Calibrating a Biological Conditional Gradient Model to the Mobile Bay Estuary
Interim Report, March 2014

Prepared by Barry A. Vittor & Associates, Inc.

Introduction

The Mobile Bay National Estuary Program (MBNEP) is identifying biological indicators and calibrating a Biological Conditional Gradient (BCG) Model to gauge progress toward meeting the objectives and goals established in its Comprehensive Conservation and Management Plan. The MBNEP and its Science Advisory Committee (SAC) are investigating how a BCG could be used to assess and communicate to the public the health of the Mobile Bay estuary. A BCG model is a tiered system of aquatic life use designation along a gradient that describes how biological attributes change in response to increasing levels of human disturbance (Davies and Jackson, 2006). A BCG approach for the MBNEP would provide a method of ecosystem assessment using biological information as a means to measure the status and trends of habitat quality.

BCG Framework Development to Date

The first step in BCG framework development was a review of past efforts to develop biological indicators for the MBNEP study area (Attachment 1). After evaluating the potential of previously identified indicators for use in a BCG framework, two approaches were considered by the SAC: 1) Restoration of a historic acreage balance among different habitats and 2) Monitoring of soft-sediment benthic invertebrates as an indicator of biological integrity. In May 2011 the SAC initially opted to pursue a BCG approach based on recent historic change in both the quantity and quality of coastal habitats, similar to the Tampa Bay restoring balance approach.

After further consideration and discussions among SAC members in August 2011, it was concluded that that seeking to restore a proportional balance of acreage among habitats did not capture the productive aspect of the estuary. It was also recognized that the need to translate biological condition and environmental trends into something that people use or look at would most effectively convey estuarine condition to the public. The SAC was concerned that a restoring balance framework would not address important community uses and the ecosystem services that support them. There was general agreement over the importance of ecosystem services driving the prioritization of habitats and resources to be monitored, and that restoration efforts address the anthropogenic stressors that deteriorate the estuary's biological condition.

A list of priority habitats previously identified by the MBNEP (Stout et al., 1998; TNC, 2009) was compiled during the fall of 2011, along with their ecosystem services and anthropogenic stressors. The SAC adopted the list of study area habitats, services, and stressors for further analysis. Stressor consideration was limited to those whose impacts can be mitigated through adaptation or policy change.

First the 12 members of the SAC, then an additional 12-15 scientists completed a Habitat and Ecosystem Service Evaluation Sheet to determine which ecosystem services and habitats are most vulnerable to a host of present-day stressors. The intent was to rate existing stressor impacts, not historic or potential impacts. The evaluation matrix included 12 ecosystem services, 12 priority habitats, and 13 stressors (Table 1). Scientists completed this evaluation by rating on a scale of 0 (no impact) through 3 (high impact) the present-day level of impact that each stressor has on the ecosystem services of the various priority habitats. Evaluators were asked to leave blank any combination of stressor, ecosystem service, or habitat that was outside of their expertise.

Table 1. Ecosystem services, priority habitats, and stressors evaluated in the Habitat and Ecosystem Service Evaluation Sheet.

Ecosystem Services	Priority Habitats	Anthropogenic Stressors
Biodiversity Carbon Sequestration Fisheries habitat Flood control Groundwater replenishment Nesting habitat for birds and turtles Oyster production Primary production Sediment and nutrient retention and export Storm buffer/hazard protection Water quality enhancement Wildlife habitat	Beaches and Dunes Freshwater Wetlands Intertidal Marsh and Flats Longleaf Pine Habitat Maritime Forest Oyster Reefs Pine Savanna Forest Riparian Buffers Streams and Rivers Submerged Aquatic Vegetation Subtidal habitats	Chemical contamination Dredging and filling Fire suppression Freshwater discharge Habitat fragmentation Invasive species Land use change Nutrient enrichment Pathogens Resource extraction Sedimentation Sea level rise

Based on the aggregate evaluation scores of estimated average stress levels, the ecosystem services under most stress are biodiversity, wildlife habitat, water quality, and primary production. The habitats with the greatest amount of stress on ecosystem services are freshwater wetlands, intertidal marshes and flats, and streams and rivers and their riparian areas. Stressors having the most impact on estuarine condition are land use change, habitat fragmentation, dredging and filling, and sedimentation.

Recommendations

According to EPA the most applicable attributes for estuarine BCG include ecosystem function, habitat connectivity, and habitat mosaics. Measuring habitat quality and ecosystem services provision addresses the function aspect. The mosaic of rivers and streams, coastal wetlands, and ultimately Mobile Bay and its environs incorporates structural and functional connectivity of the landscape.

It is expected that a range of biological values will be identified for each ecosystem service or habitat metric to correspond to BCG condition tiers. As a mathematical model, the BCG accommodates incorporation of multiple metrics, and each metric can be weighted to represent to its relative contribution to the overall environmental condition. Metric weighting will provide a method to measure trends in the condition of different ecosystem components and processes. Ideally, the individual parts of the BCG framework will collectively comprise a broad measure of estuarine condition as it relates to regional stressors.

Wetland Quality Assessment

The quality of coastal wetlands can be assessed using one or more rapid assessment methods that are widely recognized as valuable tools for assessing the status of these resources. Rapid assessment methods hold a central position in monitoring programs because once established, they can provide sound, quantitative information on the status of the wetland resource with a relatively small investment of time and effort (Fennessy et al., 2004). Wetland assessment methods assign numerical values to wetland functions, and the quantifiable aspect is well suited for incorporation into a BCG model framework.

There are existing wetland quality indices suitable for status and trends assessment in the MBNEP study area, notably the hydrogeomorphic (HGM) approach. HGM is a collection of concepts and methods that use mathematically derived indices to assess the capacity of a wetland to perform specific ecological, geochemical, and hydrological functions in comparison to similar wetlands within a geographic region. One advantage of the HGM approach is that an individual site may be assessed for a suite of functions or a subset of functions, as determined by project management objectives. In a review of the effectiveness of three wetland functional assessment methods used widely for regulatory purposes -- HGM, Wetland Rapid Assessment Procedure (WRAP), and the State of Florida's Uniform Mitigation Assessment Method (UMAM) -- HGM was determined to be the most appropriate method because of the thorough scientific review involved in developing the method (Beever et al., 2013).

