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Morphological characteristics of five bycatch sharks caught by southern Chilean demersal longline fisheries

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SUMMARY: The by-catch of sharks in artisanal demersal pink cusk-eel (*Genypterus blacodes*) and yellownose skate (*Dipturus chilensis*) fisheries is frequent within their fishing effort. Nevertheless, there is no registry of landings, which could help to control this problem. This is particularly evident for endemic species, which includes most coastal and deep water Chilean sharks. The main systematic characteristic of these Chondrichthyan species is the external morphology of the neurocraneum. The form and arrangement of the teeth and dermal denticles allow specific differences to be identified. The objective of this paper is to contribute to the biology and systematic knowledge of demersal shark species, teeth and dermal denticle morphology and neurocraneum morphometrics of two species of Scyliorhinids, the redspotted catshark (*Schroederichthys chilensis*) and the dusky catshark (*Halaelurus canescens*), as well as three Squaliforms, the granular dogfish (*Centroscyllium granulatum*), the birdbeak dogfish (*Deania calcea*) and the spiny dogfish (*Squalus acanthias*).

Keywords: shark bycatch, teeth, dermal denticles, neurocraneum morphology.

RESUMEN: Características morfológicas de cinco tiburones capturados por la pesquería palangrera demersal del sur de Chile. – El descarte de tiburones en las pesquerías demersales artesanales de congrio dorado (*Genypterus blacodes*) y de la raya volantín (*Dipturus chilensis*) es frecuente dentro de sus faenas de pesca, sin embargo, no existe un monitoreo sobre los desembarques que permita controlar este problema. Esto es evidente en especies endémicas, como son la mayoría de los condrictios costeros y de aguas profundas. El principal carácter sistemático de estas especies es su morfología externa, además de la forma del neurocráneo y disposición de dientes y dentículos dérmicos los que nos permiten identificar diferencias específicas. El objetivo de este trabajo es contribuir al conocimiento biológico y taxonómico de cinco especies de tiburones demersales en cuanto a la morfometría del neurocráneo, y morfología de dientes y dentículos dérmicos, de dos especies de Scyliorhínidos, *Schroederichthys chilensis* y *Halaelurus canescens*; además de tres Squaliformes, *Centroscyllium granulatum, Deania calcea* y *Squalus acanthias*.

Palabras clave: descarte de tiburones, dientes, dentículos dérmicos, morfología del neurocráneo.

INTRODUCTION

The high mortality levels of discarded sharks in mid-demersal trawl net, purse seine net and pelagic long-line fisheries often exceed target species catches (Bonfil, 1994). Hall *et al.*, (2000), describe these discarded species as facultative ("by-product") or permanent ("by-catch"). The first corresponds to species that are incidentally caught that may be landed for local consumption or returned live to the sea. The second corresponds to species that are incidentally caught generally dead, but returned to the sea because they do not have any economic interest. Although coastal shark populations are seriously affected by discard, there are few records of shark landings. This is particularly evident for endemic species, which includes most coastal and deep water Chilean sharks (Lamilla, 2003). In Chilean waters up to 53 species of sharks have been recorded from six orders: 4 hexanchiforms, 25 squaliform, 1 squatiniform, 1 orectolobiform, 6 lamniforms and 16 carcharhiniforms (Lamilla and Bustamante, 2005). Low

