Synthesis of Knowledge Concerning Estero Bay Ecology and Physical Processes Coupled With a Gap Analysis

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Background. Fourteen speakers presented results of their research conducted in Estero Bay at the Estero Bay Science Symposium held at the Sugden Welcome Center on the campus of Florida Gulf Coast University November 5 and 6, 2008 (please refer to accompanying program schedule). The steering committee distilled the material presented in the above talks into six categories for further discussion: hydrology, water quality, geology, oyster reefs, seagrass beds, and plankton. The first three subjects were discussed on the first day of the meeting (Wednesday, November 5), with the latter three discussed on day 2 (Thursday, November 6), coupled with the integration of the previous day's conclusions.

The steering committee asked each working group to address the following questions when discussing each topic:

1. What are the scientific questions?
2. What is hindering the answers to these questions? (i.e. What are the data gaps?)
3. Management questions?
4. Who else should be participating in this conversation?

Below is a summary of each of the categories, followed by a synthesis of the larger picture, ending with a gap analysis designed to clarify future research recommendations. Fuller details of our knowledge base are provided in the accompanying annotated bibliography.

Hydrology. Several presentations addressed hydrologic aspects concerning freshwater flow, salinity, sea level rise, tides, hydrologic alterations (e.g., Lover's Key, 10-mile canal), and groundwater influences. In general terms, there was a consensus that we had a good working knowledge of flow (discharge and tidal) for the passes (Big Carlos, Matanzas, and Big Hickory) and several tributaries (Mullock Creek, Estero River, and the Imperial River) of Estero Bay. There was also overall agreement regarding general salinity distributions within the bay, and that modeling efforts captured much, but not all of the hydrologic dynamic processes in the bay. The hydrology working group, consisting of Peter Doering (SFWMD), Keith Kibbey (Lee County Environmental Laboratory), Aswani Volety (FGCU), Stephanie Erickson (Estero Bay Aquatic Preserve), Keith Overton (USGS), and Jeff Schmid (Conservancy of Southwest Florida), identified several gaps in our knowledge of the hydrology of Estero Bay.

What are the scientific questions?

1. Has 10-mile canal captured flow from Hendrey Creek?
2. How significant are groundwater inputs to the system?
3. Is the hydrology of Hell Peckney Bay distinct from the rest of Estero Bay?

4. What proportion of the discharge moves north into/through Fish Trap Bay versus south into Little Hickory Bay and eventually out Wiggins Pass?
5. How have coastal development/modification projects altered the hydrology of Estero Bay?
    a. Several examples of hydrologic alteration were presented in various talks including the closing of tidal inlets through the construction of the causeway over Lovers Key; the dredging of 10-mile canal; the diversion of Estero River and Spring Creek to the Imperial River as a result of I-75 construction; and the increase in impermeable surfaces (e.g., asphalt and concrete) due to land development. Impacts of these alterations remain largely unknown, although an abandoned tidal delta is clearly evident near the causeway at Lovers Key. Additionally, there is some evidence of flow modifications in the Hendry Creek/Mullock Creek/10-mile canal system in the northern bay, and the Imperial River has had flooding issues as recently as Fall 2008. It is likely that some/all of the above alterations have increased the flashiness of inputs into Estero Bay, although no studies have been conducted to date to determine if such is the case.
6. Why do seagrasses grow well in the southern part of the bay versus oyster reefs in the northern reaches? What role does hydrology play in this distinction?
7. Should the bay be compartmentalized into similar hydrologic and/or biologic units to compare/contrast with each other?

What is hindering the answers to these questions? (i.e. What are the data gaps?)

