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Effects on the Luminous Reflectances of Adhesive Organisms on the Underwater Visibility

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Colour and size of an object change as a result of adhesive organisms after it is set underwater for a long time and results in a great difference in underwater visibility. Samples of articles hung in the sea and removed at different time intervals for examination in the laboratory of its luminous reflectance. Underwater visibility of net twines (blue, grey and natural twine) increases with the adhesion of organisms on the twines and it was found that in about 40 days after being set it increases about two fold. In the present estimation, the apparent contrasts increase rectilinearlly with the decrease of visual angles and the luminous reflectances of objects decrease with the increasing of the underwater visibility. Apparently, it shows that the optical properties of the adhesive organisms greatly influence on the underwater visibility.

How visibilities of underwater objects are seen is very important for people who work under sea. The measurements of underwater visibility have been carried out in laboratory and in situ by a number of investigators and reported by means of various methods.[1-7] In the clear water, it is rare for a diver to see any object farther than 40 meters away and in turbid water it is often within 1 meter, namely visibilities of underwater objects are depended upon the optical properties of sea water as well as the characteristics of object itself.

Colour and size of an object change as a result of adhesive organisms after it is set underwater for a long time and results in a great difference in underwater visibility. The author has measured underwater visibility in laboratory of sea hunging samples collected in different day and examined the influence of the luminous reflectance of the samples.

Samples and Device

Samples used in the experiments and the luminous reflectance and the transmittance of them were also shown in Table 1. Samples with a total length of 10 meters were hung 1.5 meters below the surface at a device shown in Fig. 1. Aqua-lung was used in collecting

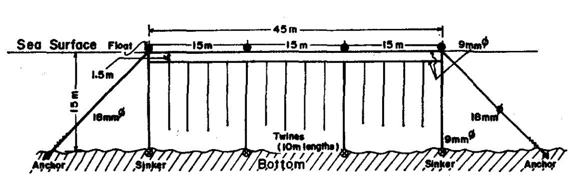

Fig. 1 Hanging device of net twines in the sea.

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Table 1. Samples of net twines

Colour	Material	d(mm)*1	R(%)*2	T(%)*3
Red	Dyed 'Nylon'	0.91	3.3	
Yellow	Dyed 'Nylon'	0.91	27.6	
Green	Melt dyed 'Nylon'	0.52	5.1	27.2
Blue	Melt dyed 'Nylon'	0.52	6.1	18.0
Grey	Melt dyed 'Nylon'	0.52	5.6	34.5
Natural	'Nylon'	0.52	7.7	36.2
Black	Melt dyed 'Nylon'	0.52	2.0	
White	'Vinylon'	0.98	82.0	
White	'Polypropylene'	1.20	90.0	
White	'Nylon'	0.56	78.0	
White	'Span Nylon'	1.20	71.5	

*1 Diameter of twines
*2 Reflectance of twines
*3 Transmittance of transparent twines

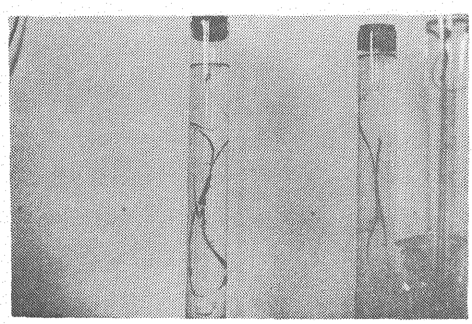

Photo. 1 Bottle for transport the samples to the laboratory.

samples from a same depth of 4 meters below the surface. These samples were kept in a bottle shown in Photo. 1 for transport to the laboratory before its underwater visibility was examined. Apparatus and method were written in the previous papers.[4,8)]

