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FULL PAPER

Egg capsules of the yellownose skate *Zearaja chilensis* (Guichenot 1848) and the roughskin skate *Dipturus trachyderma* (Krefft and Stehmann 1974) (Rajiformes: Rajidae) from the south-eastern Pacific Ocean

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Abstract Egg capsules of *Zearaja chilensis* were obtained from individuals kept in captivity and from dead specimens captured in Valparaíso Bay, central Chile. One female under laboratory conditions deposited three pairs of egg capsules in 6 days. The egg capsules of *Dipturus trachyderma* were obtained from a female captured in Valdivia, south Chile. Fresh egg capsules of both species were golden-brown and thick walled. Size of egg capsules of *Z. chilensis* ranged from 94 to 144 mm in capsule length and 64 to 76 mm in capsule width. Those of *D. trachyderma* ranged between 197 and 199 mm in capsule length and 110.0 and 129.0 mm in capsule width. Range and mean values of capsule length and width of egg capsules described in this study were smaller than those reported for the same species in the south-western Atlantic Ocean. This is the first report on egg-laying rate of *Z. chilensis* and the first description of egg capsules of *Z. chilensis* and *D. trachyderma* from the south-eastern Pacific Ocean.

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Introduction

The egg capsule is the tertiary egg envelope in oviparous cartilaginous fishes that protects the embryo throughout its development on the sea floor (Hamlett and Koob 1999) or any other type of substrate (Oddone and Vooren 2002; Treloar et al. 2006; Concha et al. 2009, 2010). Comprehensive descriptions of capsules have been considered as a useful tool for systematics, reproductive behaviour and phylogenetic relationships (Clark 1922; Ishiyama 1958; Concha et al. 2009; Ishihara et al. 2012).

The yellownose skate *Zearaja chilensis* (Guichenot 1848) and the roughskin skate *Dipturus trachyderma* (Krefft and Stehmann 1974) are two commercially important fishes in South America with similar geographic distributions, occurring on the continental shelf from central Chile to southern Brazil (Agnew et al. 2000; Menni and Stehmann 2000). Along the entire distribution range, both species are caught as target or bycatch in bottom longline (Bustamante et al. 2012) or trawl fisheries (Cedrola et al. 2005). Despite some aspects of the life history of *Z. chilensis* being previously reported (Licandeo et al. 2006; Licandeo and Cerna 2007; Paesch and Oddone 2008a; Bustamante et al. 2012), little information is available for *D. trachyderma* (Licandeo et al. 2007). Recently, Mabragaña et al. (2011) described the egg capsules for both species, together with 19 elasmobranchs from the south-western Atlantic. Nevertheless, descriptions of the egg capsules or egg-laying rate of skates in the south-eastern Pacific are still lacking in the literature. The aim of this work is to provide a detailed description of the egg capsules of both species, based on Chilean samples, and to

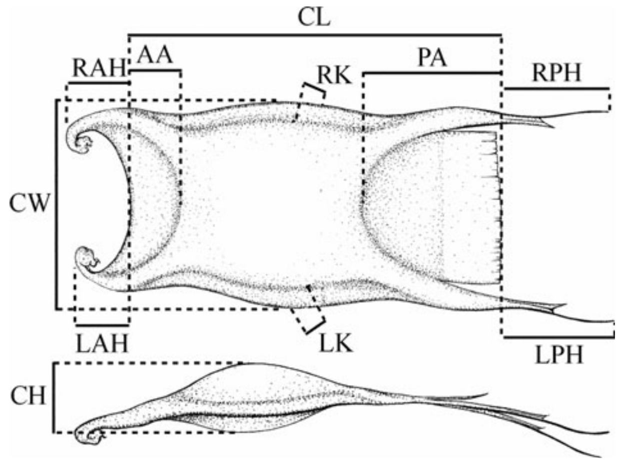

Fig. 1 Measurements performed on the dorsal and lateral faces of the egg capsules. *CH* capsule height, *CL* capsule length, *CW* capsule width, *AA* anterior apron length, *PA* posterior apron length, *RAH* right anterior horn length, *LAH* left anterior horn length, *RPH* right posterior horn length, *LPH* left posterior horn length, *RK* right keel, *LK* left keel

provide the first observations of egg-laying rate of *Z. chilensis* in captivity.

