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Chondrichthyan egg cases from the south-west Atlantic Ocean

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Egg cases of 21 oviparous chondrichthyan species from the south-west Atlantic Ocean are described and compared. The catshark *Schroederichthys bivius* has a cigar-shaped egg case with curled tendrils only at the posterior end. Egg cases of the elephant fish *Callorhinchus callorynchus* are spindle-shaped with anterior and posterior tubular extensions and lateral flanges. The skate *Amblyraja doellojuradoi* presents medium-sized egg cases (71 mm in length) with a lateral keel extending to the first portion of the horns. The endemic skate species of the genus *Atlantoraja* have medium to large egg cases (69–104 mm in length) and present relatively large posterior horns. Egg cases of the genus *Bathyraja* have a medium size, 75–98 mm in length, and are characterized by a very similar morphology, a relatively smooth to rough surface case and posterior horns strongly curved inwards. Egg cases of the genera *Dipturus* and *Zearaja* are very large, 115–230 mm in length, and have a well-developed posterior apron. Despite the problematical identification of skates at species level, the egg capsules of the endemic genus *Psammobatis* are easily diagnosed; the capsules are small (25–53 mm in length), those of *Psammobatis rutrum* being the smallest known to date in the world. Egg cases of *Rioraja agassizi* have a medium size, 61–68 mm in length, relatively straight sides, a smooth surface and silky attachment fibres placed in the lateral keel next to each horn. Those of the genus *Sympterygia* are small to medium sized, 51–86 mm in length, and display the thickest lateral keel and the longest posterior horns among the skates of the world. Egg cases can be a useful tool for identifying species and egg-laying areas; therefore, a provisional key for the south-west Atlantic Ocean chondrichthyan capsules is presented.

Key words: Argentina; capsules; identification key; skates; sharks.

INTRODUCTION

Chondrichthyans display a great variety of reproductive modes, from oviparity to different kinds of viviparism (from yolk-sac viviparity, the dominant mode of reproduction in Chondrichthyes, to placental viviparity in some sharks) (Hamlett, 2005).

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Oviparity is characterized by the production of fertilized eggs, encapsulated in a structurally complex capsule, that develop and hatch externally. Oviparity is found in all skate and holocephalan species, and in some sharks (Hamlett, 2005).

Oviparous chondrichthyans in the Argentine continental shelf are represented by 24 species of skates, the elephant fish *Callorhinchus callorynchus* (L. 1758) and the narrowmouthed catshark *Schroederichthys bivius* (Müller & Henle 1838) (Menni *et al.*, 1984; Cousseau *et al.*, 2007; Diaz de Astarloa *et al.*, 2008). Two other oviparous sharks, the polkadot catshark *Scyliorhinus besnardi* (Springer & Sadowsky 1970) and the freckled catshark *Scyliorhinus haeckeli* (Miranda Ribeiro 1907) occasionally occur in the area (Menni & Lucifora, 2007).

In spite of the fact that chondrichthyan catches in the south-west Atlantic Ocean have considerably increased in recent years (Massa *et al.*, 2004; Cousseau *et al.*, 2007), several aspects of their reproductive biology are yet unknown. Egg cases have been described for some skates in the south-western Atlantic Ocean (Braccini & Chiaramonte, 2002; Mabragaña *et al.*, 2002; Oddone & Vooren, 2002, 2005, 2008; Mabragaña & Cousseau, 2004; Oddone *et al.*, 2004, 2006; Oddone, 2005; San Martín *et al.*, 2005; Ruocco *et al.*, 2006; Mabragaña, 2007; Concha *et al.*, 2009). Two of these works include an identification key based on egg-case morphology of species of *Psammobatis* Günther 1870 (Mabragaña, 2007), and of species of *Atlantoraja* Menni 1872, *Sympterygia* Müller & Henle 1837 and *Rioraja* Whitley 1939 (Oddone & Vooren, 2008); however, a comparative study including capsules morphology and morphometry of all chondricthyan genera occurring in the area is lacking.

Egg case morphology is species specific (Ishiyama, 1958; Ebert, 2005; Ebert & Davis, 2007) and is used as a taxonomic and ecological tool. Variations in egg case morphology between species may also indicate differences in the habitat of where they are deposited (Ebert *et al.*, 2006). The identification of demersal egg cases furnish valuable information concerning the distribution and reproductive biology of species (*e.g.* breeding season, fecundity and fertility, incubation period and egg laying and nursery areas). This information is crucial for the conservation of these species. Given the importance of egg case identification, the aim of this study was to provide the description and diagnostic characteristics of specific egg cases occurring in the Argentine continental shelf.

MATERIALS AND METHODS

Oviparous species were collected from bottom-trawl surveys carried out by the Instituto Nacional de Investigación y Desarrollo Pesquero, (INIDEP; National Institute of Fishery Research and Development, Argentina). The survey area included the south-west Atlantic Ocean between 34° and 55° S, from the coastline to 200 m depth (Fig. 1). For egg case identification associated with the correct species, capsules were removed from females in the uterus, except those of *C. callorynchus,* which were obtained from the sea bed. Additionally, egg cases were taken with a dredge close to banks of Patagonian scallop *Zygochlamys patagonica*. Egg cases were also collected, after deposition, from specimens in captivity in the Museo del Mar aquariums. Egg cases were fixed and preserved in 10% formalin, and deposited in the collection at Laboratorio de Ictiología de la Universidad Nacional de Mar del Plata, Mar del Plata, Argentina.

Eight morphometric characteristics were recorded following standard methods (Hubbs & Ishiyama, 1968; Ishiyama & Ishihara, 1977; Ebert & Davis, 2007). In addition, keel thickness and straight distance from the anterior apron margin to the curvature of the anterior horn

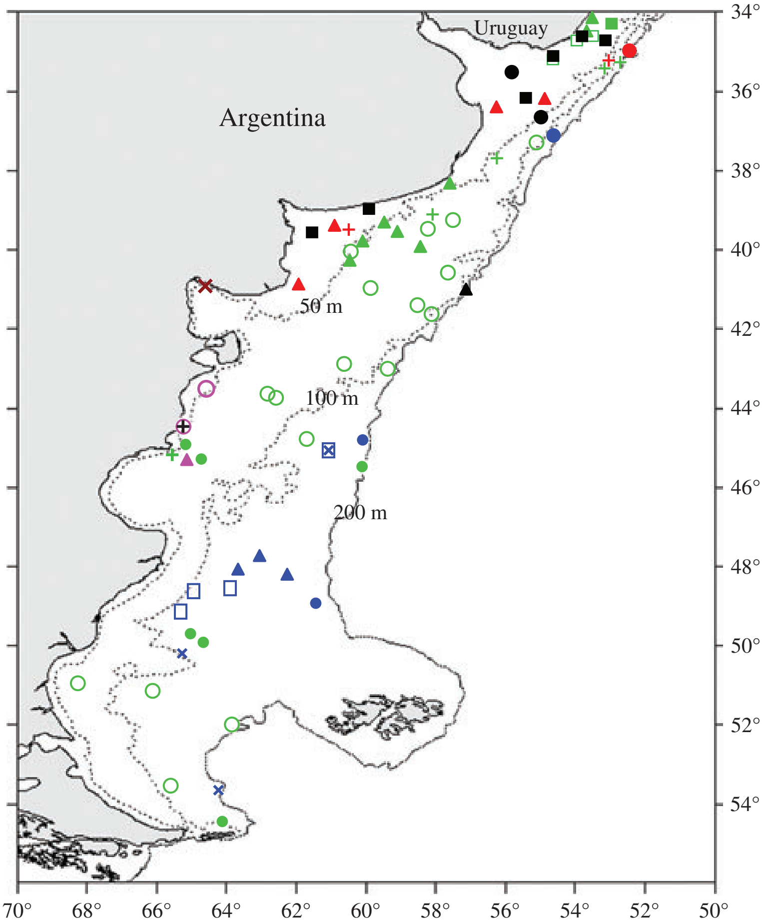

FIG. 1. Study area showing the sites where females bearing egg cases were found: ▲, *Amblyraja doellojuradoi*; ▲, *Atlantoraja castelnaui*; +, *Atlantoraja cyclophora*; ●, *Atlantoraja platana*; ●, *Bathyraja albomaculata*; ▲, *Bathyraja brachyurops*; ×, *Bathyraja macloviana*; □, *Bathyraja magellanica*; ×, *Callorhinchus callorhynchus*; ○, *Zearaja chilensis*; ▲, *Dipturus trachyderma*; ▲, *Psammobatis bergi*; ■, *Psammobatis rutrum*; □, *Psammobatis extenta*; ○, *Psammobatis normani*; ●, *Psammobatis rudis*; +, *Psammobatis lentiginosa*; ■, *Rioraja agassizi*; +, *Schroederichthys bivius*; ●, *Sympterygia bonapartii*.

(aHL2) were recorded (Fig. 2). All measurements were taken with vernier calipers at 0·1 mm precision.

STUDY AREA

The Argentine continental shelf comprises a part of the south-west Atlantic Ocean between 34° and 55° S. Water masses in this region consist of several water types: coastal, sub-Antarctic, subtropical and mixed waters (Bisbal, 1995). In the north, the circulation is influenced by the warm, more saline, south-flowing Brazil Current, which runs along the continental margin of South America and moves offshore at *c*. 36–38° S (Olson *et al*., 1988). In the south, a low salinity current of sub-Antarctic origin flows north along the coast, from the Strait of Magellan (52° 30′ S) to 40–42° S, where it veers offshore and flows northwards over the outer shelf and slope. These water masses are modified substantially by inflow of

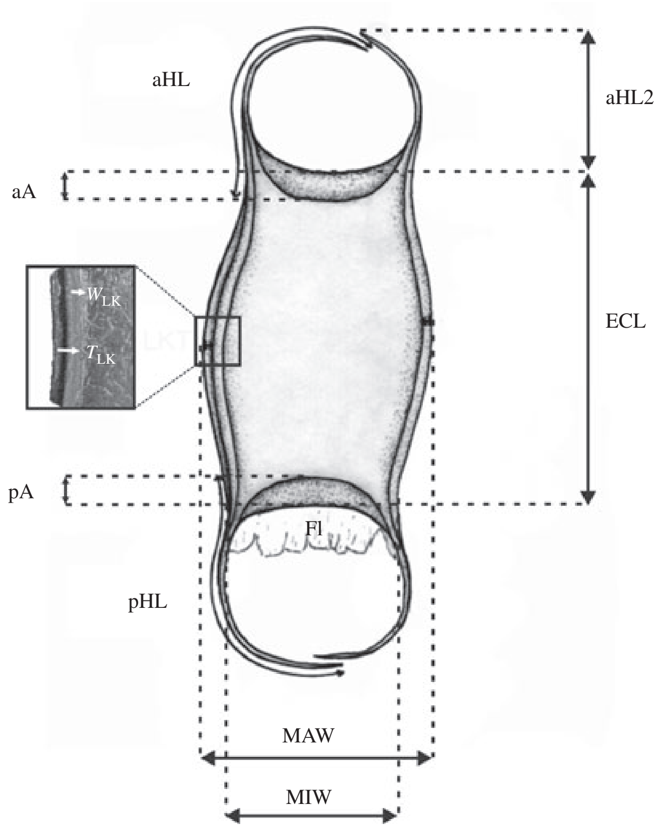

FIG. 2. Generalized egg case showing the morphometric characters utilized in the study: ECL, egg case length (without horns); MAW, egg case width (maximum); MIW, egg case width (minimum); L_{aH}, unfurled anterior horn length; pHL, posterior horn length; LKW, lateral keel width; LKT, lateral keel thickness; aA, anterior apron; pA, posterior apron; aHL2, straight distance from anterior apron to apex of anterior horn; Fl, flange.

glacial waters from the Magellan Strait at 52° 30′ S and freshwater inputs from the Negro and La Plata Rivers (Guerrero & Piola, 1997). These systems correspond to two biogeographic provinces: the Argentine Province in the north, extending north to Rio de Janeiro, Brazil, and the Magellanic Province in the south, which also includes southern Chile (Menni & López, 1984).

