

REPORT OF THE FLORIDA BAY SCIENCE OVERSIGHT PANEL
Perspectives from the 2003 Florida Bay Science Conference
Submitted to the
Program Management Committee of the
Interagency Florida Bay Science Program

By

John E. Hobbie, chair
Marine Biological Laboratory
Woods Hole, Massachusetts

William C. Boicourt
Horn Point Laboratory
University of Maryland Center for Environmental Science
Cambridge, Maryland

William Dennison
Horn Point Laboratory
University of Maryland Center for Environmental Science
Cambridge, Maryland

Edward T. Houde
Chesapeake Bay Laboratory
University of Maryland Center for Environmental Science
Solomons Island, Maryland

Steven C. McCutcheon
Hydrologic and Environmental Engineering
Athens, Georgia

Hans W. Paerl
University of North Carolina
Morehead City, North Carolina

INTRODUCTION

The Florida Bay Science Oversight Panel (FBSOP) is an independent peer-review group charged with providing regular, broad, technical, and management review of the Interagency Florida Bay Science Program (hereafter called the Florida Bay Program). This panel was first convened August 17, 1993, at the request of George T. Frampton, Assistant Secretary for Fish and Wildlife and Parks of the U.S. Department of Interior. The panel reviews agency plans, Program Management Committee (PMC) strategies for program development, scientific quality of research, modeling and monitoring, and research results (Armentano et al. 1994; Armentano et al. 1996). The FBSOP consists of six senior scientists with significant experience in estuarine research and major estuarine restoration programs; they have no involvement in Florida Bay Program projects. Since the 2001 review and report, Kenneth Heck has resigned from the FBSOP, William Dennison has joined the panel, and Hans Paerl has rejoined the panel after a one-year hiatus. Following the initial August 17, 1993, evaluation, the PMC has requested reviews that have taken place October 17-18, 1995; December 10-12, 1996; May 12-14, 1998; November 1-5, 1999, and April 24-26, 2001. Starting in 1995, the FBSOP has participated in the Florida Bay Science Conferences by formally leading question and answer sessions and by providing written reports to the PMC that present critical reviews and recommendations for advancing and coordinating the program. The five previous reports are Boesch et al. 1993, 1995, 1997, and 1998 and Hobbie et al. 2000, and 2002.

At the request of the PMC, FBSOP members also suggest membership and chair ad hoc advisory panels of experts in specialized subject areas who participate in technical workshops where critical research issues, interagency coordination, and management alternatives are addressed. These advisory panels also provide written recommendations that the PMC accepts as guidance in coordinating the interagency program (Armentano et al. 1997). The Florida Bay workshops have included the Modeling Workshop (April 17-18, 1996), Nutrients (July 1-2, 1996), Design and Specification of the Florida Bay Water Quality Model (October 22-24, 1996), Higher Trophic Level Initiative (November 4-5, 1997), Seagrass Model Workshop (January 13-14, 1998), Paleoecology and Ecosystem History (January 22-23, 1998) and Progress Review of Florida Bay Models (May 11, 1998). Other PMC workshops and research team meetings, at which members FBSOP were not present, include the Physical Science Team Workshop (September 4-5, 1997), Hurricane Georges Retrospective (November 20, 1998), Physical Science Team meeting (March 22, 1999), Phytoplankton Bloom Workshop (May 25-26, 1999), Higher Trophic Level Team Planning Workshop (June 14, 1999), Florida Bay Salinity Modeling Workshop (August 30-31, 1999), and Florida Bay Water Quality Model (September 13, 1999). In January 2000 the Higher Trophic Level Team met with new FBSOP member Ed Houde.

The 2003 Florida Bay and Adjacent Marine Systems Science Conference was held at the Westin Innisbrook Resort, in Tarpon Springs, Florida, on April 14-16. As in past conferences, the five major questions (see below) were each taken up; however, questions 2 and 3 were combined to keep the presentations to two full days. The format of the meeting was slightly changed at the request of the SOP. In early January the SOP submitted a list of questions to the PMC for the Conference. This list is intended to guide this SOP report. Each of the four sessions of presented papers began with a member of the PMC summarizing and answering the applicable questions. Speakers were strictly

limited to 15 minutes and questions took up 5 minutes more. At the end of each of the four sessions, there was a 45-minute period devoted to more questions, first from the SOP and then from the audience. There were 60 posters presented; abstracts of the posters were available for the Conference (Anonymous 2003).

The completion of the first draft of a comprehensive scientific synthesis document in March, edited by William Nuttle, was an important milestone for the project. This was given to the SOP in hardcopy and also placed on the web site.

The Florida Bay Program is clearly moving from providing information on scientific questions of how the whole system operates to providing the answers to management questions. These management answers, of course, are based on scientific understanding. The FBSOP believes that this shift represents a proper change in direction of the end result of the research. We endorse the philosophy of the program managers that states that 1) the information has to arise from a fundamental scientific understanding about Florida Bay, and 2) research and synthesis must continue in order to reach the appropriate level of understanding.

In this context of changes in the program, we would like to emphasize that the present function of the Florida Bay Scientific Oversight Panel is to review and advise on the quality and direction of the science completed and proposed. It is not in our purview to oversee the management and restoration of the Florida Bay resources, which the FBSOP hopes will be based on this scientific understanding, or the interactions of the program with the private, state, and federal organizations, agencies, taskforces, and plans.

Based on the information presented in the 2003 synthesis document and at the 2003 Florida Bay Conference, the Scientific Oversight Panel concludes that:

- The overall quality of the research is good; the understanding of the parts of the system now available, that is, the physics, chemistry, and biology, now need to be integrated across disciplines into quantitative food webs, into process-based models ecosystems, and into scenarios of possible environmental changes linked to the restoration of the Everglades.
- There has been strong progress in the development of the data and models to describe the hydrodynamics in Florida Bay.
- The application of the hydrodynamic modeling to problems of the impacts of flow change in the Everglades and of interactions of phytoplankton and seagrass with salinity and nutrients will necessitate a change to intensive cooperation among modelers; the community modeling approach is probably the best way to make rapid progress.
- The FB Program is beginning to shift to a more focused program aimed at predicting the changes caused by the Comprehensive Everglades Restoration Project. This appropriate shift in goals and emphases will be made more effective when the various parts of the program work more closely together and analyze their data in a holistic, ecosystem context.
- There has been major progress in understanding the immediate cause of seagrass die-offs. Models of the interactions of climate, hydrodynamics, transport of materials, plant growth and biogeochemistry are the next step to elucidate the steps leading to the die-off.
- Benthic biota and their processes are still in need of study. Microalgae at the surface of the sediments potentially mediate nutrient exchange and serve as a source of

planktonic populations. Filter-feeding and deposit-feeding invertebrates are key constituents of the food web for fish; sponges are important filter feeders and could serve as ecological indicators.

GENERAL FINDINGS OF THE SCIENTIFIC OVERSIGHT PANEL

The global impact of the Florida Bay Project

Florida Bay and its extensive South Florida watershed are adjacent to a rapidly growing international city. The ecological footprint of the Miami/Fort Lauderdale region includes the water and agricultural resources of the watershed that ultimately discharges into Florida Bay. Florida Bay is a shallow subtropical environment dominated by mangrove and tropical seagrass habitats containing a diverse community of mostly tropical organisms. The large watershed area and small water volume and low exchange of Florida Bay make it particularly vulnerable to human perturbation. As such, the situation in South Florida is representative of one of the most pressing environmental challenges globally. Rapidly growing mega-cities in the coastal zone of the tropics presents a major global environmental challenge, arguably THE major global environmental challenge. Resolving the environmental problems of water allocation and ecosystem alteration in South Florida with an integrated science and management approach would have a significant global impact. Key elements of the ongoing program of managing at a large, watershed scale over long time frames will provide a valuable case study to regions of the world with some of the same environmental problems but with less resources for science or management.

