ECOHAB: KARENIA NUTRIENT DYNAMICS IN THE EASTERN GULF OF MEXICO, A FWRI/MOTE COOPERATIVE RED TIDE RESEARCH PROGRAM

YEAR 2 PROGRESS REPORT FOR FWC Agreement No. 06219 BETWEEN THE FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION AND MOTE MARINE LABORATORY


SUBMITTED TO:
DR. CYNTHIA HEIL
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
FISH AND WILDLIFE RESEARCH INSTITUTE
100 EIGHTH AVE. S.E.
ST. PETERSBURG, FLORIDA 33701
(727) 896-8626

SUBMITTED BY:
L. KELLIE DIXON
DR. GARY J. KIRKPATRICK
MOTE MARINE LABORATORY
1600 KEN THOMPSON PARKWAY
SARASOTA, FLORIDA 34236

Mote Marine Laboratory Technical Report No. 1399

June 18, 2008
ECOHAB: KARENIA NUTRIENT DYNAMICS IN THE EASTERN GULF OF MEXICO

Overall Project Background and Research Objectives

The project overall will focus on addressing two outstanding questions: 1) what are the nutrient sources (N and P) fueling the massive, persistent biomass accumulations and 2) where were they coming from? Until these are identified, management activities will continue to be ineffectual in controlling or forecasting blooms and their initiation.

To address these hypotheses, a collaborative research effort has been designed which includes biological, chemical, and physical scientists that will focus on comparing the physical and chemical environment and physiological characteristics of *K. brevis* during three bloom stages (combined initiation and development, maintenance, and decline) and in three different bloom environments (lagoonal, estuarine, and coastal). Building on prior research results, the objectives are to:

1. Compare the nutritional physiology (carbon (C), N, and P) of *K. brevis* within various bloom stages and across environments where blooms occur and in cultures grown under a range of environmentally relevant conditions.
2. Evaluate potential sources of new and regenerated nutrients from: a) regeneration from N\textsubscript{2} fixers (e.g., *Trichodesmium*, *Lyngbya*, and unicellular diazotrophs) and other microbes, b) zooplankton excretion and assess their overall contribution to nutrient budgets, c) the flux of particulate and dissolved inorganic and organic material from estuaries to coastal waters d) atmospheric deposition, e) benthic fluxes, and d) photochemical reactions.
3. Evaluate the importance of the microbial loop as a regulator of nutrient availability and quality.
4. Examine the role of migratory behavior and photochemistry on nutrient acquisition by *K. brevis*.
5. Examine the physical context of the west FL shelf (WFS) and the influence of the coastal ocean and estuarine inputs on advection and concentration of *K. brevis* cells in three-dimensional space and time.
6. Couple circulation physics with the quantitative biology and chemistry to construct an ecologically relevant model for forecasting the frequency, duration, and magnitude of *K. brevis* blooms in space and time.

These goals will be accomplished through a combination of retrospective analyses of PI data from the 2001 bloom, field measurements of nearshore and offshore nutrient sources and inputs, comparative physiological and biogeochemical studies during different blooms stages and in different bloom environments, and measurements of circulation and estuarine flow. These efforts will contribute to and be synthesized in coupled biophysical models describing *K. brevis* bloom dynamics. Feedback between modelers and observational/experimental scientists will ensure that the appropriate parameters necessary for ecological modeling are well-defined. It is important that this effort be undertaken now given both projected increases in coastal nutrient inputs due to rapid rates of coastal development in southwest FL and current combined state and federal resources focused on *K. brevis* blooms in FL.
Overall Approach and methods

In order to address the central hypotheses, the project aims to take a phased, multi-faceted approach that will include:

1. synthesis of extant data from the 2001 bloom;
2. laboratory experiments examining nutrient kinetics within clones and between species as well as effects of migratory behavior and photochemistry on nutrient utilization;
3. comparative field measurements of uptake and regeneration of inorganic and organic N, P, and C during different stages of blooms in four environments: lagoonal, estuarine, coastal and offshore;
4. interannual and seasonal measurements of uncharacterized nutrient sources to blooms within these environments, including coastal inputs;
5. characterization of ocean circulation in bloom environments; and
6. 3-D coupled biophysical modeling of near and offshore *K. brevis* environments.

