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Review of Bioluminescence in Deep Sea Sharks Species

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Abstract

Bioluminescence is the visible light produced by living things. These creatures are rare on land but very common in the oceans. Marine organisms can generate light using either their own luminous system, called intrinsic bioluminescence, or extrinsic bioluminescence refers to luminous bacteria that are symbiotic. Bioluminescent sharks are currently exclusively found in the Squaliformes family, primarily in the *Etmopteridae, Dalatiidae*, and *Somniosidae* families. The ventral body surface of most bioluminescent sharks emits blue light. Based on the light patterns, the biological roles of this bioluminescence have been considered, however the bioluminescence process has yet to be discovered. The squamation and physiological control of these unusual deep-sea sharks' photogenic organs are discussed.

Keywords: Shark; Elasmobranch; Bioluminescence; *Etmopteridae; Dalatiidae; Somniosidae*; Photophore

Introduction

Bioluminescence is the ability to live organisms to create visible light this was first mentioned by Aristotle he described in his book named "De Anima. Charles Darwin, onboard the Beagle saw and described the light in water as milky seal in his logbook. The first studies representing the mechanisms of bioluminescence came in Robert Boyle, who depicted the oxygen needed for luminescence production [1].

We can categorize bioluminescence into two types

(i) **Intrinsic bioluminescence**: when the organism is able to make its own light

(ii) **Extrinsic bioluminescence**: when the light is made by symbiotic bacteria. Bioluminescence is the creation of a spontaneous exergonic chemical reaction involving the oxidation of a Lucifer in catalyzed by a luciferase which produces a transitory excited state that finally relaxes by producing a photon with oxyluciferin as the final product [2].

Luminous capability is mainly seen in specific types of bacterium, cnidarians, echinoderms, and fish and often exists in from coastal, shallow waters to the deep abyss. Luminous creatures found in the 200-1000 m depth in mesopelagic zone. Luminous systems have either separate components of luciferase and Lucifer in or a composite molecule called "photo protein" that contains a peroxidase Lucifer in and a luciferase activity. Luciferins are found across a wide range of taxa, whereas luciferases are assumed to be species-specific.

Despite the fact that studies of shark luminescence have been documented for over two centuries shark luminescence research has, with detailed phylogenetical, ecological, and physiological studies now available for numerous species, this article is providing view of shark luminescence [3,4].

Diversity of the Deep Sea Bioluminescent Sharks: In cartilaginous fishes, only sharks have evolved the ability to emit light. Bioluminescence in sharks appears restricted to Squaliformes, for now, only these three families *Dalatiidae, Somniosidae,* and *Etmopteridae* have luminescent ability .Indeed, although bioluminescence has once been suggested for the specific supralabial white band of the mega mouth shark, Megachasma pelagios, but this is a form of symbiosis relation-ship and cannot be true bioluminescence.

Fossil studies estimate the *Etmopteridae* are evolved around 90 million years ago, molecular data shows a separation of *Etmopteridae* from other *Squaliformes* in the Upper Cretaceous (i.e., 65-90 million years ago). The *Dalatiidae* family are evolved in later, during the after the Cretaceous or Paleocene mass extinction 65-105 million years ago [5].

In the *Etmopteridae* family, photogenic structures appear to be common (Four genera: *Trigonognathus, Aculeola, Centroscyllium* and *Etmopterus*; 52 species). *Dalatiidae* (seven genera: *Dalatias, Isistius, Mollisquama, Euprotomicroides, Squaliolus, Euprotomicrus* and *Heteroscymnoides*; 10 species). Nevertheless, the only Z *somniosid* shark known to have photophores in parallel is the *squamulosus*; luminescence has only been recorded in 15 species in the wild.

Capacity for bioluminescence southern lantern shark (*Etmopterus granulosus*), the slender tail lantern shark (*Etmopterus molleri*) the smooth lantern shark (*Etmopterus pusillus*), the blurred smooth lantern shark (*Etmopterus bigelowi*), the black belly lantern shark (*Etmopterus lucifer*) the smalleye pygmy shark (*Squaliolus aliae*), the taillight shark (*Euprotomicroides zantedeschia*), the kitefin shark (*Dalatias licha*), the cookiecutter shark (*Isistius brasiliensis*), the pygmy shark (*Euprotomicrus bispina-tus*), the green lantern shark (*Etmopterus virens*), the splendid lantern shark (*Etmopterus splendidus*), Z. squamulosus, the viper dogfish (*Trigonognathus kabeyai*). In addition, there are luminous species in the *Etmopteridae* and *Dalatiidae* families [6].

Shark luminescence ecology: It is extremely difficult to research the ecological functions of luminescence in unusual creatures like deep-sea sharks. Indeed, field observations are very rare and lab experiments are known to be difficult to perform. A camouflage method is used by mid water organisms hiding their shadow from upward-looking organisms using a glow mimicking down welling sunlight is possibly the main purpose of shark luminescence, for both protective and hunting purposes [7-9].

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Even though, shark photophores are mostly situated on the ventral surface area 16 and produce a light that has a color (wavelength) that is alike to that found in coastal. Even though, shark photophores are mostly situated on the ventral surface area (Figure 1) and produce a light that has a color (wavelength) that is alike to that found in coastal which are blue-green and oceanic blue environments (Table 1).

Some etmopterid species living in the same deep environment have greater swimming speeds and muscular enzymatic processes than their non-luminous cousins, according to studies [10, 11]. *Somniosidae and Dalatiidae* produce "simple" luminous patterns on the ventral surface of etmopterid sharks, complex luminous photophore aggregations can be seen, as well as on the flanks, fins, tail, around the eyes, spiracles, gills and the epidermal tissue covering dorsal spines [12-14] (Figure 2).