RESULTS

One hundred and forty-six egg cases of 21 species of Chondrichthyes belonging to nine genera were examined.

SUBCLASS HOLOCEPHALII, ORDER CHIMAERIFORMES

There is only one species in the south-west Atlantic Ocean, *C. callorynchus*, endemic to South America.

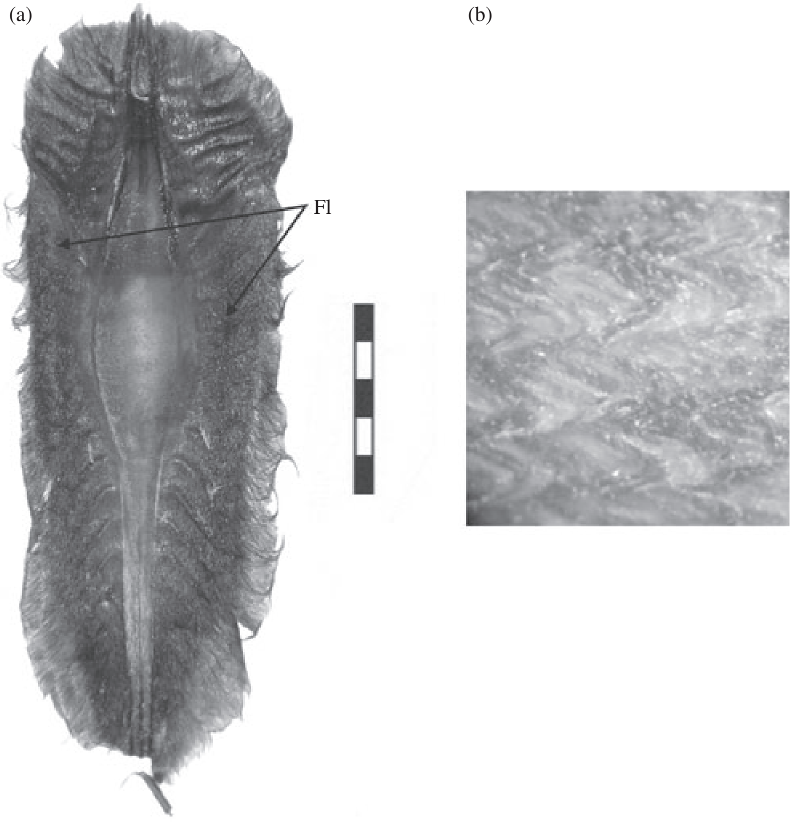

FIG. 3. (a) Dorsal view of the egg case of *Callorhinchus callorynchus* (Fl, flange). Scale bar = 1 cm per unit. (b) Surface of case (×40).

Callorhinchus callorynchus has relatively large and spindle-shaped egg cases [Fig. 3(a)], with anterior and posterior tubular extensions and lateral flanges. The dorsal surface of the case is relatively rough to touch due to the presence of undulate longitudinal striations in a zig-zag pattern [Fig. 3(b)]. The ventral surface is smooth. The lateral flanges show transversal grooves oriented anteriorly on the anterior tubular zone, straight or transversal in the section that houses the egg and in the posterior two thirds part of case the flanges have two strong grooves oriented posteriorly and followed by less pronounced grooves. The posterior tubular extension has a mid keel and two lateral keels, whereas the anterior tubular extension only possesses two pilous lateral keels. The dorsal case surface presents fibrous sheets of byssus-like material, especially on lateral flanges.

Egg case measurements ($n = 3$): length: 240–248 mm; maximum width: 75–92 mm; case width without flange: 36–42 mm.

Callorhinchus callorynchus is widely distributed in the south-west Atlantic Ocean from 23° to 55° S (López *et al*., 2000), and in the south-eastern Pacific Ocean to 15° S, from the coast to 200 m depth (Chirichigno, 1998). Egg cases were collected from benthic samples at 40° 55′ S at 135 m depth (Fig. 1).

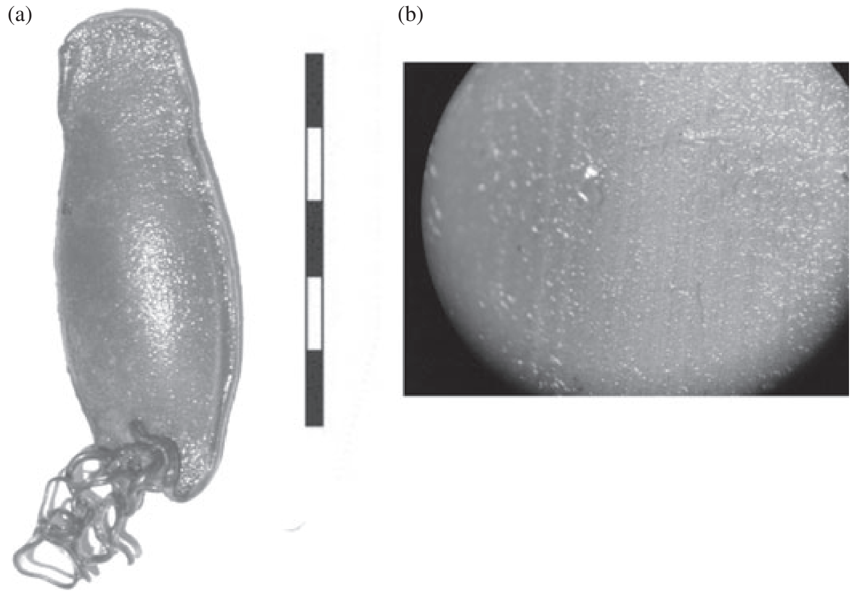

FIG. 4. (a) Dorsal view of the egg case of *Schroederichthys bivius*. Scale bar = 1 cm per unit. (b) Surface of case (×40).

SUBCLASS ELASMOBRANCHII, ORDER CARCHARINIFORMES, FAMILY SCYLHIORHINIDAE

This family in the south-west Atlantic Ocean comprises four species; three of them have been recorded in the Argentine Continental Shelf (Menni & Lucifora, 2007; Eschmeyer & Fricke, 2011): *S. bivius*, *S. besnardi* and *S. haeckeli*; but only the first is commonly found in Argentine waters and their capsules are described here. The other two species have been reported from Uruguayan waters and their egg cases were described from Brazil waters (Gomes & de Carvalho, 1995).

Schroederichthys bivius has a cigar-shaped egg case [Fig 4(a)], with fine and straight longitudinal striations on the dorsal and ventral surfaces [Fig. 4(b)]. The lateral flanges are narrow and posses fine transversal striae. The anterior border is convex and tendrils are absent. The posterior border of the case has curled, filamentous tendrils, longer than the egg case length [Fig. 4(a)].

Egg case measurements ($n = 13$): length: 58–68 mm; width: 22–27 mm; lateral keel width: 1·7–2·5 mm; keel thickness: 1·5–4 mm.

Schroederichthys bivius occurs in the south-west Atlantic Ocean from southern Brazil (33° S) south to the Beagle Channel (55° S) (Soto, 2001), and in the south-east Pacific Ocean to Valparaiso (33° S), from 80 to 200 m depth. Females bearing egg cases were found in northern Patagonian waters (Fig. 1).

ORDER RAJIFORMES, FAMILY RAJIDAE

Egg cases of skates are generally rectangular in shape with a horny process in each corner. Measurements are presented in Table I. Diagnostic characteristics for each genus and species are given below.

TABLE I. Measurements (range and mean ± S.D.; mm) of the egg cases of 19 species of skates from Argentinian waters (Fig. 1)

Species	n		ECL	MAW	MIW	aHL	pHL	LKW	LKT	aA	pA	aHL2
Atlantoraja	3	Range	69·0–75·0	37·5–44·6	33·7–39·6	52·0–54·0	98·0–103·0	2·4–2·5	1·1–2·0	5·0–5·6	11·0–12·0	23·0–27·0
cyclophora		Mean ± S.D.	51·7 ± 3·2	38·1 ± 3·8	34·4 ± 3·3	38·0 ± 1·0	73·5 ± 2·5	4·0 ± 0·1	1·5 ± 0·5	4·7 ± 0·3	9·9 ± 0·6	30·1 ± 2·0
Atlantoraja	5	Range	96·7–103·8	68–78·2	63·6–70·3	67·0–77·0	118·0–155·0	5·0–8·0	1·9–3·4	6·2–10·5	12·1–22·3	50·0–61·0
castelnaui		Mean ± S.D.	99·8 ± 3·7	72·4 ± 3·8	66·3 ± 2·5	71·0 ± 5·0	133·6 ± 13·4	6·9 ± 1·1	2·4 ± 0·6	7·6 ± 1·8	15·9 ± 3·8	55·7 ± 4·5
Atlantoraja	3	Range	71·0–72·0	44·8–47·2	39–40·2	43·6–56·3	110–128	2·3–2·6	1·6–2·0	4·8–6·7	10·8–13·6	24·7–25·0
platana		Mean ± S.D.	71·6 ± 0·5	46·1 ± 1·2	39·7 ± 0·6	50·6 ± 6·5	121·7 ± 10·1	2·5 ± 0·2	1·8 ± 0·2	5·5 ± 1·1	12·1 ± 1·4	24·8 ± 0·2
Amblyraja	5	Range	67·0–73·0	47·3–54·2	38·0–48·0	43·0–50·0	50·0–68·0	4·3–6·0	0·3–0·6	6·0–8·3	12·5–16·0	21·0–26·0
doellojuradoi		Mean ± S.D.	70·0 ± 2·5	50·7 ± 3·0	43·6 ± 3·9	45·3 ± 3·0	60·8 ± 8·5	5·5 ± 0·8	0·5 ± 0·1	7·5 ± 0·9	14·5 ± 1·7	24·4 ± 2·0
Bathyraja	8	Range	89·7–98·0	52·5–68·4	49·0–53·0	61·0–75·0	60·0–88·0	3·9–6·2	2·3–2·8	5·8–8·0	15·0–26·0	28·7–45·0
albomaculata		Mean ± S.D.	95·9 ± 3·6	60·0 ± 4·9	51·2 ± 1·5	70·0 ± 5·0	70·0 ± 8·6	5·1 ± 1·0	2·6 ± 0·2	7·0 ± 0·8	20·8 ± 3·7	33·8 ± 5·5
Bathyraja	11	Range	82·0–93·0	53·0–65·4	42·0–58·0	60·0–103·0	70·0–117·0	3·2–6·0	0·5–1·6	3·4–9·0	11–19·6	31·0–39·0
brachyurops		Mean ± S.D.	89·0 ± 3·5	57·5 ± 4·0	48·0 ± 4·9	84·6 ± 13·6	87·7 ± 15·4	4·7 ± 0·9	0·9 ± 0·3	6·0 ± 1·7	15·7 ± 2·3	35·0 ± 2·5
Bathyraja	8	Range	75·0–84·9	43·5–48·5	37·8–42·0	44·0–60·0	47·0–63·0	2·5–4·0	2·5–3·0	5·0–12·0	12·4–17·0	21·5–29·0
macloviana		Mean ± S.D.	80·6 ± 4·0	45·7 ± 1·9	40·3 ± 1·3	50·4 ± 5·7	54·4 ± 6·0	3·2 ± 0·5	2·8 ± 0·2	7·8 ± 2·4	14·6 ± 1·5	25·9 ± 2·8
Bathyraja	5	Range	79·8–88·0	55·5–60·0	42·4–45·3	40·0–59·0	85·0–150·0	7·0–8·7	0·5–1·0	6·0–9·0	13·5–17·5	28·0–30·3
magellanica		Mean ± S.D.	83·6 ± 4·0	57·6 ± 2·2	43·9 ± 1·0	48·0 ± 7·3	119·8 ± 32·1	7·4 ± 0·7	0·7 ± 0·3	7·0 ± 1·2	15·5 ± 2·0	29·6 ± 0·9
Zearaja	14	Range	115·0–158·0	58·7–70·8	52·7–67	53·0–73·0	63·0–117·0	3·9–7·9	0·9–2·5	7·0–18·0	33·0–54·0	21·0–36·0
chilensis		Mean ± S.D.	131·5 ± 14·4	65·7 ± 4·2	59·4 ± 5·1	62·2 ± 6·1	89·6 ± 16·6	5·0 ± 1·2	1·7 ± 0·5	12·4 ± 3·4	41·4 ± 5·7	27·6 ± 4·3
Dipturus	2	Range	222·0–230·0	163–154·0	100·0–107·0	78·0–88·0	74·0–78·0	43·0–33·0	0·5–1·0	65·0–70·0	56·0–65·0	15·0
trachyderma		Mean ± S.D.	226·0 ± 5·7	158·5 ± 6·4	103·5 ± 4·9	83·0 ± 7·1	76·0 ± 2·8	38·0 ± 7·1	0·8 ± 0·4	67·5 ± 3·5	60·5 ± 6·4	15·0
Psammobatis	10	Range	39·6–43·5	34–35·4	31·9–33·9	28·0–40·0	51·0–67·0	1·9–2·9	0·5–1·3	1·78–2·5	4·1–9·0	19·0–23·8
bergi		Mean ± S.D.	41·9 ± 1·4	34·7 ± 0·4	32·8 ± 0·6	35·4 ± 1·05	56·8 ± 2·8	2·3 ± 0·1	0·8 ± 0·3	2·1 ± 0·1	6·1 ± 1·2	21·0 ± 1·8