Materials and methods

Six female *Zearaja chilensis*, ranging in size from 1,003 to 1,053 mm total length (TL), were caught as bycatch in the artisanal trawl fishery at 50 m depth off Caleta Higuerillas, Chile (32°55′47.81″S, 71°32′18.23″W) in May 2010. Seven egg capsules were obtained from the uteri of four dead specimens, while two skates that survived the trawl were transported alive and kept in aquaria at Laboratorio de Biología y Conservación de Condrictios, Universidad de Valparaíso facilities, where, after 2 days in captivity, they laid eight egg capsules. The egg capsules were maintained in aquaria until hatched and later fixed in 80 % ethanol and deposited at the egg capsules collection at Universidad de Valparaíso (museum accession numbers CCM-16 to CCM-32). Additionally, a single pair of egg capsules of *Dipturus trachyderma* were obtained from the uterus of a 2,640 mm TL female captured at depth of 300 m by a demersal longline fishing vessel off Valdivia, Chile (39°50′S) and stored in the same collection (museum accession numbers CCM-175 and CCM-176). Measurements of the egg capsules were taken point to point to the nearest 0.01 mm (Fig. 1), and terminology follows Oddone et al. (2004) and Concha et al. (2009).

Results

Recently laid or in uteri egg capsules of *Zearaja chilensis* (Fig. 2) are golden-brown in colour, becoming darker with

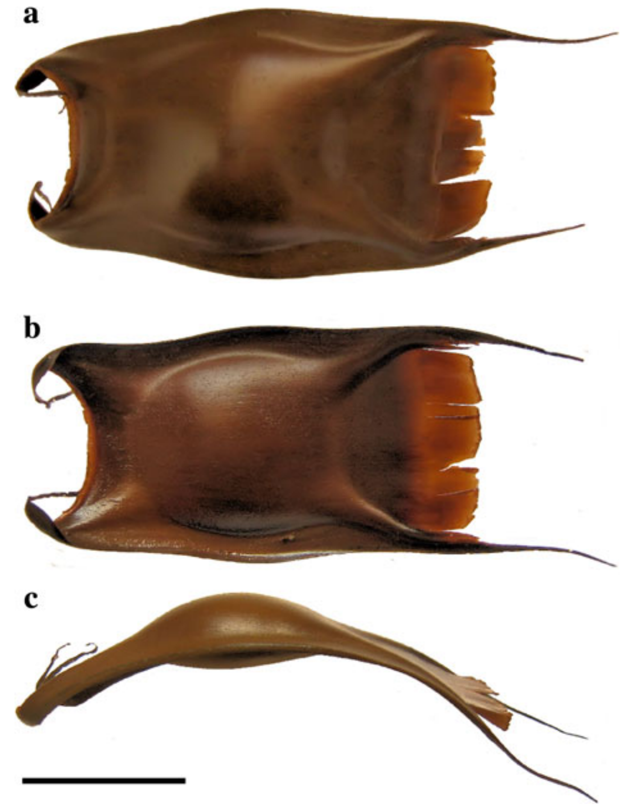

Fig. 2 Dorsal (**a**), ventral (**b**) and lateral (**c**) views of the egg capsules of *Zearaja chilensis*. *Scale bar* 50 mm

time. Egg capsules are stout, thick walled, non-translucent and barrel shaped, with a soft surface lacking striations. Five months after deposition, respiratory fissures open and the capsules become less turgid. In lateral view, the dorsal face of the capsule is noticeably more convex than the ventral face. The anterior horns are short, stout and curved ventrally inwards but do not cross over. The tips of the horns are dorsoventrally flattened and non-tendril like. Capsule edges are strongly secured; the anterior margin is sealed by a concave apron and laterally by thick keels (ca. 8.5 mm), while the posterior apron is conspicuously larger than the anterior one. The posterior horns are longer and thinner than the anterior horns. An additional horn stems from the inner face of the posterior horns of recently laid and in uteri egg capsules. These are shorter and more flexible than the outer, reaching about 75 % of the outer horns' total length. These inner posterior horns disappeared after 5 months of incubation, giving way to groove-shaped respiratory fissures. Morphometric measurements of these egg capsules are presented in Table 1.

Three of the four pairs of egg capsules were laid after 2 days in captivity. One female laid three pair of fertilized eggs during a period of 6 days (27 May, 30 May and 1 June). The female died on 4 June, and no egg capsules were found in the reproductive tract. Mature oocytes were

Table 1 Proportional dimensions as percentage of egg capsule length (CL) for *Zearaja chilensis* ($n = 15$)

Measure	Proportion	Mean	SD	Range
CL	1	126.2	13.1	94–144
CW	0.58	72.2	4.1	64–76
CH	0.19	23.2	2.6	19–27
AA	0.1	12.7	3.8	6–17.5
RAH	0.25	31.3	4.1	22–37
LAH	0.26	31.9	4.8	23.5–38
PA	0.2	25.7	11.1	9–57
RPH	0.61	81.5	22.8	35–100
LPH	0.76	95.4	7.8	8–108
RK	0.07	8.4	1.8	6–11
LK	0.07	9.1	1.8	7–11.5

Mean value (mean), standard deviation (SD) and range are indicated for each measurement (in mm). Abbreviations of egg capsule measurements are indicated in Fig. 1

