EULIMNADIA BELKI, A NEW CLAM SHRIMP FROM COZUMEL, MEXICO (CONCHOSTRACA: LIMNADIIDAE), WITH A REVIEW OF CENTRAL AND SOUTH AMERICAN SPECIES OF THE GENUS *EULIMNADIA*

JOEL W. MARTIN

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ABSTRACT

A new species of *Eulimnadia*, *E. belki*, is described from the Chankanaab National Park in Cozumel, State of Quintana Roo, Yucatan Peninsula, Mexico. The species also occurs in Venezuela. *Eulimnadia belki* can be distinguished from all other species of the Limnadiidae in the New World by the unusual morphology of the eggs. The morphology of the external egg shell, a promising taxonomic character, is compared to that of all species of *Eulimnadia* known from Central and South America.

The conchostracan family Limnadiidae is known from nearly all corners of the world. Members of the family are easily recognized by the presence of a pedunculate frontal organ on the midline of the head region (with few exceptions), the absence of a supportive ridge (fornix) on either side of the rostrum, and the presence of few to many concentric growth lines on the laterally compressed valves. The genus *Eulimnadia*, containing about 40 described species, is the most diverse genus not only of the Limnadiidae but possibly of the entire order Conchostraca (see Belk, 1982; Straškraba, 1965) (=order Spinicaudata; see Fryer, 1987). In September of 1985, a small lot of undescribed limnadiid conchostracans belonging to the genus *Eulimnadia* was collected from a shallow surface pool in the Parque de Chankanaab, Quintana Roo, Cozumel, Mexico; the lot was later brought to my attention by Jill Yager. The species is described below.

MATERIALS AND METHODS

Conchostracans (15 females, 3 males) were collected by D. Williams and J. Bozanic from a shallow surface pool in the Chankanaab National Park, Cozumel, Mexico. Approximate area of the pool was 10 × 4 m with a depth of 16 cm. Salinity of the pool at the time of collection was less than 1 ppt. Conchostracans were initially fixed in fresh-water Formalin and later transferred to 70% ethanol.

Illustrations were prepared using a Wild M-5A stereoscope and M-11 compound microscope, both with camera lucida. Specimens were prepared for scanning electron microscopy (SEM) following procedures outlined by Felgenhauer (1987) but without postfixation in osmium and with 100% ethanol used as the transitional fluid. All specimens have been deposited in the Natural History Museum of Los Angeles County (male holotype, LACM No. 85-188.1; female allotype, LACM No. 85-188.2; 12 female and 1 male paratypes, LACM No. 85-188.3).

Specimens of other *Eulimnadia* were borrowed from various museums and from private collections as follows. British Museum (Natural History): *E. chacoensis* Gurney, syntypes, 1928.2.23.1–15, Makthlawaiya, Paraguayan Chaco, collected by G. S. Carter; *E. antillarum* (Baird), 52–23, Santo Domingo, collected by M. Salle. Hungarian Museum of Natural History, Collectio Dadayana Phyllopoda: *E. antillarum* (Baird), Santo Domingo, CDP I/C–133, 1913.–11; *E. brasiliensis* Sars, Iparanga, CDP I/C–134, 1913.–116; *E. geayi* Daday, Venezuela, CDP I/C–143, 1913.–125; *E. "columbica"* (named in vial only, see Forró and Brtek, 1984; = *E. geayi*; see Discussion), CDP I/C–136, 1913.–118. Private collections of Dr. Denton Belk: *Eulimnadia* sp. A [DB 305], Argentina, Catamarca, Rt. 1, km 45, 30 December 1973, collected by A. Hulse; *Eulimnadia* sp. B [DB 632], Paraguay, Chaco Parque Nacional Defensores del Chaco, Tribo Nuevo, "econtrado en regiones bajas de laguna recien inundada," 23 November 1984, collected by T. Bonace and D. Drenner.

Eulimnadia belki, new species
Figs. 1–3, 4A, B

Material.—Mexico: Parque de Chankanaab, Cozumel, State of Quintana Roo; 3 ♂♂, 15 ♀♀, collected by D. Williams, J. Bozanic, 19 September 1985.

Measurements.—Holotype ♂ 3.75 mm length, 2.38 mm height; other ♂♂ both 3.63 mm length, 2.19 mm height (1 specimen destroyed for SEM). Allotype ♀ 4.94 mm length, 3.19 mm height; other ♀♀ 3.56–4.56 mm length, 2.19–2.75 mm height (2 specimens destroyed for SEM).