Integration beyond the synthesis document

The excellent effort involved in producing a synthesis document prior to the April 2003 meeting is to be commended. As well as being an important tool in the scientific review, this synthesis document will likely prove to be an important technical publication for the program. There has to be a continuing effort to improve and update this document. Eventually it should be published. But there are some very important yet unpublished results that have to be incorporated now (should be on a case-by-case basis). The updates must not wait until the next Florida Bay Workshop.

It would be helpful if the final document contained a brief synopsis of the history of the major scientific conceptual models that have been put forward (e.g., eutrophication induced seagrass loss, 'river of sand') in the context of the current understanding of the ecosystem processes.

The SOP recommends that the synthesis effort be continued with a focus on integration—that is to say, integration between each of the central questions, and linking the findings to the management issues. One possibility is a workshop on a cross-cutting theme. This is not meant to be a theme within a discipline, for the physical oceanographers will always talk with other physical oceanographers, but one that cuts across the disciplines. Perhaps another way to structure this integration effort would be to have an 'integration team' address each of the synthesis points that have been developed and address the following question: Given what we now know, what are the implications for a) management recommendations, b) monitoring needs, and c) future research? The other aspect of integration would be to continue to develop the Florida

Bay conceptual diagram, even to the point of a series of nested regional diagrams. These conceptual diagrams can become unifying devices that allow more effective communication between scientists and between scientists and stakeholders.

Begin development of future scenarios

A variety of future scenarios should be developed so that research and modeling approaches can be designed to better inform managers and decision makers about the consequences of the different scenarios. This is a good way for scientists to inform management discussion and issues and should be carried out even though we do not yet know exactly what will happen in the future. For example, the impact of salinity changes of 2, 4, and 6 psu annually for selected ecosystems could be determined.

This scenario development should ultimately involve the broadest possible range of stakeholders through extensive public consultation. Rather than await outcomes of this potentially protracted scenario development, the scientific team could develop some preliminary scenarios for initial testing. The preliminary scenarios could focus on the potential changes in water flow into Florida Bay and/or changes in water circulation with removal of fill material between the Keys.

Enhanced modeling

Modeling must be encouraged. In particular the support of the Army Corps of Engineers should be sought. In addition the concept of a community model and a community modeling exercise has to be incorporated into the project. This means a model that is developed by a group of modelers and is supported and updated by some organization. It may be used by anyone; it is updated; it will be around for a long time so can be continually improved. The panel recommends that a community-based model of physical process go forward as expeditiously as possible; the plan should incorporate both the agencies and the academic community.

Revision of central questions

The use of five central questions to focus the ongoing research over the past several years has provided an important tool for guiding and managing the scientific effort. The choice of these original questions has been validated by the knowledge accumulated over this period. The use of the central questions insured that the major topics of concern were adequately addressed, with the caveat that there are some lingering gaps in understanding. While these questions have served the scientific and management community well, it is the opinion of the Scientific Oversight Panel that it is an appropriate time to reevaluate these questions. In particular, with the focus on restoration with a large-scale adaptive management experiment effected through changes in water flow patterns, a recasting of the central questions to encompass this focus would be appropriate. Some of this evolution of the questions has occurred with the creation of an ecosystem history synthesis and the combining of the nutrient and phytoplankton questions in the April 2003 synthesis (Nuttle et al.).

Science communication needed

The completion of the recent synthesis provides an opportunity to disseminate the current understanding of the Florida Bay ecosystem to a wider audience. The use of conceptual diagrams, maps, photographs, tables and figures in a layout design could enhance the management—science linkages. The quality of PowerPoint presentations in many of the talks at the April 2003 conference insures that there are abundant images and graphics to illustrate the key points. Maintaining the peer-reviewed scientific literature mode of science communication is also a key part of a sustained effort. However, peer-reviewed literature is often sequestered in specialized journals and bringing the key findings into an accessible format in which the context is provided in a synthetic manner would be valuable for non-specialists. The non-specialist audience includes other scientists, both researchers and managers. This science communication could also augment the outreach program to the more general lay audience.

Meso-scale experimentation recommended

The large-scale manipulations of water flow and distribution planned as part of the CERP can be considered a large-scale experiment, operating at the scale of the entire Florida Bay. However, most of the field experiments that have been conducted to date are at the scale of one square meter or smaller. Rather than just relying on models to translate the small-scale measurements to the entire bay, a suite of meso-scale experiments could be conducted to test various scenarios. Small natural basins could be used as experimental units, and environmental factors like water flow, nutrients or dissolved gases could be manipulated.

Results from these experimental units would augment public education as well as advance scientific understanding. A benefit of meso-scale experimentation could be enhanced collaboration, a typical outcome of this style of research. The National Park Service would need to be closely involved so that research permits and security issues would be addressed.

Changes in funding and management reduce the effectiveness of NOAA research

The implementation of CERP (Comprehensive Everglades Restoration Plan) adds an additional requirement to NOAA's program for Florida Bay. The NOAA SFP program should return to the funding level originally planned. To assure maximum cost efficiency and relevancy, the management and decision-authority should be in the hands of regional agency managers who are best situated to understand the regional interagency process of working with CERP and SFERTF.

The need for continued participation by the State of Florida

The panel notes that the Florida Bay Science Program is a joint state and federal effort. The Program Management Committee recognizes this partnership and considers all levels of involvement in its decision process. Yet, the source of funds for the necessary science has increasingly shifted towards federal sources. The only non-federal agency with a substantial Florida Bay Science contribution is the South Florida Water Management District. The panel notes that significant fish and wildlife and water quality science needs remain in Florida Bay and encourages the Florida Fish and Wildlife Conservation Commission (and the Florida Department of Environmental Protection) to

endeavor to find State sources of funds to support science that focuses on these important information needs and to be full partners in the Florida Bay Science Program.

The impact of a reduction in the Critical Ecosystem Studies Initiative Program of DOI

Since its inception in 1997, the Critical Ecosystem Studies Initiative Program (CESI) has been the primary Department of Interior (DOI) funding source for research supporting decision-making by DOI resource managers regarding Greater Everglades ecosystem restoration, including Florida Bay. CESI funds or has funded 13 National Park Service and four U.S. Geological Survey projects dealing with Florida Bay. In addition, CESI funds the operation of the Florida Bay Interagency Science Center in Key Largo that supported over 15550 scientist-days of use in the past year (boats, lab, and dorm). The Science Center also provides office space for seven agencies and organizations. Both the results from the funded research and the logistics support have been extremely useful to the Florida Bay Program and to resource managers.

Past support for the Seagrass Research came almost entirely from CESI: the continuity of funding contributed greatly to the program's success. In particular, CESI supported the development of the *Thalassia* and *Halodule* unit models and the Florida Bay landscape model. Other important CESI projects included long-term seagrass and light monitoring in the Bay and a series of studies of *Labyrinthula*.

The SOP Panel notes the recent reduction in CESI funding from 12 to 4 million dollars and the elimination of the dedicated connection to Florida Bay research. This represents a substantial threat to the success of the Florida Bay Science Program.

