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BIOLUMINESCENCE IN THE MARINE TELEOSTS, *ANOMALOPS* AND *PHOTOBLEPHARON* FROM THE BANDA ISLANDS*

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ABSTRACT

The two luminous fishes *Anomalops* and *Photoblepharon* have a large luminous organ half-moon in shape located below the eye. The former can shut off display of luminescence at will, by rotating the organ, and the latter extinguishes light by a black membrane covering the luminous surface just like the eyelid does. Both fishes can be seen all the year in dark night, but don't appear in the moon-lit night.

The cultivation of luminous bacteria from the luminous organs of these fishes were tested, and variations were observed in the light intensities of the sea water emulsions of the luminous organs according to effects of salt, temperature and chemicals respectively.

The result of the test cultivation was negative. However, summarising the results of the experiments; the contents of luminous body of the two fishes are luminous bacteria, which were recognized clearly in the electron microscopic.

ALTHOUGH bioluminescence is a very common characteristic of deep-water fishes, some shallow-water fishes are also known for their luminosity. Among the most famous are those belonging to the small family Anomalopidae, consisting of three genera and species : *Anomalops katoptron, Photoblepharon palpebratus*, and *Kryptophanaron alfredi. Kryptaphanaron* is known from a single specimen caught at Jamaica, West Indies. *Anomalops* and *Photoblepharon*, the best known members, are indigenous to the waters around the Banda Islands, located at the eastern end of the Indonesian Archipelago. When observed in the water at night, *Anomalops* produces a series of rapid flashes as it swims through the water. The light from *Photoblepeharon* is more nearly continuous and such flashing is infrequent. The blinking produced by the fishes is so spectacular that they have drawn the attention of students of bioluminescence over the years. However, due to the remoteness of the region in which these fishes occur, relatively few studies have been carried out.

The studies by Vorderman (1900), Steche (1907, 1909), Harvey (1921, 1922, 1925), Haneda (1943, 1953, 1955), and Bassot (1968) have shown that the light is emitted from a pair of relatively large light organs, roughly elliptical in shape, each lying in a suborbital depression. In a specimen of *Anomalops* approximately 90 mm in standard length, the light organ measures about 11 mm in the long axis, 4 mm in the short axis, and 1 mm in thickness. The standard length and dimensions of the light organ of *Photoblepharon* are approximately the same. The light-emitting face of

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the organ is cream-coloured, whereas the opposite face is nearly black due to a black pigmented cell layer. The light-emission is continuous. The anatomy and morphology of the light organs in the two species are also very similar. Each organ is lined by many parallel tubes that run from the pigmented base layer to the transparent, cream-coloured face. Numerous blood capillaries also run parallel to the tubes. When a transverse section across the tubes is examined, the tubes are found to have a polygonal shape and are arranged in a rosette pattern around the capillaries. The tubes contain what appear to be bacteria, which, if luminous, could account for the constant light emitted by the organ. The methods employed by each fish to extinguish its light are unusual. In *Anomalops*, this is accomplished by rotating the entire organ along its long axis so that the luminous face is turned down and toward the body, presenting the pigmented face to the outside. The rotation takes place through a small cartilagenous tissue located at the dorso-anterior edge which attaches the light organ to the fish. In the case of *Photoblepharon*, however, the light is extinguished by drawing up a black fold over the organ. Why two species so closely related and with organs so similar anatomically should develop entirely different methods for occluding the light remains a mystery.

Most previous studies have indicated that symbiotic luminous bacteria present in the tubules are responsible for the light production. Thus, Harvey (1922) found that an emulsion of a light organ in sea water behaved similarly to an emulsion of luminous bacteria. Bassot (1968) has found stained sections of the light organs of *Anomalops* to contain bacteria in the tubules when examined with a light microscope. However, Haneda (1943) could not obtain a culture of luminous bacteria from the organs. This finding is potentially significant since virutally all symbiotic luminous bacteria obtained from the light organs of fish, for example, *Leiognathus*, *Physiculus*, *Monocentris*, and *Acropoma*, are culturable on synthetic agar medium. The present study, therefore, was undertaken to investigate this problem further. Some of the experiments were carried out at Nanda, using fresh material, and others were conducted in the laboratory. With luminous emulsions prepared by grinding fresh organs in sea water, the following results were obtained : (1) an increase in temperature caused a decrease in light intensity, (2) various enzyme-cofactors, including adenosine triphosphate (ATP), which stimulate light emission from extracts of different luminous organisms, did not stimulate light emission, (3) diluting with fresh water immediately extinguished the light, but sea water added to a control caused only a moderate decrease in intensity, (4) air-dried organs did not luminesce when moistened with water, and (5) luminous bacteria did not grow on nutrient agar containing 3% NaCl. Electron microscopic studies were carried out on organs preserved in 10% formalin-sea water. The tissues were found to contain numerous bacterial cells, resembling luminous bacteria. Cell-free extracts prepared from dried organs were found to luminesce when reduced flavin mononucleotide (FMN) and a long-chain aldehyde were added, indicating the presence of bacterial luciferase. We conclude that luminescence in *Anomalops* and *Photoblepharon* is due to the presence of symbiotic luminous bacteria and that the bacteria are distinctly different from other luminous bacteria in some essential nutrient requirement. We are grateful to the Japan Society for the Promotion of Science, National Science Foundation and Alpha Helix 1969 Biological Expedition to New Guinea, Scripps Institution of Oceanography, University of California, for supporting this work.

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