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Feasibility of Red Tide Detection around Korean Waters using Satellite Remote Sensing

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Introduction

Korea has experienced a *Cochlodinium polykrikoides* red tide 10 out of the last 10 years (1993-2002). This species of red tide has been experienced at least once by all the southern coast of the Korean peninsular and has been transported up the southeastern coast all the way to the northeastern coast since 1995. The impression is that red tide is spreading and becoming more common, not only in the nearest coastal water, but also in the offshore.

The monitoring activities at National Fisheries Research and Development Institute (NFRDI) in Korea have been extended to all the coastal water of Korean waters after the worst outbreaks of fish killing *C. polykrikoides* blooms in 1995. Mitigating red tide impacts requires an ability to monitor for blooms and to forecast occurring and spreading of red tide. Nowadays NFRDI is looking forward to finding out the feasibility of red tide detection around Korean waters using satellite remote sensing of NOAA/AVHRR (Advanced Very High Resolution Radiometer), Orbview-2/SeaWiFS (Sea Viewing Wide Field-of-View Sensor), IRS-P4/OCM (Ocean Colour Monitor) and Terra/MODIS (Moderate Resolution Imaging Spectroradiometer) on real time base.

For remote sensing to be effective, red tide must be detectable, either directly through its effect on the water color, or indirectly by correlation with algal blooms or association with a water mass that can be monitored by other remotely sensed characteristic such as sea surface temperature (Tester *et al.*, 1991; Keafer and Anderson 1993).

In this study, I used several alternative methods including a climatological analysis, spectral and optical methods which may offer a potential detection of the major species of red tide in Korean waters.

Material and Method

The sea surface temperature (SST) data were derived from the infrared channels of AVHRR sensor on NOAA satellites from 1995 to 2002 (Suh *et al.*, 2000; McClain *et al.*, 1985). There were two channels (channel 1 (ch1): 571-686 nm, channel 2 (ch 2): 713-989 nm) on AVHRR to apply ocean color remote sensing in 1995. At that time, I just used the band ratio (ch1 of AVHRR/ ch2 of AVHRR) to detect the major species of algal bloom, *C. polykrikoides*, *Ceratium furca* and *Notiluca* in 1995 as Gallegos (1990) did it.

To estimate chlorophyll *a* derived from SeaWiFS and OCM were analyzed by using ocean color chlorophyll 2 algorithm, OC2 (OReilly *et al.*, 1998). In case of Terra/MODIS data, we used visible channels and near-infrared channel to get the spectral band ratios to estimate distribution of red tide.

In climatological analysis, the estimated chlorophyll *a* concentration derived from the ocean color satellites for red tide occurring day is compared to that of before red tide occurring day. Distribution of the SST differences derived from NOAA infrared data between daytime and nighttime in the red tide occurring coastal water was made to detect indirectly the distribution of algal bloom using the biological characteristics of daily vertical migration of phytoplankton.

Absorption spectra between 250 nm and 800 nm of *C. polykrikoides*, *H. akashiwo* and *P. minimum* were measured by spectrophotometer (Verian Carry 100).

Result and Summary

The relationship between the distribution of SST and *C. polykrikoides* bloom areas was studied. The cold water was formed by upwelling water from deep layer in the southeastern coast of the Korean peninsula played a role in blocking the spreading of red tides during summer season. The red tides that initially bloomed at the coast of Pohang on September 21, 1995 moved to the coast of Uljin on September 26, 1995. The skipped appearance of the red tides in the areas between Pohang and Uljin was due to the East Korean Warm Current, which was moving offshore from Pohang to approach to Uljin.

We used corrected vegetation index (CVI) to detect floating vegetation and submerged vegetation containing algal blooms as Sonia Gallegos did it in 1990. However, we have got different result because of different species of algal bloom. Algal bloom areas were estimated by ratios of ch1 digital values (60-80) and ch2 digital values (90-120). The major species of algal bloom were *C. polykrikoides*, *Ceratium furca* and *Noctiluca*. Among the major species, *Notiluca* was detected by CVI in 1995.

In climatological analysis, NOAA, SeaWiFS, OCM satellite data in 20th and 26th August 2001 were chosen using the known *C. polykrikoides* red tide bloom area mapped by helicopter reconnaissance and ground observation. The August 26, 2001 SeaWiFS chlorophyll *a* anomaly imageries against the imageries of non-occurring red tide for August 20, 2001 showed the areas *C. polykrikoides* occurred.

The standard global chlorophyll algorithm (Ocean Color 2) tends to overestimate chlorophyll in the southern coast of Korea like case 2 waters (Suh *et al.*, 2002). When a coastal correction is not applied, may increase this error another two fold. However, the anomalies of chlorophyll *a* concentration from satellite data between after occurring red tide and before occurring red tide showed the similar distribution of *C. polykrikoides* red tide in August 26, 2001.

The distribution of the difference in SST between daytime and nighttime also showed the possibility of red tide detection. The simple result of optical absorption from *C. polykrikoides* showed that if we use the characteristics of response for the red tide we will be able to get the feasibility of the red tide detection.

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