An HGM guidebook for tidal marshes was produced Shafer et al. (2007) for application to the Alabama coastal area. It is recommended that the SAC consider adopting this HGM index to assess and track habitat function and quality for study area tidal marshes. For other wetland types it is recommended that an HGM approach or other index also be adopted for quantifying habitat function and quality.

High quality reference wetlands will provide a baseline of minimally degraded conditions for each wetland type in the study area. The MS-AL Habitat Mapper identifies Priority Conservation Wetlands (TNC, 2009), including riparian areas, which could be used as initial reference wetlands in the BCG. Refinement of the wetland database would further identify locations containing the highest quality wetlands. Reference site conditions will represent the best range of minimally impaired conditions that can be achieved within each wetland classification category in the MBNEP area.

A BCG framework incorporating wetland quality metrics can be applied on a watershed basis to identify highly perturbed locations in the study area. In this way, management and restoration activities can be prioritized to address hotspots of degradation and loss of important ecosystem services. A BCG metric for habitat quality could include average condition of a given wetland category (tidal marsh, riverine forested, etc.), as determined by HGM or other assessment methodology.

Clean Water Act Section 404 regulations allow wetland destruction or use under certain circumstances. Special conditions attached to such impacts may include compensatory mitigation, but as a practical matter the loss of wetland values are likely to continue to occur for the foreseeable future. A wetland acreage goal of no net loss therefore is not realistic. Potential options for wetland metrics addressing acreage could include a reduced rate of wetland loss, acres of quality enhancement of degraded wetlands, and acres of restoration at locations where wetlands had occurred in the past. Consideration should be given to limiting certain acreage goals to the coastal zone (below the 10-ft elevation contour), where wetlands are afforded greater regulatory protection. The percentage of wetland acreage protected by conservation easements is potentially an appropriate metric to include in the BCG framework.

Streams and Rivers

The State of Alabama does not use a calibrated index of biological integrity (IBI) for wadable streams in the coastal area. The ADEM uses a combination of physical and biological data, some collected by third parties, to assess water quality in coastal streams and rivers. The SAC should assess the practicability of calibrating an IBI for coastal streams and rivers of the study area. Stream IBI metrics typically include measures for assemblage composition, taxa richness, perturbation tolerance/intolerance, and trophic characteristics (Barbour et al., 1999).

O'Neil and Shepard (GSA, 2012) investigated a limited number of Coastal Plains streams in Mobile and Baldwin Counties using a fish IBI, and found stream condition at 21 stream reaches ranged from good to very poor. The GSA IBI is a freshwater index, and its utility for streams in proximity to estuarine waters is unknown.

Though not based on biota, the Rosgen (1996) stream classification system categorizes various stream types by morphological characteristics, including stream gradient, sinuosity, width/depth ratio, channel materials, entrenchment, confinement, and soil/landform features. Potential applications of the Rosgen Index include riparian management guidelines and fisheries habitat interpretations, but the relationship between stream morphology and biological communities has not been validated for the MBNEP study area.

The MS-AL Habitat Mapper identifies Priority Conservation Streams (TNC, 2009), which potentially can inform the location of streams or stream reaches representing minimally impaired reference conditions. A BCG metric for stream quality could include average stream condition, as determined by an IBI or other quality index. The percentage of total stream reach length listed as impaired under the ADEM 303d assessment program is potentially an appropriate metric to include in the BCG framework.

Indicators for Mobile Bay

Subtidal habitat did not rank high in the habitat and ecosystem service evaluation, yet use of an open water ecosystem component as an indicator for Mobile Bay and adjacent waters would assist in directly assessing the environmental status of the bay. Identifying aquatic biota for indicator use in Mobile Bay and adjacent subtidal waters has been problematic, however.

Land use change was identified as the most impactful stressor in the evaluation, and sedimentation ranked high as well, but the relationship between land use change in local watersheds and downstream biological condition is, depending on the potential indicator, poorly or incompletely understood in the MBNEP study area. The ecosystem components that appear most usable in a biotic assessment of the estuarine condition of Mobile Bay proper and adjacent subtidal waters are those benthic habitat types that constitute the predominant substrata: unconsolidated sediments, oyster reefs, and submerged aquatic vegetation.

The feasibility of a BCG approach based on benthic macroinvertebrates as indicators of sediment and water quality was addressed in the indicator review (Attachment 1) and considered during subsequent SAC discussions. While macroinvertebrate IBIs are a commonly used method for water quality assessment, major hurdles with this approach for Mobile Bay include a lack of a historical baseline or benchmark that could be used to detect the impacts of coastal development on soft sediment habitats within the MBNEP study area (Stout et al., 1998). In order to calibrate a BGC model focused on soft sediment macroinvertebrate assemblages, comprehensive benthic studies would likely have to be conducted to define a baseline of natural community composition for the range of sediment habitats across the freshwater, oligohaline and mesohaline zones in the study area. Routine monitoring of sediment benthos would entail high monetary costs.

Both oyster reefs and SAV are indicators of water quality and are related to fisheries production. Oyster reefs occur mostly in the southern half of Mobile Bay and in Mississippi Sound, so their extent is relatively limited for estuary-wide assessment. SAV occurs throughout the study area, and its current and historic occurrences extend to smaller bays and upstream water bodies.

Beginning in the mid-20th century, SAV extent declined throughout the bay and adjacent estuarine waterbodies. The decline in SAV was coincident with increased land cover change in the MBNEP study area, particularly increases in impervious surfaces and urbanization. Attachment 3 presents maps showing differences in historic (1940, 1955, 1966) and recent (2002) SAV occurrence for portions of the study area. Declines in SAV extent are believed to be principally the result of increasing inputs of sediments and nutrients into estuarine waters, which increase turbidity and reduce light availability necessary for plant growth and survival. Improvement of water quality through effective watershed management would presumably result in better conditions to support SAV. SAV therefore has potential as a biological indicator on a watershed basis, particularly at locations near open bay waters where it occurred historically. Before incorporating an SAV indicator in the BCG framework it may be prudent to first assess potential SAV restoration locations with respect to existing conditions (water quality, light regime, physico-chemical), to evaluate the potential of eventual success.