The format of the 2003 Conference

The format of the 2003 Florida Bay Conference along with the 2003 Synthesis Document improved the ability of the SOP to understand the present state of knowledge of the Florida Bay Program. The SOP suggests, however, that the choice of speakers should be based, in part, on insights and conclusions. It was not helpful to hear about brand-new projects with little data. The conference calls used by the SOP to develop overview questions for the Conference were a valuable exercise. The questions themselves were only partially successful in producing answers that gave the SOP an integration of concepts and a report card of progress over the past two years. For more details, see a later section on Questions posed by the SOP.

QUESTIONS POSED BY THE SOP BEFORE THE 2003 MEETING: COMMENTS ON ANSWERS

For the Florida Bay Conference in April 2003, the SOP has decided to base its report on a series of questions given to the Program Management Committee in advance.

Overview questions

- 1) *What new findings have been made and how have these advanced our understanding of Florida Bay?* The PMC embedded new findings in the Synthesis Report, conference presentations, and posters. The report captures some advances through 2001 and puts those advances into context with what has been learned about Florida Bay since 1994. The answers presented at the beginning of each session were more along the lines of guides to the work to be presented (talks, posters) instead of the interpretive statements about the real advances in knowledge. In the future, these presentations by the PMC should be treated as opportunities to communicate new and exciting findings to the SOP and to resource managers. In addition, it is important that the SOP understand how the outreach program is proceeding.
- 2) *How is the program addressing resource management questions? These management issues pertain to marine sanctuaries, Everglades National Park, and Everglades restoration.* The Florida Bay Program has undergone a remarkable transformation in the last 24 months to address the science needs of specific resources management objectives. This transformation is due to the Florida Bay Program finally taking responsibility for the Florida Bay and Florida Keys Study and for the program determining the critical freshwater flow. This, along with the “what if” questions posed by the Army Corps of Engineers, provides a new focus. Nevertheless, the Florida Bay Program has other objectives beside these two new assessments. There is a continuing need to provide day-to-day information for the management of the sanctuaries, park, and natural resources of the region. In addition, there is a need to provide foresight into future management issues. These efforts deserve the same focus as the new assessments.
- 3) *How is the synthesis process for the major scientific questions progressing since the last conference? This includes synthesis appropriate for scientific colleagues, for the interested public, and for management groups. What are the plans for enhancing synthesis such as funding for special projects, such as bringing in outside experts, or such as setting up a team to oversee synthesis? What are the gaps in understanding? How are new questions and hypotheses, especially those that fall outside the current five strategic questions being addressed?* The synthesis report is highly useful to the SOP and should be useful to the Florida Bay Program and the resource managers that depend on the program. The report could be useful to the Florida Bay science community and science community at large if widely distributed. The production of an agency report on synthesis is certainly a good interim goal, but the PMC should consider reporting the Florida Bay Program advances in book form to solidify the synthesis process and gain further support from the scientific community at large. A published synthesis would not only establish science leadership but might draw other research groups to the Bay. Given the outstanding scientists involved, it may be easier to get full collaboration for a book than a report.

The next iteration of the synthesis document whether in the form of a report or book should clearly highlight advances and gaps in knowledge and be based on the latest information. For example, neither the report, presentations nor posters [seemed to] note the recent coral die-off north of Key West. Furthermore, there was no presentation of the phytoplankton model of Jackson and Byrd.

Other general questions

- 1) *What has been the impact of losing the administrative coordinator for the Florida Bay Science Program on the synthesis process and management of the program?* Despite the better focus of the Florida Bay Program and solid advances, two vital types of communication are still missing from the Program that the coordinator should be able to easily organize and manage. First, the SOP wonders about the interactions between managers and the Florida Bay Program: how are the manager's issues articulated and how is information transferred? Second, there was no evidence about how the public at large is being kept informed to maintain a public consensus for this work. There were brief mentions of the NOAA outreach program and there have been Sea Grant programs and newsletters in past but none of these efforts were in evidence at the Conference.
- 2) *One topic of SOP interest is not covered by any specific question. This topic, the scientific quality of the research, includes publication in journals, applicability to management questions, appropriate use of information from the scientific literature, and evidence that the FB scientific and management lessons are being used elsewhere. As a part of this evaluation, the SOP requests that this general topic be discussed by the PMC and conclusions buttressed by a list of scientific publications to be provided before the conference. Although the list of publications was not provided in a timely fashion, there are many publications in a number of peer-reviewed scientific publications. This is certainly one indication of scientific quality. That is, these publications are at least as good as papers about other estuaries. In addition, the Florida Bay Program contrasts strongly with programs where most of the information remains in the gray literature. It is difficult to document the general impact of the FB work on the thinking of other scientists. There are informal indications that research on marsh grass die-off on the Georgia coastline has benefited from the conceptual models derived from investigation of sea grass die-off in Florida Bay.*
- 3) *In 2001, the PMC brought up the issue of the need to update the strategic plan (explained in the 2001 SOP Report, Findings 9, 10, and 11). What progress has been made?* Aside from reiterating the importance of a new strategic plan, there was only brief mention of progress. One idea was to retain the same structure of five disciplinary questions but recast the questions so they are up-to-date. The questions could relate to the restoration and management questions. Another idea is to have a completely different structure with cross-cutting questions or themes that require more than one discipline to address. In this context, the FEASIBILITY STUDY is intellectually driven, not driven by engineering needs or agency questions so the ideas incorporated here are also important to include.
- 4) *Are there plans for a synthetic document that clearly presents the available knowledge on the past history of Florida Bay, the knowledge gaps, and the ecological understanding of what degrees of restoration are attainable?* The SOP has

commented in the past that paleoecology, sedimentology, and other issues outside the five major strategic questions are difficult to track in terms of scientific progress and contribution to management and resource objectives. More recently, the Comprehensive Everglades Restoration Plan (CERP) mentions restoration targets (i.e., the ecological state that is the restoration goal). This synthesis document on past history and future restoration would be ideal for guiding interpretation of such targets. One example is the constant reference to a “gin clear” Florida Bay as a target.

- 5) *How does the PMC plan to deal with the comments and suggestions of the two recent NRC reports (from 2002 and underway for 2003)?* There was little discussion on this point.

PROGRESS IN ADVANCING THE EXISTING STRATEGIC PLAN FOR FLORIDA BAY

CENTRAL QUESTION #1: How and at what rates do storms, changing freshwater flows, sea level rise and local evaporation/precipitation influence circulation and salinity patterns within Florida Bay and the outflow from the Bay to adjacent waters?

As the management context has changed with CERP, RECOVER, and the associated Florida Bay and Florida Keys Feasibility Study, the basic scientific needs in the arena of hydrology, circulation, and distributions of salinity have remained comparatively invariant. Especially with regard to modeling, these needs have become sufficiently acute that a sense of “frustration” was expressed on the part of both the science and management communities. Not only were previous failures cited, but also the “inaction” following these failures. Observational studies on the circulation of Florida Bay were proceeding well, yet were located primarily at the periphery of the Bay and not in the challenging, but crucial interior. Boundary condition formulations for the larger model domain did not materialize from the Corps of Engineers and the early work of NOAA (employing the Gulf of Mexico model based on the Princeton Ocean Model) was not brought to bear. Furthermore, the modeling efforts raised uncertainties with regard to freshwater input values.

