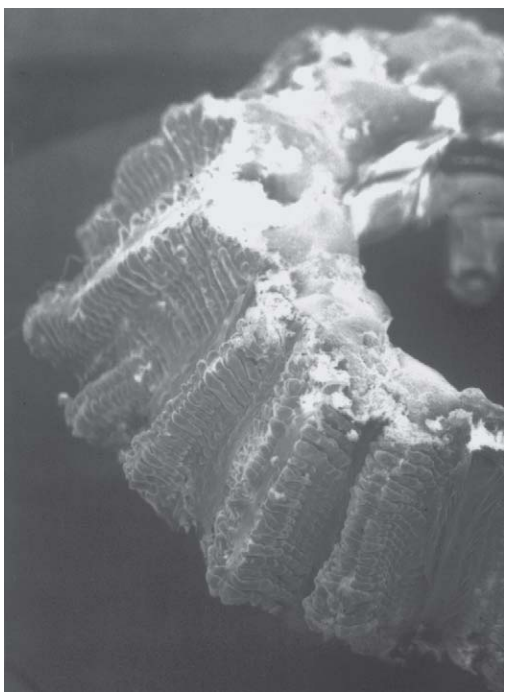

FIGURE 7. Oblique SEM view of *Calyptolepas bjorndalae*. Diameter of specimen 6 mm.

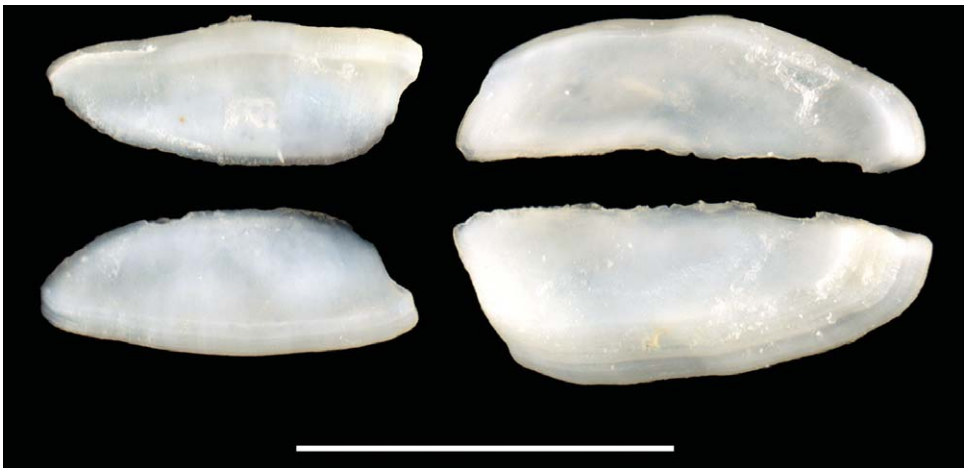

Figure 8. *Calyptolepas bjorndalae* YPM IZ 048385. Opercular plates. Scale bar 2 mm.

Figure 9. YPM IZ 042078. Lateral view of a young *Calyptolepas bjorndalae* specimen from a loggerhead turtle from Georgia, USA, with *en chevron* suture located at the center of the photograph. Scale bar 1 mm.

connects to the shell) from this same population of turtles has confirmed its relatively common occurrence on Georgia turtles (Frick, pers. observ., 2008 and 2009, Wassaw Island). One large specimen (ca. 15 mm RCD) from the shell of a nesting loggerhead on Wassaw Island collected on 10 July 2008 bore such large lateral folds that the barnacle was visibly stellate when observed in situ. However, most specimens appear round or oval in shape when embedded in host turtles, because the lateral folds or projections occur beneath the apical margin of the barnacle shell and are therefore obscured from a cursory examination of the host turtle. The above specimen was embedded directly into the center of the second marginal scute on the right side of the nuchal scute of the host turtle. It lay flush with the keratinized surface and was pried, using sharp forceps, but the force necessary to remove the animal would clearly have destroyed it. Specimens collected for this study were embedded in the thick cartilaginous areas of the carapace and plastron of immature turtles. Such areas of the carapace are replaced by bone as the turtle grows older. Note, however, that these areas do not represent the most common attachment locations for *C. bjorndalae*. Instead, they are areas where *C. bjorndalae* can be more readily collected from host turtles with the least amount of effort or damage to the host and commensal.

Host data (Dodd 1988; Hirth 1997) indicate that *Calyptolepas bjorndalae* enjoys a wide distribution if it is a long-lived symbiont. Together, western Atlantic populations of *Chelonia mydas* and *Caretta caretta* commonly occupy a range encompassing the entire North Atlantic and Mediterranean basins. The epizoic barnacles from other turtle populations within this region should be carefully scrutinized to detect the presence or absence of this new species.

Etymology. Named in honor of Karen A. Bjorndal of the Archie Carr Center for Sea Turtle Research at the University of Florida

in Gainesville, for her seminal work in sea turtle ecology and her continuing inspiration to biologists around the world.

Distribution. Currently Florida and Georgia, USA (western North Atlantic Ocean).

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