Phytoplankton community composition observed by autonomous underwater vehicles

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Abstract

Laboratory and field studies have demonstrated the feasibility of detecting *Karenia brevis* blooms in the eastern Gulf of Mexico utilizing light absorbance spectra. Development of this technique has aimed at providing more timely access to data and information on the initiation, transport, and effects of *K. brevis* blooms. Management efforts to mitigate the harmful effects of blooms will require temporal and spatial monitoring of phytoplankton community taxonomic composition and dynamics. To achieve taxonomic discrimination, laboratory cultures of 12 species of microalgae representing five taxonomic classes were used to develop a library of target classes. A fitting routine involving multiple least-squares analyses was applied to BreveBuster absorbance spectra to determine the 'best fit' estimates of chlorophyll a concentration contributed by each class in both laboratory culture mixes and natural mixed populations. A 10-day deployment of a BreveBuster on an autonomous underwater vehicle (AUV) off the west coast of Florida in September and October 2004 detected a *Karenia brevis* population associated with cyanobacteria and diatom populations which had not been observed by manual sampling. Multiple transects across the shelf by the AUV over this period illustrated the spatial and temporal dynamics of the phytoplankton community.

Introduction

Harmful algal blooms in the Eastern Gulf of Mexico are most often composed of toxic dinoflagellates from the genus *Karenia*. Though much has been learned about the organism and its blooms, little is known about the transitions in phytoplankton community structure during the very early and late stages of the blooms.

Mitigation of some of the harmful effects of the blooms depends on an ability to detect the initiation stage and forecast development and transport. For instance, shellfish aquaculture operations can effectively utilize a few days early warning of a developing bloom to harvest or move their crop. An understanding of species succession sequences leading to and following a mono-specific *Karenia* bloom may uncover the processes necessary to form a bloom and hence a means to forecast the bloom and its demise. However, acquiring this knowledge requires continuous presence in areas of potential bloom development and continuous evaluation of the phytoplankton community structure.

Recent advances in automation of optical instrumentation have provided a means to continuously estimate the phytoplankton community class structure on fixed and mobile underwater platforms. This paper reports results from two field deployments of the optical phytoplankton discriminator referred to as the BreveBuster (due to its origins as a *Karenia brevis* detector) on two types of autonomous underwater vehicles.

Methods

Field deployments of the BreveBuster (Kirkpatrick *et al.* 2000; Robbins 2006) were conducted using autonomous underwater vehicles. A buoyancy propelled Slocum glider (Webb Research Corp) repeatedly traversed a cross-shelf survey between 28 September and 12 October 2004. On 21 January 2005 a propeller-driven REMUS (Hydroid, Inc.) conducted two circuits of a 5-km long survey line at two depths 15 km offshore from Sarasota, Florida in an area known to contain moderate-high concentration of *Karenia brevis*.

The class discrimination algorithm used by the BreveBuster fits a set of known 'standard' absorbance fourth derivative spectra to sample fourth derivative spectra collected during the deployments using multiple regression analysis (Fig. 1). The resulting set of regression coefficients provided estimates of the chlorophyll biomass of each taxonomic class present in the sample. When applied to natural phytoplankton

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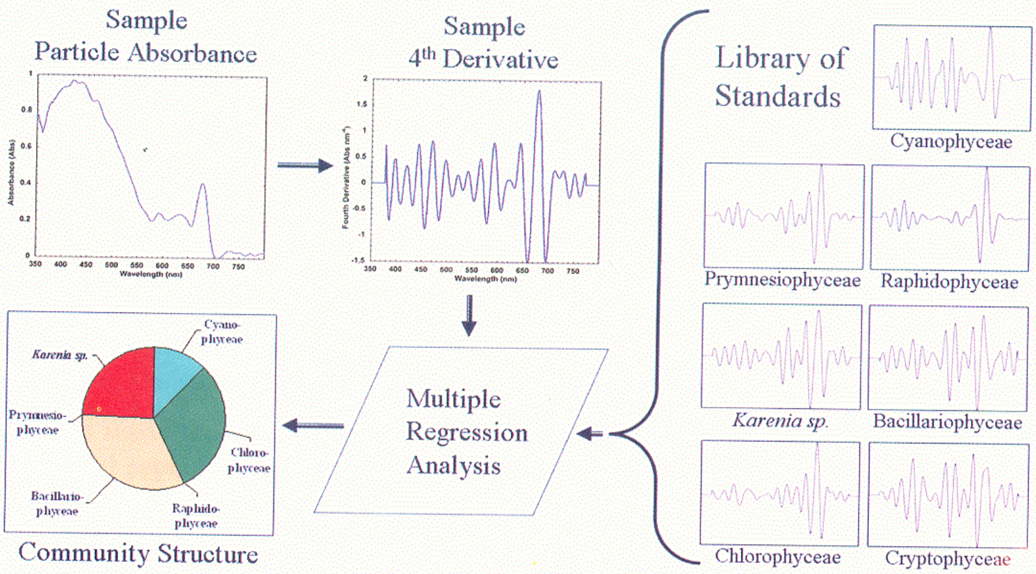