TABLE I. Continued

Species	*n*		ECL	MAW	MIW	aHL	pHL	LKW	LKT	aA	pA	aHL2
Psammobatis extenta	10	Range	25·5–30·9	17·9–20	14·9–16·6	17·0–26·0	27·0–45·0	1·0–1·3	0·5–0·9	1·0–1·9	3·0–6·0	11·0 – 15·0
		Mean ± S.D.	28·7 ± 2·1	19·1 ± 0·6	15·7 ± 0·6	21·7 ± 2·9	33·6 ± 4·9	1·1 ± 0·1	0·7 ± 0·2	1·5 ± 0·3	4·6 ± 1·0	13·2 ± 1·4
Psammobatis rutrum	1	Value	26·7	19·6	16·3	16·0	37·0	1·4	0·6	1·7	2·6	13·0
Psammobatis normani	18	Range	41·0–52·0	28·8–36	25·0–32·5	25·0–63·0	55·0–76·0	2·2–3	0·4–0·8	2–3·8	4·52–8	21·4–29
		Mean ± S.D.	45·7 ± 3·5	31·5 ± 2·3	27·8 ± 2·2	45·4 ± 8·6	63·8 ± 5·8	2·5 ± 0·2	0·6 ± 0·1	2·6 ± 0·5	6·2 ± 1·0	24·7 ± 2·5
Psammobatis rudis	6	Range	45·6–53·5	26·1–36·9	23·0–32·8	24·0–36·0	50·0–74·0	2·3–3·7	0·6–0·6	2·4–3·6	5–6·6	11·5–24
		Mean ± S.D.	49·8 ± 3·2	32·9 ± 4·8	29·5 ± 4·4	28·7 ± 5·0	63·8 ± 10·8	3·0 ± 0·6	0·6 ± 0·0	3·0 ± 0·5	5·8 ± 0·6	17·6 ± 4·4
Psammobatis lentiginosa	6	Range	34·6–40·6	24–27·7	19·2–24·5	18·0–25·0	35·0–48·0	1·8–2·0	0·6–1·0	2–3·8	5·6–7·7	11·0–15·6
		Mean ± S.D.	37·9 ± 2·5	25·5 ± 1·7	21·3 ± 2·5	20·0 ± 3·2	39·3 ± 5·2	1·9 ± 0·1	0·8 ± 0·2	2·9 ± 0·7	6·9 ± 0·7	13·9 ± 1·9
Rioraja agassizi	5	Range	61·0–68·0	37·5–40·5	35·5–37·0	47·0–56·0	62·0–79·0	2·3–3·0	0·9–1·7	4·0–8·0	9·2–10·5	32·0–38·2
		Mean ± S.D.	63·8 ± 2·6	39·0 ± 1·1	36·1 ± 0·5	52·8 ± 4·1	69·6 ± 6·9	2·8 ± 0·3	1·3 ± 0·4	5·1 ± 1·7	10·0 ± 0·5	34·6 ± 2·8
Sympterygia acuta		Range	51·2–57·5	32·4–36·0	26·4–29·0	29–39·7	180–293	1·0–2·0	2·8–3·4	2·5–4·9	4·0 – 7·2	14·0–22·3
	10	Mean ± S.D.	54·8 ± 2·4	34·4 ± 1·5	27·6 ± 0·9	34·9 ± 3·0	232·1 ± 41·9	1·3 ± 0·4	3·1 ± 0·2	3·7 ± 0·8	6·1 ± 1·0	18·4 ± 3·1
Sympterygia bonapartii	8	Range	68·3–86·5	41·4–52·2	37·0–44·8	40·0–58·0	117·0–158·0	0·5–1·9	5·0–6·2	3·7–6·2	6·6–12·0	26·0–32·0
		Mean ± S.D.	81·2 ± 5·6	49·6 ± 3·4	42·5 ± 2·4	50·6 ± 5·3	135·3 ± 16·6	1·5 ± 0·4	5·7 ± 0·4	5·4 ± 0·7	10·4 ± 1·8	28·9 ± 2·3

n, sample size; ECL, egg case length (without horns); MAW, egg case width (maximum); MIW, egg case width (minimum); aHL, anterior horn length; pHL, posterior horn length; LKW, lateral keel width; LKT, lateral keel thickness; aA, anterior apron; pA, posterior apron; aHL2, straight distance from anterior apron to apex of anterior horn.

Amblyraja

This genus comprises at least four species in the south-west Atlantic Ocean: the southern thorny skate *Amblyraja doellojuradoi* (Pozzi 1935), the thickbody skate *Amblyraja frerichsi* (Krefft 1968), the whiteleg skate *Amblyraja taaf* (Meisner 1987) and the Antarctic starry skate *Amblyraja georgiana* (Norman 1938), but only the first inhabits the Argentine continental shelf (Menni & Stehmann, 2000; Cousseau *et al*., 2007).

The egg cases of *A. doellojuradoi* are medium size, 67–73 mm in length (horns excluded), with maximum egg case width (MAW) *c*. 66–80% of egg case length (ECL) and possess a remarkable lateral keel, *c*. 9–12% of MAW, extending the length of the case, tapering off along the outer edge of the horns. The anterior horns finish abruptly, whereas the posterior horns taper progressively [Fig. 5(a)]. The dorsal surface of the cases, including both the lateral keels and the horns base, are covered with fine fibroids. The dorsal and ventral surfaces of the cases are finely striated without ridges but with fine transversal scars along the stries [Fig. 5(b)]; apparently, no other skate egg cases have these scars. Attachment fibres are absent. The anterior horns curl ventrally, and are flattened and hook-like towards the tips; the length of the anterior and posterior horn is *c*. 62–68% of ECL. The posterior apron is wider than the anterior one. The posterior horns are flattened to a filamentous tip, relatively short (70–100% of ECL) but longer (1·1–1·6 times) than the anterior horns.

Amblyraja doellojuradoi is distributed in the south-west Atlantic Ocean between 36° and 56° S, and from 51 to 642 m depth; but is relatively more abundant between 36° and 42° S. (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found at 40° 59′ S; 57° 05′ W at 143 m depth (Fig. 1).

Atlantoraja

This genus comprises three species, the spotback skate *Atlantoraja castelnaui* (Miranda Ribeiro 1907), the eyespot skate *Atlantoraja cyclophora* (Regan 1903) and la Plata skate *Atlantoraja platana* (Günther 1880), endemic to the south-west Atlantic Ocean (Menni & Stehmann, 2000; Cousseau *et al*., 2007). The egg cases (Fig. 6) are medium to large, 69–104 mm in length (horns excluded) and present relatively large posterior horns.

Atlantoraja castelnaui [Fig. 6(a)] has the largest case within the genus, >95 mm in length, with MAW *c*. 66–81% of ECL. The base of the horns and lateral margins are covered by adhesive fibrils. The dorsal surface of case is densely covered with woven-like fibres [Fig. 7(a)]. Both case surfaces, except the fibrous layer, are relatively smooth, finely striated and without ridges; these striae are irregular in size [Fig. 7(b)]. The anterior horns are slightly curved ventrally; their length is *c*. 66–78% of ECL. The posterior apron edge is relatively flat and wider than the anterior apron. The lateral keel width (LKW) is narrow, *c*. 7–10% of MAW. The posterior horns are long, *c*. 1·2–1·5 times ECL and *c*. 1·7–2·0 times the length of the anterior ones. The aHL2 is relatively large, >50% of ECL.

Egg cases of *A. cyclophora* [Fig. 6(b)] are medium size (<75 mm on length), with MAW *c*. 54–59% of ECL. The base of the horns, lateral margins and dorsal face of the capsule are covered by a layer of sticky fibrils. The surface of the case is longitudinally striated with marked ridges on the dorsal face [Fig. 7(c)]. The anterior horns are relatively short, *c*. 49–53% of ECL. The posterior apron edge is markedly convex. The LKW is narrow, *c*. 6–7% of MAW. The posterior horns are long, *c*.

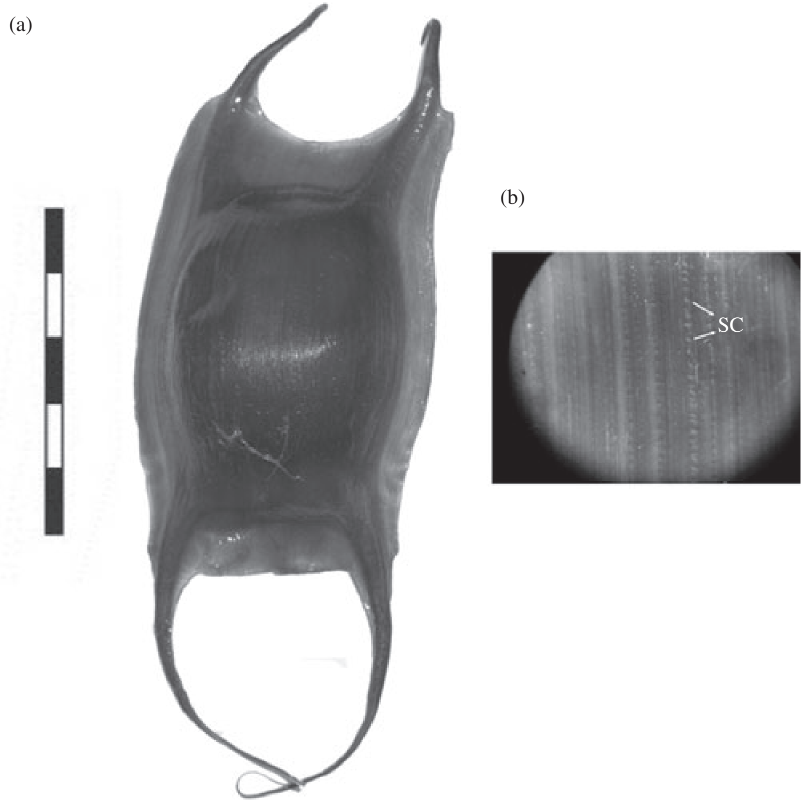

FIG. 5. (a) Dorsal view of the egg case of *Amblyraja doellojuradoi*. Scale bar = 1 cm per unit. (b) Surface of case (×40). SC, scars.

1·3–1·4 times ECL, and *c*. 1·9 times the length of the anterior horns. The aHL2 is relatively short, <40% of ECL.

Egg cases of *A. platana* [Fig. 6(c)] are medium size (<75 mm in length) with MAW *c*. 63–66% of ECL. The base of the horns, lateral margins and both faces of the capsule are covered by sticky fibrils. The case surface is longitudinally striated with marked ridges especially on the dorsal face [Fig. 7(d)]. The posterior apron edge is relatively flat. The LKW is narrow, *c*. 5–6% of MAW. The anterior horns are curved inwards, their length *c*. 55% of ECL. The posterior horns are long (>1·5 times ECL) and *c*. 2·3–2·5 times the length of the anterior horns. The aHL2 is relatively short (<40% of ECL).