preservation potential means that other cartilaginous fish are under-represented in fossil basins. Teeth, dermal denticles and calcified vertebral centres are the only elements that can be preserved and are often represented in archaeological registries (Wheeler and Jones, 1989). The main systematic characteristic that differentiates these Chondrichthyan species is the external morphology (Chirichigno, 1974; Compagno 1984, 2001). Within external morphological characteristics, the form and position of teeth and dermal denticles allows specific differences to be identified. Meléndez and Meneses (1989) presents four Chilean Scyliorhinidae species including a brief description on the form and arrangement of teeth and dermal denticles in addition to external morphological characteristics. In situations in which species are not identified accurately, they suggest adding other characteristics to the descriptions when external morphology is not diagnostic. Thus, the morphology of the neurocraneum could also be considered for identifying living sharks. According to Ishiyama (1958), these characteristics can be used as indicators for determining species since the structure of the neurocraneum is considered to be highly preservative in adults. According to Tanaka *et al*. (2001), the dermal denticles have specific species characteristics that could be useful for identifying shark fins or carcasses. The main objective of this paper is to contribute to the biology and systematic knowledge of demersal shark species, teeth and dermal denticles morphology and neurocraneum morphometrics. Our study includes two species of Scyliorhinids: the redspotted catshark, *Schroederichthys chilensis* Guichenot 1848; and the dusky catshark, *Halaelurus canescens* Günther 1878; as well as three Squaliforms: the granular dogfish, *Centroscyllium granulatum* Günther 1887; the birdbeak dogfish, *Deania calcea* Lowe 1839; and the spiny dogfish, *Squalus acanthias* Linnaeus 1758.

MATERIAL AND METHODS

Samples were obtained from the bycatch of artisanal demersal long-line pink cusk-eel (*Genypterus blacodes*) and yellownose skate (*Dipturus chilensis*) fisheries at depths between 44 and 400 m along the coast of Valdivia (Fig. 1). 330 specimens were collected on 17 fishing trips by onboard observers during the fishing season of 2005 (January to June). The specimens included 62 *Centroscyllium granulatum*, 56 *Deania calcea*, 92 *Squalus acanthias*, 64 *Halaelurus canescens* and 56 *Schroederichthyes chilensis*. Specimens were transported to ELASMOLAB (Elasmobranchs Laboratory) at Universidad Austral (UACH) where they were analyzed and preserved in formalin (10%). Morphometric parameters were obtained for each species for the neurocraneum, teeth and dermal denticles following the methodologies described for the neurocraneum (Ishiyama, 1958; Compagno, 1984), teeth (Applegate, 1965; Jhons *et al*., 1997) and dermal denticle (Deynat, 2000; Tanaka *et al.,* 2001; Gravendeel *et al.,* 2002) morphology.

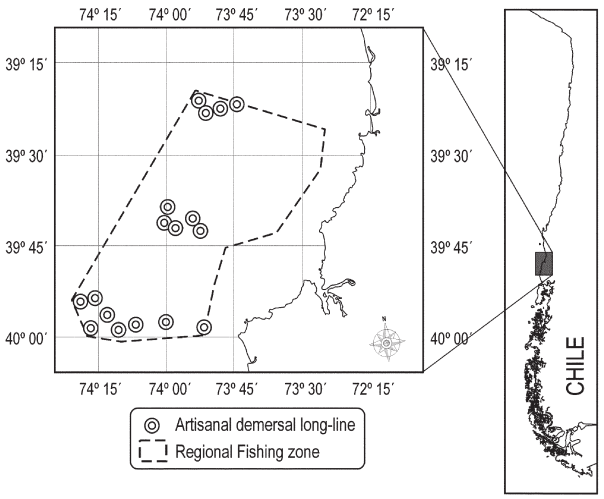

FIG. 1. – Sampling zone of the artisanal fisheries of *Genypterus blacodes* and *Dipturus chilensis* during 2005. Fishing trips and regional fishing zone are indicated

For the body and neurocraneum, the Compagno methodology and similar references for other biological characteristics were used. The list of terms and glossary adapted from this author (Compagno, 2001) were also used to describe the position and parts of the teeth and dermal denticles.

RESULTS

Demographic parameters for by-catch sharks off the coast of Valdivia are indicated in Table 1 with total length values. The most abundant species recorded during this season were Squalus *acanthias* (28%) followed by *Centroscyllium granulatum* and *Halaelurus canescens* (both 38%). 72% of females of *C. granulatum* were pregnant with mid-term embryos in the uterus. Most females (51%) of *H. canescens* had one egg-capsule per oviduct.