1. There is a lack of flow data from Hendry Creek, and an inability to distinguish inputs from 10-mile canal versus Mullock Creek.
    a. Greg Tolley presented biological evidence that Hendry Creek may have had higher flow in the past, and there was some suggestion that 10-mile canal may have captured flow from Hendry Creek.
    b. Additionally, the weir is being rebuilt in Mullock Creek which will provide an opportunity to put more flow down this tributary in the future.
2. There is a lack of real-time tide data in the bay that could assist in water depth and light attenuation estimates.
3. The role of groundwater inputs is unknown. Groundwater inputs may affect the discharge of Mullock Creek, but there are no data to address this possibility at this time.
4. Hell Peckney Bay appears to have different hydrologic characteristics that the rest of northern Estero Bay, possibly due to the influence of the Caloosahatchee River, Cow Creek/Slough, and/or groundwater inputs. Modeling results were generally poor in this region, suggesting further study is needed. Mike Savarese also pointed out that Hell Peckney Bay had sedimentological characteristics indicative of higher flow, possibly deltaic in nature, suggesting an underlying geology that may be (partially) responsible for some of the distinguishing characteristics of Hell Peckney Bay.
5. Other gaps noted in various discussions include the lack of velocity data within the bay proper; influence of CDOM versus turbidity in light attenuation, explanation for the differences in salinity noted in the northern versus southern sections of the bay.

Management questions?

1. From a management perspective, the above questions/gaps need to be addressed in order to set minimum and maximum flow targets for the various tributaries in Estero Bay.
    a. In some cases, data may already exist that can address some of the above subjects (e.g., flashiness), but previous and current activities/data need to be compiled and made accessible in order to conduct such analyses. For example, Eduardo Patino mentioned that the USGS has flow data for the Imperial River going back to the 1940s. A compilation of such known data (coupled with the known recent trends in development), may allow us to assess the impact of development on freshwater inputs into the bay.
    b. In recently developed areas where flow data do not exist, flow stations can be set up to study the impacts of such development on flow.
2. The hydrologic model should drive salinity and water quality; in doing so, the model will provide a means to better understand the distribution of sediments, oysters, seagrasses, and perhaps other organisms/features, from which minimum and maximum freshwater flows can be better ascertained.

Who else should be participating in this conversation?

1. David Fugate (FGCU)

Geology. While there is overlap between hydrology and geology, the scope of this working group was to focus on the substrate and sedimentology of Estero Bay. There were talks that presented data on benthic composition throughout the bay, fluvial versus tidal inputs of sediment, and characteristics of the inner fringe of the bay (it appears to be geologically stable). The geology working group consisted of Erin Dykes (FDEP), Greg Tolley (FGCU), Sasha Linsin-Wolphart (FGCU), Mike Parsons (FGCU), Mike Savarese (FGCU), Neil Ayres (Estero Bay Aquatic Preserve), Heather Stafford (Estero Bay Aquatic Preserve), Mike Byrne (USGS), and Teresa Coley (SFWMD). The geology working group developed the following responses for the four questions asked:

What are the scientific questions?

1. How does substrate limit/determine the benthos?
2. What is the source of turbidity in the bay (or different regions of the bay)?
3. How does geomorphology link to substrate types?
4. How stable are the various substrate types?
5. How is sediment transported through the bay?
6. What is the source of the muds identified in the bay? Siliciclastic versus carbonate? Terrestrial versus marine?
7. How is the geomorphology of the system changing due to natural and anthropogenic processes?
8. What are the sources of sediment being transported into/through the bay, and how might they change with adaptive management, restoration, and/or general development (urbanization) processes?
9. What are the basins of the bay as determine by geomorphology (substrate type)?

What is hindering the answers to these questions? (i.e. What are the data gaps?)

1. the lack of a sediment/substrate map
2. the lack of a sediment budget
3. the lack of a sediment transport map

Management questions?

1. Is it possible to define the "perfect" conditions for seagrass beds and oyster reefs and to then recreate these conditions elsewhere to aid in restoration efforts?

Who else should be participating in this conversation?