Carapace.—Carapace (Figs. 1A, B, D, 3A) in both sexes oval, with 4 concentric growth lines in males and 4 or 5 in females. Umbo lacking. Area between growth lines minutely granulate except for narrow band on either side of growth lines (Fig. 3A). Posterior half of dorsal hinge more or less flat and straight. Anterior carapace narrow in dorsal view,

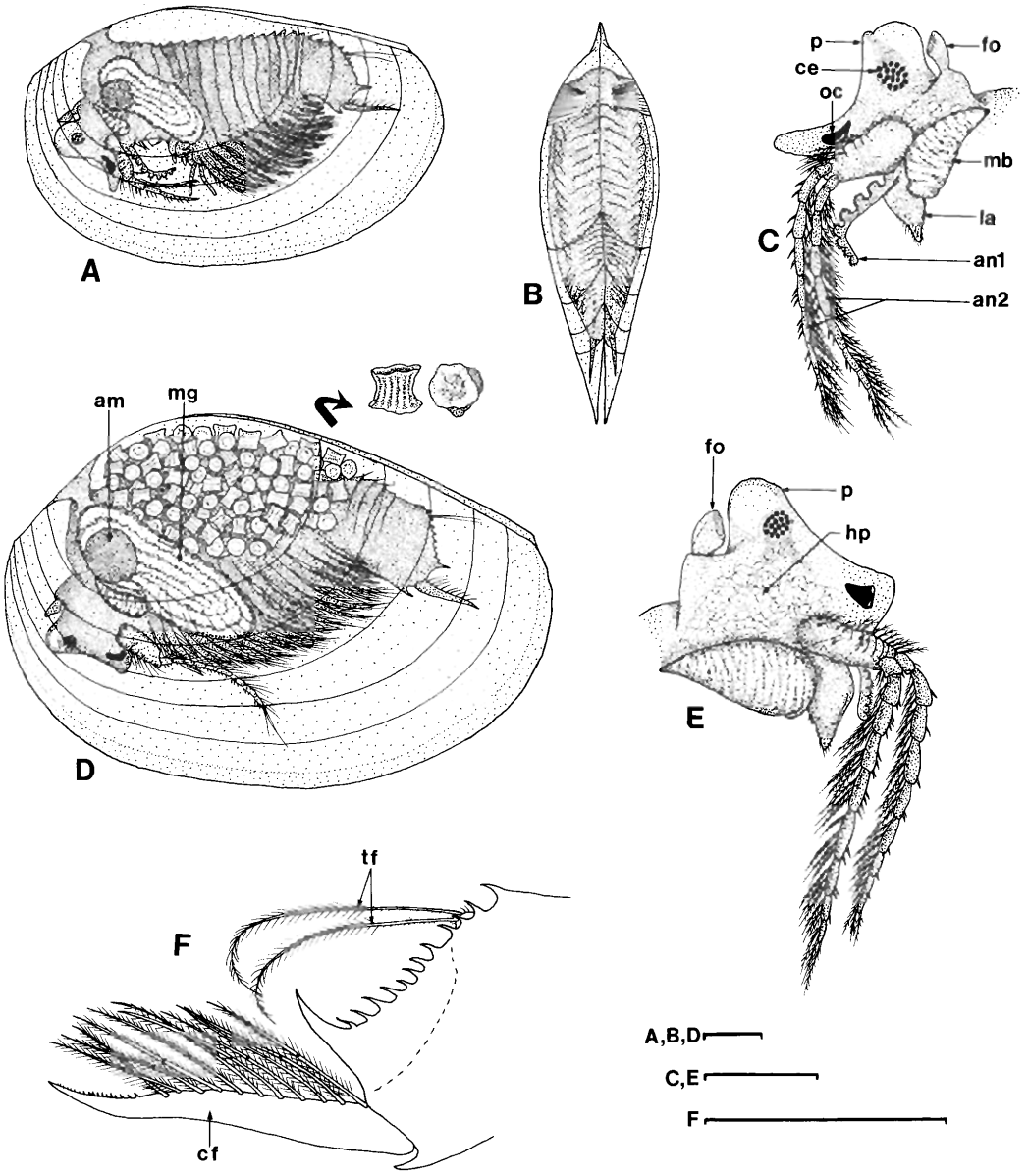

Fig. 1. *Eulimnadia belki,* new species, holotype male (A–C, F) and allotype female (D, E). A, male, lateral view; B, male, dorsal view; C, male, head region, lateral view; D, female, lateral view, with eggs slightly enlarged in figure at upper right; E, female, head region, lateral view; F, male, caudal region, lateral view. Abbreviations: am = adductor muscle, an1 = first antenna (antennule), an2 = second antenna, ce = compound eye, cf = caudal furca, fo = frontal organ, hp = hepatopancreas, la = labrum, oc = ocellus, p = approximate position of frontal pore, tf = telsonal filaments. Scale bar = 0.5 mm for A–F.

widening rapidly posteriorly (Fig. 1B). Maxillary gland (mg) elongate and surrounding adductor muscle (am). Females slightly larger and more inflated, especially so if ovigerous.