Atlantoraja castelnaui and *A. cyclophora* are distributed in the south-west Atlantic Ocean between Rio de Janeiro (22° S) and north Patagonia (42° S), from the coast to 100–130 m depth, but are more abundant in shallower waters <60 m (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in northern Argentina at 38–60 m depth (Fig. 1). *Atlantoraja platana* is distributed in the south-west Atlantic Ocean from Espirito Santo (Brazil, 20° S) south to San Matías Gulf (Argentina, 42° S), from the coast to 149 m depth (Menni & Stehmann, 2000;

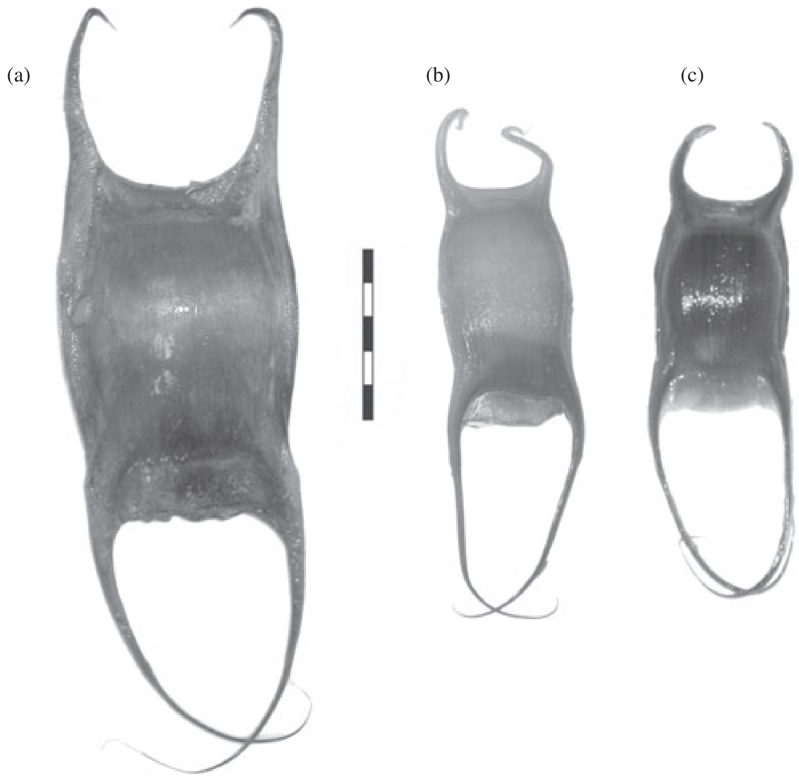

FIG. 6. Dorsal view of the egg cases of (a) *Atlantoraja castelnaui*, (b) *Atlantoraja cyclophora* and (c) *Atlantoraja platana*. Scale bar = 1 cm per unit.

Cousseau *et al*., 2007). Females bearing egg cases were found in waters adjacent to northern Argentina and Uruguay at 120 m depth (Fig. 1).

Bathyraja

The genus comprises 11 species in the south-west Atlantic Ocean, but is represented by eight species in the Argentine continental shelf, the white-dotted skate *Bathyraja albomaculata* (Norman 1937), the broadnose skate *Bathyraja brachyurops* (Fowler 1910), the joined-fins skate *Bathyraja cousseauae* Díaz de Astarloa & Mabragaña 2004, the greytail skate *Bathyraja griseocauda* (Norman 1937), the Patagonian skate *Bathyraja macloviana* (Norman 1937), the Magellan skate *Bathyraja magellanica* (Philippi 1902), the multispine skate *Bathyraja multispinis* (Norman 1937) and the cuphead skate *Bathyraja scaphiops* (Norman 1937) (Menni & Stehmann, 2000; Cousseau *et al*., 2007). The capsules of four of these species are described below.

The egg cases are medium to large size, 75–98 mm in length, and have a very conservative morphology (Fig. 8). The posterior horns are strongly curved inwards and the aHL2 is relatively short (<50% of case length). The surface of cases is generally coarse, often with prickles, and rough to the touch.

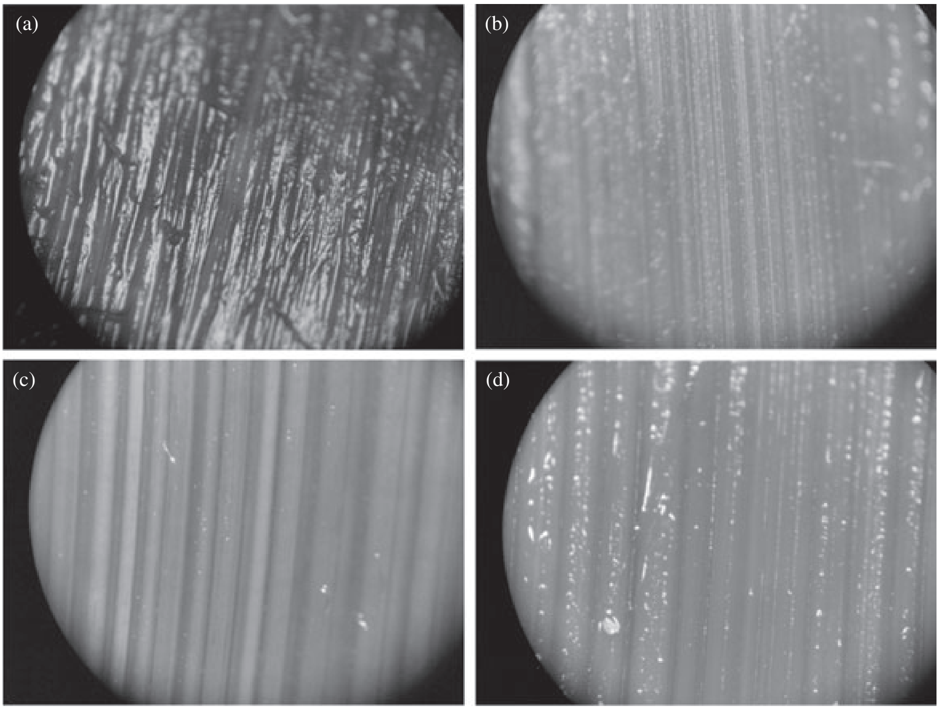

FIG. 7. Surface of case of *Atlantoraja* species showing the different patterns at magnification (×40). (a) *Atlantoraja castelnaui* with woven-like fibres, (b) *Atlantoraja castelnaui* showing structure beneath fibrous layer, (c) *Atlantoraja cyclophora* and (d) *Atlantoraja platana*.

Bathyraja albomaculata [Fig. 8(a)] has large egg cases (89–98 mm in length), with MAW *c*. 54–75% of ECL. The case surface bears longitudinal striations with long and thin prickles of different sizes, giving a velvety texture to the touch [Fig. 9(a)]. Attachment fibres are absent. The LKT is relatively thick (>2 mm). The LKW is narrow (6–11% of MAW). The posterior apron is wider (2·1–3·6 times) than the anterior apron. The anterior and posterior horns are similar in length and relatively short (<90% of ECL).

Egg cases of *B. brachyurops* [Fig. 8(b)] are large (82–93 mm in length), with MAW *c*. 70–81% of ECL. The egg case surface is relatively smooth, finely striated, with rasp-like denticles and without prickles [Fig. 9(b)]. Attachment fibres are observed at the bases of the posterior horns and posterior apron. The LKT is relatively thin (<2 mm). The LKW is narrow (6–11% of MAW). The posterior apron is wider (1·9–4·2 times) than the anterior apron. The anterior and posterior horns are similar in length and relatively short (<1·3 times ECL).

Bathyraja macloviana [Fig. 8(c)] has the smallest egg case within the genus (75–84 mm in length), with MAW *c*. 52–59% of ECL. The surface texture is coarse and very rough to the touch due to papillose longitudinal ridges. The prickles have different sizes and shapes [Fig. 9(c)]. Attachment fibres are absent. The LKT is relatively thick (>2 mm) and the LKW is narrow (6–9% of MAW). The posterior apron is wider (1·2–3 times) than the anterior apron. The anterior and posterior horns are relatively short and similar in length (<75% of ECL).

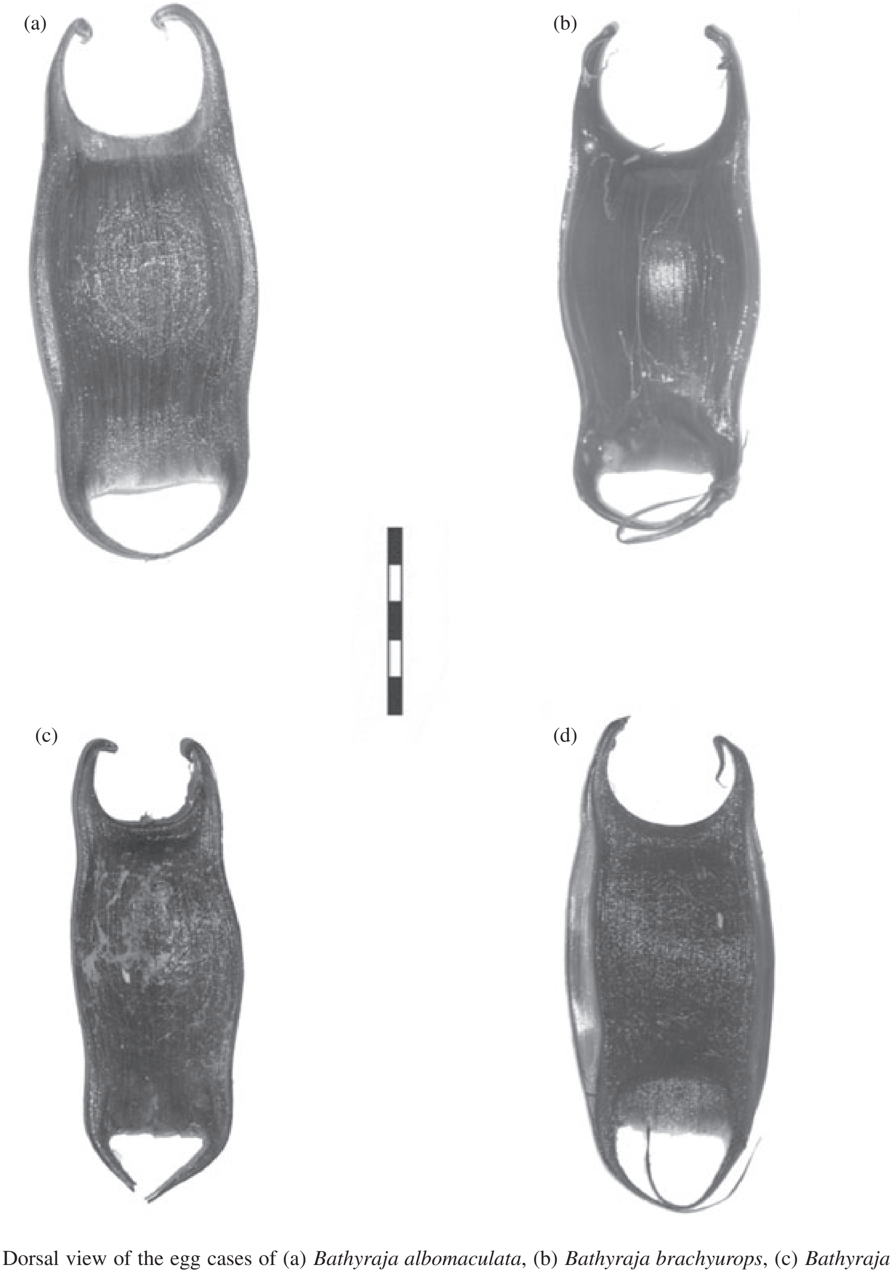

FIG. 8. Dorsal view of the egg cases of (a) *Bathyraja albomaculata*, (b) *Bathyraja brachyurops*, (c) *Bathyraja macloviana* and (d) *Bathyraja magellanica*. Scale bar = 1 cm per unit.

