STUDY ON OPTICAL PROPERTY OF RED TIDE ALGAL SPECIES

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ABSTRACT : This research is about the optical characteristic of red tide which is collected from Nam-Hae for basic research of red tide remote sensing technique development. 21 kinds of red tide organisms are cultivated to investigate optical characteristic of them on the level of laboratory, and chlorophyll specific absorption coefficient(a^*) and backscattering coefficient(b_b^*) are estimated by using spectrophotometer. Absorption spectrums according to species are appeared diversely from 0.005 to 0.06 (mg/ m^2), and the shapes of spectrums are also different. The range of b_b^* are appeared 10^{-2}~10^{-4} mg/ m^2, which have around 100 times differences between species, and the shape of spectrum also have significant difference between species. These results are able to use as an input data of inverse model from ocean color.

KEY WORDS: Red tide, Absorption coefficient, Backscattering coefficient, Optical property

1. INTRODUCTION

Red tide is a phenomenon that the color of seawater turns to red due to a mass reproduction of phytoplankton. It is reported that there are around 150 sorts of organisms internationally which affect red tide occurrence, and there are about 40 species which cause a red tide in Korea. It is indispensably necessary to detect and predict red tide because temporal and spatial distribution of harmful red tide is getting larger. To monitor the development and movement of red tide, observing activities involved in ships are mainly used so far, but those methods have difficulty in getting effective monitoring due to limit of time and space. Therefore, it is effectual to use remote sensing technology which can observe objective area inclusively and repeatedly. If singular red tide species made bloom, there would be the change of ocean color in some species because the spectral characteristic of sea water's color is changed. The fact that it is possible to remake ocean color according to species means that species can be classified by the color of sea water. The values of specific absorption coefficient and specific backscattering coefficient according to species are necessary to remake model about the change of color of seawater affected by red tide organisms. This research is about specific absorption coefficient and specific backscattering coefficient to utilize optical property of red tide organism as an input variable of the model.

2. MATERIAL AND METHOD

2.1 Culture of red tide organism

Samples in experiment were collected at various stations and these species were bred single-species by Pasteur-pipette method. Culture media completed cultivation were used for measuring optical property. Media which were in low concentration were enriched and in high concentration were diluted.

2.2 Chlorophyll concentration of samples

To measure chlorophyll density of sample, pigment of sample was extracted by filtering and went through baseline correction by beam spectrophotometer and estimate optical density by scanning ranged from 400nm to 750nm and then analyzed its density by Jeffrey and Humphrey(1975)'s formula (1).

$$< Chl >= \frac{C \times v}{V} \quad (1)$$

Where, $C = 11.86 E_{664} - 1.54 E_{647} - 0.08 E_{630}$, E_λ means that optical density by wavelength of pigment measured by spectrophotometer, v is that acetone volume(ml) for extracting the pigment and V means filtered seawater volume(l).

2.3 Measuring optical properties of red tide organism

Spectrophotometer Lambda-19 is used for measuring optical density and backscattered light of red tide organism. This implement is able to measure absorption coefficient(a) and attenuation coefficient(c) at the same time and scattering coefficient(b) is gained by subtracting absorption coefficient(a) from attenuation coefficient(c) (Formula 2.

$$b = c - a \quad (2)$$

2.3.1 Absorption Coefficient of red tide organism

After sample cell and reference cell are measured by placing in front of the I.S(Integrating sphere), optical density is measured by adding the sample bred phytoplankton. Absorption coefficient was calculated by the formula(3). Formula(4) shows specific absorption coefficient(a^*_{ph}) of chlorophyll. a^*_{ph} is light absorption coefficient and that is the most important factor in ocean color remote sensing.

$$a(\lambda) = \frac{O.D(\lambda) \times 2.3025}{0.01} [m^{-1}] \quad (3)$$

$$a^*_{ph} = \frac{a_{ph}(\lambda)}{< chl >} [m^2 / mg] \quad (4)$$

Where, O.D is Optical Density, "2.3025 is a constant to convert from common logarithms to natural logarithm. "0.01" is optical path because 1cm optical cell is used in this experiment (Truper and Yentsch, 1967).