Morphological characteristics of the teeth were obtained by observing the anterior and anterolateral

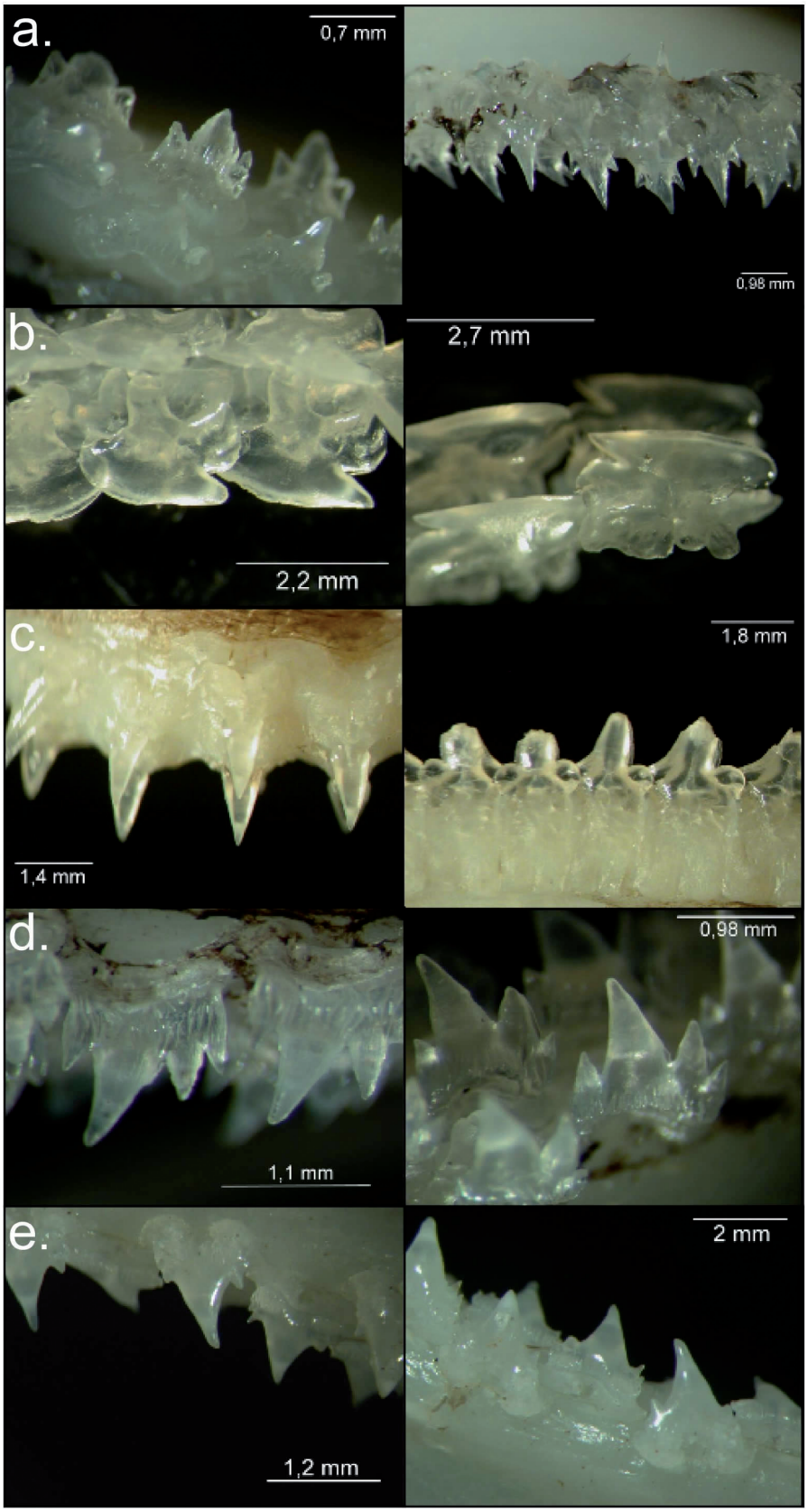

FIG. 2. – Frontal teeth of upper (left) and lower (right) jaws of (a) *Centroscyllium granulatum*; (b) *Squalus acanthias*; (c) *Deania calcea*; (d) *Halaelurus canescens*; and (e) *Schroederichthys chilensis*. Scale bar (in mm) is indicated on each photograph.

