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RESEARCH NOTE

Caliraja gen. nov., a new skate genus (Rajiformes: Rajidae) from the eastern North Pacific

Caliraja gen. nov., un nuevo género de rayas (Rajiformes: Rajidae) del este del Pacífico Norte

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Abstract.- A new genus of skate (*Caliraja* gen. nov.) is described based on egg case morphology and the number of embryos per egg case. *Caliraja* gen. nov. egg cases differ from those of the genus *Beringraja* by a combination of following characteristics: egg cases relatively small in size, lacking ridges, fine striations on the capsule surface, and moderately long horns about the size of the capsule compared to the much larger *Beringraja* egg cases that possess distinctly prominent ridges, no striations, and short or obscure horns. The most significant difference is the new genus has a single embryo per egg case, while *Beringraja* have 1-9 embryos per egg case, averaging 3-5 per egg case. Evolutionarily the egg case morphology of *Beringraja* is more primitive than the new genus *Caliraja* gen. nov.

Key words: Rajidae, Hardnose skate, new genus, *Beringraja*, *Caliraja* gen. nov.

INTRODUCTION

Skate egg case morphology is an important taxonomic tool for individual species identification and to determine phylogenetic interrelationships among species (Ishiyama 1958a, b, 1967; Hubbs & Ishiyama 1968, Ishiyama & Hubbs 1968). The genus *Beringraja* Ishihara, Treloar, Bor, Senou, and Jeong, 2012 was described based on egg case morphology and clasper characteristics, with the eastern North Pacific (ENP) Ocean *Raja binoculata* Girard, 1855 designated as the type species. Two species were assigned to this genus, that is, *B. binoculata* (Girard, 1855) and the western North Pacific (WNP) Ocean *B. pulchra* (Liu, 1932). These two species along with four other ENP species were previously assigned to the North Pacific *Raja* Assemblage (McEachran & Dunn 1998).

In addition to *B. binoculata* and *B. pulchra*, the other four species that previously comprised the North Pacific *Raja* Assemblage (McEachran & Dunn 1998) were recently reassigned to the genus *Beringraja*, but without detailed explanation (Last *et al*. 2016). The four species formerly assigned to the genus *Beringraja*, include *B. cortezensis* (McEachran & Miyake, 1988), *B. inornata* (Jordan & Gilbert, 1881), *B. rhina* (Jordan & Gilbert, 1880), and *B. stellulata* (Jordan & Gilbert, 1880). However, the generic placement of these four species is not satisfactory given the distinct morphological differences of the egg cases (Ishihara & Ishiyama 1986, McEachran & Miyake 1986, McEachran & Dunn 1998, Ishihara *et al*. 2012) and by molecular data (Naylor *et al*. 2012, Chiquillo *et al*. 2014). Therefore, these differences indicate that continued placement of these four species in *Beringraja* is untenable, and requires they be reassigned to a new genus. Therefore, in this work *Caliraja* gen. nov. has been described as a new genus to include four species previously in the genus *Beringraja*.

Materials and methods

Individual skate species egg case descriptions for *B. binoculata*, *B. inornata*, *B. pulchra*, *B. rhina*, and *B. stellulata*, previously provided by Ishiyama (1958a, b) and Ebert & Davis (2007) are cited for descriptive analysis. The egg cases of *B. cortezensis* have not been described and were unavailable. Egg case terminology and abbreviations followed Ebert & Davis (2007) (Fig. 1): Egg case length (ECL) measured longitudinally between the anterior and posterior apron borders; anterior border width (ABW) is the distance between the bases of the anterior horns; anterior horn length (AHL) is the distance from the horn base to the tips; posterior border width (PBW) is the distance between the bases of the posterior horns; posterior horn length (PHL) is the distance from the posterior horn base to the tips; maximum case width (MAW), the transverse width of the case in its lateral plane at its widest part of the case; minimum case width (MIW), the transverse width of the case in its lateral plane at its narrowest part of the case; lateral keel width (LKW) is the distance from the capsule keel junction to the keel edge.