Adequacy of the Existing Ecosystem Inventory

It is recommended that a remote sensing strategy be used for MBNEP ecosystem monitoring. Analysis of aerial imagery, combined with surface level observations, is a cost-effective method to determine long-term trends and short-term changes of wetlands and other natural features. A database of spatial distribution and habitat quality should be periodically updated and refined to account for future landscape change, and to ensure consistency and accuracy of habitat characterizations.

The existing MBNEP spatial database is the MS-AL Habitat Mapper, which contains location data for coastal wetlands and watercourses. The Habitat Mapper is based on Alabama GAP data (2001), which was developed using Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper satellite imagery. The imagery consists of raster-based land-cover maps at 30-meter resolution. Such coarse resolution data present methodological difficulties in creating spatially accurate land cover classification. At coarse resolution, pixels often contain a mixture of cover types even in a fairly general classification scheme, creating difficulty in deciding on the correctness of the assigned label. Because of this, raster-based imagery data set should be used primarily as a screening tool for broad management decisions. Small features and temporal changes should be verified with native imagery at a higher resolution.

It is recommended that high-resolution mapping of wetlands be performed in the development of a resource database to serve as a foundation of the BCG framework. It is recommended also that wetland boundaries be delineated using the methods described and outlined in the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual, which presents a 3-parameter approach to identifying and delineating wetlands: 1) the presence of hydric soils; 2) evidence of wetland hydrology; and 3) a predominance of hydrophytic vegetation. Use of this methodology would be consistent with Clean Water Act Section 404 assessment, which is used to identify wetlands afforded State and Federal protection.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling, 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Beever, J.W., W. Gray, D. Cobb, and T. Walker, 2013. A watershed analysis of permitted coastal wetland impacts and mitigation assessment methods within the Charlotte Harbor National Estuary Program. Florida Scientist, 76(2): 310–327.

Davies, S.P. and S.K. Jackson, 2006. The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications, 16(4): 1251-1266.

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula, 2004. Review of Rapid Methods for Assessing Wetland Condition. EPA/620/R-04/009. U.S. Environmental Protection Agency, Washington, D.C.

O'Neil, P.E. and T.E. Shepard (GSA), 2012. Calibration of the Index Of Biotic Integrity For The Southern Plains Ichthyoregion in Alabama. Open-File Report 1210, Geological Survey of Alabama, Ecosystems Investigations Program. Tuscaloosa, AL.

The Nature Conservancy (TNC), 2009. Prioritization Guide for Coastal Habitat Protection and Restoration in Mobile and Baldwin Counties, Alabama. 37 pp.

Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Shafer, D.J, T.H. Roberts, M.S. Peterson, and K. Schmid, 2007. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing the Functions of Tidal Fringe Wetlands Along the Mississippi and Alabama Gulf Coast. U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS. 76 pp + appendices

Stout, J.P., K.L. Heck, Jr., J.F. Valentine, S.J. Dunn, and P.M. Spitzer, 1998. Preliminary Characterization Of Habitat Loss: Mobile Bay National Estuary Program. MESC Contribution Number 301. 183 pp.

Attachment 1 – Biological Indicator Review

Introduction

The Mobile Bay National Estuary Program (MBNEP) is identifying environmental indicators that will be used to gauge progress toward the objectives established in the MBNEP Comprehensive Conservation Management Plan. The intent of the MBNEP is to calibrate a Biological Condition Gradient (BCG) model to the Mobile Estuary. The BCG is a conceptual model that can be adapted and applied to specific regions or estuaries. A BCG model is a tiered system of aquatic life use designation along a gradient that describes how ten biological attributes change in response to increasing levels of human disturbance. A BCG approach for the MBNEP would provide a method of ecosystem assessment using biological information as a means to measure the status and trends of habitat quality.

For estuarine BCG, ten biological attributes are contained within five categories:

"Structure"

1. Historically documented, sensitive, long-lived or regionally endemic taxa
2. Sensitive and rare taxa
3. Sensitive but ubiquitous taxa
4. Taxa of intermediate tolerance
5. Tolerant taxa

"Non-native"

6. Non-native taxa

"Condition"

7. Organism condition

"Function"

8. Ecosystem functions

"Connectivity"

9. Spatial and temporal extent of detrimental effects
10. Ecosystem connectance

Each of the five Attribute categories may be applied to a single habitat, or to a mosaic of habitats that comprise the estuary as a whole. Attributes are then assigned a level of condition based on the amount of anthropogenic stress or change from the natural condition. The gradient represented by the BCG to describe the ecological state of the attributes is divided into 6 tiers or levels of condition, ranging from a natural/native condition (1) to severe changes in the structure of the biotic community and major loss of ecosystem function (6).

The MBNEP has reviewed and evaluated potential indicators to identify those that could be recommended as supporting BCG and biological monitoring of the estuary condition. Existing biological and physical environmental data, including data from previous studies and monitoring programs in the MBNEP study area, are being examined to determine if they are adequate to apply to the BCG. Identified resources consisting of one or more habitat types or other biological indicators will be assigned to the five estuarine Attribute categories. Identification of natural conditions would set a goal for restoration of degraded habitats within the MBNEP study area.

Indicator Review

As part of the indicator development process, the MBNEP solicited input from stakeholders, including the general public, local officials and scientists, and other experts in methods of environmental assessment. The public was invited in 2004 to participate in an online survey of attitudes and perceptions of the environment in the MBNEP study area. An analysis of the survey results was presented in an Online Survey Indicators Report (Battelle, November 2004). Subsequent to the online survey, an Indicators Workshop was held in Mobile in February 2005, bringing together local citizens and environmental professionals from federal and state agencies, universities, and non-profit organizations.

The Online Survey Indicators Report and the Executive Summary for the Indicators Workshop were reviewed to assess prior public and stakeholder input into the identification of environmental indicators of interest in the MBNEP study area, with a focus on those which could be applied to a BCG model approach. The online survey report assessed participant responses in terms of their relevance to potential indicators in five categories, which were also the focus of the indicator workshop, including:

Water Quality
Habitat Management
Living Resources
Human Uses
Education/Public Involvement

A BCG model assesses the status of ecological attributes, and therefore review of the online survey and indicator workshop results focused primarily on biological indicators in the first three categories. Indicators of interest are those metrics with potential for application to a BCG model approach that assesses environmental status and trends across the entire MBNEP study area. To be considered, potential BCG indicators must meet two basic requirements:

I. The indicator must be applicable to estuary BCG, either for a single habitat or for a habitat mosaic approach.

II. The indicator must be practicable for use in a MBNEP monitoring program assessing estuary-wide status and trends.

The following sections present a brief review of the 2004 Online Survey Indicators Report and the Executive Summary for the 2005 Indicators Workshop. Potential indicators are discussed based on applicability to a BCG approach and practicability for a MBNEP monitoring program.