1. David Fugate (FGCU)

Water Quality. The primary water quality talks given at this symposium were by Judy Ott (CHNEP) and Jennifer Thera (FDEP). While it is evident that water quality data is being collected in Estero Bay, many questions abound regarding data analysis, coordination of efforts, and setting TMDLs. The water quality working group, consisting of Keith Laakkonen (Town of Fort Myers Beach), Chenxia Qiu (SFWMD), Miao Li Chang (SFWMD), Jennifer Thera (FDEP), Eduardo Patino (USGS), Ai Ning Loh (FGCU), Cheryl Clark (Estero Bay Aquatic Preserve), Yongshan Wan (SFWMD), and Jennifer Nelson (FDEP), addressed these and other topics in their report:

What are the scientific questions?

1. What are the major concerns?
    - Nutrients, DO, fecal coliform (These are the major problems identified through the TMDL process)
    - Are pesticides/metals a problem for Estero Bay?
        - DEP conducted a study in 2007 of 7 sites within the Bay (and at mouths of tribs) looking at pesticide and metal concentrations in oyster tissue, water column, and sediments. All concentrations were below national averages. Nothing of major concern was found except for low-level Atrazine present throughout the study. This is also found state-wide. Are these low levels of herbicide having any impact on SAV? (e.g. sub-lethal impacts/stress)
        - Copper has been targeted in Hendry/Mullock creeks in past studies, however (refer to the annotated bibliography)
2. What are the water quality issues related to valued biological resources?
    - For example – SAV, oysters, finfish (turbidity, chl a, CDOM, metals, DO, mercury)
3. What do we have the capability to manage?
    - For example – Color (CDOM). While CDOM is a major factor in light limitation, many questions remain as to the specific sources and the capability we have to manage it. CDOM sources are known to be from natural sources (wetlands, mangroves) and we therefore may choose to target other parameters. Follow-up question: Does CDOM loading change with land use changes?

4. Where and how often should we sample? Can efforts be coordinated? Should inter-lab/agency comparisons/calibrations be conducted?

What is hindering the answers to these questions? (i.e. What are the data gaps?)

1. What are the historic conditions and/or the target conditions?
2. What are the most appropriate EMCs/loading numbers for Estero Bay watersheds?
3. What are the Bay dynamics that allow for nutrient impairments in the tributaries but not in the Bay itself?
4. How has land development impacted water quality?
5. How do we address non-point source pollutants?
    a. Watershed land-use breakdowns for different tributaries.
6. Need to use the hydrodynamic model to feed a water quality model
7. Always need more data

Management questions?

1. Water quality restoration (TMDL implementation/BMAP)… how do we most effectively identify nonpoint nutrient sources in the watershed, and then allocate load reductions?
2. How can the scientific community best assist in the TMDL efforts of the DEP?
    a. Information/data sharing
    b. Being active in the TMDL process
    c. Making links between biological resources and/or physiochemical processes and water quality standards
3. How do the TMDLs and hydrologic efforts/projects (MFLs, SWFFS, etc.) fit together?
    a. Hydrology is inextricably linked to water quality
    b. Increased flows with constant concentrations = increased loading and vice versa
    c. Coordination is very important
4. Water quality targets should probably be habitat-specific (i.e., seagrass beds may differ from oyster reefs)

<u>Plankton</u>. There were three talks given on zooplankton and larvae (James Evans, Jennifer Nelson, and Greg Tolley), and none on phytoplankton. Hydrology plays an important role in zooplankton distribution, but the plankton working expanded the discussion to include phytoplankton and other ecological factors. The plankton working group consisted of Mike Byrne (USGS), Peter Doering (SFWMD), Yonshan Wan (SFWMD), Greg Tolley (FGCU), Stephanie Erickson (Estero Bay Aquatic Preserve), Ai Ning Loh (FGCU), and Mike Parsons (FGCU). The plankton working group developed the following questions:

What are the scientific questions?