2.3.2 Backscattering Coefficient of red tide organism

There is a technique, formula (5), to measure intensity of backscattering light by integrating β (Θ), angular distribution of scattered radiation (volume scattering function), to space π in space $\pi/2$. However there is no perfect flawless way to measure backscattering light because suspended particle is volume scattering.

$$b_b = 2\pi \int_{\pi/2}^{\pi} \beta(\theta) \sin\theta \, d\theta \quad (5)$$

If the intensity of scattering light at 141 degrees (β_{141}) is the most similar to sum of backscattering coefficient (b_b) and formula (5) is simply expressed, formula(6) can be gained.

$$b_b(\lambda) = 2\pi x \beta_{141}(\lambda) \quad (6)$$

Where, x is conversion factor which is transform β_{141} to b_b. Ahn et al. (1993) theoretically demonstrate that value x, between optical cell having special light trap structure for obtaining backscattering coefficient spectrum of suspended particle and Integrating sphere, usually has an invariable constant to wave length, but it can be slightly changeable if absorption includes very large particle. And the value $2\pi x$ means that it is appeared from 5.5 to 7 according to kinds of plankton species. The technique of Ahn et al. (1993) is also used in this research. However, the value of $2\pi x$ (GF; Geometrical factor of optical cell) is supposed to about 6 and the value of GF is multiplied by measured value(b_{bm}) in this research. And GF is supposed to invariable value in this research even though it is some variable value according to wave length.

$$b_b(\lambda) = b_{bm}(\lambda) \times GF \quad (7)$$

Where, $b_{bm}(\lambda)$ is value of measuring by spectrophotometer, GF (Geometrical factor of optical cell) is adopted constant 6. Chlorophyll specific backscattering light is gained by following formula. (Formula 8)

$$b^*_b = \frac{b_b(\lambda)}{< chl >} \quad (8)$$

3. RESULT

3.1 Chlorophyll Specific Absorption Coefficient for each species

In this graph, a magnitude of absorption is shown to have various values ranging from 0.0005–0.06 mg/m^2 at wavelength 440nm. As Fig (1) shows, there are two main absorption bands. One is appeared peak at wavelength 440-444nm and the other is appeared peak at wavelength 680nm because of fluorescence. Therefore, in case of phytoplankton, light signal by fluorescence may have a large influence on satellite sensor at wavelength 680nm and remote sensing is possible by using this fluorescence signal.

3.2 Chlorophyll Specific Backscattering Coefficient for each species

Backscattering of phytoplankton is indispensable condition, with absorption affect, for development of red tide ocean color algorithm because it causes change of ocean color. Range of chlorophyll specific backscattering coefficient of phytoplankton value has about 100 times difference (10^{-2} – 10^{-4} mg/m^2) in each species. Value, backscattering coefficient of phytoplankton, in wavelength is usually shown decrease at absorbing band and increase at non-absorbing band which is extremely small value compared to a^*. The shape of spectrum is appeared opposite shape of absorbing spectrum up and down. The value is decrease at optical absorbing area, 440nm, and increase at non-absorbing area, 550nm.

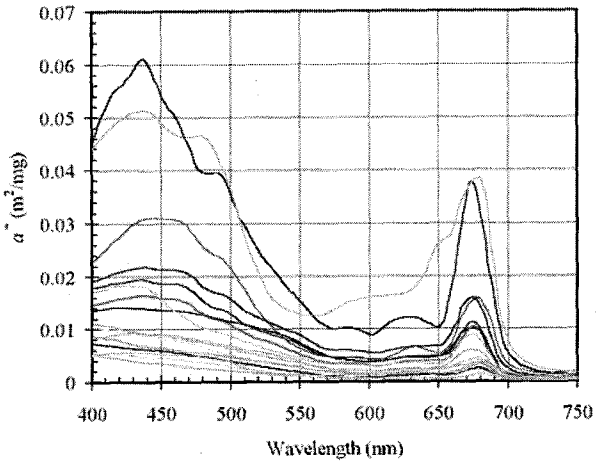

Figure 1. All spectral values of specific absorption coefficient (a^*), measured on 21 algal species

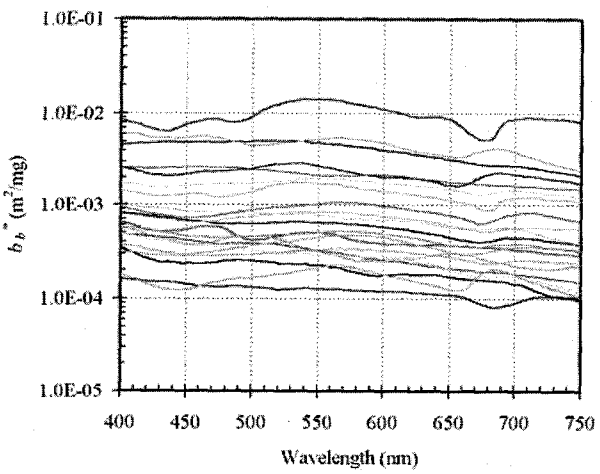

Figure 2. All spectral values of specific backscattering coefficient (b_b^*), measured on 21 algal species