Egg cases of *B. magellanica* [Fig. 8(d)] are large (80–88 mm in length), with MAW *c*. 68–70% of ECL. The capsule exhibits a wide lateral keel that is remarkably lighter in colour than the rest of the case. The case surface is similar to that of *B. abomaculata*, but the prickles are all of uniform size [Fig. 9(d)]. Attachment fibres are absent. The LKT is relatively thin (<2 mm). The LKW is broad (12–15% of MAW). The posterior apron is wider (1·4–3 times) than the anterior apron. The

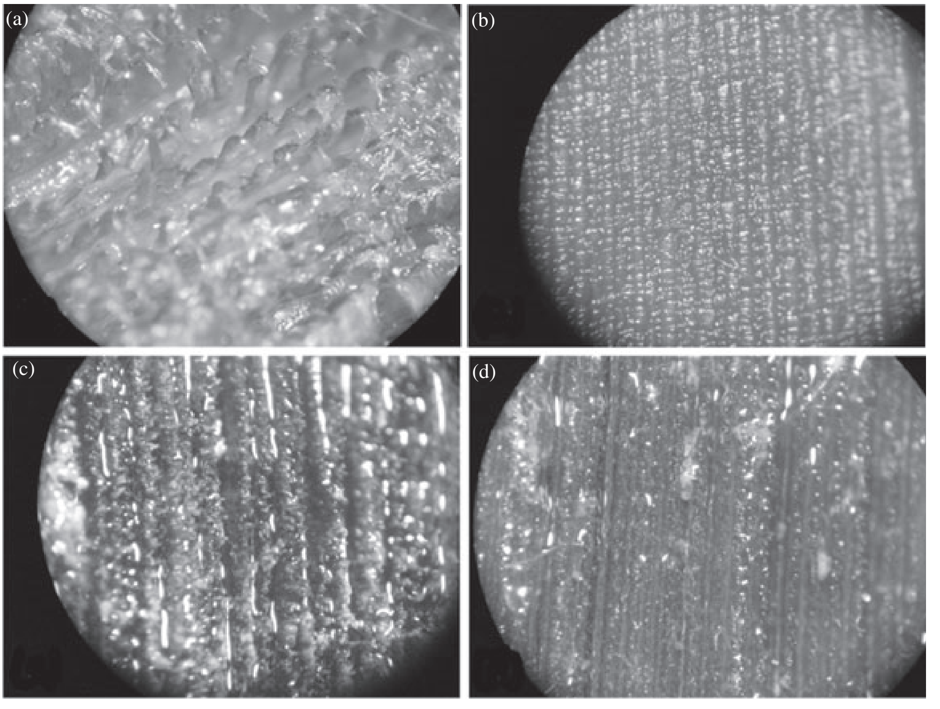

FIG. 9. Surface of case of *Bathyraja* species showing the different patterns (×40). (a) *Bathyraja albomaculata*, (b) *Bathyraja brachyurops*, (c) *Bathyraja macloviana* and (d) *Bathyraja magellanica*.

posterior horns are relatively short (*c*. 1·0–1·7 times ECL) but longer than the anterior ones.

Bathyraja albomaculata occurs in the south-west Atlantic Ocean from 37° to 55° S, from 70 to 815 m depth, and in the south-east Pacific Ocean to 45° S (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found along the shelf at 116–154 m depth (Fig. 1). *Bathyraja brachyurops* is widely distributed in the south-west Atlantic Ocean from 37° to 55° S, from 82 to 500 m depth, and in the south-eastern Pacific Ocean to 45° S (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in Patagonian waters at 104–137 m depth (Fig. 1). *Bathyraja macloviana* is widely distributed in the south-west Atlantic Ocean from 36° to 55° S, from 82 to 505 m depth, and in the south-east Pacific Ocean to 51° S (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in Patagonian waters at 106–144 m depth (Fig. 1). *Bathyraja magellanica* is distributed in the south-west Atlantic Ocean from 45° to 55° S, from 51 to 137 m depth, and in the south-east Pacific Ocean to 42° S (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in southern Patagonian waters at 100–113 m depth (Fig. 1).

Dipturus

In the south-west Atlantic Ocean, the genus *Dipturus* is represented by six species (Díaz de Astarloa *et al*., 2008). Three of them inhabit the Argentine continental

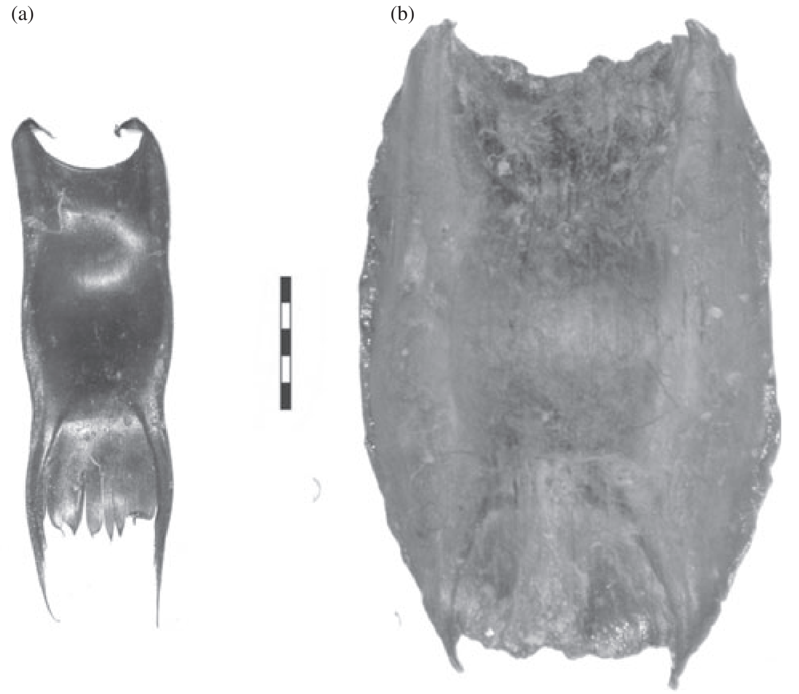

FIG. 10. Dorsal view of the egg cases of (a) *Zearaja chilensis* and (b) *Dipturus trachyderma*. Scale bar = 1 cm per unit.

shelf: the yellownose skate *Dipturus chilensis* (Guichenot 1848), [Last & Gledhill (2007) discusses the species recent transfer from *Dipturus* to *Zearaja*], the roughskin skate *Dipturus trachyderma* (Krefft & Stehmann 1975) and the Argentine skate *Dipturus argentinensis* Díaz de Astarloa, Mabragaña, Hanner & Figueroa 2008. A fourth species, the south Brazilian skate *Dipturus mennii* Gomes & Paragó 2001, has been recorded at the border of Brazilian and Uruguayan waters (Bernardes *et al*., 2005) and could be found in Argentine waters. The capsules of only the first two species are described here.

The egg cases (Fig. 10) are very large, 115–230 mm in length (horns excluded), with a well-developed posterior apron and a very short aHL2 (<40% of case length). The dorsal and ventral surfaces of the case are covered with dense woven-like fibres. The surface of the cases beneath the fibrous layer is relatively smooth, finely striated and without ridges [Fig. 11]. Fibre attachments are absent.

The egg cases of yellownose skate *Zearaja chilensis* (Guichenot 1848). [Fig. 10(a)] are large (115–158 mm in length), with MAW *c*. 39–60% of ECL. The LKW is narrow (6–11% of MAW), the posterior apron is very broad (37–36% of ECL) and wider than anterior apron. The anterior horns are relatively short (37–62% of ECL), robust at the base, curving ventrally and flattened towards the tips. The posterior horns are longer than the anterior horns (1–1·9 times), but still relatively short (<90% of ECL), and possess a lighter flange along their inner edge.

The egg cases of *D. trachyderma* [Fig. 10(b)] are very large (>200 mm in length), with MAW *c*. 67–73% of ECL. The LKW is very broad (21–26% of MAW) and

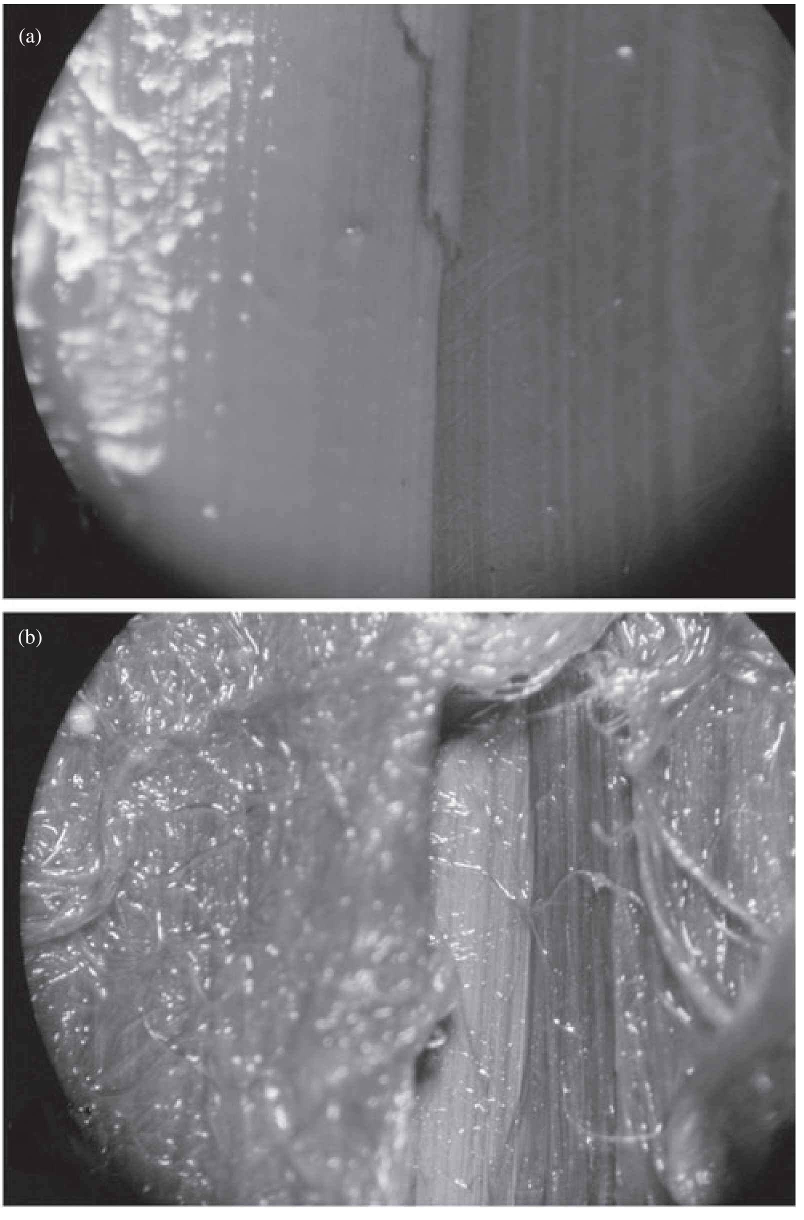

Fig. 11. Surface of egg cases of (a) *Zearaja chilensis* and (b) *Dipturus trachyderma* showing the different patterns (×40).

the anterior apron is also very broad (*c*. 30% of ECL) and wider than the posterior apron. The anterior and posterior horns are similar in length and very short (<40% of ECL).

Zearaja chilensis is widely distributed in the south-west Atlantic Ocean between 33° and 55° S, from 25 to 435 m depth, being more abundant between 50 and 150 m depth. In the south-east Pacific Ocean, this fish occurs as far south as 35° S

(Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in northern Patagonian waters at 50 m depth (Fig. 1). *Dipturus trachyderma* occurs in the south-west Atlantic Ocean from southern Brazil to 45° S, from 80 to 200 m depth, and in the south-east Pacific Ocean to southern Chile (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in central Patagonian waters at 83 m depth (Fig. 1).