Results

Samples were set in early August for one and half month with frequent storms, for this reason only three kinds of transparency net twine (blue, grey and natural twine) were collected and measured. Underwater visibility of twelve samples was measured before set in situ. As an example, the results for 200 lm/m^2 were shown in Fig. 2. Underwater visibility of all samples increase with times and about 40 days after set, it increases about two times. The increase of underwater visibility is due to thicken of the diameter by means of adhesive organisms as well as difference in colour of adhesive organisms and spectral radiance of the water background. After seven days the visibilities of the blue and the natural twine were less than before these were set, it may be caused by the optical properties of the adhesive organism itself, The relation between the thickening of diameter by adhe-

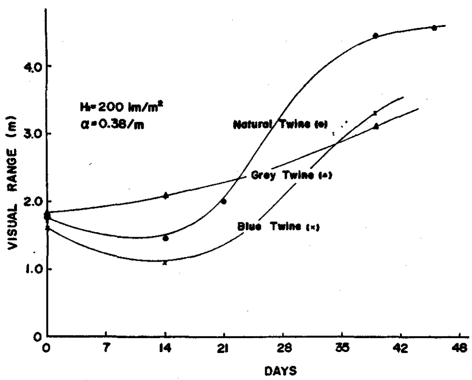

Fig. 2 Nnderwater visibility of samples collected in different time interval.
Surface Irradiance (H_1): 200 lm/m²
Attenuation coefficient (α): 0.38/m

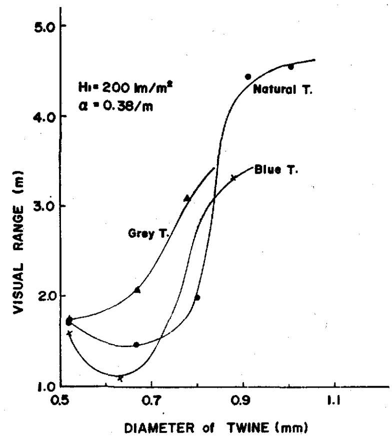

Fig. 3 Relation between the thickening of diametr by adhesiue organism and its underwater visibility.
Surface Irradiance (H_1): 200 lm/m²
Attenuation coefficient (α): 0.38/m

sive organism and its underwater visibility are shown in Fig. 3. The increasing tendency of the underwater visibility is similar when samples grow to a certain diameter,

Discussion

The light proceeding from an object to the eye is reduced in intensity partly by absorption in water mass and partly by loss through scattering. Simultaneously there is an inerease in intensity due to light from other directions being scattered into the eye. An object is visible only when the contrast between it and its background is large enough to detect. The apparent contrast is defined by the equation:

$$C_r=\left|\frac{B_o-B_h}{B_h}\right| \tag{1}$$

where B_o is the spectral radiance of the object, B_h is the spectral radiance of the water background, C_r is the contrast at the distance r (the apparent contrast) and its quantity depending on two radiances, B_o and B_h. The approximative equation for the visibility is as follows[8]:

$$C_r=\left|\frac{R\cdot H_2\cdot Q\cdot h}{\alpha^{A-1}\cdot b\cdot E\cdot(1-e^{-\alpha L})\cdot\pi^2}\cdot\int_{p=o}^{p=r}\frac{p}{(h^2+p^2)^2}\times exp\{\alpha(\sqrt{h^2+p^2}+r)\}dp+\frac{R\cdot e^{-\alpha r}(1-e^{-\alpha r})+e^{-\alpha L}-e^{-\alpha r}}{1-e^{-\alpha L}}\right| \tag{2}$$

In transparent objects, equation (2) has to rewrite as follows[8]:

$$C_r=\left|\frac{R\cdot H_2\cdot Q\cdot h}{\alpha^{A-1}\cdot b\cdot E\cdot(1-e^{-\alpha L})\cdot\pi^2}\cdot\int_{p=o}^{p=r}\frac{p}{(h^2+p^2)^2}\times exp\{\alpha(\sqrt{h^2+p^2}+r)\}dp+\frac{R\cdot e^{-\alpha r}(1-e^{-\alpha r})+(T\cdot e^{-\alpha r}-1)(e^{-\alpha r}-e^{-\alpha L})}{1-e^{-\alpha L}}\right. \tag{3}$$