Table 2. Spectral characteristics of absorption and backscattering of the 21 species

spices	Optical property		
	Apperent color	Absorption spectrum	Backscattering spectrum
Diophyceae			
Alexandrium catenella	Yellowish brown	-	Toward long-wavelength decrease
Cochlodinium polykrikoides	"	400nm absorption increase	flat-decrease
Gymnodinium catenatum	"	400nm absorption increase	value decrease toward long wavelength, indentation
Gymnodinium sanguineum	"	400nm absorption increase	value decrease toward long wavelength
Gyrodinium sp.	"	-	wavelength decrease large
Gyrodinium aureolum	"	575, 625nm	Toward long-wavelength decrease, indentation
Gyrodinium impudicum	Brown	400nm absorption increase	value decrease toward long wavelength
Heterocapsa triqutra	Yellowish brown	460nm, 500nm	550nm hump
Katodinium rotundatum	"	-	
*Prorocentrum minimum**	"	460-470nm 490nm	550nm hump
Prorocentrum micans	Brown	525nm	550nm hump
Prorocentrum dentatum	Yellowish brown	525nm	value decrease toward long wavelength, 550nm hump
Prorocentrum triestium *	"	470, 490, 525nm	Wavelength decrease, 550nm hump
Serippsiella trochoidea *	Red	450-550nm	Wavelength decrease, hump
Raphidopeaceae			
Chattonella sp.	Golden brown	-	Toward long-wavelength
Chlorophyceae			
Chlamydomonas sp. *	Green	450 - 500nm 650nm	550nm hump
Chlorella ellipsoidea *	Green	450 - 500nm	550nm hump
Chlorella schroeteri *	Green	450 - 500nm 650nm	550nm hump
Euglophyceae			
Eutriptiella gymnastica	Green	450 - 500nm 650nm	value decrease toward long wavelength
Haptophyceae			
Isocrysis galbana *	Brown	440-460, 490nm, 635nm	550nm hump
Bacillariophyceae			
Coscinodiscus sp.	Yellowish brown	400nm absorption increase	value decrease toward long wavelength
Phaeodactyrum tricornutum	"	480-490nm 630nm	550nm about hump

3.3 Absorption band for each species and relative photosynthesis pigment

There are 7 - 8 spices which have a different characteristics of absorption and backscattering spectrum shape in the 21 spices, and these are able to apply spices to distinguish using remote sensing.

Table 1. Light absorption bands and related photosynthetic pigments of phytoplankton.

	in-vivo absorption bands(nm)	Pigments
1	410 - 412	chlorophyll-a
2	438 - 440	chlorophyll-a like
3	442 - 445	chlorophyll-a
4	468 - 472	Carotenoids
5	492	phycoerythrins
6	548 - 550	phycoerythrins
7	585	-
8	625 - 630	Phycocyanins
9	650 - 655	chlorophyll-b
10	675 - 680	chlorophyll-a

In this study photosynthesis pigments that are relative absorbing band of red tide organism are arranged according to E. Rabinowitch(1969) and Morel et al. (1993)'s research result.

4. CONCLUSION

This research considered optical character of red tide organism as a input variable of the model used for modeling the change of sea water color according to red tide species for remote sensing of red tide. To do that, 21 red tide organisms collected around Nam-Hae are cultivated, and their sample's chlorophyll density and optical character are investigated. Specific absorption coefficient and Specific backscattering coefficient (a^*, b^*_b), which are main factors of change of sea water color, are estimated to identify optical character. There are difference of each spices value in Specific absorption coefficient and Specific

backscattering coefficient spectrum, and there are also difference in the form of spectrum. In visible range, absorbing band of red tide organisms are categorized by two main absorbing band (440nm and 680nm) and about eight photosynthetic assistant absorbing band. There is big difference in composition of absorbing band of each species, but there is significantly similar composition of absorbing spectrum in same species. However the values are remarkably different in the assistant absorbing band. Among 21 species, about 7-8 species can be used for identifying remote sensing species because they have apparently different shape of absorbing spectrum compared with others. However there are big difficulty using red tide organisms because their spectral character is not well classified in a great amount of species. Besides, it is needed to study, in the future, about optical property research of marine organism-originated debris, which have not been studied yet, and the change of optical character according to physiological state of red tide organisms.

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