Results reported to the Florida Bay Joint Conference show significant and gratifying progress on several important fronts. Observational efforts have moved to the interior and produced valuable data and analyses. A description of the semidiurnal (M_2) tidal attenuation as it propagates from the Gulf of Mexico into the Bay revealed the strong filtering role of the bank and basin system. In addition, the role of wind stress in controlling the interior circulation was clearly described. Some progress was made in re-examining the western boundary conditions and the propagation of the M_2 tidal signal into the Bay wind tide effects. Surface and groundwater flows have been integrated into one Everglades model, a model covering the entire boundary condition of northern Florida Bay. Surface and groundwater flows have been integrated into one model, a model covering the entire domain of interest. Substantial progress has been made in circulation modeling, despite the remarkably small amount of funding committed so far to the use of the Environmental Fluid Dynamics Code (EFDC). But as important as these

advances have been, perhaps even more valuable at this pilot stage are the lessons accruing on how such success may be sustained throughout the model development process. Results reported to the Florida Bay Joint Conference show significant and gratifying progress on all three fronts. Observational efforts have moved to the interior and produced valuable data and analyses. Surface and groundwater flows have been integrated into one model, a model covering the entire domain of interest. Substantial progress has been made in circulation modeling, despite remarkably small-scaled efforts. But as important as these advances have been, perhaps even more valuable at this pilot stage are the lessons accruing on how such success may be sustained throughout the model development process.

In this regard, the modeling center being established by the SFWMD and JAX (Loren Mason, science advisor, U.S. Army Corps of Engineers Jacksonville District, personal communication, April 16, 2003) in the Management District is an outstanding, if belated, response to the past failure of the Jacksonville District to produce a reliable, calibrated model of circulation and salinity.

Observations

The observations on the interior of Florida Bay concentrated on one central basin, Whipray (Lee, 2003). These interior observations were in direct response to suggestions from the SOP, and was conducted with judicious and skillful use of shallow-water sampling techniques. Single vertical current profilers were arrayed in all known channels, and fluxes through these passes were estimated by relating the bottom-mounted measurements to shipboard Acoustic Doppler Current Profiler (ADCP) tidal surveys conducted across the channels (Lee 2003).

Additional profilers were intentionally placed at previous current stations on the western boundary of the Florida Bay domain. Tidal and subtidal water-level fluctuations (resulting from wind forcing) were found to be the dominant circulation drivers, as would be expected in this shallow, bank-and-basin system, except near the freshwater sources, where gravitational circulation becomes dominant. A fascinating mix of tidal and seabreeze signals was revealed in the current records in the various passes, reflecting the combined effects of wind and the strong filtering of this highly restrictive shallow channel-and-basin system on the eastward propagating semidiurnal tide. Flux estimates were combined into an overall water budget from which the sum of evaporation and groundwater were then estimated by difference. This sum was sufficiently constrained that assigning a reasonable evaporation value left the groundwater comfortably within the range of existing estimates. With the new detailed descriptions of the eastward propagation and attenuation of the semidiurnal tide and the wind-driven fluctuations of water level and circulation come the desire to fill out the picture even more completely.

Interior circulation measurements have been partially motivated by the need to provide calibration and validation data for reliable model development. These data are crucial for guiding the development phase of circulation models and should be specified as an additional standard data set to define the required performance. Decisions on such issues as vertical and horizontal resolution, techniques to reduce errors arising from modeled flow over abrupt topography, and turbulence closure schemes should be determined by the vital processes revealed by the observational studies. For example, the sea breeze signals in the channel current records provide an outstanding opportunity to

calibrate and test an interior circulation model. By comparison, the simulation of sediment resuspension and deposition in Lake Okeechobee due to evening sea breezes was taken as an important confirmation of the formulation of a new sediment dispersion model for lacustrine and estuarine settings (look up the circa 1995 Research Summary for Sheng's model). This indicates that the observations are well matched to the scales and dynamics of potential hydrodynamic models being applied to Florida Bay. In this regard, the present observational program still appears to be on a fruitful track.

Modeling

As mentioned earlier, modeling efforts have gone forth over a broad front. An insightful ground water-surface water model of the Everglades promises reliable specification of fresh water flows into Florida Bay after calibration. Within Florida Bay, two pilot circulation modeling efforts were presented at the Joint Conference, as was a recent update on the application of the FATHOM box model. In addition, an appeal has been made to adapt the output from the operational HYCOM model to provide the essential boundary conditions for the smaller Florida Bay domain.

The Environmental Fluid Dynamics Code (EFDC) pilot study is commendable for a variety of reasons beyond the obviously heartening sense of progress. This implementation, while far from a finished calibration, demonstrated efficient and skilful application of a publicly available open-code formulation within a short time. Open-boundary conditions were set by an inverse procedure that ensured accuracy for the pilot study while other inputs were investigated. Evaporation, a perennially difficult exchange variable to simulate or measure, was estimated from the inverse application of the model. The clever use of data assimilation to investigate freshwater input accuracies is an exceptional advance. Analysis suggested that simulations suffered from inaccurate flow estimates during storms, when sea level was high and hence a higher proportion of the fresh water flow is ungauged, distributed sheet flow over shallow ridges. This hypothesis was tested by a model extension and an excellent case was made for this explanation (Hamrick 2003). Given these promising results, the calibration of the Environmental Fluid Dynamics Code simulations for storm surges should be completed and this or a similar community model calibrated to simulate circulation and salinity conditions in the interior of FB between storms, including the onset and persistence of hypersalinity. The calibration must include testing of wetting and drying or the shallow flow over the interior banks.

Sheng and Davis (2003) demonstrated both the immensity of the circulation and salinity modeling task and possible complementary and cooperative pathways to achieve success *via* a community model approach. These model simulations focused on resolution and new massively parallel techniques to meet the associated computational needs. A change from coarse to fine resolution and the inclusion of a good wetting-and-drying algorithm greatly affected the capability to properly represent the mudbank network, which constitute 32% of the total area (Sheng and Davis 2003). A consequence of this change was substantially improved tidal propagation. Given the scale of these banks, however, and the resolution of the model, this conclusion should be investigated further to determine whether the apparent improvement is the result of the grid representation or some other cause. Unfortunately, the model used by Sheng and Davis

(2003) is not an open source code that could be readily adapted to community modeling such as EFDC and POM.

Both modeling efforts revisited the previously identified need to upgrade the bathymetric representation of Florida Bay, especially over flats and mudbanks. The use of LIDAR was mentioned as a possible solution to this difficult problem, but as of yet, no specific effort is underway. Because the synthesis report does not record the circa 1997 to 1999 effort by the U.S. Geological Survey Mapping Division to define the modern bathymetry, it is not possible to determine whether additional bathymetry work is necessary or not.

A significant challenge for modeling any region of the coastal ocean is setting the ocean boundary conditions. In Florida Bay, this challenge is particularly acute because, as the observational program has shown, small changes in water level have large consequences to the circulation in the shallow, basin-and-bank geometry of the interior. The move to start with the output of the large-scale, operational HYCOM model and dynamically scale down to the Florida Bay boundary (Kourafalou and Lee, *et al* 2003 in Abstract volume for 2003 Conference) seems to be on the right path but the PMC needs to put this effort into context to define why it is needed and what specifically will be produced.