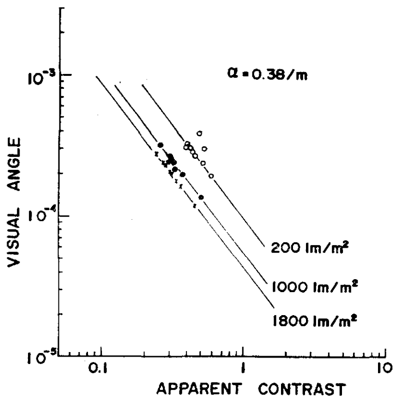

Fig. 4 Relation between the visual angle and the apparent contrast.

From equation (3) it is evident that the apparent contrast, C_r can be calculated. If it is plotted against the visual angle ($\log \theta$), results of a straight line is shown in Fig. 4. It will be noted that $\log C_r$ increases in a straight line with the decrease of $\log \theta$. The contrast presented by an object at the eye falls as the object recedes from the eye according to the approximation.[9]

$$C_r = C_o \cdot \exp(-\alpha r + k \cos\theta \cdot r) \qquad (4)$$

where C_o is the contrast at zero distance (the inherent contrast), θ is the angle of sight measured from the vertical. In this experiments the path of sight is horizontal so that $\theta = 90°$. As $Cos\ 90° = 0$ the equation (4) can be somewhat simplified.

$$C_r = C_o \cdot e^{-\alpha r} \qquad (5)$$

By substituting apparent contrast, C_r of samples computed from equation (2) into equation (5), inherent contrast, C_o can be calculated. The values of inherent contrast, C_o of blue, grey and natural twine are shown in Table 2. And then the luminous reflectance of the samples collected in different time interval can be calculated using equations (2) and (5). The values of luminous reflectance of blue, grey and natural twine are shown in Table 3. Those become considerably small as compared with the sample before it was set. When C_r falls below a certain amount the eye can no longer distinguish the contrast and the objects become invisible. As the spectral radiance of a target is depended on its luminous reflectance, and if the relation between the reflectance and the underwater visibility is examined, the above may be proved. The relation between the calculated reflectances and the measured underwater visibility can be seen in Fig. 5. It is found that the luminous reflec-

Table 2. Inherent contrasts of blue, grey, and natural twine

Samples	Co*
Blue	0.708
Grey	0.754
Natural	0.724

* Inherent contrast

Table 3. Luminous reflectances of blue, grey, and natural twine calculated using eqns. (2) and (5)

Samples	14th	21th	39th	46th
Blue	2.67		0.77	
Grey	1.76		0.66	
Natural	2.19	1.55	0.42	0.35

tance decreases with the increasing of the underwater visibility. The three (*X*) are values of the blue, grey and natural twine before set and the difference can be hardly seen. Apparently it shows that the optical properties of the adhesive organisms have influence on the underwater visibility greatly. But because of the species of adhesive organisms may be varied from each water, the tendency of curves may be different from Fig. 5. Therefore, samples of net twines with adhesive organisms from various coast are needed.

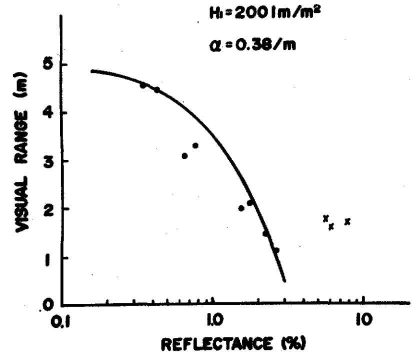

Fig. 5 Relation between the calculated reflectances and the measured visibilities.
Surface Irraciance (H_1): 200 lm/m²
Atenuation coefficient (α): 0.38/m

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