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연구논문

Spatial and Temporal Analysis Methods of Red Tide Using HABAS

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HABAS를 이용한 적조의 시-공간분석기법

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요 약

본 연구의 목적은 한반도 연안해역에서 적조로부터 양식장을 보호하기 위한 연안환경모니터링시스템을 구축하는데 있다. 1995년 이후 적조의 발생은 한반도 남부 연안해역에서 빈번하게 발생하고 넓게 확산되었다. 따라서 적조연구의 가장 중요한 점은 유해성적조의 발생 초기단계에 적조를 탐지하는 것이다. 지리정보시스템 기술은 적조발생의 공간적, 시간적 변화를 분석하는데 필요한 적조모니터링 시스템을 만드는데 적합하다. 유해성 적조 분석시스템 프로그램은 매일 매일의 적조 분포범위, 적조 생물 종, 적조 밀도 등을 제공해준다. 우리는 유해성 적조분석프로그램을 이용하여 적조로부터 양식장의 보호지역을 찾을 수 있다. 적조의 공간분석은 현장조사에 의한 참조자료를 바탕으로 수행되었다.

주요어 : 적조, HABAS, GIS, 공간분석

I. Introduction

Korea has experienced 14 occurrences of red tide blooms within last 14 years from 1993 to 2006. Especially since 1995, HABs (Harmful Algal Blooms) have become more frequent and widespread in whole coastal areas of the Korean South Sea and East Sea of Korean peninsula, spanning more than two months.

These HABs have eventually declined the health of marine ecosystem and environments, and have given a great damage of coastal fish-

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eries and caused national problems of socio-economics. Thus it is necessary to know beforehand the characteristics of meteorological and oceanographic conditions, and the possibility of satellite monitoring and prediction for preventing disasters related to red tides. Therefore, an early HAB warning system is very necessary to mitigate serious economic loss of aquaculture industries.

Several studies pertaining to red tides have been carried out at the limited fields as taxonomy, physiology, ecology and molecular biology (lizuka and Mine, 1979), but they have not given full and satisfying answers. Recent investigations have studied the mechanisms causing red tides in the fields of physics, dynamics, remote sensing, and GIS (Jeong, 2003; Ahn *et al*., 2005).

In the fields, HAB monitoring was carried out by vessel cruising, patrolling coastal waterfront, aircraft observation and remote sensing. The dispersion area of HABs was collected by vessel cruising and aircraft observation images (NFRDI, 2003, 2004, 2005, 2006).

The biological and chemical parameters of coastal water environment were monitored, including phytoplankton abundance, density, chlorophyll concentration, nutrients and physical parameters such as temperature, salinity, pH, water transparency and tidal currents. Meteorological data such as wind, precipitation, sun light intensity were analyzed for the dispersion of HABs (Kim, 2003). However, we need to make the more organized HAB information system for HAB database system and to develop the detection algorithm using satellite data. The aim of this study is to analyze the temporal and spatial distribution aspects of HABs using HABAS (Harmful Algal Blooms Analysis System) program (Fig. 1.).

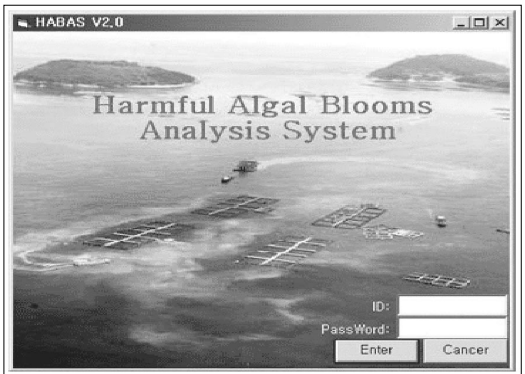

Fig. 1. The *HABAS main page* (developed by Jeong, 2005)

II. Method

In this study, we introduce the HABAS (developed by Jeong, 2005), which is developed by visual basic 6.0, ArcGIS 9.1 and Mapobjects. HABAS program shows the dispersion area, species and density of daily algal bloom from 1995 to 2005 in Korean waters. The damage caused by HABs takes place according to various aspects such as the species, concentration and spatial distribution of red tide plankton. Therefore, in order to prevent the damage of red tide it is important to understand the distribution characteristics of red tide by each species according to time and space. In this perspective, we analyzed the area of early outbreak, frequency and spatial distribution and migration of red tide using HABAS program. The spatial data used for this study was constructed by digitizing from the red tide quick report of NFRDI (National Fisheries Research and Development Institute) and coupling with various attributes such as species, concentration and sea surface temperature.