Psammobatis

This genus, endemic to South America, comprises eight species, six of which are present in the Argentine continental shelf: the shortfin sand skate *Psammobatis normani* McEachran 1983, the smallthorn sand skate *Psammobatis rudis* Günther 1870, the freckled sand skate *Psammobatis lentiginosa* McEachran 1983, the blotched sand skate *Psammobatis bergi* Marini 1932, the zipper sand skate *Psammobatis extenta* (Garman 1913) and the spade sand skate *Psammobatis rutrum* Jordan 1891 (Menni & Stehmann, 2000; Cousseau *et al*., 2007; Mabragaña, 2007). Another species (the smalltail sand skate *Psammobatis parvacauda* McEachran 1983) has been recorded in the south-west Atlantic Ocean around the Falkland Islands (McEachran, 1983) but has never been found in the Argentine continental shelf.

The egg cases (Fig. 12) are small. Cases vary from 25 to 53 mm in length (horns excluded) and are relatively smooth to the touch but finely striated under magnification.

Egg cases of *P. bergi* [Fig. 12(a)] are smaller than 50 mm in length (horn excluded) and square shaped. The MAW is >80% of ECL and has a relatively convex anterior apron edge. The surface of the case is finely striated. The dorsal surface is covered with a layer of longitudinal fibres, whereas the ventral surface is naked [Fig. 13(a)]. The LKW is narrow (5–8% of MAW); the posterior apron is wider (1·8–4·5 times) than the anterior one. The posterior horns are relatively short (1·2–1·6 times ECL) but longer (1·4–2 times) than the anterior horns.

The egg cases of *P. extenta* [Fig. 12(b)] are very small (<31 mm in length), with MAW *c*. 59–78% of ECL. The case surface bears fine longitudinal striations and ornamentation only visible under magnification [Fig. 13(b)]. Attachment fibres are observed along the lateral keel. The LKW is narrow (5–7% of MAW). The posterior apron is wider than the anterior ones (2–6 times). The posterior horns are relatively short (0·9–1·45 times ECL) but longer (1·1–2·2 times) than the anterior horns.

The egg cases of *P. lentiginosa* [Fig. 12(c)] are small (40 mm in length, horn excluded), with MAW *c*. 63–71% of ECL. The aHL2 is very small (<40% of ECL) and the posterior apron edge is slightly concave. The case surface and fibres are arranged similar to those of *P. bergi*, and fibres on the dorsal face are fine and scattered [Fig. 13(c)]. The LKW is narrow (7–8% of MAW) and the posterior apron is wider (2–3·3 times) than the anterior ones. The posterior horns are relatively short (0·9–1·2 times ECL) but longer (1·9–2·0 times) than the anterior horns.

The egg cases of *P. normani* [Fig. 12(d)] are small (50 mm in length, horn excluded), with MAW *c*. 64–73% of ECL. The surface of the case is finely striated. Attached fibres at both lateral keels are close to each horn. The dorsal surface is covered by a layer of longitudinal fibres, whereas the ventral surface is naked [Fig. 13(d)]. A large aHL2 (49–60% of ECL) and a relatively flat posterior apron are also present. The LKW is narrow (7–9% of MAW) and the posterior apron is

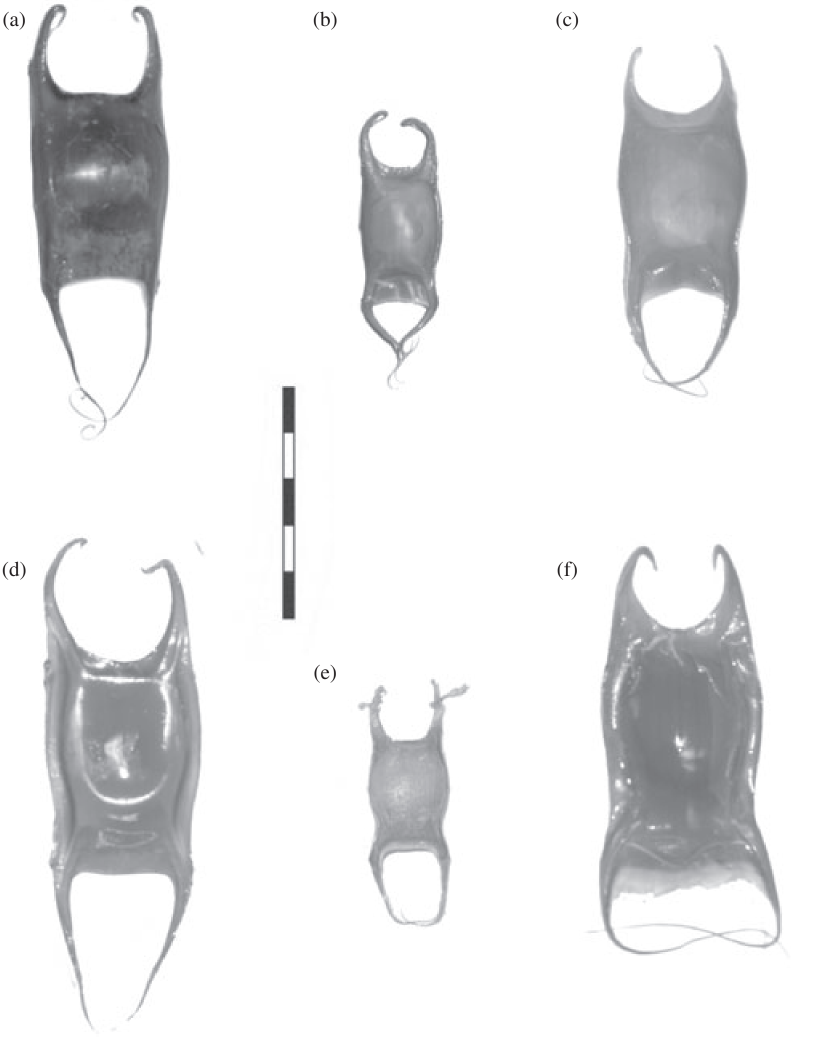

FIG. 12. Dorsal view of the egg cases of (a) *Psammobatis bergi*, (b) *Psammobatis extenta,* (c) *Psammobatis lentiginosa,* (d) *Psammobatis normani,* (e) *Psammobatis rutrum* and (f) *Psammobatis rudis.* Scale bar = 1 cm per unit.

wider (3·6 times) than the anterior ones. The posterior horns are relatively short (1·2–1·6 times ECL) but longer (1·1–2·6 times) than anterior horns.

Psammobatis rutrum [Fig. 12(e)] possess a very small egg case (<30 mm in length), with MAW *c*. 73% of ECL. The surface of the case presents fine longitudinal striations [Fig. 13(e)] and attached fibres along the lateral keel. The LKW is narrow (7% of MAW). The posterior apron is relatively narrow (10% of ECL) but wider than the anterior one (1·5 times). The posterior horns are relatively short (1·4 times ECL) but longer (2·3 times) than anterior horns.

The egg cases of *P. rudis* [Fig. 12(f)] are small (50 mm in length, horn excluded), with MAW *c*. 57–70% of ECL. The capsules have a flange at their posterior end,

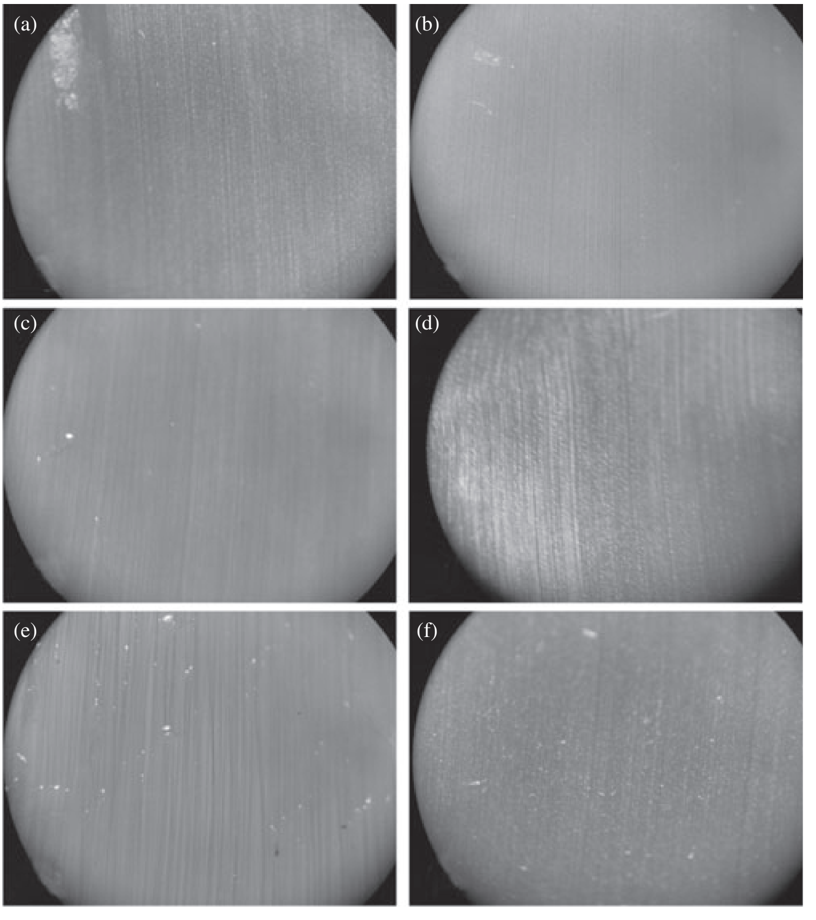

FIG. 13. Surface of egg cases of species of *Psammobatis* showing the different patterns (×40). (a) *Psammobatis bergi*, (b) *Psammobatis extenta,* (c) *Psammobatis lentiginosa,* (d) *Psammobatis normani,* (e) *Psammobatis rutrum* and (f) *Psammobatis rudis.*

which is characteristic of this species. The aHL2 is short (22–48% of ECL). The surface of the case and pattern of attachment fibres are similar to those found in *P. normani*, but the lack of a layer of fibres on the dorsal face distinguishes *P. rudis* from the latter [Fig. 13(f)]. The LKW is narrow (8–10% of MAW) and the posterior apron is wider (2·4 times) than the anterior ones. The posterior horns are relatively short (0·98–1·6 times ECL) but longer (1·8–3·1 times) than the anterior ones.

Psammobatis rudis and *P. normani* are widely distributed in the south-west Atlantic Ocean between 35° and 55° S, ranging from 49 to 350 m depth, but they are more abundant between 70 and 180 m depth. In the south-east Pacific Ocean, these species occur south to 30° S (Menni & Stehmann, 2000; Cousseau *et al*., 2007; Mabragaña, 2007). Females of *P. rudis* bearing egg cases were found in Patagonian waters (45–55° S) between 75 and 116 m depth (Fig. 1), whereas those of *P. normani* were found throughout the shelf from 71 to 182 m depth (Fig. 1). *Psammobatis lentiginosa* is distributed in the south-west Atlantic Ocean from 32° to 46°

S, from 49 to 164 m depth, being more abundant from 60 to 120 m depth (Menni & Stehmann, 2000; Cousseau *et al.*, 2007; Mabragaña, 2007). Females bearing egg cases were found at 35–45° S, between 63 and 116 m depth (Fig. 1). *Psammobatis bergi* and *P. extenta* are distributed in the south-west Atlantic Ocean from 23° to 45° S, and from the coast to 70 m depth, being more abundant between 25 and 66 m (Menni & Stehmann, 2000; Cousseau *et al.*, 2007; Mabragaña, 2007). Females bearing egg cases were found in northern Argentina from 25 to 66 m depth (Fig. 1). *Psammobatis rutrum* occurs in the south-west Atlantic Ocean from southern Brazil to 37° S, from 51 to 100 m depth, but has been occasionally recorded in the Argentine continental shelf (Menni & Stehmann, 2000; Cousseau *et al.*, 2007; Mabragaña, 2007). A single female bearing an egg case was found in northern Argentina at 100 m depth (Fig. 1).