Head Region.—Male head region (Fig. 1C) with large frontal organ (fo) arising from protuberance just posterior to compound eye (ce); area dorsal to compound eye with large "empty" space, possibly connecting to out-

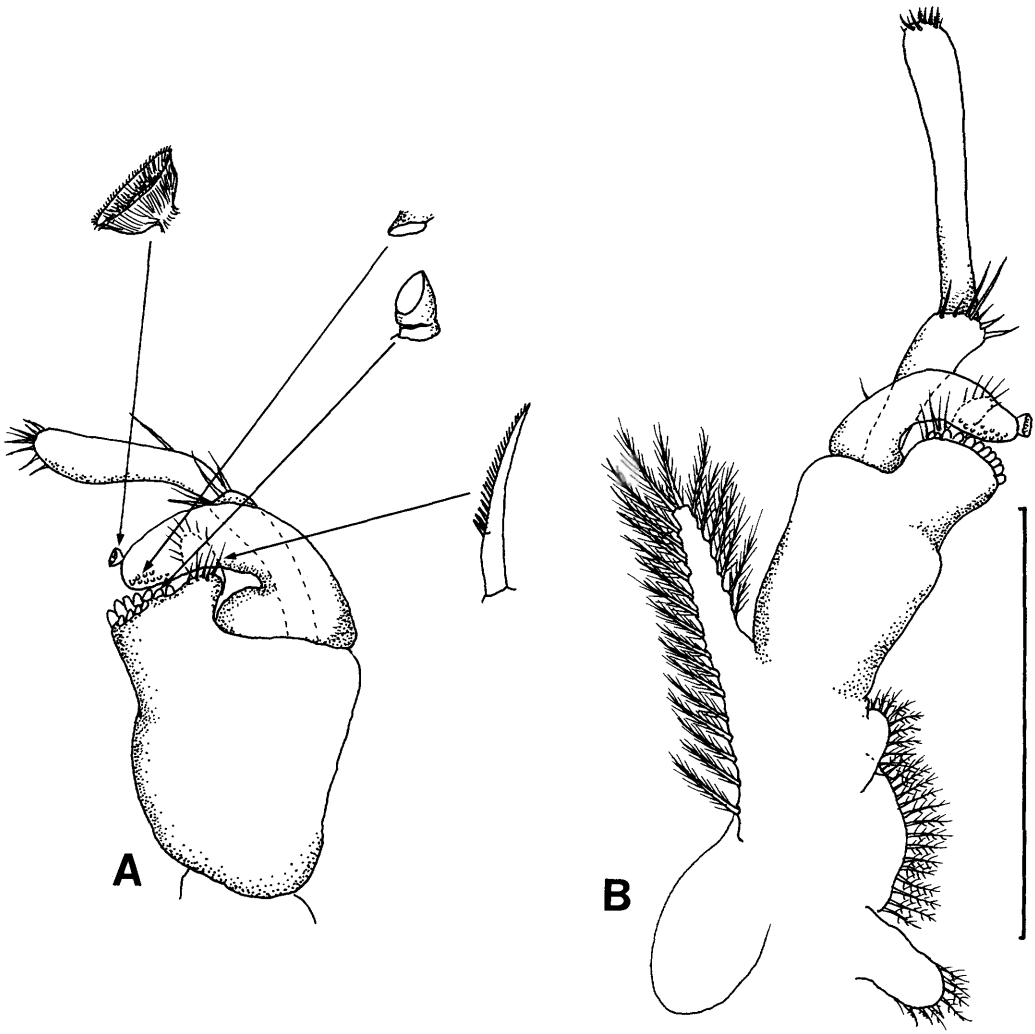

Fig. 2. *Eulimnadia belki,* first thoracopods (claspers) of holotype male. A, left thoracopod 1, anterior surface; B, right thoracopod 2, anterior surface. Scale bar = 0.5 mm. Setal types and suckerlike distal prominence not drawn to scale.

side environment via pore (p) located on midline just dorsal and anterior to compound eyes, head region being wide in frontal view (Figs. 1C, 3B). Small low rounded lobe just dorsal to compound eye. Rostrum produced into long narrow blunt projection bearing internally naupliar eye or ocellus (oc) variable in shape. Hepatopancreas (hp) extending slightly into rostrum and into dorsal (proximal) part of labrum (1a). Female head region (Fig. 1E) similar, with "empty" area and midfrontal pore, but with rostrum not as narrow or as produced as in male, terminating in obtuse blunt angle bearing internally ocellus; hepatopancreas as in male.

Antennae.—First antenna (antennule) (an1) extending to about fourth segment of posterior antennal flagellum, indistinctly segmented with 8 or 9 lobes bearing short sensory setae. Second antenna (an2) with indistinct segmentation of peduncle and with 9 segments on both anterior and posterior flagella, each bearing short, sharp dorsal spines and longer natatory ventral setae (Fig. 1C, E).

Male Thoracopods.—First thoracopod (Figs.