Table 2 Proportional dimensions as percentage of egg capsule length (CL) for *Dipturus trachyderma* ($n = 2$)

Measure	Proportion	CCM-175	CCM-176	Mean	SD
CL	1	199.0	197.0	198.0	1.0
CW	0.6	110.0	129.0	119.5	9.5
CH	0.06	15.7	8.2	12.0	3.8
AA	0.26	48.0	54.0	51.0	3.0
RAH	0.35	69.0	71.0	70.0	1.0
LAH	0.37	73.0	73.0	73.0	0.0
PA	0.27	52.0	55.0	53.5	1.5
RPH	0.38	75.0	75.0	75.0	0.0
LPH	0.40	76.0	81.0	78.5	2.5
RK	0.13	24.0	26.0	25.0	1.0
LK	0.15	32.0	28.0	30.0	2.0

Mean value (mean) and standard deviation (SD) are indicated for each measurement (in mm). Abbreviations of egg capsule measurements are indicated in Fig. 1

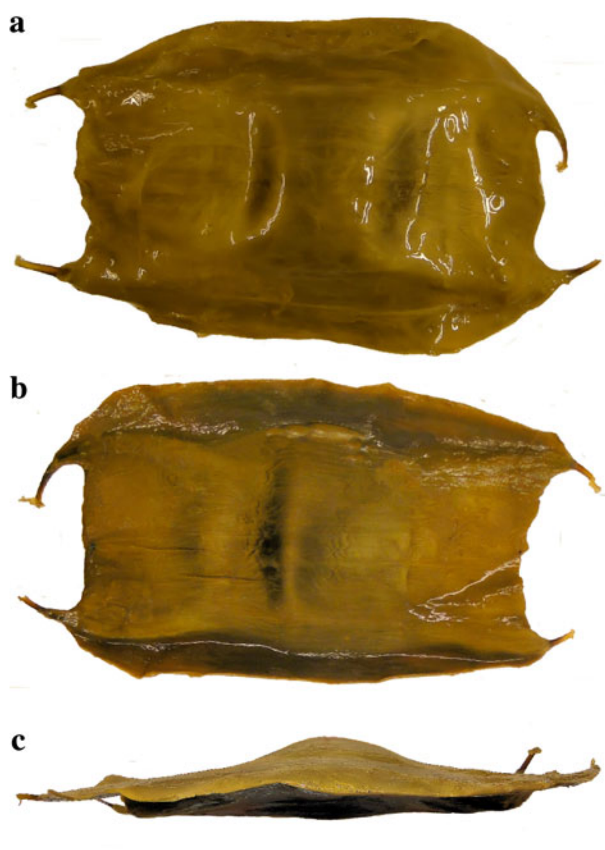

Fig. 3 Dorsal (**a**), ventral (**b**) and lateral (**c**) views of the egg capsules of *Dipturus trachyderma*. *Scale bar* 100 mm

observed in both ovaries, and nidamental glands were fully formed and functional.

The egg capsules of *D. trachyderma* are golden-brown in utero (Fig. 3). Egg capsules are stout, thick walled, non-translucent against transmitted light and barrel shaped; the surface is covered with thick longitudinal fibrils. Longitudinal grooves or striations are absent on egg capsule surface. In lateral view, the dorsal face is convex, while the ventral face is flat. Anterior and posterior horns are very short, thin, flexible and inwardly curved. The tips of the horns were brown and tubular, not flattened and translucent. Edges of the capsule were strong and keeled. The anterior apron is concave, and the posterior apron is similar but larger. Morphometric measurements of these egg capsules are presented in Table 2.

Discussion

Elasmobranch egg capsules exhibit distinctive morphologies between genera and even species. Accurately identified egg capsules may therefore provide information on the distribution and reproductive biology of skates. Numerous authors have provided descriptions of egg capsules in several skate genera of South America over the last few years, such as *Atlantoraja* Menni 1972 (Oddone 2005; Oddone and Vooren 2008; Oddone et al. 2004, 2008), *Bathyraja* Ishiyama 1958 (Paesch and Oddone 2008b), *Dipturus* Rafinesque 1810 (Paesch and Oddone 2008a; Mabragaña et al. 2011), *Psammobatis* Garman 1877 (Mabragaña and Cousseau 2004; Concha et al. 2009), *Rioraja* Whitley 1939 (Oddone et al. 2006), *Sympterygia* Müller and Henle 1837 (Oddone and Vooren 2002; Mabragaña et al. 2002; Jañez and Sueiro 2009) and *Zearaja* Whitley 1939 (Mabragaña et al. 2011). However, information of egg capsules of skates from the Pacific coast remains poorly reported, being restricted to five species of the genus *Psammobatis* (Mabragaña and Cousseau 2004; Concha et al. 2009) and one species each of *Zearaja* and *Dipturus*, with almost all descriptions based on individuals from off the Atlantic Ocean (Mabragaña et al. 2011). It is important to note that both range and mean values of length and width of egg capsules analysed in this study were considerably smaller than those reported for the same species in the Atlantic Ocean (Mabragaña et al. 2011). This could be due to female size or geographic variation. The growth pattern reported by Licandeo and Cerna (2007) indicated that specimens from both the southern and Patagonian sheltered fjords attained larger L_{∞} and grew more slowly than those skates from central and southern Chile (Fuentealba and Leible 1990; Licandeo et al. 2006; Licandeo and Cerna 2007). Nevertheless, larger sample sizes from both (Pacific and Atlantic) populations are still needed to confirm these observations.