The ocean color sensor, such as SeaWiFs, OCM, MODIS were used for detection of HABs and compared with in-situ data collected by ves-

sel cruising (Tyler, M. A. and R. P. Stumpf, 1989). But, these satellite data have some problems because of inadequate spatial resolution and no appropriate algorithm has been developed for detecting the HABs from satellite data.

However, field survey monitoring was carried out by vessel cruising during the outbreak of HABs every year. We compared the area of HAB with detectable feature in the Landsat imagery, which means that the filament features of HABs are wider than 30 m. The Landsat satellite images of HABs were processed by 2-Dimension scatter plot analysis and displayed with HABAS program.

The study area of this research is the Korean South Sea and the temporal period is from 1995 to 2005. The remote sensing study of HABs detection has led to the derivation of the distribution maps for the Korean South Sea. Field data collected by NFRDI during different cruises were available on the NFRDI web site, and report and NFRDI field survey data were also essential to the production of maps of the HABs for Korean South Sea.

Advance warning of HABs increases the options for managing these events. The HAB forecasting system provided by HABAS supplies information on the location, extent, and potential development or movement of algal blooms in coastal waters.

The forecasting system relies on satellite imagery, field observations, and buoy data and provides the large spatial scale and high frequency of observations required assessing the bloom location and movements. Conditions are posted to this system everyday during the HAB season. Additional analysis is included in the HABAS system that is provided to state and local resource managers in the region.

The HABAS is an interactive mapping tool that can be used to access recent data on HABs in coastal waters on the environmental conditions that may affect the spread of these blooms. This interactive mapping tool is powered by ESRI's ArcGIS and users can use the tool to select data layers, zoom in and out of areas, pan around different areas, query data by location and data type, and print custom maps (Fig. 2).

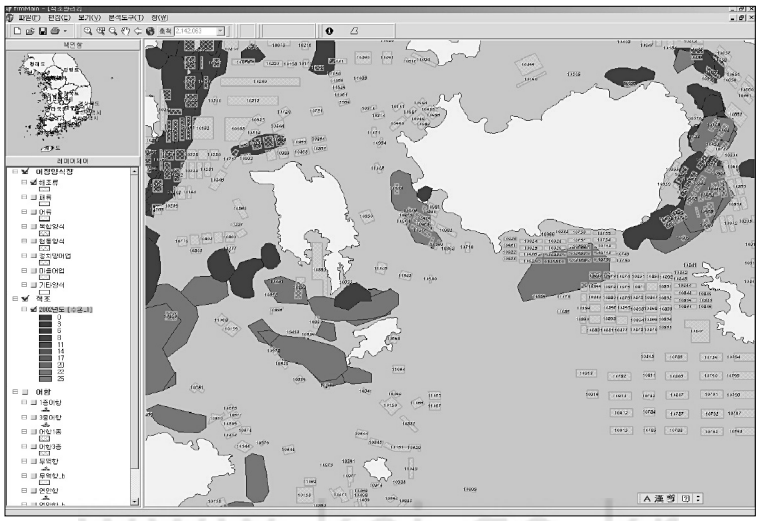

Fig. 2. The HABAS main structure and HAB distribution map display with more information such as water temp, cell number, Species, and fish farm site...

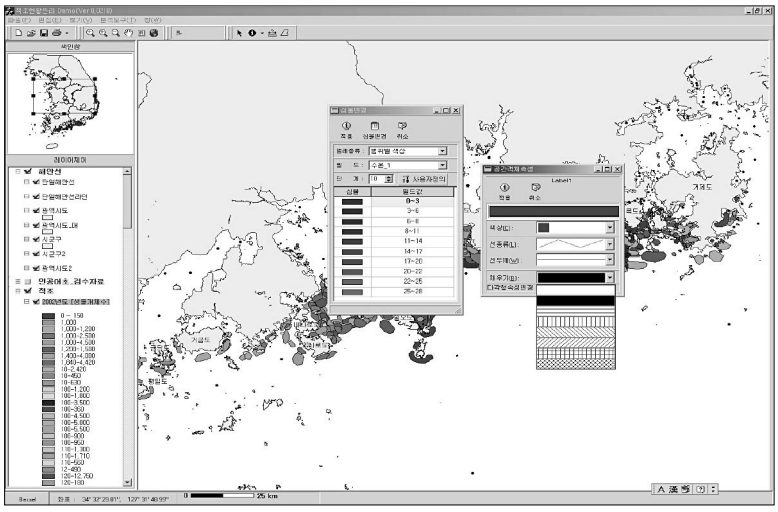

Fig. 3. The HABs distribution map from field observation data and display technique for attribute data