The specific tasks (maintaining the numbering of the original proposal to NOAA) in which Mote Marine Laboratory has a role are listed below. Descriptions of progress for each task appear below task descriptions.

**Task 1. Retrospective analyses (2001 bloom) (All PIs, Dixon and Kirkpatrick)**

The 2001 *K. brevis* bloom was the first bloom for which extensive nutrient related physiological data were collected. In Yr 1, synthesis of the disparate pre-existing biological, chemical and physical datasets on the 2001 bloom (all collected from projects of co-PI's on this proposal) will be accomplished during an initial meeting of PI’s during which data sets will be compiled, analyzed and provided to modelers.

Data inventory is complete for the 2001 bloom as is retrieval of all riverine flow data, rainfall data from unaged coastal areas, and atmospheric deposition data form the pertinent monitoring locations within the Florida peninsula. Data have been obtained and collated from 42 rainfall sites, 24 riverine discharge sites (plus associated rainfall if available), and from nine atmospheric deposition sites. Data have been updated through the most recent values obtainable from the various agency sources. A technical report summarizing methods and data sources has been produced for freshwater inflows to the study areas. Electronic appendices consist of daily flow estimates for the coastal region north of Tampa Bay, Tampa Bay, Charlotte Harbor, and the Caloosahatchee River,

**Task 3. Comparative field study of nutrient dynamics and bloom requirements (Bronk, Dixon, Heil, Hitchcock, Kirkpatrick, Mulholland, O’Neil)**

During Y2 –Y5, collaborative field studies will be undertaken in bloom environments: lagoonal, estuarine and coastal and offshore, to address the following questions:

1. *What N forms are used and/or preferred by K. brevis in the different environments and at different stages of the blooms?*
2. *Are organic forms preferentially used as a K. brevis bloom develops – particularly humic-N and urea?*
3. *What percent of phytoplankton P requirements are met by P regeneration resulting from enzymatic hydrolysis, grazing, and photochemical reactions?*
4. How do rates of carbon uptake change across bloom environments and as blooms evolve?

5. Is mixotrophic utilization of DON, DOP, or DOC a factor in K. brevis out-competing other resident phytoplankton species?

6. Does exposure to UV radiation result in the production of labile N and P forms?

7. How does aggregation behavior influence N and P acquisition by K. brevis?

Field sampling: Field campaigns were conducted in October 2007 and were fortunate to encounter a relatively discrete but high cell number bloom in the southern portion of the study area. Vessel draft limited access to nearshore and lagoonal sites forcing a re-evaluation of the role and value of supporting nutrient data collected by small boats. Discussions with modelers indicated that detailed nutrient mapping from the main research platform (R/V Pelican) during the initial phase of the field campaign was preferable and was accomplished. During this period, cruise tracks were developed adaptively to visit chlorophyll anomalies detected on satellite imagery, to maximize spatial coverage of the study area for mapping purposes, and to revisit areas of interest as time permitted.

Spatial variation along the cruise tracks were evaluated through the detailed mapping of surface dissolved inorganic nutrients from the R/V Pelican’s flow-through system using two SubChemPak Analyzers (“Subchem”) which provided for high-resolution, real-time measurements of PO$_4$, NO$_2$, NO$_2$+3, NH$_4$, and SiO$_2$ using a continuous-flow spectrophotometric analyzers and wet chemical techniques.