Figure 1. Flowchart of taxonomic class discrimination algorithm used by the BreveBuster.

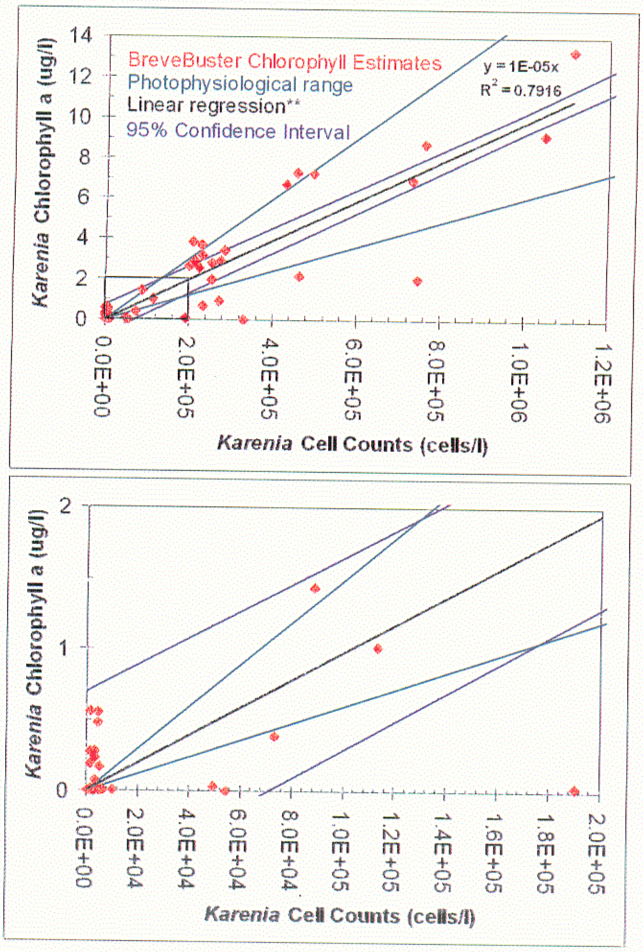

Figure 2. The relationship between BreveBuster estimated *Karenia* sp. chlorophyll a and the *Karenia* sp. cell count. A significant linear regression is indicated by the black line and the equation in the upper-right corner of the upper panel. The green lines indicate the typical range of cellular chlorophyll content for *Karenia brevis*. The bottom panel is an expanded view of the cell count range from 0 to 200,000 cells per liter.

communities, the taxonomic class discrimination algorithm successfully estimated the concentration of *Karenia* sp. compared to microscopic enumeration. The amount of chlorophyll a per *Karenia* sp. cell was estimated at 10 pg/cell using this method (Fig. 2), the value commonly cited as the average for *K. brevis* (Shanley and Vargo 1993; Tester *et al.* 1998; Higham *et al.* 2004).

Results

The Slocum Glider mission in 2004 yielded eight days of spectral absorbance data for taxonomic class discrimination analysis. The fitting routine produced 145 fits with coefficients of determination above 0.6 for the first 2-day transit 50 km offshore. Fits with c.o.d. less than 0.6 were not used in this evaluation. Six of the seven taxonomic classes in the library of standards were detected during the first and second transits (Fig. 3). During the first transit, diatoms dominated most of survey area, with the exception of the central portion of the transit where Cryptophyceae dominated. *Karenia* sp. were only found at low concentration in the lower water column in the outer half of the transit. This community distribution was similar during the second 2-day transit across the shelf with the exceptions that diatoms were less prevalent offshore and that *Karenia* sp. were detected higher in the water column nearshore as well as near the bottom offshore.