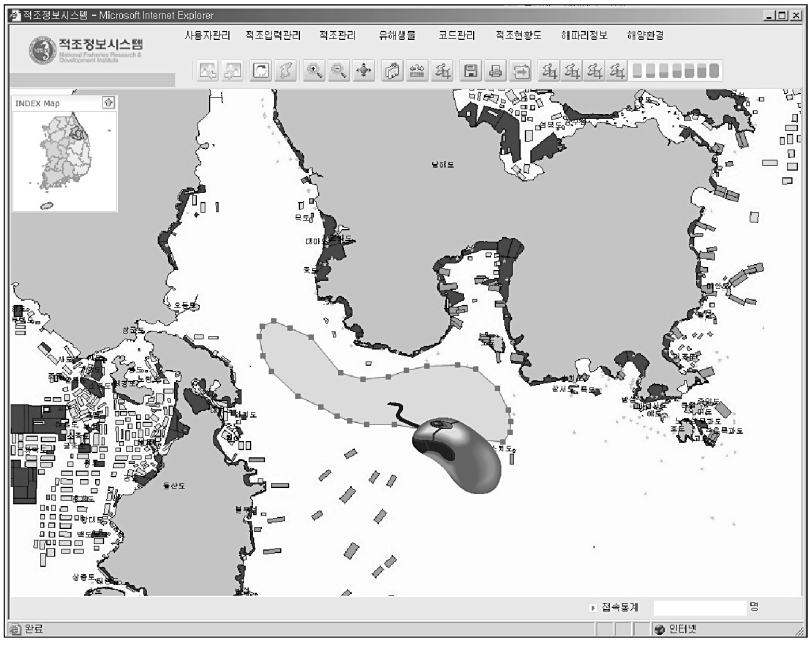

Fig.4. The HABs sites of geo-referenced polygon were derived from red tide news and satellite data.

Map products for HABAS include HAB distribution map from field observations using research vessel (Fig. 3), geo-referenced HAB distribution area derived from digital mapping method(Fig. 4) and estimated areas of HABs from the satellite imagery (Fig. 5).

III. Results

The HABAS is an interactive searching system

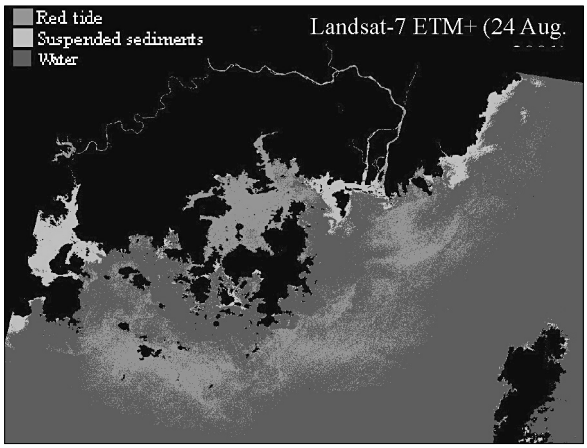

Fig. 5. Detection of HABs from Landsat-7 ETM+ image of 24 August 2001 using Minimum Spectral Distance Classification (MSD) technique (Ahn *et al.*, 2006).

that can be used to access brief description of data layers, sea surface temperature (SST) images, cell counts, bathymetry contours. The cell counts results of the most recent in-situ sampling for red tide are obtained. The process of the derivation of map is described in detail in Fig. 6.

Available data layers are displayed within a folder structure. Folders can be opened and closed by clicking on them. The layers can be turned on and off in the map window using the check boxes, and the active layer can be chosen by clicking on the button. Different layers are viewable at different scales. Legends for the layers can also be viewed in this window by clicking the toggle buttons.