<u>2004 Online Survey Report</u>

The online survey report developed potential environmental indicators based in part on the survey results. The report states that subjective methods were used to compile the respondents' input in developing the potential indicators.

Table 1 presents the water quality (WQ) indicators derived from the online survey. Many of the WQ indicators are not biological metrics, and cannot be assessed within a BCG framework. These indicators include numbers of stormwater upgrades and permitted outfalls, the number of beach closure days, various hydrologic parameters, and area closed to fishing. Indicators such as bacteria/pathogens load and fecal coliform counts are biological metrics, but within a BCG framework represent stressors that would affect natural community indicators.

Table 1. Water quality (WQ) indicators derived from the 2004 online survey.

WQ indicators not applicable to BCG	WQ indicators potentially applicable to an estuarine BCG model
Percent open space	Species abundance over time (A, B)
Number of stormwater upgrades	Bioaccumulation (A)
Number of permitted outfalls	Loss of beach/year (B)
Freshwater inflow	Fish tissue toxics data (A)
Toxics (PCBs, mercury, pesticides)	Chlorophyll *a* (A)
Number of beach closure days	Seagrass nutrient pollution index (A)
Nutrient loads	Incidence of disease for fish/shellfish (A)
Sediment loads	Level of contaminants in representative shellfish and at-risk humans (A)
Number of commercial fishing licenses	
Temperature & salinity	
Dissolved oxygen	
Fish consumption advisories	
Area of shellfish bed closure by year	
Area closed to fishing	
Number of recreational fish landings	
Bacteria/pathogens load	
Fecal coliform counts at oyster growing sites over time	
Fecal coliform counts at recreational sites over time	
	A = single habitat; B = habitat mosaic

Of the identified WQ indicators that are potentially applicable to an estuary BCG approach, most are not practicable for use in a monitoring program assessing status and trends across the entire study area. Programs assessing tissue toxins and contaminant levels are costly, and toxin sources may not be apparent, particularly in motile populations that may originate or venture outside the study area. Bioaccumulation studies are also cost-intensive and complicated in their analyses. Moreover, detectable bioaccumulation often has no apparent effect on the functioning of natural communities.

Chlorophyll *a* is useful as an indicator for detecting nutrient loading, which may cause water quality degradation and harmful algal blooms. Background or natural levels in the study area are largely unknown, however, which would be problematic when assessing degrees of degradation from natural levels, which is the basis of the BCG approach.

Of the potential WQ indicators, “Species abundance over time” appears to have the greatest potential for use in a BCG model framework, either for a single habitat or a habitat mosaic approach. The provenance of this indicator is unknown, since it was not included in the WQ survey questions.

“Loss of beach/year” or some metric related to beach habitat has potential as an indicator in a habitat mosaic approach. The most-often cited method of “contact with coastal waters” of survey respondents was at the beach (89%), and a strong majority of responses to the issue of beach erosion were very concerned (55%) or concerned (31.7%), though beach erosion is more an issue of habitat loss than of water quality.

Table 2 presents the habitat management (HM) indicators derived from the online survey results. As with the potential WQ indicators, some of the HM indicators are not applicable to BCG (e.g., water transparency).

The specific aspect(s) of "Native species diversity" as an indicator is not explicit in the wording of the survey question regarding diversity (Question 9), nor is the reasoning behind the formulation of the indicator explicitly informed by the survey responses. A majority of respondents (74.7%) rated the plant and animal communities of the Mobile Bay estuary as diverse (41.5%) or very diverse (33.2%). Within a BCG framework, "Native species diversity" would be assessed as changes through time compared with an established baseline condition. Use of this indicator for any specific species or guild would effectively be the same as use of the WQ indicator "Species abundance over time".

Table 2. Habitat management (HM) indicators derived from the 2004 online survey.

HM indicators not applicable to BCG	HM indicators potentially applicable to an estuarine BCG model
Water transparency	Native species diversity (A, B)
Sediment transport	Changes in habitat and species diversity (B)
Percent open space	Coastal wetlands (A, B)
Area and percent designated for permanent habitat protection	Changes in land-water ratios (A, B)
	Reclaimed habitat (A, B)

A = single habitat; B = habitat mosaic

The indicator "Changes in habitat and species diversity" may be more appropriately expressed as "Changes in habitat diversity", to distinguish it from the "Native species diversity" indicator. This indicator could be addressed though a habitat mosaic BCG approach. Diversity measures generally are related to the relative proportions of a set of different biotic components.

Survey respondents viewed wetlands as an important habitat. Majorities of respondents indicated that wetlands were either "insufficient" to support, or needed increased conservation with regard to, migratory birds (19% and 46%, respectively), removal of excess nutrients (28% and 49%), and threatened species (19% and 50%).

The HM indicators derived from the online survey are potentially applicable to a BCG model, either for individual habitats or the habitat mosaic approach. Majorities of respondents believed that there are insufficient amounts, and need for increased conservation, of wetlands, oyster reefs, and seagrass beds. A large majority (93.2%) responded that restoration of sensitive habitats throughout Alabama's coastal waters was either very important (60.6%) or important (32.6%). Restoration of various critical habitats would be addressed in a restoring habitat balance BCG approach.

Table 3 presents the living resources (LR) indicators derived from the online survey results. The "Number of fish and wildlife species" indicator was not explicitly included in the LR survey questions. Depending on the particular biotype or ecological guild of interest for BCG, this indicator may be interchangeable with the WQ "Species abundance over time" and HM "Native species diversity" indicators.