Samples and physical profile data were collected at seven locations, described as 1) two coastal locations (approximately at the 10m isobath - one slightly offshore of Tampa Bay, one offshore of Charlotte), 2) in the outgoing tidal plume from Sarasota Bay, 3) an offshore location, and 4) estuarine stations inside Charlotte Harbor and Tampa Bay, and 5) at a chlorophyll anomaly that proved to be a K. brevis bloom. Investigations by other PIs were conducted at these locations as well. Additional stations (profiles, surface and bottom discrete samples) were collected between these locations for mapping purposes, resulting in 102 samples for the effort (including replicates and blanks). Samples were processed for inorganic (PO$_4$, NO$_2$+3, NH$_4$, and SiO$_2$) and organic (DTN, DTP, and Urea) nutrient concentrations, biomass indicators (HPLC pigments and CHEmTAX analyses, particulate P, N and C), and have been provided in previous reports.

Task 4. Measurement of uncharacterized nutrient sources to blooms

Benthic Flux: (Dixon) Sediment nutrient flux will be measured using an in situ chamber method (Murphy and Hicks, 1983) with the diver deployment of opaque large-volume, stirred, annular chambers in the two estuaries, the lagoonal, and the coastal station during the late fall season. Benthic flux and sediment oxygen demand determinations are planned for three years, at four sites each year, with three determinations per site. Procedures include the use of a blank chamber to remove water column changes and an initial recirculation phase with filtration (0.45 µm) will minimize water column phytoplankton (isolating any observed nutrient flux to the sediment-water column interface alone). Samples for nutrient analyses will be withdrawn periodically. Duration of incubation will vary by environment and in response to monitored O$_2$ levels, but are expected to range between 8 and 20 hours. Surficial sediment samples (0-5 cm) will also be secured for determination of grain size (Coulter 1994, Folk 1974), percent organics (Standard Methods 2540G), and total nitrogen and phosphorus (Plumb 1981; EPA/CE-81-1, p.3-227 [e], p.3-201,2) to develop correlations of nutrient flux with bulk sediment characteristics.
Fieldwork will be carried out by Philip J. Murphy of HydrO2, Water quality Associates, Inc., under subcontract to Mote Marine Laboratory, with analytical support provided by Mote Marine Laboratory (L.K. Dixon).

Sediment nutrient flux measurements took place over a period of October 18-23, 2007. Four sites were sampled, one each in southern Tampa Bay, Sarasota Bay, nearshore coastal waters off Sarasota, and Charlotte Harbor. At each site, four domes deployed for approximately 8 hours. Physical water quality data were gathered and dissolved oxygen was monitored over the entire incubation. One dome was not in contact with the bottom and three were exposed to sediments. All were incubated during daylight hours. Water samples were removed from each dome at the beginning, midpoint, and end of the incubations. Sediment samples were collected from adjacent to the domes at the end of incubation. Aqueous samples were processed for dissolved inorganic and total nutrients (N and P), chlorophyll, urea, and silicates. Sediments were processed for total Kjeldahl N and total P, percent organics, and grain size. All incubations were successfully completed. All analyses are complete. The report from HydrO2 has been finalized and a presentation of results made to NOAA Project Manager in April, 2008.

**Atmospheric Flux:** (Dixon) Model inputs for atmospheric fluxes will be compiled from existing sampling programs operated by the National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) and the Atmospheric Integrated Research Monitoring Network (AIRMoN). The two sites pertinent to this study area both presently in operation and include data for the 2001 retrospective period. The NTN site in rural Sarasota County collects weekly composite samples of wet-only deposition in inorganic N (representing a lower bound of inorganic flux due to possible transformations during the week accumulation period). The AIRMoN site in Tampa Bay collects precipitation samples daily (representing relatively unbiased inorganic nitrogen wet deposition from a highly urbanized environment). The weekly samples will be apportioned into daily time steps for model inputs using rainfall records and precipitation-weighted concentrations. Previous work (Dixon et al. 1996, 1998), can provide estimates of the relationship of inorganic:total nitrogen in bulk deposition samples and the relationship of bulk:wet only deposition loads for producing potential ranges of atmospheric deposition as inputs to planned modeling efforts. Bulk deposition values are expected to provide a good representation of atmospheric loads to estuarine waters, while inorganic wet-only loadings may provide a better representation for coastal and offshore waters due to distance from particulate sources and the relative lack of strong latitudinal gradients in wet inorganic nitrogen deposition.