Because photophores cover male claspers of all species, luminescence could be employed as a mating aid, allowing males to detect females from afar. Visualize their cloaca and pectoral fins (etmopterid's are brighter) the fourth luminescence function is aposematism, which is a method by which an animal uses warning light patterns to frighten predators away. They trick the predators by the light patterns to make them think they are poisonous thus saving their life.

Etmopterid sharks (contrary to *dalatiid* and *somniosid* species) have large sharp defensive spines connected with their dorsal fins which also have luminous capability (*E. spinax*) it can occur because of the tissue around the spikes which has photophores acting as a warning sign to predators [15]. Etmopterid and dalatiid sharks show a unique set of physical changes (in the eyes) which is not found in non-

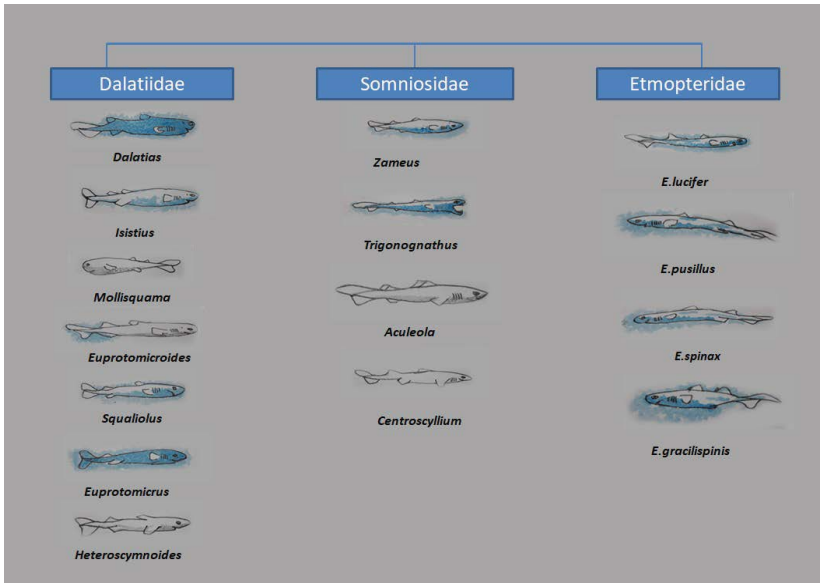

Figure 1: Biolumnicant Shark specis list in *Dalatiidae,somniosidae,Etmopteridae.*

Figure A: Viper dogfish Mouth

Figure B: Viper dogfish Head

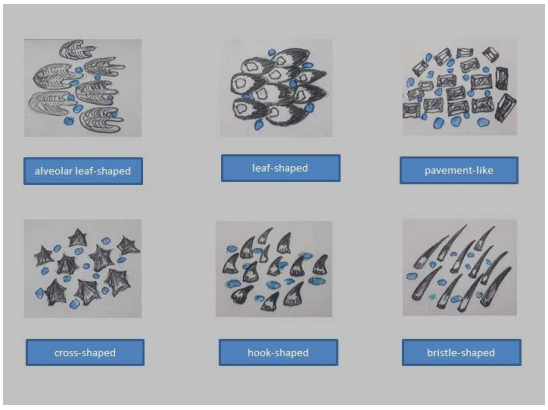

Figure 2: Types of the Dermal denticles in sharks.

Table 1: Shark luminescence color.

Species	Structure	Luminescence Color
Isistius brasiliensis	Photophores	Dark blue
Squaliolus aliae	Photophores	Dark blue
Euprotomicroides zantedeschia	Pelvic pouch (fluid)	Dark blue
Dalatias licha	Photophores	Blue
Euprotomicrus bispinatus	Photophores	Blue
Etmopterus splendidus	Photophores	Blue
Etmopterus molleri	Photophores	Blue
Etmopterus bigelowi	Photophores	Blue
Etmopterus granulosus	Photophores	Blue
Etmopterus lucifer	Photophores	Blue
Trigonognathus kabeyai	Photophores	Blue
Etmopterus spinax	Photophores	Blue-green
Zameus squamulosus	Photophores	Blue-green
Etmopterus virens	Photophores	Green
Etmopterus pusillus	Photophores	"Whitish"

luminous species. It seems that when bioluminescence evolved in these sharks that live in the deep, their eyesight coevolved with the ability to produce light. This may help in better vision in the murky depths and may also help in finding prey a mate each other or maybe even potential predators (Table 1) (Figures 1and 2).

Conclusion

Bioluminescent sharks have interested humans for almost two centuries. Research on these elusive deep sea creatures involving spectrophotometry, luminometry, pharmacology, light/electron microscopy, biochemistry, molecular analyses, and transcriptomics began only 2 decades ago. From a key function of camouflage in *Dalatiidae, Somniosidae*, and *Etmopteridae*, shark bioluminescent patterns steadily became an intra- and interspecific communication tool in found etmopterid sharks.

It clearly appears that the future of shark bioluminescence research will also be driven by new molecular data and techniques. These studies paved the way for future transcriptomic, proteomic, and genomic studies on luminous sharks. Among an infinite number of fascinating questions, these studies could focus on the identification of the light-emitting molecular toolkit (luciferase, photoprotein, etc.) in luminous sharks.

Even though recent research allowed us to understand a clear picture of the evolution, ecology and physiology of shark luminescence, our knowledge of these fascinating animals is not all complete there is much more to know and see.

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