Table 3. Living resources (LR) indicators derived from the 2004 online survey.	
LR indicators not applicable to BCG	LR indicators potentially applicable to an estuarine BCG model
Costs of invasive species control	Number of fish and wildlife species (A, B)
Number of annual fishing licenses (commercial and recreational)	Presence or absence of unique habitats (A, B)
Number of shellfish licenses (annual)	Change in the number of acres of wetlands affected by invasive, non-native species (A)
Commercial and recreational fishing economic value	Shrimp abundance over time (A, B)
	Oyster abundance on public seed grounds over time (A)
	A = single habitat; B = habitat mosaic

The methodology used to identify "Presence or absence of unique habitats" as a potential LR indicator is unknown. The LR survey questions did not include the topic. Similarly, though respondents were asked to provide a level of concern for the potential threat of particular invasive species, mostly animals, the reasoning behind the formulation of the indicator "Change in the number of acres of wetlands affected by invasive, non-native species" is unknown. Nevertheless, these two indicators have potential as metrics in a habitat mosaic-based BCG approach.

The LR fauna identified in Table 3 are not practicable as status and trends indicators. Shrimp and oyster populations are managed by state agencies, and it is unlikely that a direct effort conducted through a MBNEP monitoring program would add value to those existing, routine assessments, unless additional data were collected to document spatial and temporal patterns.

Of the question addressing levels of concern for sustaining populations of inshore commercial species (Question 17), respondents were "very concerned" about shrimp (76%), blue crab (74%), and oyster (73%), though blue crab was not included as a potential indicator in the survey report. Likewise, for the question regarding sustaining inshore game species (Question 16), the species of greatest concern (flounder, redfish, speckled trout) were not identified as potential indicators. For all species of concern identified by survey respondents, incorporation into a BCG model would be most effective using indirect consideration through monitoring of changes in the areal extent of their critical habitats. The survey responses are potentially useful in the development of key faunal guilds, as a means to identify their critical habitats that could be assessed in a restoring habitat balance approach.

<u>2005 Indicators Workshop</u>

The MBNEP Indicators Workshop held in 2005 was constrained by a mandate that indicators considered would be limited to those supported by datasets produced under (then) existing monitoring efforts. The workshop results therefore are not necessarily comprehensive with respect to indicators potentially usable within a BCG framework. They do nonetheless represent a consensus view of those environmental indicators most representative of a healthy estuarine ecosystem.

Table 4 presents the WQ indicators identified during the workshop. Because they are not biological metrics, many of the potential indicators developed by the workshop would not be applicable to a BCG model, even though to some degree they could affect floral and faunal populations.

Table 4. Water quality (WQ) indicators identified during the 2005 Indicator Workshop.	
WQ indicators not applicable to BCG	WQ indicators potentially applicable to an estuarine BCG model
Dissolved oxygen	Harmful algal blooms (A)
Light attenuation	Chlorophyll *a* (A)
Secchi depth	Tissue chemistry – fish and shellfish (A)
Sediment chemistry	Enterococcus monitoring (A)
Atmospheric mercury	Fecal coliform (A)
Loadings (TRI, NPDES)	
Potentially Important	*Potentially Important*
Suspended sediments	Macroalgal biomass/benthic productivity (A, B)
Temperature	
Salinity	
	A = single habitat; B = habitat mosaic

As with the identified WQ indicators derived from the online survey results, and which are potentially applicable to an estuary BCG approach, most of the indicators identified at the workshop are not practicable for use in a monitoring program assessing status and trends across the entire study area. The indicator “Macroalgal biomass/benthic productivity” appears to have the greatest potential for use in a BCG model framework, either for a single habitat or a habitat mosaic approach.

Table 5 presents the HM indicators identified during the workshop. HM indicators usable within a BCG model framework are those that would be addressed through a habitat balance approach -- acres of habitat by type, changes and trends, and acres protected and restored.

Though most of the potential HM indicators could be used in both the single habitat and habitat mosaic approaches, the latter approach would be most useful as a status and trends assessment program for the entire estuary. HM indicators usable within a BCG model framework are those that would be addressed through a restoring habitat balance approach, including acres of habitat by type and acres protected and restored.

Table 5. Habitat management (HM) indicators identified during the 2005 Indicator Workshop.	
HM indicators not applicable to BCG	HM indicators potentially applicable to an estuarine BCG model
Pollution trends	Acres of habitat quantity by type (B)
	Acres of habitat protected or restored (A, B)
	Shoreline/riparian change trends (A, B)
	Hydrologic/bathymetric change (A, B)
	Land use, cover changes, and trends (A, B)
	A = single habitat; B = habitat mosaic

Table 6 presents the LR indicators identified during the workshop.

Table 6. Living resources (LR) indicators identified during the 2005 Indicator Workshop.

LR indicators not applicable to BCG	LR indicators potentially applicable to an estuarine BCG model
Number of threatened/endangered species	Biodiversity of bottom-dwelling species: blue crabs, oysters, flounder (A, B)
Number of species on special concern list	Biodiversity of mid-water species: largemouth bass, red drum, mullet, and other forage (A, B)
	Biodiversity of birds: pelicans, waterfowl, neotropical migrants (A, B)
	Number of ospreys and eagles (A, B)
	Acreage of non-native macrophytes (A, B)
	Frequency of occurrence of non-native species (A)
	Occurrence of non-native crabs (A)
Future Study	*Consider for Future Study/Monitoring*
Distribution of coarse and soft bottoms	Diversity and composition of riparian insect assemblages (A, B)
	Number of listed species relative to year (x) and related habitat acreage (A, B)
	Crawfish
	Alligators
	Tadpoles
	Gulf sturgeon
	Diamond back terrapin
	Alabama red-bellied turtle
	Nutria

A = single habitat; B = habitat mosaic

Many of the identified LR indicators are monitored under existing federal and state programs, including federal- and state-listed species of concern, various birds, and certain fishery resources. Biodiversity indicators were developed for ecological guilds, including bottom-dwelling species, mid-water species, and birds. Each indicator guild included three or four specific taxa or species categories, but it is unknown whether the indicators are intended to be restricted to those named components. There is increasing interest in use of biodiversity indices to assess environmental status and trends, and though the measures of biodiversity identified by stakeholders are important, their applicability to assessment of estuary-wide status and trends is not clearly defined. In addition, establishing a baseline condition would be problematic. Monitoring biodiversity at a guild or species level would entail large monetary costs and levels of effort.