1. What are the phytoplankton doing?
2. What are the water residence times in the different sub-basins of the bay?
3. How can continuous monitoring aid plankton studies?
4. Is hypersalinity an issue?

5. What is distinctive about Hendry Creek and Intrepid waters?
6. To what degree are estuarine fish species estuarine-dependent?
7. Which group (or region) of primary producers most supports fish productivity?
8. How does planktonic biomass and composition change up the tributaries and around the bay?
9. How does nutrient loading affect primary productivity?
10. What factor(s) limit primary productivity?

What is hindering the answers to these questions? (i.e. What are the data gaps?)

1. lack of nutrient baseline data (including ranges of values)
2. nutrient loading controls – unknown
3. role of discharge in turbidity – unknown
4. groundwater versus baseflow inputs

Management questions?

1. How will flow regulation affect
    a. larval recruitment and retention?
    b. larval production and distribution?
    c. estuarine dependence?
    d. primary production?

Who else should be participating in this conversation?

1. Ernst Peebles (USF)
2. Kelly Dixon

Oyster Reefs. Aswani Volety gave two presentations on oysters for the symposium, focusing on restoration efforts and the effects of freshwater inputs on oyster growth and survival. The oyster reef working group continued with these themes and consisted of Erin Dykes (FDEP), Keith Kibbey (Lee County Environmental Laboratory), Aswani Volety (FGCU), Keith Laakkonen (Town of Fort Myers Beach), Chris Stafford (FWRI), Heather Stafford (Estero Bay Aquatic Preserve), and Miao Li Chang (SFWMD). The oyster working group made the following report:

What are the scientific questions?

1. How are the early life stages of oysters affected by:
    a. salinity
    b. predation
    c. contaminants?
2. What are the distribution and tolerance ranges of the introduced green mussel?
3. Is there a resource competition or partitioning between green mussels and oysters?

What is hindering the answers to these questions (I.e., what are the data gaps)?

1. lack of information on Hendry/Mullock creek flows
2. lack of groundwater hydrology information
3. lack of knowledge on the ecology of green mussels in the area

4. need for a more recent oyster reef map
5. no reservoir capacity – so how do we manage for flows?

Management questions?

1. Where should we restore oysters?
    a. collaborate with resource agencies to provide better ecosystem services to other habitats
2. Can we broaden the distribution of larvae?
    a. link with hydrodynamic models
3. Can we decrease sediment loads?

Who else should be participating in this conversation?

1. Nobody listed

Seagrasses. There were three talks that included data on seagrasses, including those given by Judy Ott, Stephanie Erickson, and Jeff Schmid. Most of the data addressed seagrass distribution and abundance on spatial and temporal scales. The seagrass working group expanded on these data to include water quality and productivity components as outlined below. This working group consisted of Judy Ott (CHNEP), Jennifer Thera (FDEP), Jeff Schmid (Conservancy of Southwest Florida), Teresa Coley (SFWMD), Neil Ayres (Estero Bay Aquatic Preserve), and Chenxia Qiu (SFWMD).

What are the scientific questions?

1. To what extent do hydrology and water quality drive seagrass distributions?
2. To what extent does hydrology drive water quality (e.g., salinity, color, turbidity, chlorophyll-a, and nutrients) distributions in Estero Bay?
3. To what extent do each of the primary water quality parameters (color, turbidity, chlorophyll-a, and nutrients) control seagrass distribution, species composition, and abundance (density)?
5. What is the effect of variability (timing) of water quality on seagrass distribution, density, and species composition?
6. What are benthic algae (macro and micro) doing?
7. What is the critical water depth for seagrasses?

What is hindering the answers to these questions (I.e., what are the data gaps)?

1. accurate seagrass distribution maps
2. random sampling scheme to monitor seagrass health
3. aerial imagery (and accompanying ground-truthing)

Management questions?