TABLE 1. – Demographic parameters of sharks obtained in artisanal fishery bycatch off the Valdivia coast. Values shown are: total length (in cm), and its minimum (MIN), maximum (MAX), mean (MEAN) and standard deviation (SD) for each species

SPECIES	SEX	n	MIN	MAX	MEAN	SD
Squalus acanthias	males	48	53	75	63.04	4.33
	females	44	56	79	68.34	5.72
Centroscyllium granulatum	males	12	38	42	39.65	1.60
	females	50	17.5	51	43.56	8.18
Halaelurus canescens	males	60	50	73	60.43	6.02
	females	4	70	71.5	70.75	1.06
Deania calcea	males	36	66	85	72.33	4.86
	females	20	88	104	92.30	4.88
Schroederichthys chilensis	males	42	44	60	52.14	4.65
	females	14	39.5	59	48.07	7.23

TABLE 2. – Morphological neurocraneum characteristics of five sharks, all measurements are in mm and Cranial Longitude percentage. * = Absent measure.

Neurocraneum character	*C. granulatum*		*D. calcea*		*S. acanthias*		*H. canescens*		*S. chilensis*	
	(mm)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)
Cranial Longitude	40	100	125	100	67	100	59	100	72	100
Rostral cartilage longitude	18	45	33	26.4	22	32.8	26	44.1	29	40.3
Prefontanel longitude	10	25	5	4	24	35.8	17	28.8	23	31.9
Craneal width	28	70	46	36.8	46	68.6	41	69.5	35	48.6
Interorbital width	19	47.5	30	24	25	37.3	9	15.2	18	25
Rostral cartilage basin	18	45	15	12	18	26.8	11	18.6	15	20.8
Rostral cartilage width	5	12.5	7	5.6	17	25.4	10	16.9	14	19.4
Fontanel longitude	8	20	20	16	7	10.4	9	15.2	13	18.1
Fontanel width	5	12.5	10	8	5	7.5	4	6.8	5	6.9
Rostral appendix longitude	4	10	14	11.2	9	13.4	8	13.5	10	13.8
Rostral appendix width	6	15	9	7.2	11	16.4	15	25.4	19	26.4
Cranium height	16	40	31	24.8	28	41.8	6	10.2	8	11.1
Rostral cartilage height	4	10	10	8	7	10.4	*	*	*	*

tooth on the upper and lower jaws of each species. *C. granulatum* has a tricuspid homodont dentition, with smaller teeth on the lower jaw, a narrow sharpened principal cusp with smaller lateral cusp and smooth striated labial enamel (Fig. 2a). *S. acanthias* has small superposed teeth (2.2 mm wide root), the main cusp is curved towards the mouth angle, and there are smooth sharpened edges without serrations on the deep notch and shoulder (Fig. 2b).

D. calcea exhibits heterodonty, with straight wide rooted unicuspid teeth on the upper jaw and smooth, mouth angle recurved cusp teeth on the lower jaw. It has compressed and sharp edged teeth on both jaws (Fig. 2c). *H. canescens* has multicuspid homodont teeth, with the smallest cusplets almost half the length of the main distal cusp, and coarse striated labial enamel (Fig. 2d). *S. chilensis* has homodont teeth similar to those of *Centroscyllium*, but without striation on the labial enamel, and with an angular main cusp distal with smaller lateral cusplets (Fig. 2e).