Egg-laying rates were previously reported for *Raja brachyura* Lafont 1873 (see Clark 1922), *Raja montagui* Fowler 1910, *Raja clavata* Linnaeus 1758 (see Holden et al. 1971), *Leucoraja naevus* (Müller and Henle 1841) (see Du Buit 1976), *Okamejei kenojei* (Müller and Henle 1841) (see Ishihara et al. 2002), *Dentiraja lemprieri* (Richardson 1845), *Dipturus confusus* Last 2008 (see Treloar 2008) and *Sympterygia bonapartii* (Müller and Henle 1841) (see Jañez and Sueiro 2009). These authors reported rates fluctuating between 0.24 and 0.5 egg capsules per day. Nevertheless, Holden et al. (1971) mentioned that *R. clavata* could even deposit one egg capsule each 24 h (one pair in 48 h), as we observed in this work. The influence of both body size and experimental conditions on the egg-laying rate requires a further research effort to determine accurate egg-laying rates and size at birth.

The egg capsules of *D. trachyderma* are, until now, the largest elasmobranch egg capsules in South America, with lengths comparable to those reported for *Raja brachyura*, from the north-east Atlantic (Gallagher et al. 2004), and *Beringraja binoculata* Girard 1855, from the north-east Pacific (Eschmeyer et al. 1983; Ebert and Davis, 2007). Based on our observations we confirm that *Z. chilensis* and *D. trachyderma* are single oviparous skates, bearing one egg capsule per oviduct at a time, with synchrony in nidamental gland synthetic activity as in other rajoid species (McEachran and Aschliman 2004; Ebert and Compagno 2007).

Numerous authors have treated the egg capsules of skates and oviparous sharks as a diagnostic taxonomic character due to their species-specific morphology and low intraspecific variation (Treloar et al. 2006; Ebert and Davis 2007; Ishihara et al. 2012). The genus *Dipturus* contains at least 46 nominal species with 31 currently recognized as valid (Ebert and Compagno 2007). Several species currently included in this genus are questionably placed, and its composition remains in a state of taxonomic flux (McEachran and Aschliman 2004). *Zearaja chilensis* was formerly placed in *Dipturus*, but later assigned to the current genus based largely upon clasper anatomy (Last and Gledhill 2007). Ishiyama (1958) suggested that the egg capsule morphology of Japanese skates could be used to determine phylogenetic relationships between species; however, the value of egg capsule morphology as a phylogenetic tool requires assessment within both local and worldwide rajoid assemblages. Treloar et al. (2006) noted a range of morphological features that aid the identification of skate egg capsules. These authors argued that, despite some overlap in egg capsule size between species, other features such as horn and apron lengths, shape, and presence/absence of a lateral keel and attachment fibres may be analysed, whether the egg case is fresh or not. Oddone et al. (2004) observed that apron morphology could be used to distinguish capsules of *Atlantoraja platana* (Günther 1880) and *Atlantoraja cyclophora* (Regan 1903) in instances when these were of similar sizes.

The egg capsules of *D. trachyderma* have proportionally smaller horns, located closer to the apron terminal zone than those of *Z. chilensis* egg capsules. This is similar to *Dipturus* cf. *gudgeri* (Whitley 1940) in which the posterior horns enclose the apron (Treloar et al. 2006). However, further research is required to determine the taxonomic value of this character, and the significance that should be placed upon it when describing egg capsules. On the other hand, Ishiyama (1958) provided pictures and schemes of the egg capsules of *Dipturus tengu* (Jordan and Fowler 1903) (referred to as species “W” or “*Raja* sp.”) and *Dipturus gigas* (Ishiyama 1958) (referred to as species “T”), the latter of which showed remarkable similarities to those of *D. trachyderma*. The relative absence of egg capsule descriptions limits their use in phylogenetic analyses, but the gradual increase of knowledge on the reproductive biology of Neotropical skates may help clarify the numerous and confusing phylogenetic relationships in both living and extant oviparous elasmobranchs.

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