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Living naked: first case of lack of skin-related structures in an elasmobranch, the blackmouth catshark (*Galeus melastomus*).

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Living naked: first case of lacking of skin related structures in an Elasmobranch, the blackmouth catshark *Galeus melastomus*

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Abstract

As far as is known, in this paper the first case of lacking of skin related structures (epidermis, *stratum laxum*, dermal denticles and teeth) in a free-swimming Elasmobranch, the blackmouth catshark *Galeus melastomus*, is reported. The individual was caught by trawl in Sardinian waters (central-western Mediterranean) in July 2019 at 500 m of depth. Although this kind of morphological abnormality is potentially fatal, the observations suggested that the specimen was in good health and well developed.

Key Words

Abnormalities, *Galeus melastomus*, Elasmobranchs, skin

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Elasmobranch skin represents a fundamental organ responsible for multiple functions, due to both the properties of its cellular layers and the peculiar characteristics of the tooth-like dermal denticles (Meyer and Seegers, 2012).

The mucus secreted by the columnar-like secretory cells of the epidermis layer is considered the first part of the immune system, as it prevents the colonization of infectious microbes through different mechanisms, such as its continuous production and removal and by containing antibacterial proteins (Dash et al., 2018; Meyer and Seegers, 2012). This function is completed by other cell types included in the epidermis, like lymphocytes, macrophages and granular leucocytes (Meyer and Seegers, 2012). The tooth-like dermal denticles represent the most external and characteristic skin structures. Due to their shape and composition, they provide a mechanical barrier, protecting the organism from environment, predators and ectoparasites, reducing also potential mechanical abrasions (Feld *et al.*, 2019; Meyer and Seegers, 2012). It has been proved that they facilitate locomotion by reducing the friction with water and by altering the hydrodynamic flow on the body surface (Oeffner and Lauder, 2012). Moreover, they act concentrating the light produced by luminescent organs, as observed in some deep-sea species (Reif, 1985). Finally, juveniles of species like *Scyliorhinus canicula* take advantage of dermal denticles to hold their prey against the body during feeding (Southall and Sims, 2003).

The most reported congenital morphological abnormalities in Elasmobranchs regard skin color aberrations, reproductive system and skeleton. Skeletal malformations are usually more severe and, thus, mainly observed among embryos (Moore, 2015), as they include alterations in the axial skeleton, in the cranium and in the fins development (e.g. Afonso *et al.*, 2016; Escobar-Sánchez *et al.*, 2014; Heupel *et al.*, 1999; Lamarca *et al.*, 2017; Mancini *et al.*, 2006; Moore, 2015; Sans-Coma *et al.*, 2017; Schmid *et al.*, 2019). Skin color aberrations, as well as reproductive system abnormalities, usually represent less severe conditions and are recorded to a greater extent among adult, free-swimming individuals (Moore, 2015). Particularly, skin color aberrations include albinism, defined as the total lack of pigmentation in both the skin and iris (e.g. Ball *et al.*, 2013; Becerril-Garcia *et al.*, 2017; Bigman *et al.*, 2016; Bottaro *et al.*, 2008; Clark, 2002; Quigley *et al.*, 2018), leucism, a particular form of albinism (e.g. Bigman *et al.*, 2016; Quigley *et al.*, 2018; Veena *et al.*, 2011) and irregular coloration (Gervais *et al.*, 2016). While these kind of aberrations could lead to higher mortality rates, especially for species that depend on colouration or pattern to survive, the observation of fully grown albino and leucistic individuals proves that color changes do not always lead to a reduction in survivorship (Ball *et al.*, 2013; Bigman *et al.*, 2016).This paper reports the first case of a free-swimming shark, the blackmouth catshark *Galeus melastomus* Rafinesque 1810, which presented a severe lack of all the skin related structures: epidermis, part of dermis, dermal denticles and teeth. As far as is known, this unusual skin abnormality could be the first reported case of this kind in Elasmobranchs.

G. melastomus is a common, small-sized catshark belonging to the family Pentanchidae that reaches a maximum Total Length (L_T) of about 70 cm (Serena *et al.*, 2009). It is widely distributed in the Northeast Atlantic and Mediterranean Sea at depths of 50-2000 m, although mostly abundant from 200 to 500 m (Follesa *et al*., 2011, 2019b; Serena *et al.*, 2009), and represents a common by-catch species with very low or no commercial value (Marongiu *et al.*, 2017; Serena *et al.*, 2009).