The external body morphology and meristics of *B. binoculata* and *B. pulchra* and the four species assign to the new genus were taken from fresh specimens collected by staff and students of the Pacific Shark Research Center and from museum specimens at the California Academy of Sciences (CAS) and Smithsonian Museum of Natural History (USNM). Specimens examined include the types *Raja inornata* and *R. stellulata*, and non-type specimens of *Beringraja binoculata*, *B. pulchra*, *B. inornata*, *B. rhina* and *B. stellulata*. A total of 2,048 specimens were examined for body morphology and meristics with the breakdown by species as follows: *B. binoculata* (n= 268), *B. pulchra* (n= 7), *B. inornata* (n= 317), *B. rhina* (n= 1263), and *B. stellulata* (n= 193). In addition, external body morphology and meristics of all species, including *B. cortezensis*, were taken from literature accounts including original descriptions, if available.

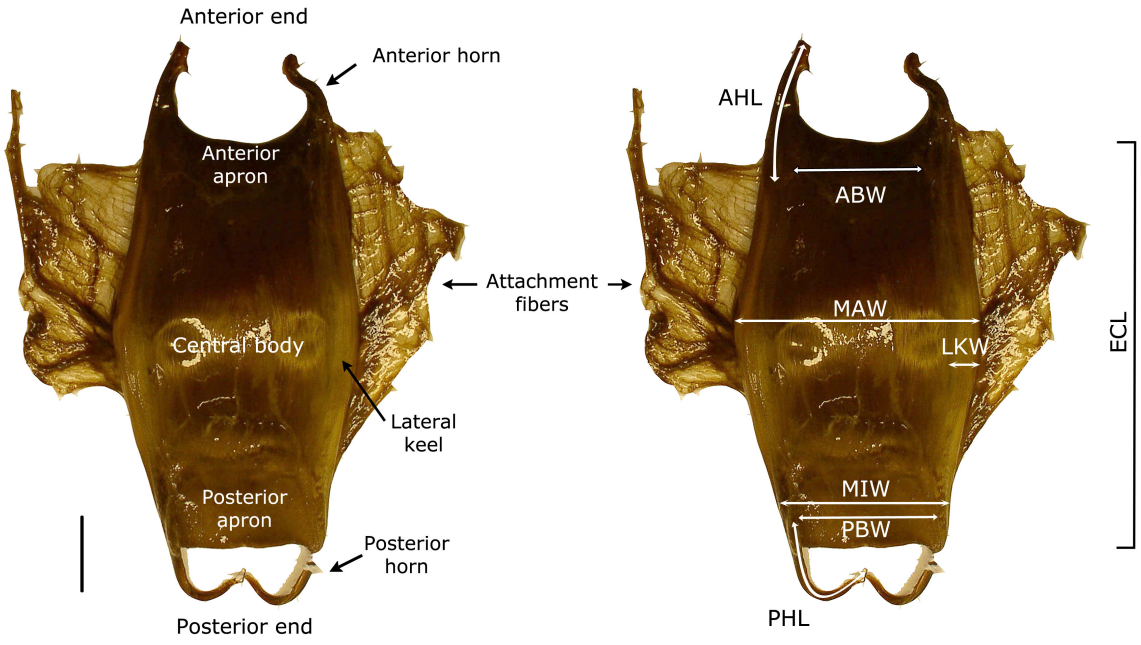

Figure 1. Skate egg case terminology (from Ebert & Davis 2007). Egg case length (ECL); anterior border width (ABW); anterior horn length (AHL); posterior border width (PBW); posterior horn length (PHL); maximum case width (MAW); minimum case width (MIW); lateral keel width (LKW). Scale bar 20 mm / Terminología de la cápsula ovígera de raya (de Ebert & Davis 2007). Longitud de la cápsula del huevo (ECL); ancho del borde anterior (ABW); longitud del cuerno anterior (AHL); ancho del borde posterior (PBW); longitud del cuerno posterior (PHL); ancho máximo de la cápsula (MAW); ancho mínimo de caja (MIW); ancho de quilla lateral (LKW). Barra de escala 20 mm

Results & discussion

***Caliraja* gen. nov.**

Type species: *Raja inornata* Jordan & Gilbert, 1881

Species. *Caliraja cortezensis* (McEachran & Miyake, 1988), *Caliraja inornata* (Jordan & Gilbert, 1881), *Caliraja rhina* (Jordan & Gilbert, 1880), and *Caliraja stellulata* (Jordan & Gilbert, 1880).