The FATHOM box model includes approximately 45 basins in which salinity and water quality is assumed to be well mixed. The degree of salinity matching within basins falls out in what appear to be rational groupings. Unfortunately, FATHOM underpredicts salinity variations in inner Florida Bay basins. FATHOM does not match salinity along the northern boundary well (Crosby et al. 2003 in Abstract volume for 2003 Conference) but the FATHOM simulation errors are instructive as to the potential cause because a scientific approach has been taken to setting up the model. Potential causes for the FATHOM discrepancies are errors in freshwater inflow or evaporation, or uncalibrated exchange rates between basins. Part of the difficulty in addressing the discrepancies is the known problem with box models with regard to handling the effectively instantaneous diffusion within boxes. There is a vital need to calibrate a community-based hydrodynamic and salinity transport model based on first principles (conservation of momentum, water, and salt). Despite the known errors in FATHOM, this model may yet provide valuable guidance in the interim, especially now that the observationalists are producing interior basin exchange rates. However, the PMC should spend some effort toward addressing this question, and come to an agreement on how best to proceed.

Recommendations

The observational program of surveys and current measurements in the Florida Bay interior provides a satisfying and consistent accounting of the circulation and water budget within an individual basin, and should be continued to ensure sufficient baseline information to support an accurate hydrodynamic and salinity model. Of specific interest is the relationship between Whipray and one or two adjacent basins, preferably on the “downstream” side of the propagating tidal wave. Working out these details may be facilitated with judicious deployment of a few water-level gauges. In addition, these gauges will enable fitting the local circulations into the context of the larger-scale Florida Bay by connecting to the existing tide gauges. Temperature-salinity surveys should also

be continued to provide the sufficiently detailed salinity information that will likely be necessary for accurate calibration and validation of the model.

Additional current information along the western boundary would also be beneficial for guidance in establishing the boundary conditions. At present, scaling down the output from a large-scale GCM would be guided by the structure resolved by only three stations taken over limited time intervals. HYCOM has been exercised to address some of these issues. HYCOM is attractive because it is an open-code, community model with a good track record and strong promise of attaining operational status. Attaining such a status at the National Center for Environmental Prediction (NCEP) will mean that, if this boundary-condition effort is successful, then these crucial inputs will be reliably available into the future. At the same time, the SOP is somewhat uncertain about the relationship between the present effort and the previous NOAA boundary-condition work. If this earlier work produced useful results, then they should be incorporated into the present effort.

With regards to the hydrodynamic modeling, the Florida Bay Program should consider following the auspicious start with the EFDC and move toward a full-scale Florida Bay implementation. The SOP might recommend moving with dispatch, but this recommendation would pale in comparison to the pressure imposed by the unrealistically short development time slated in the CERP schedule.

The program appears to be at a critical juncture, where specific models or modelers are yet to be selected. Regardless of these choices, the SOP strongly recommends that the Florida Bay Program adopt the new community modeling approach, where a distributed group of modelers attacks the problem as a team. While one institution maintains the official model version, members of the distributed team are individually tasked with solving component parts of the problem. The primary benefit of this approach is that, by engaging a larger number of experts working together, model development, calibration, and validation are greatly accelerated, to the point where the challenging deadlines may be met. The Florida Bay Program has begun to do better in integrating science and modeling and should enhance the application of community modeling with the better science integration approach that has evolved.

The group of presenters at the Joint Conference represents some of the important types needed in a community modeling organization, with those working on the Bay interior circulation dynamics, ocean boundary conditions, and boundary conditions via the hydrological model. There is already an example of how a community model might accelerate progress by working together. The inverse calculation of the hydrodynamic model EFDC could be used with the hydrological model to refine the inputs and exchanges along the northern boundary.

A successful community modeling program would not simply be a collection of individual efforts such as these, but would require a central organizational structure, coordinating these component efforts, maintaining model version control, and running management scenarios. The new SFWMD-CE modeling center is ideal for this. The SOP recognizes that there may be constraints on the available funding for such a collective enterprise. Yet given the importance of this effort to the Florida Bay Program as a whole, the increased chance for success would appear to warrant the anticipated increased expenditures. Previous experience provides ample illustration of the dangers of reliance on too small an effort in the modeling domain when management decisions loom.

A key aspect of the community model structure is including all participants from the outset. If, for instance, the Florida Bay hydrodynamic model is considered the core model, then hydrological modelers, those providing the ocean boundary conditions, and water-quality modelers should be part of the communicating whole at the outset of the construction phase. In addition, it is crucial that observationalists play a vital role at these early stages, and their contribution not be deferred to the calibration, testing, and refinement phases. The water-quality model, while tightly related to the hydrodynamic model, is sufficiently complex, and sufficiently important, to warrant a separate community model structure.

For guidance in the construction and refinement of models, and for establishing scientific credibility of these models, a Model Evaluation Group (MEG) should be established. If properly constituted, a MEG can provide model advice while acting as a reviewer to evaluate the accuracy of model forecasts for management decisions. Experience from the Chesapeake Bay case has shown that a concerted effort must be made to keep the MEG independent. The failure in Chesapeake Bay to maintain this independence resulted in a perception that the MEG was at least partially responsible for the situation where the models were deemed by a review panel to be insufficiently accurate to support management decisions. Following that review, a second group, called the Expert Panel, was constituted to help rectify this situation.

CENTRAL QUESTION #2: What is the relative importance of the influx of external nutrients and of internal nutrient cycling in determining the nutrient budget of Florida Bay? What mechanisms control the sources and sinks of the Bay's nutrients? Questions 2 and 3 are now combined.

CENTRAL QUESTION #3: What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?

In response to PMC, SOP and a broad range of agency informational needs, work is under way to examine; 1) nutrient limitation of water column microbial (phytoplankton/heterotrophic bacterial) community production (Heil et al. presentation at 2003 Conference), 2) planktonic uptake kinetics of inorganic and organic N compounds (Glibert et al. presentation at 2003 Conference), 3) the use of stable N isotope tracer techniques to identify sources and fates of N compounds (Glibert et al. & Hollander et al. presentations at 2003 Conference), 3) potential bioavailability of organic matter and effects on bacterial productivity (Dailey presentation at 2003 Conference), and 4) internal N cycling processes (N_2 fixation and denitrification) that are critical for determining N flux, fate and budgets (Cornwell et al.. presentation at 2003 Conference). Other projects that are either near completion or completed include a study of nutrient (N, P, Si) limitation, biogenic Si dynamics and their use for reconstructing diatom bloom history in the western part of Florida Bay (Jurado et al. presentation at 2003 Conference). Ongoing water quality monitoring studies (Boyer et al. presentation at 2003 Conference) and watershed nutrient processing studies (Childers et al. presentation at 2003 Conference) form the basis of current nutrient flux/input estimates and assessments of short and longer term biogeochemical change.

To varying degrees, these studies complement earlier work examining the autecology and bloom dynamics of *Synechococcus spp.*, the cyanobacteria responsible for

planktonic blooms that have occurred in the hypersaline embayments (e.g., Whipray Bay) (c.f., Phlips et al. 1999). Circulation studies (Lee presentation at 2003 Conference) showed that the hydrologic “isolation” (i.e., relatively long residence times of ~2 months) of Whipray Bay, most likely plays a critical role in promoting blooms. The long residence time of Whipray and other “lagoonal” embayments enables them to function like nutrient traps, where periodic nutrient-enriched freshets (via Taylors Slough) periodically transit these regions; then as discharge decreases and residence time increases (hypersalinity appears to be a good surrogate of this), the nutrients imported into these embayments are entrained, and effectively exchanged (between the water column and sediments) and recycled in this shallow water column. This, plus hypersalinity, sulfide tolerance (during seagrass die-offs followed by decomposition and periodic stagnancy of the warm waters), and highly-efficient nutrient (N and P) uptake and storage capabilities, set the stage for periodic dominance by *Synechococcus*. Chronic long-residence, lagoonal, hypersaline conditions, plus highly efficient N and P uptake characteristics (Phlips et al. 1999) favor the persistence of these blooms. A two-month residence time would enable *Synechococcus* to undergo 30-60 doublings, based on an assumed doubling rate of once per day. This, combined with a lack of significant grazing pressure, promotes and sustains blooms, until increases in flushing (washout) exceed the growth (doubling) rates of *Synechococcus* within the confines of the lagoonal system. Hypersalinity is known to favor *Synechococcus* in numerous other tropical lagoonal systems, including hypersaline lakes and salterns of the Bahamas and Turks and Caicos.