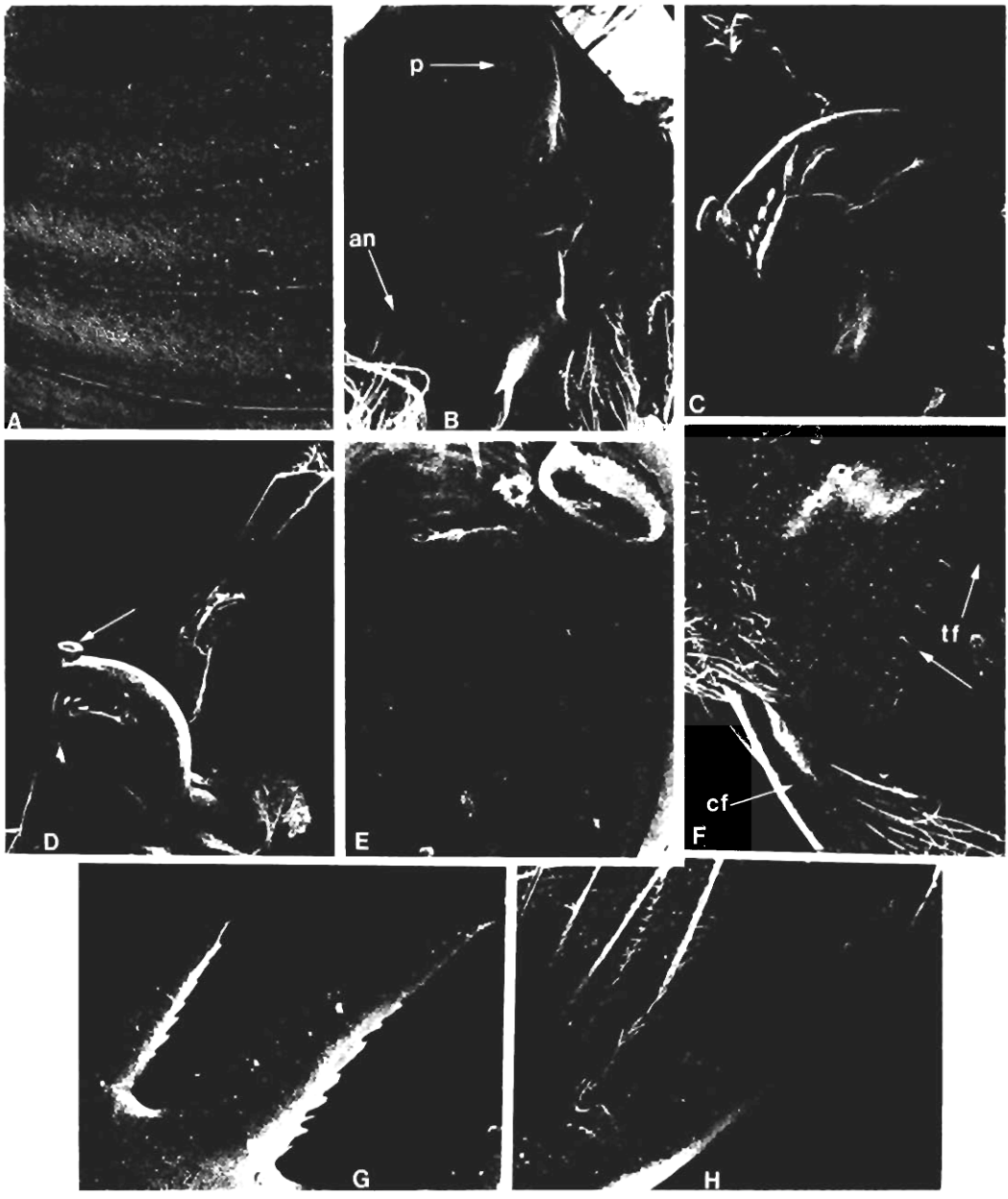

Fig. 3. Scanning electron micrographs of selected characters of *Eulimnadia belki*. A, anteroventral part of left valve of male, showing 4 concentric growth lines and details of sculpturing, ×120; B, frontal view of male rostrum, ×150; C, first male thoracopod (clasper), posterior surface, ×300; D, second male thoracopod (clasper), ×190; E, tip of clasper fingers showing suckerlike prominence (indicated by unlabeled arrow in D) and stout, flat-tipped spines and serrate spines (far right), ×1,300; F, caudal region of female, ×130; G, high magnification of posterior spines indicated by unlabeled arrow in F, ×1,500; H, distal region of left ramus of caudal furca (note small dorsal spinules), ×430. Abbreviations: an = second antenna; cf = caudal furca; p = frontal pore; r = rostrum; tf = telsonal filaments.

2A, 3C) stout, with obvious indentation in "hand" of clasper proximal to area bearing stout teeth. Movable finger of clasper smoothly curving with small suckerlike dorsodistal projection and stout, flat-tipped spines on clasping border; immovable finger with larger stout flat-tipped spines opposite those of movable finger and with long

serrate spines proximal to stout ones (Figs. 2A, 3C). Endite 4 (see Fryer, 1987, for terminology of clasper endites in nonlynceid conchostracans) short with simple setae; endite 5 (palp) 2-segmented, each segment bearing terminal setae, with total length (both segments) slightly exceeding length of movable finger. Second thoracopod (Figs. 2B, 3D) similar in general shape and spination, but with 2-segmented palp much longer than in first thoracopod, combined length of segments nearly twice length of movable finger. Spination of tip of clasper fingers similar to first thoracopod (Fig. 3E).

Telson.—Posterior region of trunk (see Bowman, 1971; Schminke, 1976, for contrasting opinions on terminology) with 12–14 large sharp spines, each minutely serrate under high magnification (Figs. 1F, 3F, G), terminal spine of series much larger than preceding ones. Caudal furca (cf) well developed, with 10–12 plumose setae and numerous small spinules on distal upturned fourth of furca (Figs. 1F, 3F, H). Telsonal filaments (tf) delicate, plumose only on distal one-half to two-thirds, arising from about level of third posterior spine (Figs. 1F, 3F); posteroventral margin of trunk (below insertion of caudal furcae) with well-developed blunt spine (characteristic of genus).