Definition. *Egg case morphology*: small to moderately large, nearly rectangular in shape with well developed aprons and lateral keels; distance from anterior to posterior apron borders about two-thirds to three-quarters egg case length (Fig. 2). Egg case surface finely striated, smooth to the touch, with or without fibrous covering; if present covering appears as dense, intricately woven-like sheath with wool-like texture. Aprons dissimilar in shape; anterior border broad, concave; posterior border nearly straight, broad, transverse, and slightly wider than anterior apron width. Lateral keel width to maximum case width narrow to very broad (<10 to 25%). Horns moderately long, up to one-half case length, flattening towards tips and hook or thread-like; respiratory fissures present at the tip of horns. Attachment fibers maybe absent or present depending on the species. Coloration is a uniform dark brown to golden brown, lighter on keels for some species. *Clasper morphology*: Terminal clasper bridge cartilage externally visible, separating two clefts, and clasper spike visible, length as long or nearly as sentinel length. *External body morphology*: Small to very large Rajini skates (from 39 cm to 204 cm TL) with the following combination of characters: disc rhombic to heart-shaped, width 1.1-1.3 times length; snout moderately to extremely elongated, 2.3-6.0 times orbit length; tooth rows in upper jaw 32-49, lower jaw 27-46. Dorsal surface covered with scattered to dense prickles. Tail thorns with distinct median row flanked by smaller rows of lateral thorns. Pelvic fins deeply notched. Two similar sized dorsal fins followed by a small to vestigial caudal fin. Ground color brown to olive brown, grayish brown or grayish, with dark blotches, rings, spots or ocelli on pectoral fins. Pectoral-fin radials 64-79; pelvic fin radials 18-23; predorsal vertebrae 68-83; Spiral valve turn count 7-12.

Distribution. Eastern Bering Sea, Alaska, Canada, United States to Gulf of California, Baja California, Mexico.

Etymology. The genus prefix name *Cali-* is in reference to the state of California, United States and Gulf of California, Baja California, Mexico, the regions where the types of all four recognized species were described. Vernacular name: California Skates.

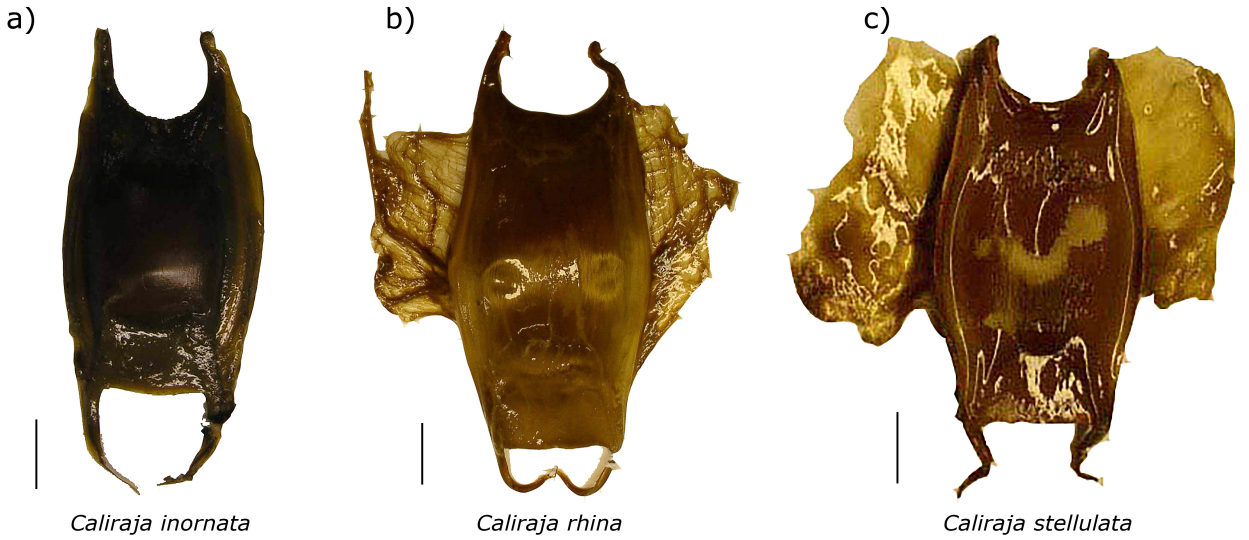

Figure 2. Egg cases of a) *Caliraja inornata*, b) *Caliraja rhina*, and c) *Caliraja stellulata*. Scale bar= 20 mm / Cápsula ovígera de a) *Caliraja inornata*, b) *Caliraja rhina*, and c) *Caliraja stellulata*. Barra de escala= 20 mm

