Biophysics process and variation visual pigment photoreceptors of eye fishes: a review

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Abstract. The eye is a sense an organism like fish and an optical instrument and vision. The vision of the eye is a biophysical process. Photic condition in the aquatic environment is influenced by many factors. The aquatic environment gives widely diversity varying in turbidity, color and contrast. Eyes of fishes are designed by environmental condition and related or influenced the optics of the eye fish to its anatomy, describe the process of accommodation and the function in vision. Eye fish have photoreceptors in duplex retina that support the vision in spatial or temporal pattern of light. Besides that, in eyes of fishes, we found many type or variation visual pigment on freshwater fishes, coral reef fishes, pelagic fishes and deep-sea fishes. This article a review about biophysics process and variation of visual pigment photoreceptor on freshwater fishes, coral reef fishes, pelagic fishes and deep-sea fishes.

1. Introduction
The eye is a very important tool for fish life in their habitat. Live fish in the water medium require adaptation to ecological aspects. These ecological aspects are biotic and abiotic factors. Biotic factors such as predators, prey, fish interactions with groups and couples involved in the process of reproduction. Abiotic factors such as water temperature, light intensity, food and stages of fish development [1].

Teleost fish eye is very similar to the eyes of vertebrate animal species. The frequent variations found among these vertebrate species are differences in photoreceptor cells and potential sharpness of the fish's eye [2].

Furthermore, the morphological variations in teleost fishes eyes are species differences, such as eyepieces, occasional eyeballs (having corneas only or lenses only) or sometimes the eye utilizes adipose on the eyelids [3].

Variations of morphology and anatomical variations in fish eyes are a form of adaptation to their living conditions. This is what affects the ability of fish to see optimally, according to their habitat in the water. Most teleostei fish that live in shallow waters have the ability to detect patterns and colors and fish eyes are well developed [1].

Furthermore, anatomical variations are found in pituitary-containing photoreceptor cells such as rhodopsin, porphyropsin and opsin which cause pigments to absorb different wavelengths of light [4]. This means that fish can see in bright conditions (photopic vision) and look at the dark (scotopic vision). In addition to the above explanation, the number, type or type, of the cone cell structure (photoreceptor cells) is affected by the habitat and species of the fish. This all affects the fish detecting certain wavelengths with a certain intensity [5]. This is required by the fish to capture the image...
(image image) in the process of viewing (vision). What are the components of the biophysical process of vision, how the biophysical processes that occur in the fish eye, and the factors that influence the process are revealed in this paper.

2. The Behavior of the Sunlight Entering the Sea Water

The common light entering into the waters is a white light beam. The white light is spreading. Spread (dispersion) forms a color spectrum. In the shallow water found the color variations that can be distinguished according to the wavelength. By contrast, at a depth of 100 m or more, only partial light can be transmitted into the ocean, i.e. only wavelengths approaching 470 nm [6].

The sunlight transmitted by seawater is a visible light wave. It is estimated, as much as 60% of light energy into the water is absorbed at a depth of 1 meter. Approximately 80% disappear after entering a depth of 10 m, only 1% is capable of penetrating clear sea water at a depth of 140 m (500 ft) and no penetration of sunlight at a depth of 1000 m (3300 ft). The behavior of visible light in water is different from that in the air. This is due to absorption at a short distance by sea water compared to the atmosphere. Conversely, in stirred waters such as in the coastal waters zone, all spectrum of light appears to experience greater fading compared to clear sea water in the open sea. Some of the spectrum of light waves are transmitted together. The spectrum of red waves which is the longest wave is so rapidly absorbed. In contrast, blue waves which are the shortest waves are transmitted further penetration into the seawater.

Furthermore, Pickard and Emery [7] when the fading of energy is very rapidly vertically through the process of radiation, light enters the ocean differently for each wavelength. The fading of light energy is formulated by exponential law:

$$ I = I_0 \exp (-kz) $$  
(1)

where:
- $I(z)$ = light intensity at depth z (candela)
- $I_0$ = the intensity of the radiation entering the water surface
- $k$ = vertical fading coefficient in water
- $z$ = water depth (m)

In light of the exponentially formulated light exposure, light enters into the sea water at a certain depth and is accepted by the fish eye at a certain intensity symbolized $I$ (candela) then the flux of light in the fish eye according to Fernald [4] is:

$$ F = \frac{(I_e e^{-kPa})}{D^2} $$  
(2)

where:
- $F$ = flux of light on fish eyes
- $I(z)$ = light intensity at depth z
- $Pa$ = pupillar area
- $D$ = distance from light source to fish pupil

Based on the above formula, the intensity of light at a certain depth affects the vision of the fish. The strength of light intensity is influenced by the fading coefficient ($k$). Clear conditions are environmental factors that influence the ecological adaptation of fish eyelets.

3. Biophysical Eye Fish Eye Process

Light is a very important physical factor to fish life. Light affects fish life activities such as foraging, avoiding predators or predators, the process of finding a partner for reproduction, growth, development and determining the home range (territorial border) of its habitat [8].

The light received by the fish’s eye is influenced by the intensity of light at a given water depth. Fish that live in shallow waters get lighter than fish that live in deeper waters or fish that live by waters [9]. Light is an important ecological factor that affects fish life. The light before entering into the water column is filtered by the atmosphere. When entering into the water column the light
undergoes refraction, reflection, dispersion and absorption (absorbed by the water column). The single light or photon that reaches the conical cell (photoreceptor of the fish eye) with the angle of the incident angle of light 970. The angle of view is constant.