Data sources have been identified for accumulation of atmospheric deposition and data from 2000 to date retrieved and updated since the last progress report. A meeting of principal investigators specific to supplying modeling data was conducted and approaches for incorporating coastal loadings identified. Modelers have indicated an intent to use TRMM or other remotely sensed daily rainfall products for the shelf region. Regression analyses of daily rainfall concentrations are being developed and applied to weekly loads as measured at a series of four other coastal atmospheric deposition sites. Products will be a latitudinally specific relationship of rainfall concentration to daily rainfall amount for ammonium, NOx, orthophosphorus, and estimates of organic nitrogen. Onshore-offshore gradients remain problematic but a literature search of stations from remote locations is underway in order to provide appropriate estimates for the SW Florida coastal shelf.
**Estuarine & Lagoonal Outflow:** (Dixon, Weisberg, Heil) Estuarine nutrient outflows for Tampa Bay, Charlotte Harbor and the Caloosahatchee River will be calculated according to the 4 methods in Vargo et al (in revision), with nutrient data provided from monitoring platforms in each area. FWRI currently maintains 1 platform in the Caloosahatchee River, and will take delivery on 2 additional platforms by fall 2006, which will be deployed at the mouths of Tampa Bay and Charlotte Harbor for this project. These mobile, pontoon based units are equipped with meteorological, current, nutrient and Chl a sensors, and transmit data via GOES satellite to a publicly accessible web page (see http://www.merhabfl.org/marvin.htm). Additionally, estuarine outflows will be estimated from the circulation model linking the WFS with the Tampa Bay and Charlotte Harbor estuaries described below. Uncertainty in computed estuarine loads will be estimated using the spatial variability in inorganic nutrient concentrations determined with the detailed underway mapping described above.

Data sources, including flow records from the most downstream gages of major rivers contributing freshwater to the Southwest Florida coast, have been identified and updated from 2000-present. A watershed ratio method has been used to estimate flows from the ungaged coastal drainage areas. Where available, point source flows (not captured by watershed ratios) and consumptive use withdrawals have been included. Groundwater contributions to Tampa Bay are provided but are based on groundwater levels that are not representative of present day conditions so are not included. Daily estuarine loads have been estimated from early 2000 through 2007 using the generally monthly water quality data available from the ambient estuarine monitoring programs of Pinellas, Hillsborough, Charlotte and Lee Counties, multiplied by the daily flow estimates of the compiled flows from each estuary. A technical report with methods and electronic version of the daily loads have been provided.

**Project Schedules, timeline and milestones chart** Yr 1 of the project will focus on a retrospective analysis of existing data from the 2001 bloom and initial laboratory experiments. Field studies are scheduled to initiate in Y2 of the project due to ship time availability and bloom timing and continue through Y5. Laboratory comparisons will be undertaken after the major field efforts are underway during non-bloom periods.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sept 06-Feb 07</th>
<th>Mar 07-Aug 07</th>
<th>Sept 07-Feb 08</th>
<th>Mar 08-Aug 08</th>
<th>Sept 08-Feb 09</th>
<th>Mar 09-Aug 09</th>
<th>Sept 09-Feb 10</th>
<th>Mar 10-Aug 10</th>
<th>Sept 10-Feb 11</th>
<th>Mar 11-Aug 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 Retrospective analysis</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Comparative field studies</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Lab studies</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Source Mrmts</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>PI meetings</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Synthesis Symposia</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Data analysis</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
<tr>
<td>Mss prep</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
<td>- &gt;</td>
</tr>
</tbody>
</table>

Based on proposal time lines and project initiation date, all phases of Mote project activities are on schedule.