Rioraja

This is a monospecific endemic genus distributed in temperate coastal waters of the south-west Atlantic Ocean (Menni & Stehmann, 2000; Cousseau *et al.*, 2007).

The Rio skate *Rioraja agassizi* (Müller & Henle 1841) has a medium-sized egg case [Fig. 14(a)], 61–68 mm in length (horns excluded); with MAW *c*. 60–62% of ECL. The surface of the case is finely striated without ridges, being smooth to the touch [Fig. 14(b)]. The dorsal surface is covered with fine longitudinal fibres. The aHL2 is large (>50% of case length). Egg cases possess silky attachment fibres placed in the lateral keel close to each horn. The LKW is narrow (6–8% of ECL). Both the anterior and posterior horns are relatively straight. The posterior apron is wider (1·3–2·6 times) than the anterior one. The anterior horns are stout, relatively long (*c*. 77–89% of ECL) and curving inwards at their tips. The posterior horns taper to their tips, are moderately short (*c*. 0·98–1·2 times ECL), and longer (1·1–1·5 times) than the anterior horns.

Rioraja agassizi is a shallow water species distributed in the south-west Atlantic Ocean from Espirito Santo (20° S) south to 42° S, from the coast to 150 m depth, but in the Argentine continental shelf is more abundant at depths <60 m (Menni & Stehmann, 2000; Cousseau *et al.*, 2007). Females bearing egg cases were found off northern Argentina from 15 to 27 m depth (Fig. 1).

Sympterygia

This genus comprises four species (McEachran & Dunn, 1998; Compagno, 2005) endemic to South America. Two of them are distributed in coastal waters of the south-west Atlantic Ocean: the smallnose fanskate *Sympterygia bonapartii* Müller & Henle 1841 and the bignose fanskate *Sympterygia acuta* Garman 1877 (Menni & Stehmann, 2000; Cousseau *et al.*, 2007).

The egg cases are small to medium size, 51–86 mm in length (horns excluded). They have long and thread-like posterior horns, a very narrow lateral keel and a marked lateral keel thickness (>5% of ECL, 1·6–4·8 times LKW) (Fig. 15). The case surface is smooth and finely striated without ridges (Fig. 16). Attachment fibres are placed at the end of the posterior horns. The anterior apron border is concave while the posterior one is nearly straight.

The egg cases of *S. bonapartii* are medium size (68–86 mm in length), with MAW *c*. 59–63% of ECL. The anterior horns curved inwards, flattening towards

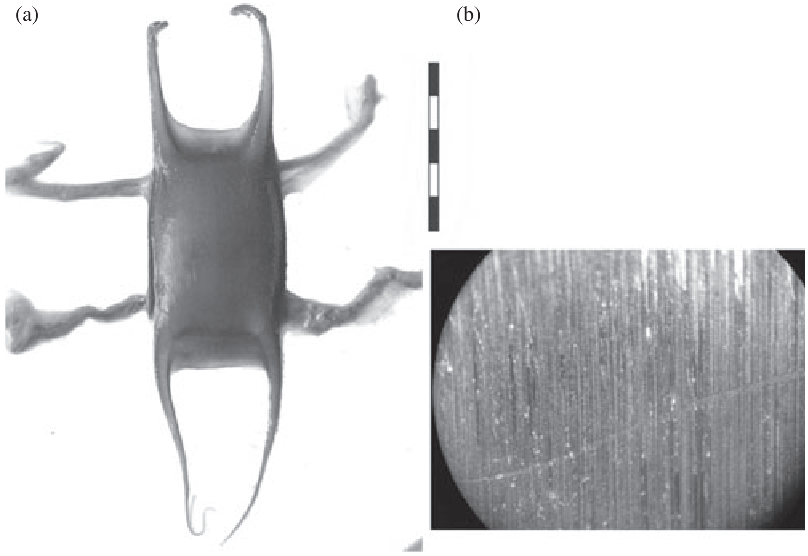

FIG. 14. (a) Dorsal view of the egg case of *Rioraja agassizi*. Scale bar = 1 cm per unit. (b) Surface of the case (×40).

the tips and are *c*. 58–67% of ECL in length. The posterior apron is wider than anterior apron (1·7–2·2 times). The posterior horns are long (>1·4 times ECL, but <2·5 times) and *c*. 2·3–3·2 times the length of the anterior horns.

The egg cases of *S. acuta* are small (<60 mm in length), with MAW *c*. 57–70% of ECL. The surface of the case is glossy. The anterior horns curve ventrally, and are flattened and thread-like toward their tips, their length *c*. 57–71% of ECL. The posterior horns are extremely long (>3 times ECL) and *c*. 5·3–9·0 times the length of the anterior ones. The posterior apron is wider (1·3–2·8 times) than the anterior apron.

Sympterygia acuta is distributed in shallow waters in the south-west Atlantic Ocean between 22° S and 41° S, from the coast to 50 m depth (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Egg cases were collected from females after the adult specimens had been deposited at the Museo del Mar aquarium. *Sympterygia bonapartii* is widely distributed in shallow waters in the south-west Atlantic Ocean from Rio Grande do Sul to 50° S, from 20 to 100 m depth (Menni & Stehmann, 2000; Cousseau *et al*., 2007). Females bearing egg cases were found in northern Argentina from 12 to 49 m depth (Fig. 1).

DISCUSSION

The American endemic catsharks, genus *Schroederichthys*, are exclusively oviparous and are represented by five species. Egg capsules of the narrowtail catshark *Schroederichthys maculatus* Springer 1966, the slender catshark *Schroederichthys tenuis* Springer 1966 and the redspotted catshark. *Schroederichthys chilensis* (Guichenot 1848) have been previously described (Springer, 1979; Gomes & de Carvalho, 1995; Hernández *et al*., 2005). The egg cases of the genus *Schroederichthys*

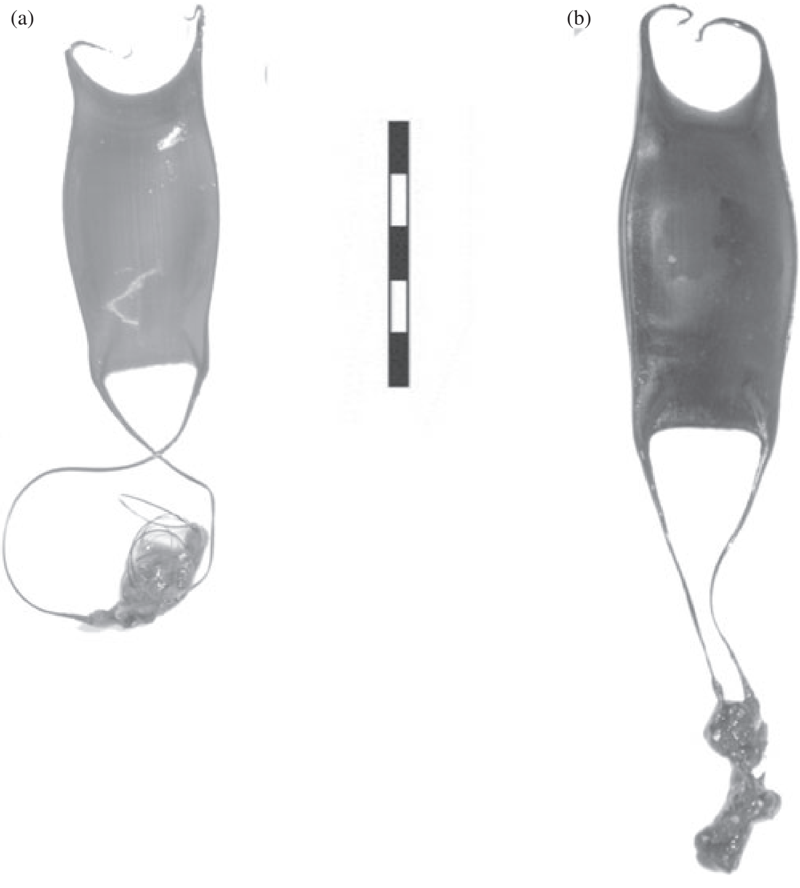

FIG. 15. Dorsal view of the egg cases of (a) *Sympterygia acuta* and (b) *Sympterygia bonapartii*. Scale bar = 1 cm per unit.

lack the typically coiled anterior tendrils of the family Scyliorhinidae. In *S. tenuis*, *S. chilensis* and *Schroederichthys saurisqualus* Soto 2001, a couple of anterior filamentous tendrils have been described (Gomes & de Carvalho, 1995; Hernández *et al.*, 2005). In contrast, anterior tendrils were not found in *S. bivius* and *S. maculatus* (Springer, 1979). Furthermore, in this study the majority of egg capsules have been laid by females kept in captivity, therefore it has been possible to confirm that *S. bivius* has capsules without anterior tendrils. Two species of *Scyliorhinus*, have been reported from Uruguayan waters: *Scyliorhinus haeckeli* (Miranda Rivero 1907) and *Scyliorhinus besnardi* Springer & Sadowski 1970. Their egg-laying area, however, is probably in southern Brazil. They also have cigar-shaped egg cases but with the anterior and posterior curled tendrils developed (Gomes & de Carvalho, 1995). The genus *Apristurus*, the largest within the family Scyliorhinidae, comprises at least three distinct species groups, the *Apristurus brunneus* (Gilbert 1892) group, *Apristurus longicephalus* Nakaya 1975 group and *Apristurus spongiceps* (Gilbert 1905) group (Nakaya *et al.*, 1999; Iglésias *et al.*, 2005; Flammang *et al.*, 2007). Similarity of egg case morphology in species of *Schroederichthys* and the *A. brunneus* and *A.*

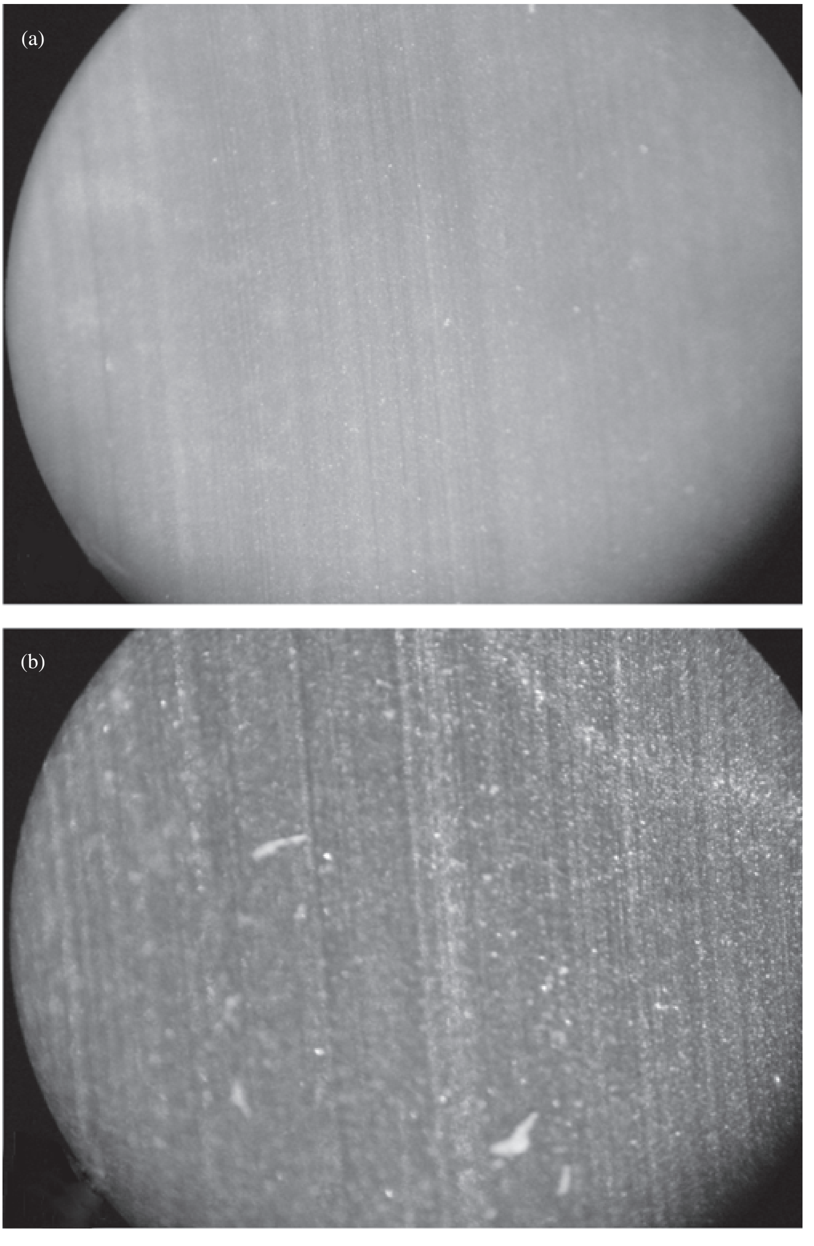

FIG. 16. Surface of egg cases of (a) *Sympterygia acuta* and (b) *Sympterygia bonapartii* (×40).

longicephalus groups suggest a similar oviposition strategy. In contrast, the lack of egg-case tendrils of the *A. spongiceps* group of catsharks suggests an evolutionary divergence (Flammang *et al*., 2007). *In vivo* observations show that egg-case tendrils of the *A. brunneus* and *A. longicephalus* groups were wrapped around sedentary organisms.