The number of ospreys and eagles not appear practicable for use in a MBNEP monitoring program due to the levels of effort required to quantify the status of their populations. As with the biodiversity indicators, their applicability to assessment of estuary-wide status and trends is not apparent. Many of the identified LR indicators may be valuable for use in developing key faunal guilds, as a means to identify critical habitat types that could be assessed in a habitat mosaic BCG model approach.

"Acreage of non-native macrophytes" presumably refers to SAV, though it may also refer to algae. If used as a metric in a BCG model, to be useful it should be included with other biological indicators, such as overall SAV acreage. By itself the indicator does not seem to be suitable for use in comprehensive assessment of estuary-wide status and trends. This is also the case with the indicators "Frequency of occurrence of non-native species" and "Occurrence of non-native crabs".

Table 7 presents the HU indicators identified during the workshop. The HU indicators potentially applicable to an estuarine BCG model are habitat-based, including those related to wetlands, natural shorelines, and land use changes. The meaning of the indicator "Percentage of shellfishing" is unknown. It might refer to the percentage of total oyster reef acreage open to harvest.

Table 7. Human Uses (HU) indicators identified during the 2005 Indicator Workshop.

HU indicators not applicable to BCG	HU indicators potentially applicable to an estuarine BCG model
Human population growth/changes	Functional wetland – protected, restored, enhanced, and created (A, B)
Municipal wastewater permit violations	Number and percentage of shorelines hardened – bulkheading (A, B)
Number of 303(d)-listed streams	Acreage of land converted to alternate use (B)
Number and types of development permits	
Impervious surfaces	
New road construction	
Future consideration	*Future consideration*
Best management practices activity	Percentage of shellfishing (A)
Quality, quantity, and identification of outfalls	
Boat ramps and access sites – linear feet and availability	
	A = single habitat; B = habitat mosaic

<u>Indicator Development Conclusions</u>

Many of the potential indicators presented in the online survey report and identified at the indicators workshop would not be applicable to a BCG model. Of those water quality indicators usable in a BCG approach, most would not be practicable for use in a MBNEP status and trends monitoring program assessing the entire estuary. For a single habitat approach assessing soft sediments, which constitute most of the study area, some measure of benthic productivity would serve as the best status and trends indicator estuary-wide.

Habitat was a primary concern among the online survey respondents and workshop participants, including restoration of altered habitats. Several indicators considered in both the online survey and workshop would be addressed a habitat mosaic BCG approach.

Species diversity was another indicator of interest, but there is no consensus regarding the community constituents, ecological guilds, or individual species that should be monitored. As a practical matter of survey logistics, costs, and design, a monitoring program would have to focus on particular species or groups of species that would be indicative of the overall estuary condition at any point in time. And establishing a baseline for comparison with future monitoring, which is a basic requirement of the BCG approach, would be difficult.

Any biodiversity monitoring should focus on ecosystem components that have relevance to water quality, habitat management, or both (e.g., brackish marsh). Because of monetary costs and survey design constraints, using one or more biodiversity indicators at a population level does not appear to be practicable. At a landscape level, biodiversity attributes could include the distribution and proportions of a number different habitats or biotopes, which could serve as proxies for the species depending on and occurring within those habitats.

Development of a Conceptual Model of a Mobile Bay Regional BCG

The first technical component of calibrating a regional BCG is to adjust the generalized conceptual model to local conditions. Calibrating the BCG model to the MBNEP study area broadly includes three components that together construct a coherent ecological description of biological response to natural and anthropogenic stressors:

1. A description of the native aquatic assemblages under natural, undisturbed conditions, to provide a baseline with which to compare and assess the condition of estuary waterbodies.

2. Identification and description of regional stressors to help define expectations for biological responses likely to occur.

3. A description of the BCG. The conceptual model of the BCG may require some example data from sites to empirically validate conclusions.

A critical aspect of Mobile Bay BCG model development will be identification of Tier 1 baseline conditions, which could be represented by a historic state, by present-day, specific locations determined to be in a natural condition, or a combination of both.

Potential BCG Approaches for the Mobile Bay Estuary

For any approach to developing a BCG Model for the MBNEP, its feasibility will be a function of the amount and quality of available data for relevant biological components, and how the data can be used in a quantitative approach that provides meaningful descriptions of environmental quality. Potential BCG approaches initially considered include restoring the historic balance among acreages of various habitat types, and monitoring of benthic habitat communities as indicators of sediment and water quality.

<u>Restoring Habitat Balance</u>

The Tampa Bay NEP has adopted a “restoring habitat balance” approach based on reestablishment of the relative proportion of habitat types (SAV, mangrove, tidal marsh, salt barren) that existed “pre-development”. In the restoring balance approach, habitats are proxies for key faunal guilds of estuarine-dependent species. To adopt a restoring balance approach, the historic extent of significant habitat types must be determined for the MBNEP study area to establish a baseline condition for incorporation into the BCG model.

Primary Advantages

- A historic SAV acreage baseline is completed for a portion of the MBNEP study area (BVA, 2005), in addition to coastal wetland (NWI) acreage (Roach et al, 1987), and the extent of natural shorelines in Mobile Bay (Douglas, 1997).

- Mapping can be performed largely on computer with periodic aerial imagery acquisition and relatively minor field validation effort; logistical issues and costs associated with large, routine faunal sampling efforts are avoided.

- Restoration activities and approaches undertaken based on habitat balance assessments would be focused on those habitat types that historically have been most disproportionately lost or degraded.

Key Hurdles

- A GIS database will have to be established for baseline "pre-development" conditions of coastal marshes and other habitats of interest.

- GIS coverage of a historic SAV acreage baseline does not currently include the delta and Dauphin Island areas.

- SAV occurrence in the study area varies naturally, often significantly, on an interannual basis; is it feasible to attempt to achieve a historic "balance" of habitats that includes SAV?

- There may be limited locations in the study area that are available and suitable for restoration of SAV, tidal marsh, and other habitat types.

- Restoration of historic habitat balance may not account for environmental degradation in locations that do not contain the habitats of interest.

<u>Benthic Habitat Monitoring</u>

Greenwich Bay (RI), part of the Narragansett NEP study area, is investigating the feasibility of a BCG approach based on benthic macroinvertebrates as indicators of sediment and water quality. Benthic community assessment potentially represents a useful approach due to the sedentary nature of benthic infauna and role their in ecosystem function.