The abnormal *G. melastomus* was caught during a commercial trawl haul carried out on 10 July 2019 at 500 m depth off Cape Carbonara in South Sardinia (38° 50'N; 9° 35'E) and preserved frozen. The specimen, which measured 302 mm in L_T and weighted 82.7 g in total mass (M_T) was an immature female with normally-developed gonads at stage 1, according to the scales proposed for the oviparous Elasmobranchs in the MED.I.T.S. protocol (Follesa *et al.*, 2019a). The skin features of the abnormal specimen were compared to those of a normal immature female at stage 1, caught by the same fishing trawler in the same zone and depth on 25 July 2019, which measured 298 mm in L_T and weighted 78.35 g in M_T. Morphometric measurements of the abnormal individual were recorded from photographs through the TPS Dig2 software (Rohlf, 2005). The species was determined according to Compagno (1984) and Compagno *et al.* (2005) as follows: anal fin origin well in front of midlength of inter-dorsal space (S_{ID}); pre-oral length (L_{POR}) comprised between 6 and 9% of the L_T (L_{POR} = 7.32% L_T); pre-narial length (L_{PRN} = 12.5 mm) smaller than eye length (L_{EY} = 13.8 mm); mouth width (W_{MO}) comprised between 6 and 8% of the L_T (W_{MO} = 8% L_T); pelvic-anal space (S_{PA} = 25.5 mm) smaller than the anal base (B_{AN} = 44.1 mm); B_{AN} comprised between 13 and 18% of the L_T (B_{AN} = 14.6% L_T); inside of the mouth black (Figures 1a, c).

From a macroscopic point of view, skin was thin, smooth and translucent, due to the lacking of the dermal denticles, and particularly reduced around the gill openings, the nictitating membrane and the ampullary pores (Figure 1a, b, e, f, g, h). The ampullary pores showed the distribution typical of the species (Atkinson and Bottaro, 2006), but appeared larger than those of the normal individual (mean pore diameter ± s.d. = 0.38 ± 0.113 mm, N = 50 and 0.27 ± 0.038 mm, N = 50 in the abnormal and normal individual, respectively) (Figure 1e, f). Teeth were strongly reduced to some rudimental structures not visible to the naked eye (Figure 1c, d). The colour was pale yellowish in almost the entire body, except for the eyes, the abdomen, the gill openings and the inside of the mouth that represented the only fully pigmented body areas (Figure 1a, c). A histological analysis was conducted on sections of skin taken from the dorsal region of both the abnormal and the normal individual, embedded in resin and stained with Hematoxylin and Eosin (Cerri and Sasso-Cerri, 2003). In the normal individual, the dermal denticles were embedded in the dermis and surrounded by the multilayered epidermis with columnar cells (Figure 1j). The dermis was constituted by a *stratum laxum*, which comprised a layer of melanocytes, and a *stratum compactum* (Figure 1j). The comparison revealed that, in the abnormal specimen, the epidermis and the *stratum laxum* were totally missing (Figure 1i). Only few rudimental dermal denticles were visible (Figure 1i). Only the *stratum compactum* of the dermis seemed to be developed, with horizontally arranged layers of collapsed collagen fiber bundles (Figure 1i).

The stomach contents and the vertebral *centra* analysis showed that these morphological anomalies did not totally impaired the predatory skills and the correct development of this individual. According to the literature on the diet of *G. melastomus* in the Mediterranean Sea (e.g. Albo-Puigserver *et al.*, 2015; Anastasopoulou *et al.*, 2013; Valls *et al.*, 2011), the stomach contents of the abnormal individual comprised the residuals of 14 items belonging to cephalopods (*Abralia veranyi*, N = 2; *Heteroteuthys dispar*, N = 3), crustaceans (*Pasiphaea multidentata*, N = 5; *Meganyctiphanes norvegica*, N = 3) and bony fishes (*Ceratoscopelus maderensis*, N = 1). The analysis of vertebral centra (stained in Toluidine Blue), showed the presence of three distinct opaque rings of the band pairs (Figure 1k), allowing to assume that the abnormal specimen was three years old at least, in agreement with the growth curve estimated for the species by Baptista *et al.* (2010), suggesting that it followed a normal growth pattern.

It is unclear how this abnormality impacted the behavior, physiology or ecology of this individual. Given the functions performed by the skin, the lack of dermal denticles, epidermis and *stratum laxum* is likely to have modified swimming, maybe increasing its energetic cost and slowing it down (Oeffner and Lauder, 2012), and should have weakened the immune system (Garner, 2013; Meyer and Seegers, 2012). However, our observations lead to think that this abnormal condition did not totally compromised either the swimming skills or the functionality of sensory structures like the ampullary pores. The lack of teeth did not influenced the feeding abilities, probably because the blackmouth catshark ingests its prey whole. It could also be hypothesized that the organization of the *stratum compactum* provided protection from the surrounding environment.

Possible explanations for morphological abnormalities have been speculated by other authors over time and include both natural and anthropogenically influenced genetic mutations (e.g. Gervais *et al.*, 2016; Grady, 1992; Mancini *et al.*, 2006; Moore, 2015). Particularly, Grady (1992) and Moore (2015), among the others, suggested that abnormalities could be related to a long-term exposure to chemically contaminated sites, while Gervais *et al.* (2016) highlighted the role of the ocean warming in skin color aberrations. These teratogenic effects could be particularly evident when the embryonic development occurs in the egg, outside the female body, as in the case of *G. melastomus* (Gervais *et al.*, 2016; Mancini *et al.*, 2006). Although the natural origin of this particular abnormality cannot be excluded, since the anthropic impact on marine ecosystems is constantly increasing, cases like this highlight the need for more studies that clarify the direct effects on living organisms and how they can adapt.