In light of the observations that periodic “lagoonalization” accompanied by hypersalinity may favor *Synechococcus* booms, several management related questions emerge: 1) What are the effects and threshold levels of increased water flushing with regard to reducing or eliminating these blooms (i.e., how much of an increase in flushing rates or decrease in residence time is needed to effectively exert a control on booms)? 2) To what extent does nutrient enrichment, either internally from seagrass die-offs and recycling vs. externally supplied via freshwater runoff, groundwater and atmospheric inputs, interact with residence time to regulate *Synechococcus* blooms? Will nutrient reductions from these sources have any effect in reducing bloom frequency and magnitude (i.e., can we control blooms just by altering the hydrologic regime, i.e., independent of nutrient controls)? What are the relative sensitivities of bloom taxa to nutrient and hydrologic forcing features (individually and combined)? 3) To what extent do inorganic vs. organic sources of nutrients play a role in controlling *Synechococcus* bloom dynamics? Under the long residence time conditions (and hence extended time for decomposition and nutrient regeneration) characterizing these regions of Florida Bay, what are the budgetary, biogeochemical and ecological impacts of inorganic vs. organic vs. total dissolved or total dissolved + particulate nutrient supplies? Lastly, 4) are *Synechococcus* booms truly a sign of eutrophication (i.e. excessive nutrient loading) or are they a result of longer term (decadal) hydrologic cycles in Florida Bay and its watershed?

To start addressing some of these questions, nutrient uptake/assimilation and growth kinetics need to be combined and complemented with hydrologic and circulation modeling efforts (i.e., Hamrick, Langevin) in order to establish bloom thresholds. At present, nutrient uptake/utilization/limitation experiments, nutrient bioavailability studies and growth dynamics work (some of which has been completed) while of high scientific

quality, appear to be conducted “*in vacuo*”, i.e., lacking synthesis in the context of either nutrient loading, hydrologic or circulation modeling efforts on the larger ecosystem scale. In this respect, would be advantageous and beneficial for nutrient cycling/productivity bloom dynamics investigators to more closely coordinate and collaborate with hydrologic and biogeochemical modelers to more directly and effectively transfer and incorporate data on growth rates, nutrient uptake dynamics into models designed to evaluate and predict the interactive effects of physical and chemical forcing factors (such as the comparative and interactive effects of flushing vs. nutrient limitation) as controls on bloom formation and persistence. The work on DOM and DON availability, while important in terms of enhancing our basic understanding of internal C and N cycling, seems uncoupled from a larger ecosystem processing and budgetary perspective. Overall, the nutrient dynamics researchers need to work more closely with hydrologic, nutrient and circulation modelers to make their process data more useful and meaningful in an ecosystem process and management perspective.

One of the presentations, on biotic use of DOM and DON, calls for comment about the methods used. When working with isotope-labeled organic compounds, such as individual amino acids, it is important that investigators use the same concentrations as are present in nature. For individual amino acids, for example, concentrations are around 40 nM in ocean water. Using higher concentrations usually creates experimental artifacts that make it appear that rates of use are much higher than is the reality of nature.

It should be recognized and emphasized that cyanobacterial bloom taxa such as *Synechococcus*, exists in both benthic and planktonic stages (Paerl 2000). Based on chlorophyll *a* concentrations, benthic microalgal community biomass can commonly exceed planktonic biomass by 10-fold in the shallow sub-basins of Florida Bay. Therefore, examinations of bloom taxa nutrient limitation, nutrient cycling and nutrient-productivity relationships should include (or be incorporated into a) a significant benthic component, as it is likely that a substantial part of the bloom ontogeny and overall dynamics takes place in this component. At present, the functional connection (i.e. nutrient cycling, transport/resuspension, trophic use and exchange) between planktonic and benthic microalgal “lifestyles” is incomplete and not being addressed with current research. A large part of the “action” in terms of nutrient-production interactions and community structuring processes is probably missed by not appropriately making this connection. On the subject of microbial “lifestyles”, there needs to be far closer interaction and consultation with local experts on the physiology, ecology, trophic and biogeochemical roles and functions of *Synechococcus*. In particular, close communication and cooperation with Ed Phlips (who wasn’t even mentioned in any of the presentations) who has previously published on *Synechococcus* (Phlips et al. 1999) is encouraged.

The principal component analysis approach that was presented by Jim Fourqurean is an excellent framework for examining and prioritizing critical forcing features that can set the framework for a combined and highly complementary approach to examine and unify benthic and planktonic forcing features to create a more “seamless” ecosystem-level process and community structure and well trophodynamic models that can be used to evaluate the impacts of external vs. internal forcing features and stressors.

Finally, the nutrient investigations have matured and evolved to focus on benthic interactions and sedimentary digenesis along with causative factors of plankton increases

in the central and western basins, but it is not clear that all these evolved studies are necessary. Furthermore, the early momentum in the synthesis of nutrient investigations seems to be lost. The preliminary nutrient mass balance still does not seem to be advanced.

References:

Phlips, E.J., S. Badyalak, and T.C. Lynch. 1999. Blooms of the picoplanktonic cyanobacterium *Synechococcus* in Florida Bay, a subtropical inner-shelf lagoon. *Limnology and Oceanography* 44:1166-1175.

Paerl, H. W. 2000. Marine Plankton. Pp. 121-148, *In* M. Potts and B. Whitton (eds.), *The biology and ecology of cyanobacteria*. Blackwell Scientific Publications. Oxford.

Internal N cycling (N₂ fixation, denitrification) in relation to nutrient flux, eutrophication and algal bloom dynamics:

It is critical that fundamental information on the spatial-temporal rates of internal N cycling be generated in order to help close the N budget and better understand the relative amounts and roles of externally vs. internally supplied N. To do this, the internal sources and sinks of N (N₂ fixation and denitrification) need to be quantified in time and space and results incorporated in a nutrient-productivity (in conjunction with hydrology and circulation) model of Florida Bay. While the N flux work currently underway (Cornwell et al.) is recognized as preliminary and in need of methodological and conceptual refinement, some estimated upper and lower bounds of rates of denitrification and N₂ fixation can be established for the purpose of incorporating these rates in biogeochemical models, budgetary estimates and starting to set some priorities as to major drivers of N cycling in Florida Bay. The SOP recognizes that as further results on spatio-temporal dynamics on rates emerge, adjustments on appropriate scaling may be needed to satisfy needs for establishing nutrient budgets and models.

It is unrealistic and highly artificial to separate benthic from planktonic processes and rates, since in this shallow system productivity and nutrient cycling are intimately coupled between the bottom and overlying waters. The N and P cycling studies should also be closely coupled (both conceptually and functionally) to seagrass and other benthic community (i.e., microphytobenthic) studies. Similarly, water column DOC and DON cycling as well as N/P/Si limitation studies should be closely coordinated and synthesized with internal nutrient cycling studies.