Fresh and preserved denticles were used to study the dermal denticle characteristics. *C. granulatum* has a spine-like morphotype (under 0.6 mm in length) with a firm apex that is curved slightly backwards (Fig. 3a). The basal plate is not fused with 7 to 9 symmetric, thin, radiated roots and open central foramen. The denticles are sparsely distributed (approx. 10 to 15 denticles.cm^{-2}). *D. calcea* denticles are moderately distributed (10 to 25 denticles.mm^{-2}) and slightly overlapping along the anterior rounded margin (Fig. 3b). Denticles have a four lobed crown with central crest in a central lobe. There is a smaller, upward-turned lobe on the anterior margin, and "W" shaped posterior margin resembling a bird's foot. The basal plate has five wide, fused, rounded roots. In *S. acanthias* denticles are small and densely distributed without overlapping (Fig. 3c). They have a three lobed crown with a smooth, blunt crest. The central crest is larger than the lateral ones. The basal plate has four wide, fused, straight roots. The denticles in *H. canescens* are densely distributed and

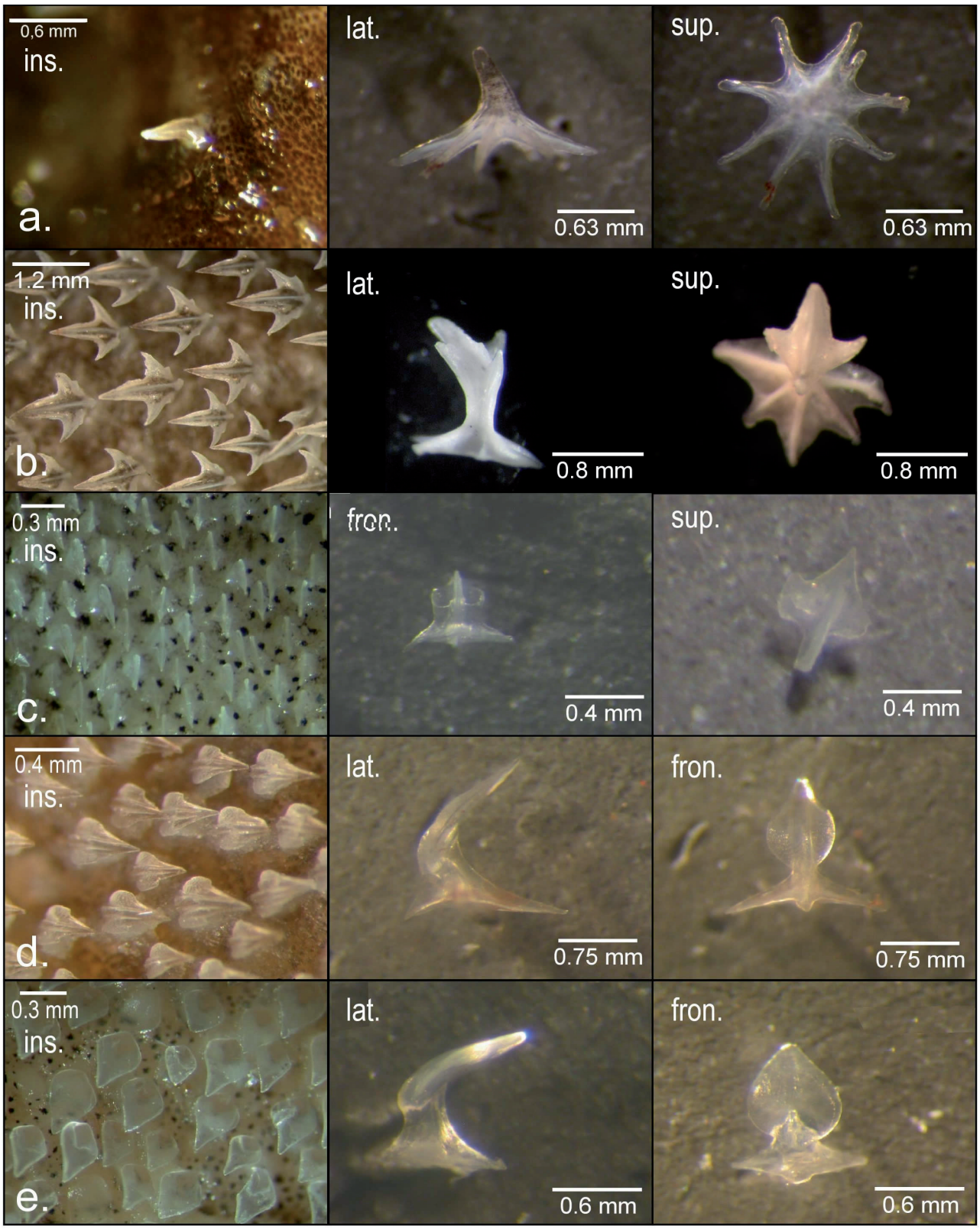