Eggs.—Stout, approximately cylindrical, with inflated rims and with smoothly rounded ridges defining narrow valleys extending parallel to each other along length of cylinder from rim to rim (Figs. 1D, 4A, B). Ends slightly concave, with parallel grooves and ridges similar to those on cylinder, not radiating outward from center but running approximately 90° to axis of cylinder and with groove occasionally extending through rim and merging with longitudinal groove of cylinder; one end usually with single groove running obliquely to other end grooves (Fig. 4B). Rims of cylinder flaring out slightly; egg diameter consequently somewhat wider at ends than if measured at midpoint. Egg surface textured with numerous minute pores.

Type Locality.—Parque de Chankanaab, Quintana Roo, Cozumel, Mexico, shallow surface pool.

Range.—Type locality and Venezuela (based on scanning electron micrographs of eggs of Venezuelan population taken by Guido Pereira).

Etymology.—Named in honor of Dr. Denton Belk for his many contributions to the biology of the Branchiopoda and for his kind and unabated assistance offered to students and colleagues over the course of his career.

Discussion

The taxonomy of the family Limnadiidae, and especially of *Eulimnadia,* is confused and badly in need of revision. Previous descriptions of members of the family, with few exceptions such as the elegant work of G. O. Sars (1896), are lacking in detailed morphology of characters that authors have previously used to distinguish species. Thus, it is often difficult to assign a specimen to a known species, and the erection of new species necessitates examination of museum holdings. Compared to the number of species of *Eulimnadia* known from North America (see Pennak, 1978; Belk, 1989), relatively few species of *Eulimnadia* have been described from Central and South America (see Table 1). Löffler (1977, 1981) listed only *Eulimnadia brasiliensis* Sars from tropical and southern South America, respectively, and *E. antillarum* (Baird) from the Caribbean; *E. antillarum* is also known from Mexico (Daday, 1926; Hartland-Rowe, 1982) and southern Brazil (Lilljeborg, 1889). In addition to these two species, *E. chacoensis* was described by Gurney (1931) from Paraguay, *E. geayi* was described by Daday (1926) from Colombia, Venezuela, and Mexico, and *E. texana* has been reported from Mexico (Moore, 1965) and São Paulo, Brazil (Daday, 1926; Lutz, 1929). An undescribed species of *Eulimnadia,* collected by Daday in "Columbia" [*sic* = Colombia] and bearing the label *E. columbica,* is housed in the Hungarian Museum of Natural History (see Forró and Brtek, 1984). Finally, an undescribed species of *Eulimnadia* was reported from Venezuela by Margalef (1961) and several additional unnamed species exist in the private collections of Dr. Denton Belk, Our Lady of the Lake University, San Antonio, Texas.

Compared to the above species, *E. belki* is somewhat unusual in possessing an acutely produced male rostrum and a very long palp on the second clasper. In *Eulimnadia*