Lastly, internal nutrient cycling studies should be better integrated in ecosystem-level nutrient flux and budgeting efforts. At present, we still don't have definitive nutrient budgets, largely because internal sources, sinks and cycling rates have not been appropriately and adequately incorporated. While this omission is in part justified due to an evolving data base on internal processes, the conceptual framework should be set so that as they evolve, flux/rate estimates can be most effectively incorporated into modeling and assessment efforts.

A substantial amount of effort should be directed towards establishing the appropriate spatial and temporal scales of resolution of N₂ fixation and denitrification

rates. This also applies to stable N isotope analyses, which while not quantitative, can be useful as indicators of the relative importance of N sources/inputs (i.e., runoff, groundwater, atmospheric, N₂ fixation, regeneration) and sinks/losses (denitrification, burial, ammonification) in different regions of Florida Bay. These efforts would run in parallel with ongoing efforts aimed at improving spatio-temporal resolution of groundwater and surface water N inputs (Reich and Shinn). They will also serve as a guide, basis and rationale for decisions on where to intensify/reduce rate measurements needed for long term monitoring and modeling purposes.

Results from internal nutrient cycling and flux studies need to be closely linked to hydrologic/nutrient loading, productivity and circulation studies in order to help develop and prioritize nutrient management strategies aimed at understanding the manifestations and reducing the risks of changes in freshwater and nutrient inputs on eutrophication and habitat alteration (i.e., algal blooms, SAV condition, fisheries, etc.). These studies should closely couple water sediment and water column exchange as well as advective (inter-basin) transport. Measurements should be scaled to appropriately reflect impacts of episodic perturbations (storms, floods) as well as more chronic forces (droughts, gradual hydrologic/nutrient loading changes due to watershed water management. Once an appropriate monitoring network and modeling effort is in place, it will greatly enhance the ability to predict biogeochemical and trophic impacts/effects of various land-based nutrient management options and strategies.

Related Issues and Comments

Integrating water column with benthic nutrient cycling, productivity and community structuring processes.

Planktonic and benthic nutrient/productivity processes and dynamics are closely linked in Florida Bay. In large part, this reflects the shallow nature of the ecosystem, a high degree of transparency and the reliance of the water column on the benthos as a source of microalgal and microbial seed populations. Planktonic blooms may well be the results of short-term perturbations (i.e. “burps”) of the benthic microalgal communities due to changes in physical-chemical forcings (mixing and resuspension, advective processes, freshets and droughts). These habitats are inseparable from biogeochemical and trophic perspectives and hence should be assessed (i.e., ecological status and change) and modeled in an integrative fashion.

Coupling biogeochemical with hydrodynamic fluxes

The SOP reiterates the need for quantifying the absolute and relative importance of internal and external physical-chemical drivers in structuring phytoplankton, microbial and higher plant communities. This need has not been addressed properly or effectively. In particular, groundwater and atmospheric N inputs need to be more closely linked with internal N inputs (N₂ fixation) and losses (denitrification). This effort could greatly benefit from some scientific leadership, guidance and coordination; preferably an individual having a good working knowledge of FLA Bay nutrient cycling needs to assume this role.

Incorporating an ecosystem perspective

While the scientific quality of currently funded projects is good to excellent, individual studies suffer from a lack of an ecosystem perspective. They are not well-linked to ecosystem-scale hydrologic and other forcing features that may synergistically be impacting the structuring and function of phytoplankton, bacterial and other microbial/plant and higher trophic level communities. Also, hydrology should be more closely linked to external and internal nutrient inputs, their microbial and higher plant processing and fates. Much closer working relationships need to be established between nutrient cycling/bloom dynamics investigators and modelers of physical-chemical and biotic (in particular macrophyte and benthic microalgal) processes. In most nutrient cycling studies such linkage is virtually non-existent. Some vision and leadership is needed. Preferably a local scientific “hero” needs to catalyze this synthesis. Unfortunately, this is not likely to emerge from the current group of investigators, who in some instances still need to familiarize themselves with the “workings” of Florida Bay. More likely candidates having a big picture perspective include Jim Fourqurean, Joe Boyer, and possibly Dan Childers. This individual should work closely with ecosystem-level agency/University thinkers like Roblee, Lee, Ortner, Rudnick and Keller. From an organizational and reporting/publication perspective, this individual could benefit from closely coordinating with Bill Nuttle.

CENTRAL QUESTION #3: What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?

Note: This question has been combined with the nutrient cycling question.

CENTRAL QUESTION # 4: What are the causes and mechanisms for the observed changes in the seagrass community of Florida Bay? What is the effect of changing salinity, light, and nutrient regimes on these communities?

The seagrass research program is rapidly maturing. The team had a healthy mix of experimental and observational research, and along with modeling, developed a multi-faceted, yet cohesive program. The program manager and researchers are to be commended for their considerable efforts. The scientific outcomes of the various field and experiments, along with various models, have produced a reasonable explanation for the acute seagrass die-offs within Florida Bay. This group has come up with a good mechanistic understanding for the cause of the acute or primary die-off (hydrogen sulfide/oxygen balance), and for the chronic or secondary die-off mechanisms (disease and light limitation). This understanding would not be as complete or comprehensive without the multiple approaches that were taken: laboratory studies, field measurements and monitoring, field experiments, mesocosm experiments and modeling. In particular, the recent research using microelectrodes in the field proved invaluable in establishing the mechanism of sulfide toxicity associated with internal seagrass oxygen balances was crucial in providing an explanation of the various field and laboratory results and informing the modeling effort. The application of both national and international expertise to the Florida Bay seagrass research program proved invaluable. Another positive aspect of the research and modeling was the generation of scenarios and attempt to predict some of the ecological outcomes. The Scientific Oversight Panel endorses and

encourages this kind of iterative activity that can inform management as well as focus research efforts.

The integration of the seagrass models with the other various models that are being developed in parallel (e.g., hydrodynamic model, transport model, biogeochemical model) needs to be enhanced. The validity of the seagrass models, as well as some of the other various models, would benefit from using 1990s data sets for calibration and hindcasting the 1980s hypersalinity events and associated acute or primary seagrass loss. This would provide a better degree of confidence that model predictions for the various future scenarios are reasonably robust. One of the challenges for the seagrass modeling effort is to be able to cope with the ecological ‘phase shift’ that can occur after seagrass is lost. This ‘phase shift’ can occur, for example, as a result of enhanced resuspension and turbidity and/or nutrient release and sediment nutrient flux.

The seagrass group was also able to articulate a few knowledge gaps that could guide future targeted research, namely a) the time scales influencing seagrass distributional patterns are not well understood, b) interactions between seagrass meadows and physio-geochemical processes as well as other ecosystems need elucidation, and c) the cycling of phosphorus in the Florida Bay ecosystem needs further research attention.

There are several aspects of the seagrass team approach that would be worth emulating in the other teams: the ongoing creation and testing of hypotheses, incorporation of key external expertise, use of models to guide research questions, multiple scale approach, use of scenarios in modeling efforts.

CENTRAL QUESTION #5: What is the relationship between environmental and habitat change and the recruitment, growth and survivorship of animals in Florida Bay?