Eye fish has been adapted to the habitat of fish that life in the water media, good fresh water, fresh water, brackish water or sea water. The water medium is different because of its salinity. Salinity 0 is freshwater salinity, salinity of 1-32 permille is brackish water and salinity 33-42 permille is salinity of seawater, where the highest salinity is in Dead Sea i.e. 42 permille. The unit of salinity permille equals the amount of salt in 1 kilogram of sea water or g / kg.

The vision of fish in the media water barrier three-dimensional water media. Water has a density of 1000 kg/m³ while the air density is 1275 kg/m³. If divided then the ratio of water and air density, water density 784 times denser than air [10].

The above-mentioned density differences cause the difference in absorbs and light illumination patterns in the water. The ability of the water to absorb light is approximately equal to or greater than 10%, when light goes into water as deep as 1 meter. Water more easily absorbs light with low frequency and long wavelength compared to shortwave and high frequency. Therefore, red waves are reflected back in shallow waters. Instead, blue light waves enter into a depth of 200 meters. This is a problem for fish. Fish eye has adapted to solve the problem perfectly [9]. Refraction, transparency and symmetry are the basic biophysical properties that differentiate optical elements of the eye from all other vertebrate tissues. Elongated lens fibers, transparent cells contain a highly concentrated crystallin protein that enhances the refraction index and determines short distances, transparent arrangements.

Refraction, transparency and symmetry are the basic biophysical properties that differentiate optical elements of the eye from all other vertebrate tissues. Elongated lens fibers, transparent cells contain a highly concentrated crystallin protein that enhances the refraction index and determines short distances, transparent arrangements. In contrast, the cornea is largely an extracellular matrix of collagen fibrils produced by cells containing abundant proteins that are water soluble, analogous to the lens crystals that can contribute to the corosal basic optical properties. Lenses and corneas can share the nature of refraction and transparency as a result of the same effect of the crystalline lens.

The same is also expressed by Razak et al. [9] the perfect form of adaptation to light refraction is the waterless fish cornea like most vertebrate eyes. The refraction function is taken by the lens of a fish eye to the maximum of which has collagen fibrils. That's why the shape of a rounded fish eye lens that provides an indication of maximal refraction function. Fish eye is designed to overcome the problem of light in the habitats especially in fish that live by waters or fish that live in the deep sea. The round shape serves to collect light and focuses on the retina containing the photoreceptor cells appropriately. The process of the fish's eye is able to utilize the light entering into the water and then captured by the fish eye to see the object with several stages that can be depicted in Figure 1.
4. Variations of Fish Eye Pigments

All vision pigments contain two main components: the opsin, which is a protein and the other component, is a non-protein called a protein-combination pair called chromophores. Specifically, it can be disclosed that the vision pigment is composed of: 1) chromatophore, 2) proteins in pairs with non-protein compounds, 3) a chain of polysaccharides with 6 sugar groups, 4) phospholipids whose molecular numbers vary by more than 30 species [11].

Chromatophore is a functional group that has the ability to absorb certain wavelengths. Colors exist because of functional clusters. The ability of the chromatophore depends not only on the functional group but also influenced by the solvent and the ambient temperature [9].

The pigment and its components determine the photoreceptor ability of the fish's eye to absorb the wavelength and the tool for converting the physical strength of light into electrical signals. Visual pigment or vision is a material that is very sensitive to light. This pigment is a chromatophore of vitamin A or ligand that joins the protein (opsin) through a Schiff base connection [12].

Furthermore, in vertebrates including fish, it has two types of chromatophore associated with the opsin, both of which are derivatives of vitamin A aldehyde compounds. The common chromatophore is 11 cis retinal binding to opsin and forming rhodopsin. In certain fish and some vertebrates require...
11 dehydroretinal cis that form pigment porphyropsin. Associated with the foregoing, Needham [13] describes the distribution of retinopsin pigment (rhodopsin and porphyropsin) in fish as shown in Table 1:

| Rhodopsin | Porphyropsin |
|-----------|--------------|
| Marine Elasmobranchi | Freshwater Elasmobranchi |
| Marine Teleost | Freshwater Teleost |
| Marine Agnatha (Petromyzon marinus) | Freshwater Agnatha |
| Half freshwater teleost have both (rhodopsin and porphyropsin) |

Further, Wald et al., [14] describes the relationship of habitat depth with the peak of light wave absorption by rhodopsin pigments. Habitat where fish live in different waters depth affects the adaptation of fish vision. This is supported by data as shown in Table 2.

| Species | Flounder | Cod | Redfish | Lancet fish |
|---------|----------|-----|---------|-------------|
| λ (nm)  | 503      | 496 | 488     | 480         |
| Depth (m)| 4-20    | 10-150 | 80-390 | 400         |

The data in Tables 1 and 2 explain that the variation of visual pigment in fish is influenced by the water medium. Seawater fish and freshwater fish differ in their pigment types or have two types of pigments at once. The ability of the fish to see is also influenced by the habitat where the fish live and adapt. Fish is perfectly adapted to its visibility that supports its life with variations of pigments affected by habitats ranging from the summit of Everest to the Mariana trough of the Pacific Ocean at a depth of 10,000 meters.

**Acknowledgment**

Appreciation and special thank for Rector UNP (Universitas Negeri Padang), Director of Graduate Programme of UNP and Chairman of LP2M UNP which gave the oppurtunity and financial support to my research and publication in the conference.

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