This window shows the interactive HAB map, with selected layers. The legends for the HABs and red tide distribution area image are displayed here. These functions play zooming the display to the selected state. These are the tools available for working within the application. Three kinds of control options, such as directly mapping on the satellite image, overlay with HAB polygon, and searching species and cell

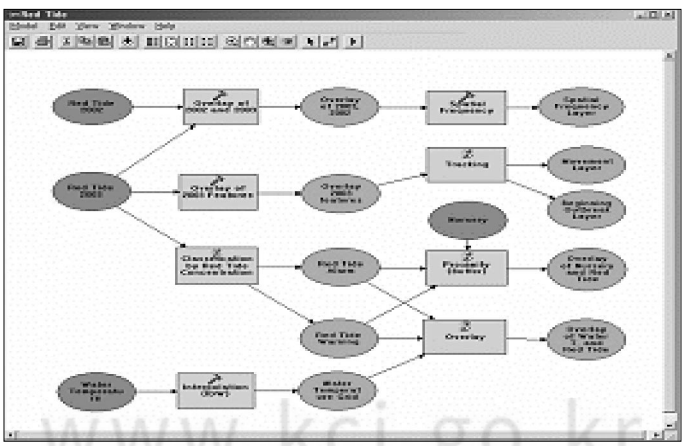

Fig. 6. The process of the derivation of map for HABAS

numbers of HABs are available in the HABAS system.

Recently *blooms of C. polykrikoides* are occurring more often and in more regions across the nation than ever before. These intense population explosions of algae can kill marine life, clog waterways, and create conditions that impact human health. While algal blooms are a natural phenomenon, it is believed that human activities, such as nutrient excess in runoff, may be triggering their increasingly common occurrence. Along the coast of the Southern part of Korea, the most common type of harmful algal bloom is the *Cochlodinium polykrikoides*.

The HABAS system is an interactive mapping tool that can be used to access recent data on HABs in the aquaculture site and on the environmental conditions that may affect the spread of these blooms. HABAS is an unique component of the red tide analysis system, responsible for monitoring water quality to manage aquaculture harvesting areas that must be closed when harmful algae or other pollutants are present.

To ensure safe seafood, the local government and NFRDI work together to test aquaculture harvesting areas for the presence of red tide and to regulate harvesting. The coastline of Korean South Sea has hundreds of miles that are identified as a suitable habitat for aquaculture. To efficiently allocate resources needed to monitor water quality, managers use the chlorophyll-a concentrations and plankton species provided by HABAS data. The information, including the interpreted image, the last-known position of the red tide bloom, and the speed and direction of local winds, is supported.

We used various spatial analysis methods such as union, intersect, tracking, buffer and spatial interpolation for analyzing temporal and spatial characteristics of HABs. From the result of analysis methods, we could get the information on the spatial and temporal characteristics of red tide using HABAS.

A red tide bloom has been identified from Goheung province to Yosu Dolsan coast, these areas were affected by frequent HABs in 2002 and 2003, and most of red tide outbreaks took place from Dolsan coastal area. Chlorophyll data obtained from in-situ field survey were compared with the areas of daily HAB dispersion and overlaid on daily polygons (Yoon, Y. H., 2001).

Considering the oceanographic factors, the favorable conditions for the initiation of HABs are as follows; the calm weather increase sea water temperature, heavy precipitation brings some pollutants in river, nutrients and other chemical substances to the ocean area, low salinity, high suspended solid, low phosphorus and high nitrogen, respectively.

We determined the potential areas in the coastal zones vulnerable to the red tide occurrence based on the oceanic parameters and frequency of HAB occurrence using HABAS. The representative criteria are selected with statistical analysis such as nutrients, sea surface temperature and suspended solids in the study area. By using GIS technique, HABAS through the overlap for three subject figures nitrogen, surface temperature and suspended solids, potential areas of red tide occurrence were obtained and compared with red tide occurrence polygons(Jeong, 2003, 2006).

IV. Conclusion

In the middle coastal area of the Korean South

Sea, the occurrence of HABs appeared and increased every year, enlarged from Yeosu to Goheung and concentrated in July, August, and September.

The spatial analysis of oceanographic factors and HABs occurrence polygons showed favorable marine environmental conditions for the red tide blooms. In order to determine whether coastal managers are supplementing aquaculture harvesting areas, spatial analysis and field measurements data matching with HABAS will support the spatial suitability of aquaculture sites.

To establish a database system with a Geographic Information System, HABAS enables efficient compilation of relevant data and information on red tides blooms in Korea. This system not only streamlines recording of all data on red tide monitoring and investigation, but also enables near real time visualization of spatial and temporal distribution of red tide near future. It therefore enables faster and more accurate risk assessment as well as facilitates prompt early warning to marine culturists and communication amongst concerned departments during red tide outbreaks. In addition, the system also enables faster response to enquiries and retrospective analysis of trends and relationships of red tide outbreaks with environmental changes which are important in further improving the effectiveness of red tide management.

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