1. What can be altered in order to make restoration of lost seagrass acreage possible/successful?
2. How will sea level rise affect seagrass productivity and restoration efforts?
3. What acreage of seagrass should we attempt to restore?

Who else should be participating in this conversation?

1. Southwest Florida seagrass working group (e.g., Kris Kaufman)
2. other groups doing similar monitoring/restoration work

Synthesis. Overall, the following gaps were evident across all working group discussions:

1. We do need to learn more about the hydrology of the system. Not only is flow data lacking for some tributaries, (e.g., Hendry Creek), but there are many questions regarding the overall dynamics of the system:
    a. How has 10-mile canal altered the flows of Hendry and Mullock Creeks?
    b. Has recent development increased the flashiness of the system?
    c. How is flow related to nutrient inputs, turbidity, and sediment transport?
    d. How much influence does the Imperial River have on southern regions of the bay?
    e. How is the hydrology of Hell Peckney Bay and Cow Slough/Creek affected by external drivers (e.g., Caloosahatchee River discharge)?
2. Biotic productivity/distribution is inevitably linked to hydrology. Additionally, there are differences in organism distributions that may (or may not) be linked to hydrology. For example:
    a. Is the dominance of oyster reefs in the northern section of the bay, coupled with the dominance of seagrasses in the southern portion of the bay, the result of different hydrologic regimes in the two regions?
    b. Can we determine the ideal hydrologic conditions for seagrass and oyster productivity, and are the two conditions compatible (and/or attainable) given the above observation?
    c. Chlorophyll-a concentrations can be exceedingly high in the bay and its tributaries according to previous reports (please refer to the annotated bibliography). What is unclear, however, is how these high levels of phytoplankton biomass are related to flow and nutrient loading. Are any nutrients limiting? Is light limitation a factor? Can grazing pressures control phytoplankton biomass?
    d. While much data has been gathered and reported concerning salinity influences on zooplankton distributions, oyster health and physiology, and oyster reef-associated biota, there remains a dearth of knowledge regarding salinity influences on reproduction and larval dispersion mechanisms. E.g., can oyster recruitment be improved with a higher flow regime? How is larval recruitment and retention affected by flow?
3. There is much concern about the exact nature of the impacts caused by land use and development in the Estero Bay watershed. There is a lack of data to truly assess the impacts, much less offer solutions. For example:
    a. Have freshwater inputs to Estero Bay been altered due to changing land use and development patterns in recent years? E.g., are inputs more flashy? There is some evidence that flow has increased overall (please refer to the annotated bibliography). Is this true, and if so, what are the impacts?

   b. Are nutrient inputs increasing into Estero Bay? Again, there is some data suggesting this is the case, but the lack of long-term data and comprehensive sampling hinders the thorough examination of this question.
   c. The cause-effect relationships of these (and other) questions need to be addressed before effective remedial measures can be taken.
4. There are many agencies and individuals collecting data in the Estero Bay watershed. If efforts could be better coordinated, comprehensive studies could be more plausible.
   a. Could there be a centralized database containing pertinent data (e.g., STORET)?
   b. Could there be a centralized webpage for Estero Bay?
   c. Should there be a master list of contacts/researchers working in the Estero Bay watershed?
5. There were other subject areas that were not well-addressed in this symposium including:
   a. Megafauna (larger fish, manatees, dolphins, birds). Philip Stevens gave a brief overview of some of the work he's been involved with (fish responses to salinity changes in Estero Bay); but otherwise, little else was presented or discussed.
   b. Role of sea level rise – brief mention, but no models, scenarios, impact-assessments
   c. Mangroves – Win Everham gave a presentation on historical trends in mangrove cover up the Estero River, but many questions were still evident; e.g., are mangroves retreating from, progressing past, or remaining stable at the inner fringe of the bay? Are the relative abundances of red, black, and white mangroves changing? Are exotic species having significant impacts?
   d. Watershed land use and development. More data on just how the watershed is changing would help to address the questions in point #3 above.