The REMUS mission conducted in January 2005 produced 120 useable class distributions (Fig. 4). The BreveBuster community structure analysis indicated that the chlorophyll biomass was highest along the near-surface (1.5 m) track. This agrees with the chlorophyll fluorometer findings of Robbins *et al.* (2006).

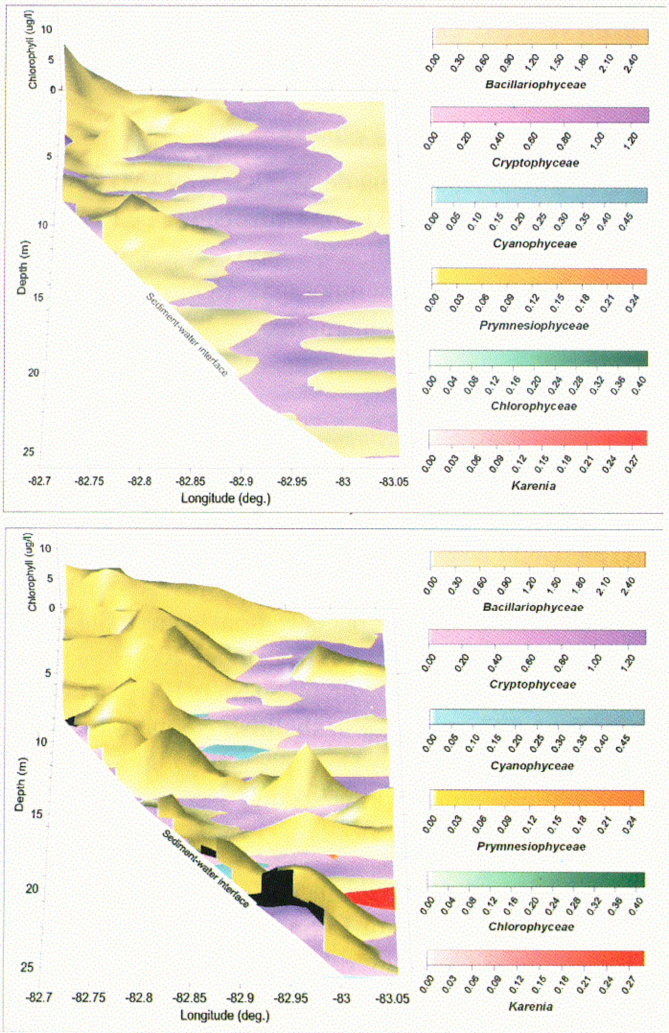

Figure 3. Three-dimension perspective cross sections of chlorophyll a biomass of the taxonomic classes detected by the BreveBuster. The BreveBuster was carried in the payload section of a Slocum glider as it undulated between 2 meters below the surface and 2 meters above the bottom. Panel A depicts results from the first transit of a survey line across the inner shelf off Sarasota, Florida, 28-30 September 2004. Panel B depicts the second transit, 1-3 October 2004. The color bars represent chlorophyll a concentration for each class and have the units of micrograms per liter.

Although there were indications of high *Karenia* sp. biomass during the first pass along the surface track the community was composed of a variety of taxonomic classes. However, the second pass along the surface track found a phytoplankton community structure dominated by *Karenia* sp. These findings can be explained through a combination of water mass advection (Robbins *et al.* 2006) and vertical migration by *Karenia* sp.

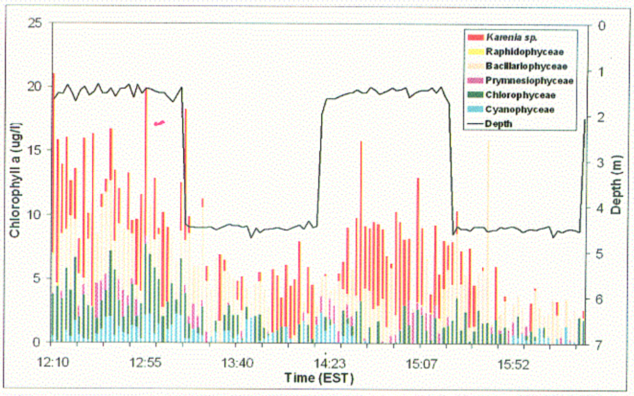

Figure 4. The taxonomic class distribution observed by a BreveBuster carried in a REMUS autonomous underwater vehicle operating in a *Karenia brevis* bloom off Sarasota, Florida on 21 January 2005. The solid black line represents the depth of the REMUS.

Acknowledgements

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