Remarks. The separation of *Caliraja* gen. nov. from *Beringraja* based on egg case morphology was documented by Ishihara *et al*. (2012) who found two distinct types of egg cases in what they referred to as genus A (*sensu* Ebert & Compagno 2007), which corresponds to the North Pacific *Raja* Assemblage of McEachran & Dunn (1998). These authors further reported that the egg cases of *B. binoculata* (Fig. 3) and *B. pulchra* were more specialized and formed their own lineage separate from Genus A, which they described as a new genus. The other lineage, which now includes *C. cortezensis*, *C. inornata*, *C. rhina*, and *C. stellulata*, remained unresolved despite distinct differences in egg case morphology. These differences included *Caliraja* gen. nov. having small to moderate size egg case (<103 mm) *vs*. very large egg case (>210 mm) for the two *Beringraja* species; moderately long horns similar in length to egg case *vs*. short stout or obscure horns; surface covered with fine striations *vs*. no striations; and dorsal surface convex without ridges *vs*. concave with prominent ridges (Figs. 2 and 3). The prominent ridges on the dorsal surface are only found in two skate species, *B. binoculata* and *B. pulchra* (Fig. 3). However, the most notable distinction in addition to these morphological characters is the *Beringraja* are the only two known skate species whose egg cases have multiple embryos per each case, ranging from one to nine embryos per egg case, with an average of three to five (Ishiyama 1958a, b, 1967; Hitz 1964, Ebert 2003, Ebert & Davis 2007, Ebert *et al*. 2008, Jo *et al*. 2010, Kang *et al*. 2013, Chiquillo *et al.* 2014, Jang 2019). All other known skate species, including all the *Caliraja* gen. nov. species have only a single embryo per egg case (Ishiyama 1958a, b, 1967; Ebert & Davis 2007, Ebert *et al*. 2008, Ishihara *et al*. 2012, Chiquillo *et al.* 2014, Jang 2019).

The claspers of *Caliraja* gen. nov. have a terminal bridge cartilage that is externally visible *vs*. not visible in *Beringraja*; claspers with two separate clefts *vs*. one cleft present; clasper spike visible, length same as sentinel length *vs*. not visible, much shorter than sentinel length. Externally, the pelvic fins of *Caliraja* gen. nov. are deeply notched *vs.* shallowly notched in *Beringraja*. Spiral valve counts slightly lower for *Caliraja* gen. nov. 7-12 *vs.* 11-15 for *Beringraja*. Furthermore, prior molecular findings confirmed these two distinct lineages (Naylor *et al*. 2012, Chiquillo *et al*. 2014), one comprised of the *Beringraja* and the other described here as *Caliraja* gen. nov.

Ishihara *et al*. (2012) proposed an evolutionary trend for skate egg cases with those having a rough external surface, short and depressed posterior horns, a poorly developed apron and lateral keel to be the more primitive condition while those egg cases having smooth external surface, long posterior horns, and well-developed apron and lateral keels to be the more advanced state. Therefore, evolutionarily based on Ishihara *et al*. (2012) hypothesis *Beringraja* egg cases with their rough external surface, short posterior horns, and poorly developed apron and lateral keels are the more primitive condition, while the *Caliraja* gen. nov. with their smooth surface, relatively long horns, and well-developed aprons and lateral keels are consider the more advanced condition among skate egg case morphology.

Figure 3. Egg case of *Beringraja binoculata*. Scale bar= 20 mm / Cápsula ovígera de *Beringraja binoculata*. Barra de escala= 20 mm

In addition, it is presented below a revised key to the *Caliraja* gen. nov. species egg cases, excluding *C. cortezensis*. (Modified after Ebert & Davis 2007)

1a. Attachment fibers absent. *Caliraja inornata*

1b. Attachment fibers present. 2.

2a. Lateral keel width broad, >10% of maximum egg case width. *Caliraja rhina*

2b. Lateral keel width narrow, <10% maximum egg case width. *Caliraja stellulata*

The genus is registered in ZooBank under: urn:lsid:zoobank.org:act:32D10903-4361-4109-928C-D874F5863D29

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