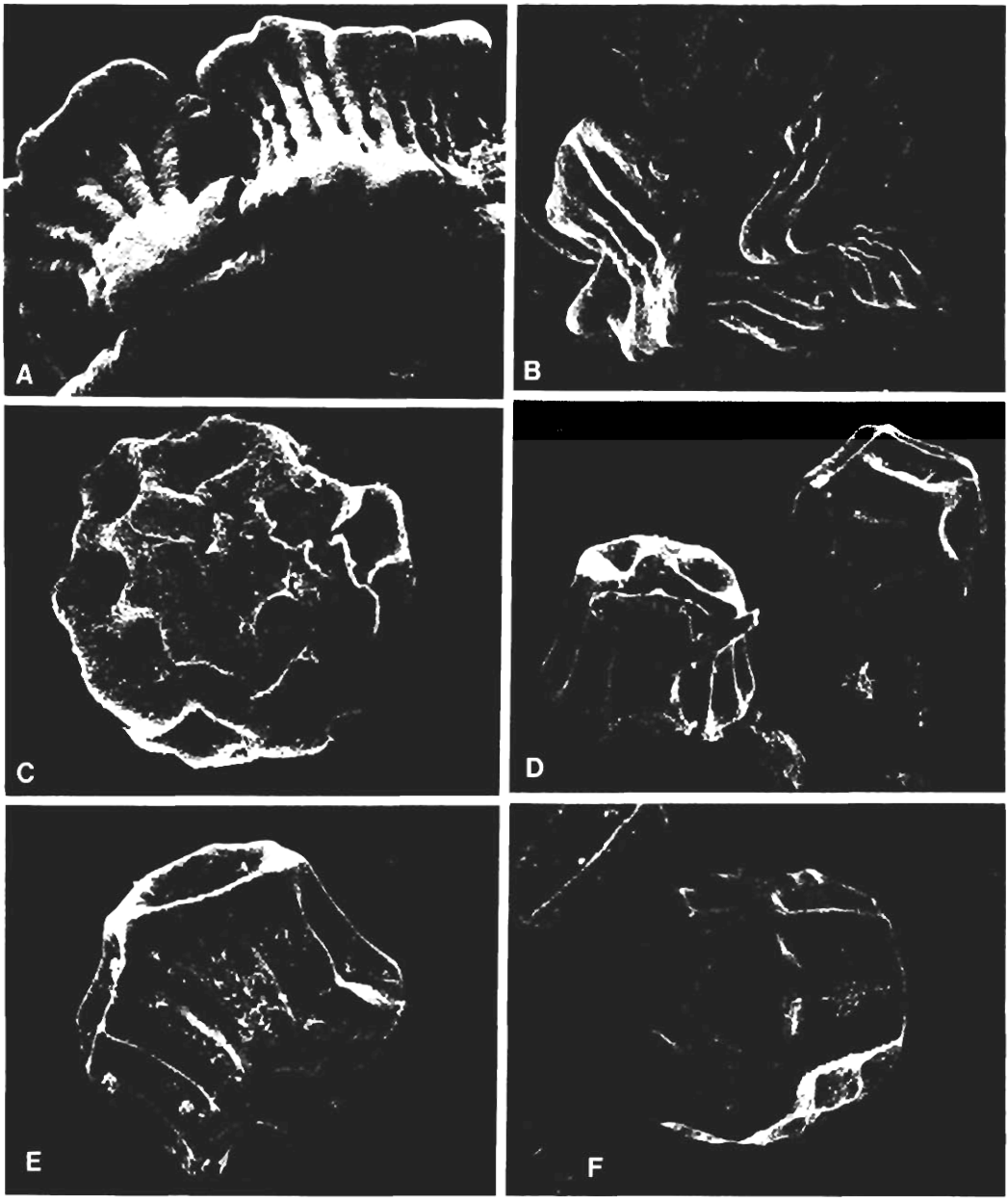

Fig. 4. Egg morphology of *Eulimnadia belki* and other species of *Eulimnadia.* A, two eggs of *E. belki* showing longitudinal grooves along cylindrical axis, ×300; B, eggs of *E. belki* with end pieces showing, ×350; C, spherical egg of *E. brasiliensis,* ×500; D, stout cylindrical eggs of *E. geayi* showing pentagonal appearance, ×350; E, egg of *E. geayi* (note one raised and one flattened end), ×500; F, egg of *E. geayi* showing detail of raised end, ×500.

sp. (Margalef, 1961: fig. 6A, B) the proximal segment of the palp is shown much shorter than in *E. belki,* and the male rostrum is short and blunt rather than acutely produced. *Eulimnadia antillarum* was only partially illustrated by Baird (1852) and later illustrated by Daday (1926); that species differs from *E. belki* in having only 2 growth lines on the valves and in having the posterodorsal caudal region nearly devoid of spines (Fig. 5A). The body of *Eulimnadia antillarum* is also slightly larger relative to