The research group addressing issues related to Higher Trophic Levels (HTL) have made notable progress in understanding the ecology, population dynamics and recruitment processes of organisms ranging from zooplankton to species categorized as ‘charismatic megafauna’ (e.g., manatees, dolphins, crocodiles) in Florida Bay. The broad array of projects that fall under the HTL umbrella represents an eclectic mix of research that is difficult to coordinate and which presents a challenge to the HTL group with respect to achieving synthesis and integration. There is evidence that the HTL research is now better integrated with other components of the Florida Bay Program than in the past, although integration and coordination remain significant challenges. Successful integration can only be achieved by thoughtful leadership and planning within the group that will assure coordination and the ‘added value’ that integration can bring to the broad research effort.

In its previous review, the SOP encouraged synthesis efforts by scientists in the Florida Bay Program. Accomplishments in this area by the HTL group were evident, as presented in the Synthesis Report produced by the PMC and in the presentations and posters at the Conference. It is notable that Dr. Joan Browder, co-leader of the HTL team, was presented with an award by the Program for her contributions to synthesis efforts over the past two years. Synthesis, to be most effective, depends on the integration of activities by scientists, including interdisciplinary collaborations that still can be improved by HTL researchers. The SOP encourages these efforts.

Circulation, Freshwater Flow and Salinity

Freshwater flow and salinity are variables that bind and organize many of the diverse HTL projects in Florida Bay. These factors, which have had important effects on water quality, seagrass productivity and algal blooms in the past 15 years, also have been demonstrated to be important for wellbeing of many higher trophic level species (e.g., roseate spoonbills, crocodiles). Along with circulation patterns, freshwater flow and salinity patterns may control recruitment of pink shrimp and other fishes and invertebrates (e.g., gray snapper) in Florida Bay.

A new understanding of how transport of shrimp larvae from the Tortugas Grounds into Florida Bay across its western boundary, rather than through channels in the Keys, is an important modification to knowledge of how physical processes control recruitment of this species. The recent contributions by physical oceanographers in the Program to understanding circulation patterns within Florida Bay promise to be valuable for ecologists who are studying recruitment of key invertebrates and fishes in the Bay. Ongoing research that relates physical processes and circulation in the Florida Keys to recruitment of fishes along the reef tract and in Florida Bay continues to be a productive component of the Florida Bay Program.

Role of the Environment

Progress in understanding the complex role of the environment in controlling production and recruitment of HTL organisms was made in the past two years. Statistical models (GAM) have been developed and applied to show the dependencies of several forage fishes on a suite of environmental factors. The SOP encourages expansion of this research to include further development of statistical modeling and broadening of its scope to add Principal Components Analysis and Discriminant Function Analysis. In this way, the HTL research will be strengthened as well as linked to similar efforts that were reported by the Seagrass team, which would serve to integrate these components of the Florida Bay Program.

Indicator and Key Species

A significant share of the research effort by HTL scientists is being directed at key or indicator species in Florida Bay. Key species are those that are abundant, serve as important predators or prey for other HTLs, or are important targets in fisheries. Bay anchovy, spotted seatrout, and pink shrimp fall into these categories. Indicator species, which also are being studied, have not been so clearly distinguished. These species are sensitive to environmental factors, are a component of habitat (e.g., sponges), or have clear habitat-water quality-environmental dependencies. Long-term monitoring and fishery-independent surveys are needed in the Florida Bay Program to identify and monitor the status of indicator and key species. Not all potential indicator species are abundant; for example, research and modeling results reported on the American crocodile suggest that it might serve well as an indicator species in Florida Bay.

The SOP noted that, except for paleoecological studies, there was little ongoing research on benthic HTL species, which is surprising considering the shallow waters of the Bay ecosystem and the probable importance of benthic-water column linkages and interactions. Filter-feeding and deposit-feeding invertebrates presumably must be key

constituents of this system and should be more prominent in the Florida Bay research. The SOP recognized that research on sponges, including diseases, is an element of the HTL research that does focus on a key component of the benthos in Florida Bay. More emphasis on the benthos is recommended.

Effects of Fishing

Relatively little information was provided to the SOP on effects of fishing in Florida Bay. Conversations with P.I.s during the Conference and comments in the Synopsis Document suggest that stocks of most fished species in the Bay are doing reasonably well. There are indications of overfishing on gray snapper and on species inhabiting the reef tract adjacent to the Keys. The need for fishery-independent surveys to assess trends in abundances and distributions of fished species with respect to habitat and environmental variables was noted several times during the Conference. The SOP endorses this recommendation. We recognize that instituting such a survey will require a significant, long-term commitment of financial and manpower resources.

Ecosystem Perspective

The draft Chapter 9 of the PMC's Synthesis Document emphasizes the need for an 'Ecosystem Perspective' in future Florida Bay research. An ecosystem perspective implies that research will be broad-based and integrative, cutting across trophic levels and broadly inclusive with respect to environmental/habitat issues. This perspective is needed in HTL research, not to the exclusion of focused studies on individual (key or indicator) species, but as a framework for HTL research on Florida Bay. Products of ecosystem-level research could include aggregative or emergent indicators of ecosystem status (e.g., measures of biodiversity, biomass at trophic levels, size and taxonomic structure of guilds and assemblages, etc.).

Development of a food-web model can be an important component of integrated HTL research that will tie primary production to zooplankton or benthic invertebrate productivity, and to higher-level consumers. Such models (e.g., network and 'Ecopath') are being developed for many marine ecosystems and could be useful to gain understanding of production potential, trophic dependencies, and fisheries yields, and to gain insight into possible effects of significant habitat or climate change on the Florida Bay ecosystem. A food-web model also could help to determine relative productive potentials of pelagic and demersal components of the HTL species assemblages and possible shifts related to environmental or anthropogenic effects, including management measures proposed by CERP.

Models and Modeling

The HTL scientists are applying and developing several modeling approaches. Included are individual-based simulation models (e.g., lobsters, crocodiles), bioenergetics models (spotted seatrout), statistical models (e.g., GAM and forage fishes), and transport models (e.g., pink shrimp). There is great potential for expanded application of statistical modeling (e.g., PCA) and ecosystem-level models (e.g., food-web models), especially to begin exploring how the Florida Bay ecosystem may respond to future water management plans, changing climate, or shifts in fishing effort.

Risk and Uncertainty

Proposed changes in water management by CERP and Florida Bay management entities have a high level of uncertainty with respect to ecosystem response. The risks to living resources of alternative management actions and probable environmental variability need to be evaluated. In this regard, the SOP endorses undertaking risk analysis and modeling approaches, such as that presented at the Conference on roseate spoonbill. The approach has merit beyond application to threatened or endangered species and should be considered in broader context to evaluate ranges of responses and alternative outcomes of Florida Bay's resources to anthropogenic stresses, environmental change, and management actions.

Reformulating Question #5

The SOP asked whether the research question that guides the HTL research has, in some ways, been restrictive and if it has limited the breadth of studies or the potential for integrative science that should link HTL science to that of other Program elements (e.g., physics, nutrients, algal blooms, seagrasses). While there was clear evidence that the HTL research group now was conducting some integrative, collaborative research, especially with physicists and seagrass ecologists, it is time to ask if a reformulation of the guiding question would help to promote an 'ecosystem perspective' as espoused in the PMC's Synthesis Document.

The SOP makes no specific recommendation on the most appropriate question to guide the HTL research, but urges the PMC and HTL team to consider it with respect to analysis of the role of HTLs as they develop a new Strategic Plan and anticipate the need to evaluate effects of new management policies on the Florida Bay ecosystem. An effective mix of research on individual species and processes, combined with a broader emphasis on ecosystem-level science, is required to insure the gains in understanding, project integration, and synthesis that everyone seeks in the Florida Bay Program.