Primary Advantages

- The MBNEP study area consists mostly of unconsolidated, non-structured sediments.

- Monitoring benthic community composition is a well-established method of assessing biotic integrity, with assemblage composition largely reflective of sediment and water quality.

- The State of Alabama conducts estuarine benthic monitoring that may be complementary to a MBNEP monitoring program, with potential for program coordination.

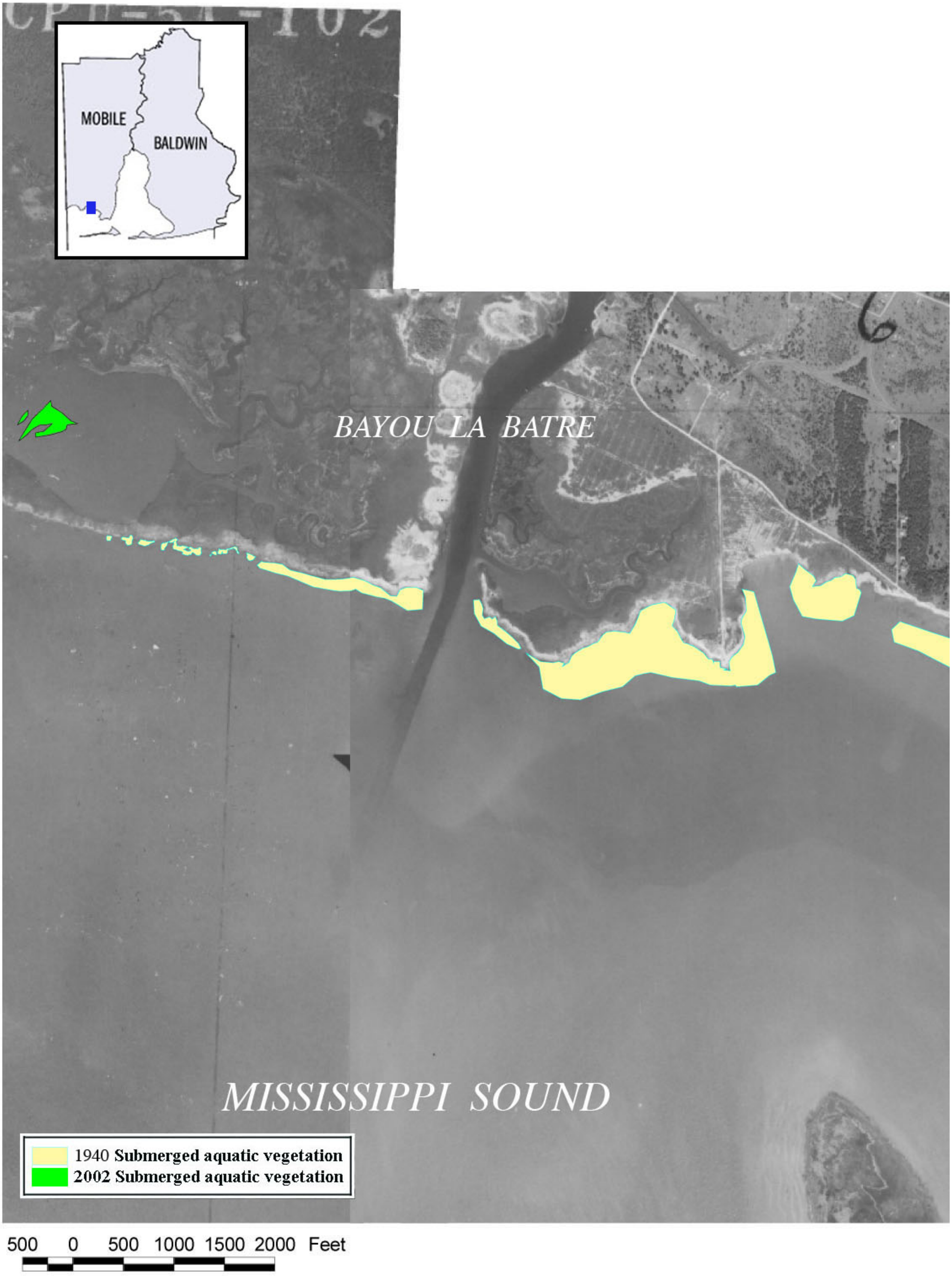
Key Hurdles

- To calibrate a BGC model to the Mobile estuary focused on soft sediment macroinvertebrate assemblages, it is likely that comprehensive benthic studies will first have to be conducted to adequately define a baseline of natural community composition for the range of sediment habitats in the study area.