FIG. 3. – Post-pectoral ventral dermal denticles of (a) *Centroscyllium granulatum*; (b) *Deania calcea*; (c) *Squalus acanthias*; (d) *Halaelurus canescens*; and (e) *Schroederichthys chilensis*. ins: dermal denticle natural insertion in skin; lat: lateral view; fron: frontal view; up: top view. Scale bar (in mm) is indicated in each photograph.

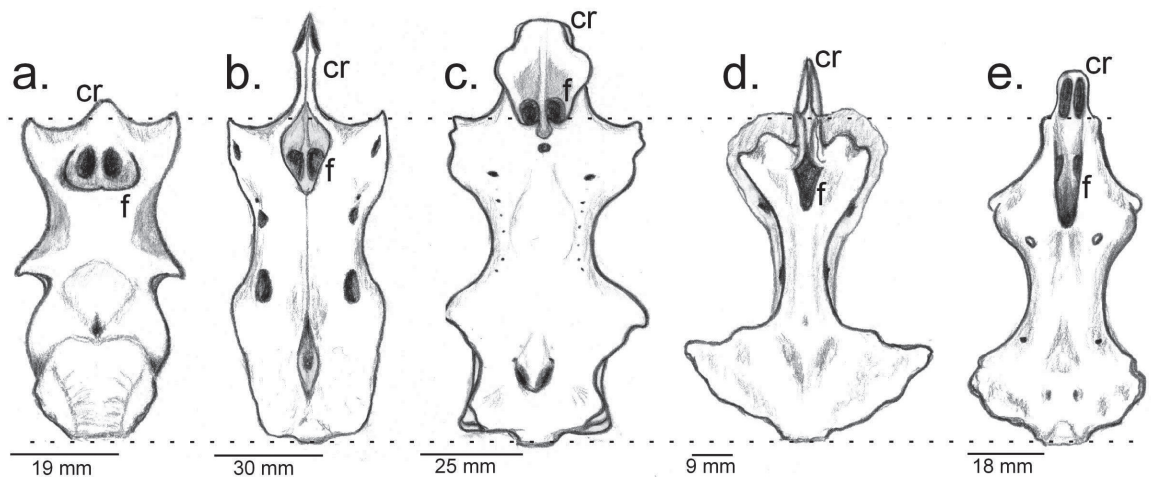

FIG. 4. – Neurocraneum of (a) *Centroscyllium granulatum* (42 cm LT), (b) *Deania calcea* (80.5 cm LT), (c) *Squalus acanthias* (68 cm LT), (d) *Halaelurus canescens* (63 cm LT) and (e) *Schroederichthys chilensis* (69 cm LT). Were cr: rostral cartilage; f: fontanel. Scale bar (in mm) is indicated in each photograph.

slightly overlapping along the anterior margin (Fig. 3d). The crown is feather-like with a wide central lobe and two symmetric crests. Lateral lobes are sometimes present in tail and young stages. The central crown lobe has scale-like ornamentations. The basal plate is fused to four thin, angular, irregular edged roots. *S. chilensis* denticles are densely distributed, overlapping the anterior and lateral margins. The crown has a feather-like shape with a single lobe and smooth "V" shaped posterior margin. The basal plate is wide and regular, with flat roots and open central foramen.