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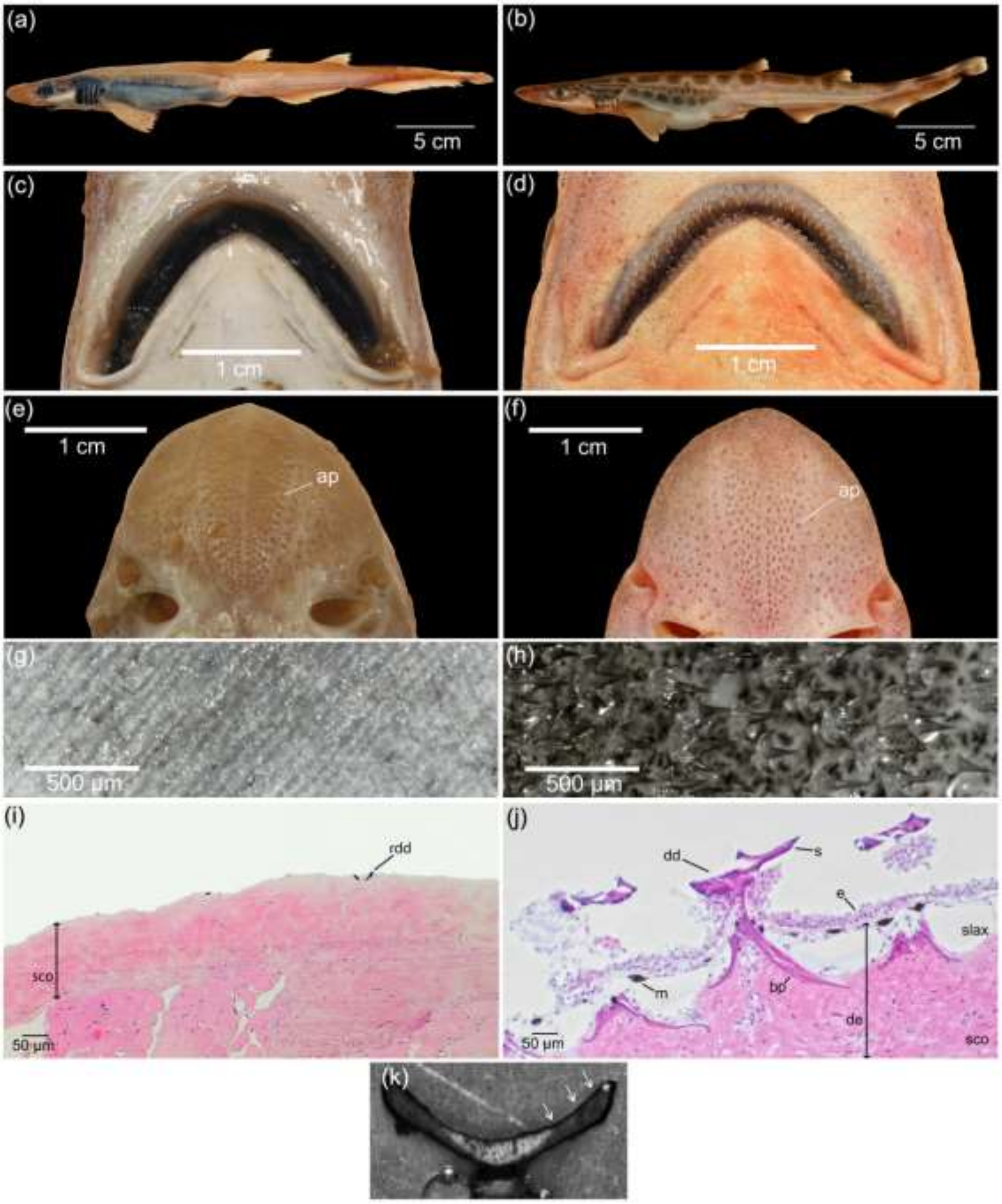
Figure 1 Caption

Comparison between the abnormal (on the left) and a normal (on the right) *Galeus melastomus*, both caught in Sardinia. a), b) lateral view; c), d) mouth, showing the lack of teeth and the normally-developed teeh in the abnormal and normal individual, respectively; e), f) ampullary pores; g), h) microscopic detail of skin showing the lack of dermal denticles and the normally-developed dermal denticles in the abnormal and normal individual, respectively; i) histological section of skin, stained with Hematoxylin and Eosin, from the abnormal specimen showing the presence of only the *stratum compactum* and a rudimental dermal denticle; j) histological section of skin, stained with Hematoxylin and Eosin, from a normal specimen showing the normally-developed layers of dermis and epidermis and the dermal denticles; k) particular of the vertebral *centra*, stained in Toluidine Blue, of the abnormal individual. Arrows indicate the opaque rings of the band pairs. The photograph was converted in black and white to enhance the band pairs. Abbreviations: ap = ampullary pore; bp = basal plate; dd = dermal denticle; de = dermis; e = epidermis; m = melanocyte; rdd = rudimental dermal denticle; s = spine; sco = *stratum compactum*; slax = *stratum laxum*.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