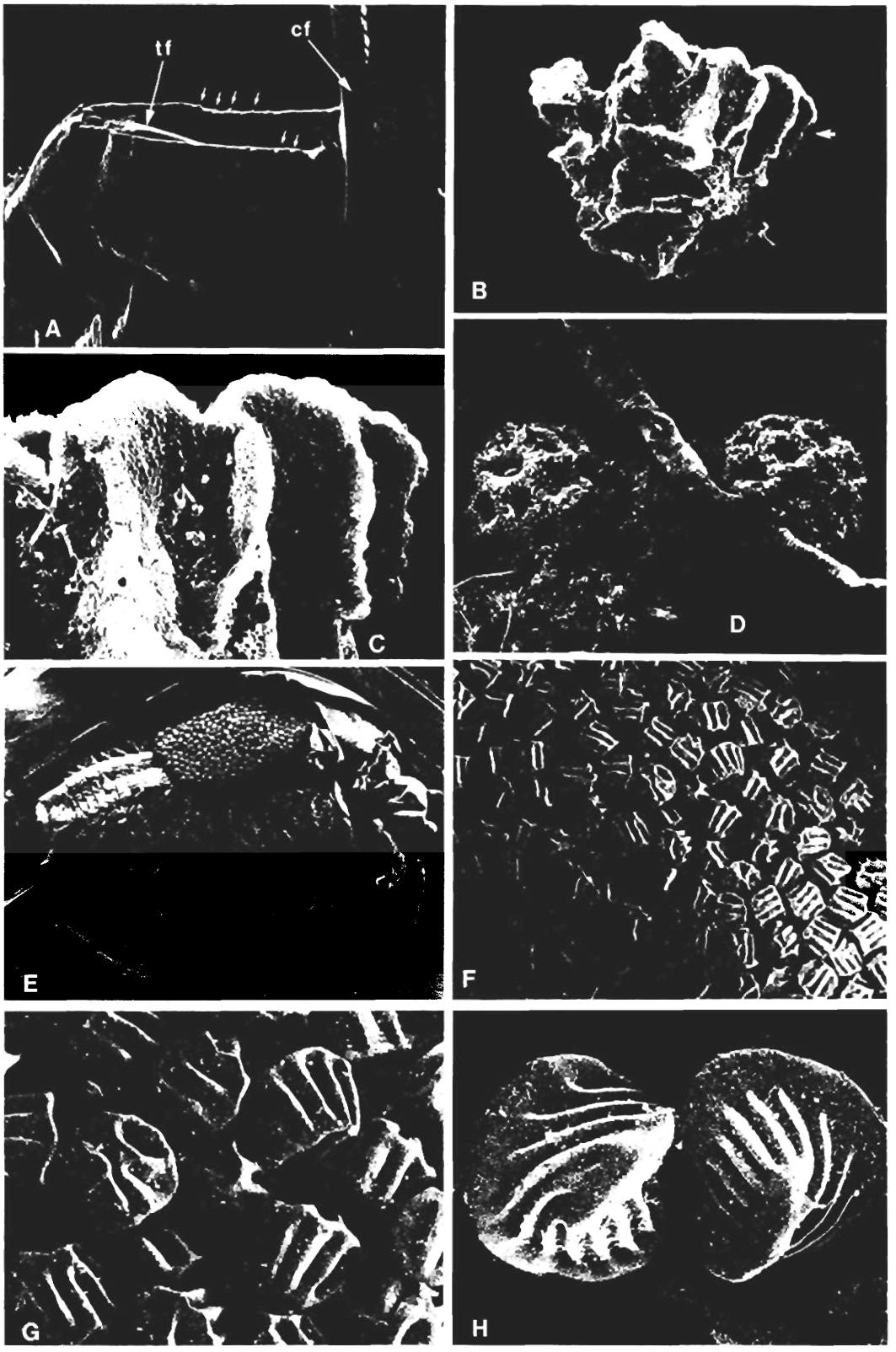
tf
cf
A
B
C
D
E
F
G
H

Table 1. Species of *Eulimnadia* reported from Central or South America and the Caribbean.*

Species	Locality
Eulimnadia antillarum (Baird, 1852)	Santo Domingo, West Indies; Mexico; Brazil
Eulimnadia belki, new species	Cozumel, Mexico; Venezuela
Eulimnadia brasiliensis Sars, 1902	Brazil
Eulimnadia chacoensis Gurney, 1931	Paraguay
Eulimnadia "columbica" (ms name only)	Colombia (see Forró and Brtek, 1984)
Eulimnadia geayi Daday, 1926	Venezuela; Colombia; Mexico
Eulimnadia texana Packard, 1871	Mexico; Brazil (and North America)
Eulimnadia sp. (in Margalef, 1961)	Venezuela

* Several additional unnamed species exist in private collections; see text.

its carapace than that of *E. belki*. *Eulimnadia brasiliensis* differs from *E. belki* in that the rostrum of the female is also produced, and the frontal organ does not appear to arise from as marked an elevation as seen in *E. belki*. Unfortunately, specimens of *E. brasiliensis* at the Hungarian Museum of Natural History (see Materials and Methods) are in very poor condition. Only the valves and a single egg of one specimen remain in the vial. Therefore, the above comparison is based upon the original description by Sars (1902). *Eulimnadia chacoensis*, which Gurney (1931) felt differed "scarcely at all" from *E. brasiliensis*, has an acute male rostrum (although not as pronounced as in *E. belki*) and very similar male claspers. Finally, *E. geayi* differs from *E. belki* not only in size (the carapace of the largest specimen of the Daday collections in the Hungarian Museum is 10.7 mm long and 7.8 mm tall; compared to 3.75 × 2.38 mm for the holotype of *E. belki*) but also in having the female rostrum produced. A vial containing specimens labeled *E. columbica* exists in the Collectio Dadayana Phyllopoda of the Hungarian Museum of Natural History (see Materials and Methods); these specimens are also large, approximately the same size as *E. geayi* (the largest "*E. columbica*" specimen was 10.5 × 7.1 mm), and the two species are herein considered synonymous (see below).

If the above differences were the only distinguishing characters I would indeed be hesitant to establish a new species, as so many characters of the family are variable (e.g., see Straškraba, 1965). Fortunately, an additional character argues strongly for distinctness of *E. belki*. The stout, cylindrical eggs bearing longitudinal grooves and having "flared" rims at either end are apparently unique in the family. Whereas many other traditionally employed characters of the Limnadiidae are variable, egg morphology seems to be a conservative character. As an example, populations of *Eulimnadia* in North America that vary in other characters nevertheless share nearly identical egg morphology (see Belk, 1989). Despite the fact that egg morphology was occasionally used to define species of *Eulimnadia* by Daday as early as 1926, egg morphology has only infrequently and relatively recently been employed in comparative studies of branchiopods (e.g., Alonso and Alcaraz, 1984; Belk, 1989; Mura, 1986; Mura and Thiery, 1986; Samyiah *et al.*, 1985; Thiery and Champeau, 1988).

