

WASHINGTON SEA GRANT PROJECT COMPLETION SUMMARY REPORT

INSTRUCTIONS: Please provide a lay summary for your completed project that includes the following project elements:

- objectives
- methodology
- rationale
- major findings
- significance of results

If relevant, also include:

- students supported (number and degree level)
- partnerships
- outreach activities

Please note that this summary will be submitted in the Washington Sea Grant annual report to the National Sea Grant Office and will be available to the public via the NIMS database and the Washington Sea Grant website.

WSG Project Number: **R/B-43**
Project Title: Linking Variability in Cell Motility to HAB Formation by
 Heterosigma akashiwo

Project period: 2/1/2004 – 9/30/2007

Principal Investigator(s) and Affiliation:
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(Please provide your summary here. Character limit: 5,000 characters, including spaces):

Heterosigma akashiwo is a HAB-forming alga in that has significant negative effects when large cell populations are concentrated into dense, toxic surface aggregations. Because *Heterosigma* cells are rapid and vigorous swimmers, cell motility is likely a significant factor determining time, location and severity of *Heterosigma* HABs. Previous observations of *Heterosigma* swimming behavior were conducted under highly constrained conditions (e.g. microscope well slides) and have yielded inconsistent characterizations of *Heterosigma*'s swimming speed and overall directional motion. Our research had three overall foci: (i) Developing video-based protocols to accurately quantify unconstrained *Heterosigma* swimming behaviors in the presence of haloclines

and other water column structures; (ii) Using quantitative movement data to derive testable predictive ecosystem-level models of *Heterosigma* HAB formation; and (iii) Support and mentoring of a post-doc and three graduate students in interdisciplinary experimental and theoretical research.

New experimental and modeling techniques

We developed a novel non-intrusive technique based on computerized video analysis to track cells swimming undisturbed in laboratory water columns. This system provides a large arena to observe behaviors ($\geq 10^4$ body lengths) while minimizing wall effects, can be stably stratified with linear salinity gradients and sharp haloclines, and has a circulating water jacket so that algal cultures can be observed indefinitely. Observations are made using infrared illumination to avoid phototaxis and to enable experimental manipulation of the day/night light cycle.

We developed a computer-controlled camera platform that enables us to program data acquisition sequences to be collected across the vertical extent of the columns and analyzed autonomously without human intervention (e.g., continuously over 24- or 48-hour experiments). This enabled us to systematically profile both *Heterosigma* cell population density and cell-level swimming behavior, simultaneously and with very high spatial and temporal resolution.

We developed analytical procedures for separating overall movement speed and direction of *Heterosigma* cells – necessary inputs into predictive spatially explicit population distribution models – from the oscillatory components of swimming movements that characterize cells' helical swimming and biomechanical properties. We incorporated these motility data into modeling frameworks that translated cell movement characteristics into population fluxes and vertical distributions.

A key attribute of our data collection and mathematical modeling analysis is that they provide a framework for testing and critically assessing quantitative strengths and weaknesses of predictive models. By simultaneously measuring both behaviors (which are the basis for deriving population models) and actual population distribution time series (which provide a “ground-truth” against which to compare model predictions) we can rigorously refine our statistical and computational modeling approaches. This research methodology has potential for wide application across many aspects of plankton biology.

Observations and experimental findings

We confirmed rapid swimming by *Heterosigma* cells, up to at least 160 microns s^{-1} (Beaton et al. 2004). However, we observed strong variability in cell swimming speed and direction. Within a given *Heterosigma* population, cells exposed to common ambient conditions exhibited distinct swimming behaviors. We observed strong swimming responses to the diurnal light cycle, in which *Heterosigma* cells switched from nearly random to strongly vertical orientations. Finally, we observed large differences in speed and orientation between strains. Spatially-explicit models of *Heterosigma* population distribution suggest that all three levels of variability are likely to have strong effects on cell accumulation in surface HABs.

Swimming behavior of *Heterosigma* cells is affected by the presence of a sharp halocline: cells stopped swimming upwards and aggregated below a fresh water interface;

cells reduced upward swimming speed with a salinity jump from 28 to 8‰, and upward swimming speed was unchanged in cells encountering a salinity jump from 28 to 16‰. A model of *Heterosigma* distribution in a two-layer, turbulent water column suggest that the ability to cross strong haloclines, coupled with the suppression of turbulence at the halocline, results in rapid accumulation of high cell populations in low salinity surface lenses.

Bioconvection is a phenomenon in which up-swimming cells that are denser than the ambient fluid form self-generated circulation patterns that prevent surface aggregations. Bioconvection's significance for HABs is unknown. We observed and modeled the onset of bioconvection in *Heterosigma* in the presence of stabilizing salinity gradients, showing that bioconvection can occur and may in some cases even be strengthened in the presence of these gradients.