The neurocraneum morphometric characteristics were analyzed in adult reproductive stages. Values are expressed in mm and cranium total length (CL). As seen in Table 2, all values for neurocraneum parameters are in accordance with those of the Squaliform order (such as the genera *Centroscyllium, Deania* and *Squalus*), the rostral appendix is fused to the rostral cartilage (Fig. 4a). Carcharhiniforms (Scyllorhinids such as *Halaelurus* and *Schroederichthyes*) present a tricuspid rostral cartilage without rostral appendix (Fig. 4d).

DISCUSSION

The global and local increase of artisanal fisheries is reflected in the increase of shark by-catch. Although Chondrichthyes catches are often recorded, the taxonomic composition of these catches is often unknown (Bonfil, 1994). This has caused a significant decline in abundance of several species that are incidentally caught or are part of the by-catch of artisanal and industrial vessels around the world (Brander, 1981). This situation can be explained by sharks' high vulnerability to overfishing compared to bone-fish. Furthermore, shark species vary in sensitivity (Walker and Hislop, 1998; Stevens *et al*., 2000).

The prevailing fishing practices are not evaluated in terms of shark capacity required to preserve the population level (Walker and Hislop, 1998). Factors such as the constant and increasing fishing effort on target species, catches before reaching first sexual maturity, changes in the sharks' dense-dependent capacity and size structure or abundance, signify a decline in species population levels and the collapse of fisheries. Compagno (1984, 2001) emphasizes that researchers and scientists dedicated to elasmobranch studies (as well as condrichtyologists) have not reached a consensus on the methodological protocols used for morphometrical measurements; therefore, most of the information available is not comparable.

This study aims to complement existing information and, in some cases, to add new information for future research.

Meléndez and Meneses (1989) systematically describe three Chilean species, *D. calcea, C. granulatum* and *H. canescens*, including a brief description of the distribution and arrangement of teeth and dermal denticles in order to complement external morphological characteristics. For example, the lower jaw teeth of *C. granulatum* are smaller than those of the upper jaw. In *H. canescens*, teeth near the mouth symphysis have four symmetrical cusps, and are not as tree-cusped as the frontal and lateral

teeth are. Morphological descriptions for the dental and dermal denticles of *S. chilensis*, contribute to the knowledge of this species, and also enhance identification between species of the Scyliorhinids family, as outlined by Valenzuela *et al.,* 2006 (i.e. *Schroederichthys chilensis* and *S. bivius*)

Descriptions of the neurocraneum morphological characteristics are comparable to those described in the specialized literature (Compagno, 1988, Ishiyama, 1958). The measurements obtained for each shark studied can be considered as a reference for the possible study of neurocraneum taxonomic comparison keys. In Chile there is no published taxonomic key for identifying Chondrichthyan species that describes isolated morphological characteristics, as in fossil or stomach content registries. In addition, taxonomic identification keys are scarce and morphological characteristics are not comparable, which generates a lack of interpretation when identifying species (Leible *et al.,* 1981).

Recent publications such as Meléndez and Meneses (1989), Lamilla and Saez (2003) and Lamilla and Bustamante (2005), include a brief taxonomic and systematic description and standard methodological protocol as suggested by Compagno (2001).

Biological and fishery information is complemented by common sharks caught by artisanal demersal pink cusk-eel and yellownose skate fisheries in Valdivia (Chile). New biological information is available for endemic species. Using teeth, dermal denticles and neurocraneum morphology is also validated as a useful tool for taxonomic identification and systematic characterization when external morphology is not conclusive.

Specific taxonomic identification requires bringing together terms and criteria used in field guides, recognition sheets and taxonomic keys, as well as including external morphological specialization due to ontogeny and environmental adaptation.

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