Of the species of *Eulimnadia* known from Central and South America (Table 1), there are no species with eggs similar to those of *E. belki*. *Eulimnadia brasiliensis*, as illustrated by Sars (1902), has spherical eggs bearing smooth bumps on the surface. The vial containing the single specimen of that

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Fig. 5. Various specific characters of species in the Limnadiidae. A, caudal region of *Eulimnadia antillarum* (compare reduced posterior spines (small arrows) to Fig. 3F, which is typical of the genus), ×150; B, cylindrical egg (damaged) of *E. chacoensis*, ×350; C, sharp crenulated ridges of egg of *E. chacoensis* (see arrow in B), ×1,000; D, spherical eggs of *Eulimnadia* sp. A [DB 305] from Argentina, ×180; E, *Eulimnadia* sp. B [DB 632], from Paraguay, showing position of egg mass on mature female; F, higher magnification of eggs shown in E, ×75; G, same, ×2,000; H, eggs of *Limnadia lenticularis* from population south of Tallahassee, Florida, ×270.

species in the Hungarian Museum of Natural History (see Materials and Methods) contained a single egg that, when subjected to SEM, agrees fairly closely with Sars' illustration; the egg is roughly spherical with smooth ridges surrounding irregular depressions (Fig. 4C). Margalef (1961) illustrated spherical eggs for "*Eulimnadia* sp.," but it is possible that the illustrations were of the "ends" of the eggs and do not show the cylindrical nature that some other limnadiid eggs possess; that species must remain unnamed for the present. Daday's (1926) illustration of the egg of *E. geayi* also shows a spherical egg with somewhat acute surface projections, but this is inconsistent with eggs of *E. geayi* in the Hungarian Museum. The eggs of *E. geayi* are short, grooved cylinders with one end of the cylinder slightly wider than the other. The wider end of the cylinder bears raised ridges, whereas these ridges on the narrow end are flattened or slightly concave, giving the egg a somewhat pentagonal appearance when viewed from the side (Figs. 4D–F). The eggs of *E.* "*columbica*" (see Materials and Methods) are essentially identical to those of *E. geayi,* confirming that this form is a synonym of *E. geayi.* Baird (1852, paper repeated verbatim in 1854) did not illustrate the eggs of *E. antillarum,* and unfortunately all of the specimens in the British Museum (Natural History), and also those in the Hungarian Museum, lack eggs. Lilljeborg (1889: 424) stated only "Eggs nodulose or angulose, with 8–10 evident nodes or angles" (English translation). Fortunately, the posterodorsal border of the caudal region in *E. antillarum* is distinctive in lacking the acute and well-developed spines typical of most other species (the spines are present in some specimens but are very small and low; Fig. 5A, compare to Fig. 3F); thus, identification is not difficult. However, Daday's illustration (his fig. 127d) of *E. antillarum* shows more developed spines than are seen in Fig. 5A, and several authors have noted the variability of these spines in the family. Therefore, perhaps the validity of *Eulimnadia antillarum* should be questioned until egg morphology is known. Gurney (1931) did not illustrate the eggs of *E. chacoensis,* but the eggs of syntypes at the British Museum appear short and cylindrical with one end bearing raised ridges, much as is seen in *E. geayi.* The one egg selected for SEM study cracked badly upon drying, but the ridges can be seen to be fairly sharp (compared to those of *E. belki*) and slightly crenulate, a condition that is not brought on by drying conditions (Fig. 5B, C). Daday (1926, fig. 138e) described the eggs of *E. texana,* a predominantly North American species that has been reported from Mexico, as having spherical eggs with small protuberances that give the eggs a stellate appearance. Daday's figures are inaccurate, since eggs of *E. texana* are stout and cylindrical (see Belk, 1989), similar to what is described below for an undescribed Paraguayan species (DB 632).

An examination of the eggs of several undescribed species, of which larger samples exist, serves to illustrate the range of egg morphology in the genus. Of the undescribed species in the private collections of Denton Belk, specimens of *Eulimnadia* sp. A [DB 305], from Argentina, have spherical eggs with small oval depressions (Fig. 5D). Finally, specimens of the Paraguayan *Eulimnadia* sp. B [DB 632] have roughly cylindrical eggs that lack flared rims and that have deep grooves separated by low, rounded longitudinal ridges (Fig. 5E–G); these eggs are very similar to those known from the predominantly North American *E. texana* (see Belk, 1989).

These and other observations (see Belk, 1989) suggest that egg morphology is species specific in the genus *Eulimnadia* and possibly throughout the family Limnadiidae. For example, the distinctive "twisted" eggs of North American populations of *Limnadia lenticularis* (Fig. 5H) are identical to those of European populations (compare Fig. 5H to Sars, 1896). A detailed description of egg morphology, preferably by means of SEM, should be included in any description or redescription of species of the Limnadiidae. In addition, size of the eggs may prove to be of systematic value, although that character was not specifically addressed in this paper.

Many authors (see discussion in Webb and Bell, 1979) have commented on the rather unsatisfactory characters employed in distinguishing between *Eulimnadia* and *Limnadia,* and in the most recent work addressing the two genera (Webb and Bell, 1979) they were synonymized, *Limnadia* Brongniart being the senior synonym. I have

elected to recognize the two genera on the basis of several morphological characters of the telson not illustrated by previous workers (see Belk, 1989). These characters will be addressed in a separate paper.

Acknowledgements

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Address: Life Sciences Division, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007.