The egg case morphology of *C. callorynchus* is similar to those of the other two described species of the genus, the cape elephantfish *Callorhinchus capensis* Duméril 1865 and the ghost shark *Callorhinchus milii* Bory de Saint-Vincent 1823 (Smith & Griffiths, 1997; Hamlett, 2005) The zig-zig pattern observed in the capsule surface of *C. callorynchus* is unique among chondrichthyans. Unfortunately, the description of egg case surfaces of other species of *Callorhinchus* is lacking.

Despite the high diversity and distribution of skates, comparative studies of their egg cases are scarce and restricted to Japanese waters and the Bering Sea (Ishiyama, 1958; Ebert, 2005; Ebert & Davis, 2007). In the northern hemisphere, egg cases of *Bathyraja* have been studied in detail since the middle of the last century (Ishiyama, 1958; Ishiyama & Ishihara, 1977; Ishiyama & Ishihara, 1985; Stehmann & Merrett, 2001; Ebert, 2005; Ebert & Davis, 2007). Egg cases in the south-west Atlantic Ocean are very similar to those of the northern hemisphere. Although *Bathyraja* shows a high species diversity, with wide distribution ranges (McEachran & Miyake, 1990) the egg cases have a very conservative morphology, with typically strongly curved posterior horns. Orlov & Biryukov (2005) suggest that this characteristic feature probably facilitates the egg emergence from the cloaca.

In the worldwide genus *Dipturus*, two distinct forms of capsules were described. *Dipturus trachyderma* possesses the largest egg case (222–230 mm) and an unusual case morphology according to the analyses made here. The egg case has well-developed aprons and lateral keel, matching with those of other species from the northern hemisphere, such as the giant skate *Dipturus gigas* (Ishiyama 1958) (235 mm) and the longnosed skate *Dipturus oxyrinchus* (L. 1758) (140–235 mm) (Ishiyama, 1958; Bor, 2006), and those from Australian waters for instance, the wedgenose skate *Dipturus whitleyi* (Iredale 1938) (220 mm) (Treloar *et al.*, 2006). The other type of capsule morphology in *Dipturus* (as shown by *Z. chilensis*) corresponds to an egg case typically shaped without a developed lateral keel and an anterior apron, similar to other conspecific dipturids (Bor, 2006). Treloar *et al.* (2006) described the capsules of several species of *Dipturus* showing a varied morphology, these included the thornback skate *Dipturus lemprieri* (Richardson 1845) and *Dipturus* sp. B (= *D. canutus*) similar to *Z. chilensis*.

With regard to species identification based on the external morphological features, the endemic genus *Psammobatis* is the most problematic; in contrast, species identification by egg case characters is less problematic. This genus possesses the smallest egg case among worldwide skates: *P. rutrum* has capsules that reach *c*. 30 mm length (Bor, 2006). The features of the capsules of the raspthorn sandskate *Psammobatis scobina* (Philippi 1857) (Concha *et al.*, 2009) are coincident with those (described here) of *P. normani*.

The genus *Sympterygia* has the largest posterior horn compared to other skates. Oddone & Vooren (2002) found capsules of *S. acuta* with posterior horns of 440 mm in length. Egg cases of *S. acuta* and *S. bonapartii* are commonly found on sandy beaches of the Buenos Aires coast, frequently attached to the debris. Long tendrils may help to secure the egg case with some form of substratum (Flammang *et al.*, 2007). The coasts of southern Brazil, Uruguay and northern Argentina generally lack hard bottom substrata and appropriate sea-floor vegetation for the attachment of egg cases. Flammang *et al.* (2007) have established that these are the reasons for the development of extremely long horns with silky fibres in these species. The absence of hard substrata could be a pressure for the development of long tendrils, which may help to secure anchorage with other capsules and then make them difficult to remove from the spawning site. This characteristic (an extremely long posterior horn) feature was also observed in the egg cases of an Australasian skate of the genus *Pavoraja* (Treloar *et al*., 2006). Capsules of *Sympterygia,* however, also possess a marked thickening of the lateral keel, which is a feature not observed in species of *Pavoraja* or any other species.

Egg cases of *A. doellojuradoi* possess a remarkable lateral keel extending the length of the case and tapering off along outer edge of horns. The anterior end of the horn finishes abruptly, whereas its posterior end tapers progressively. These characteristics were also observed in *A*.cf. *hyperborea* from Australian waters (Treloar *et al*., 2006) and in an unidentified deep-sea egg case from the eastern North Pacific Ocean (Ebert & Davis, 2007). The latter specimen was called an 'unidentified deep-sea skate egg case B', because it was collected from benthic samples and not from a female uterus. Ebert & Davis (2007) explained that a female of the broad skate *Amblyraja badia* (Garman 1899) was observed swimming in the vicinity of where these egg cases were collected. As *A. badia* is the only species of *Amblyraja* reported for the eastern North Pacific Ocean, these egg cases probably correspond to this species. Morphologically, capsules of the three species are very similar, with that of *A. doellojuradoi* being the smallest. This is unsurprising given that *A. doellojuradoi* is the smallest species of the genus reaching at least 600 mm total length (L_T), whereas *A. badia* and *A. hyperborea* reach *c*. 1000 mm L_T.

The foregoing description of egg cases of *Rioraja* and *Atlantoraja* species are consistent with those made previously for Brazilian waters (Oddone *et al*., 2006).

As egg cases can be a useful tool for identifying chondrichthyan species, a provisional key to the south-western Atlantic Ocean chondrichthyan egg cases is presented here.

IDENTIFICATION KEY FOR CHONDRICHTHYAN EGG CASES OF THE SOUTH-WEST ATLANTIC OCEAN

1a. Spindle-shaped egg case, with anterior and posterior tubular extensions and lateral flanges, and without horns or tendrils .... *Callorhinchus callorynchus*

1b. Egg case not spindle shaped, horns or tendrils on one or both ends 2

2a. Cigar-shaped egg case with tendrils 3

2b. Rectangular egg case with anterior and posterior horns 4

3a. Egg case with posterior curled tendrils .... *Schroederichthys bivius*

3b. Egg case with anterior and posterior curled tendrils .... *Scyliorhinus* spp.

Remarks: Two species of *Scyliorhinus* have been reported for Uruguayan waters (see references in text), but probably their egg-laying area is in southern Brazil. Capsules characteristics were taken from Gomes & de Carvalho (1995) and Bor (2006).

4a. Egg case length (ECL) >110 mm; well-developed posterior apron (>30% of ECL); dorsal and ventral surfaces of case covered with dense woven-like fibers; surface of the case beneath the fibrous layer relatively smooth, finely striated and without ridges . . . . *Dipturus* and *Zearaja*

4b. The ECL <110 mm; posterior apron narrow or moderately developed (<30% of ECL); only the dorsal surface of case covered with dense woven-like fibres, or surface without these woven-like fibres 6

5a. The ECL >200 mm, lateral keel >20 mm . . . . *D. trachyderma*

5b. The ECL <170 mm, lateral keel <20 mm . . . . *Z. chilensis*

Remark: Other species of *Dipturus* could be found in the Argentine continental shelf (see references in text), whose egg cases have not been observed.

6a. Posterior horns thread-like, their length >1·4 times case length, lateral keel thickness >1·6 times lateral keel width . . . . *Sympterygia* 7

6b. Posterior horns progressively thinner, of different lengths, lateral keel thickness up to one time lateral keel width 8

7a. The ECL >65 mm, posterior horns long, <2·5 times case length. . . . . *S. bonapartii*

7b. The ECL <60 mm, posterior horns very long, >3·5 times case length . . . . *S. acuta*

8a. The ECL <60 mm . . . . *Psammobatis* 9

8b. The ECL >60 mm 14

9a. The ECL ≤31 mm 10

9b. The ECL >34 mm 11

10a. Posterior apron more than twice anterior apron width . . . . *P. extenta*

10b. Posterior apron less than twice anterior apron width . . . . *P. rutrum*

11a. Square-shaped case, case width >80% of ECL, anterior apron straight or slightly convex . . . .*P. bergi*

11b. Rectangular-shaped case, case width <75% of ECL, anterior apron concave 12

12a. The ECL ≤40 mm, anterior horn straight distance <20 mm . . . . . *P. lentiginosa*

12b. The ECL >40 mm, anterior horn straight distance >20 mm 13

13a. Posterior apron with a flange, anterior horn straight distance <50% of case length . . . . *P. rudis*

13b. Posterior apron without a flange, anterior horn straight distance generally >50% (49–60%) of ECL . . . . *P. normani*

14a. Posterior horns strongly curved towards the inside, making a semicircle, surface of case rough or relatively smooth .... *Bathyraja* 15

14b. Posterior horns straight or slightly curved 18

15a. Lateral keel thickness >2 mm 16

15b. Lateral keel thickness <2 mm 17

16a. The ECL >90 mm, maximum width >50 mm, surface of case with longitudinal striation with long and thin prickles of different size, giving a velvety texture to the touch .... *B. albomaculata*

16b. The ECL <90 mm, maximum width <50 mm, egg case surface texture coarse and very rough to the touch, covered by papillose longitudinal ridges; prickles with different sizes and shapes .... *B. macloviana*

17a. Lateral keel somewhat light, ≥6 mm; surface of case with longitudinal striation with long and thin prickles of similar size, posterior horns longer than anteriors, the lateral keel width (LKW) is relatively broad, 12–16% of the maximum egg case width (MAW) .... *B. magellanica*

17b. Lateral keel somewhat dark, ≤6 mm; egg case surface is relatively smooth, finely striated, with rasp-like denticles and without prickles; LKW relatively narrow (6–11% of MAW) .... *B. brachyurops*

Remark: Other four species of the genus are present in the Argentine continental shelf where egg cases have not been observed. Possibly adult females lay its capsules at depth furthermore the continental slope.

18a. Anterior horn straight distance >50% of ECL, with attachment fibres displayed in the lateral keel next to each horn .... *Rioraja agassizi*

18b. Anterior horn straight distance <50% of ECL, if it is greater, ECL is always >90 mm, attachment fibres absents or displayed in a different way 19

19a. Posterior horns very large, longer than case length, lateral keel tapering progressively to anterior horns .... *Atlantoraja* 20

19b. Posterior horns shorter than ECL, lateral keel tapering abruptly in anterior horns .... *A. doellojuradoi*

20a. The ECL >95 mm, dorsal surface with woven-like fibres; surface of case beneath fibrous layer finely striated without ridges .... *A. castelnaui*

20b. The ECL <80 mm, without woven-like fibres; surface of case longitudinally and uniformly striated with marked ridges especially on dorsal face 21

21a. Posterior horns long, their length <1·5 times ECL; MAW <60% of ECL .... *A. cyclophora*

21b. Posterior horns very long, their length > 1·5 times ECL; MAW >60% of ECL .... *A. platana*

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