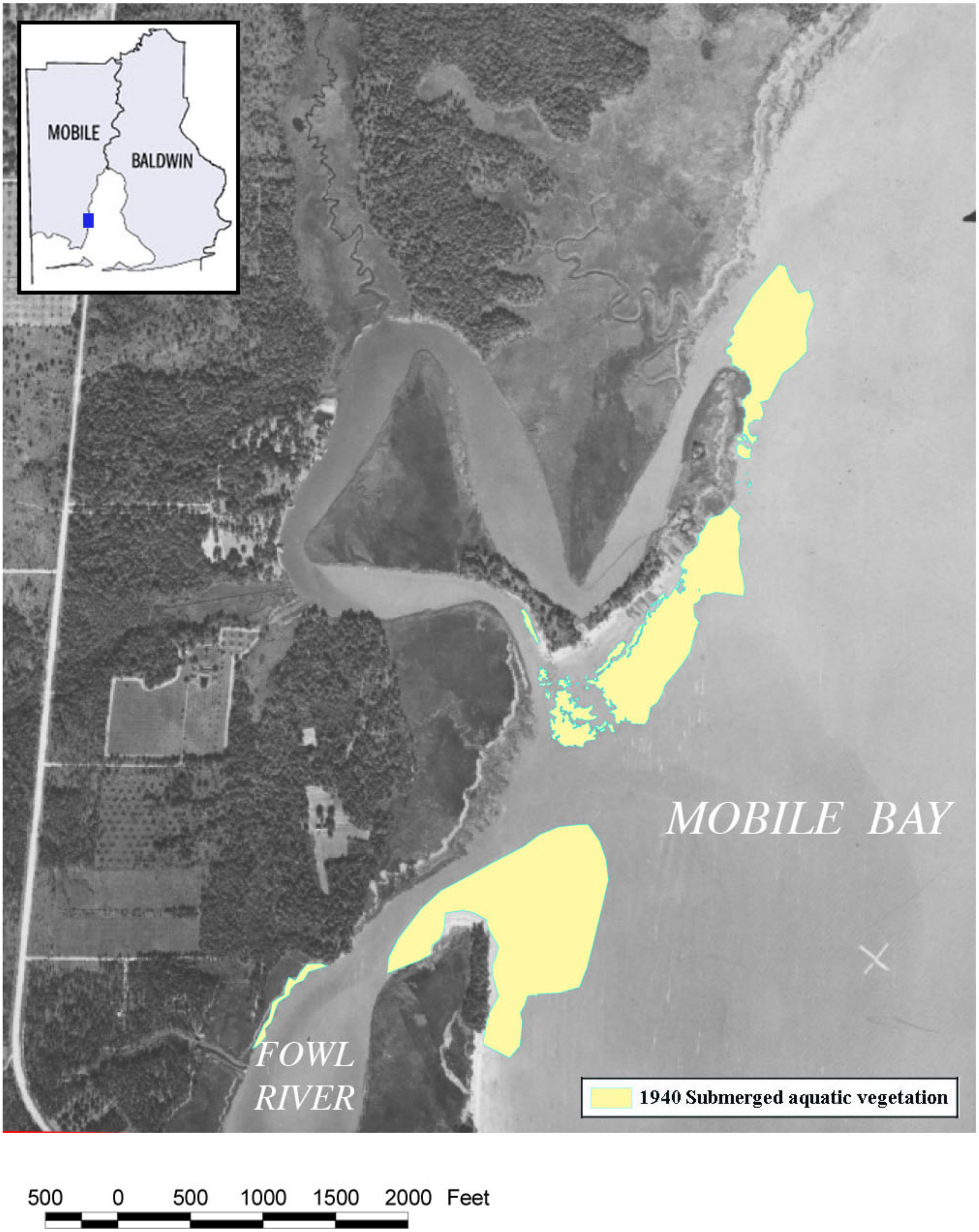
- Regional stressors have been largely defined for broad habitat effects, such as with dredging and hypoxia, but some stressor effects, such as sediment contamination influences, are poorly understood and may not be detectable.

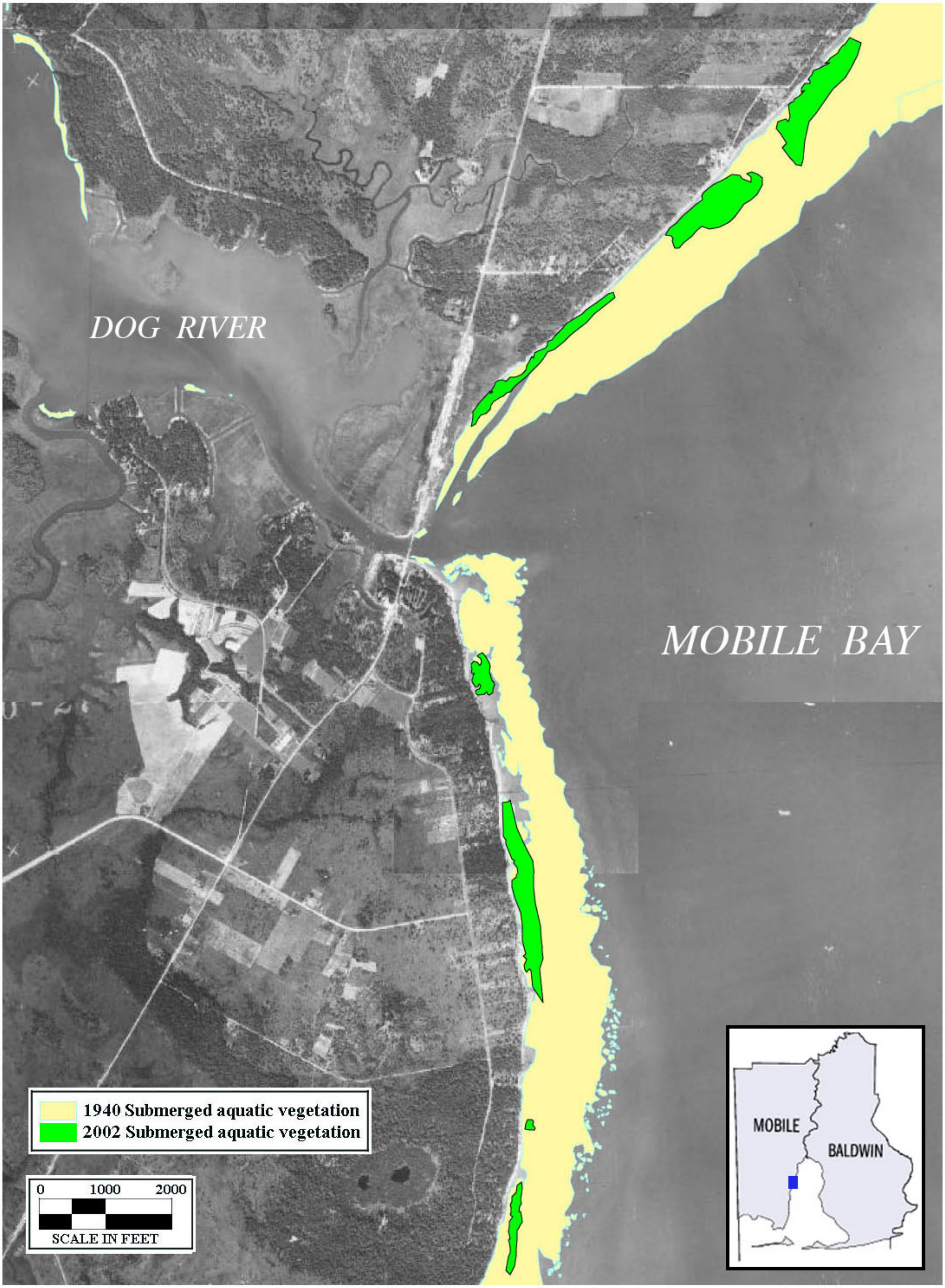
- Monetary costs of baseline and permanent field monitoring programs could be substantial.

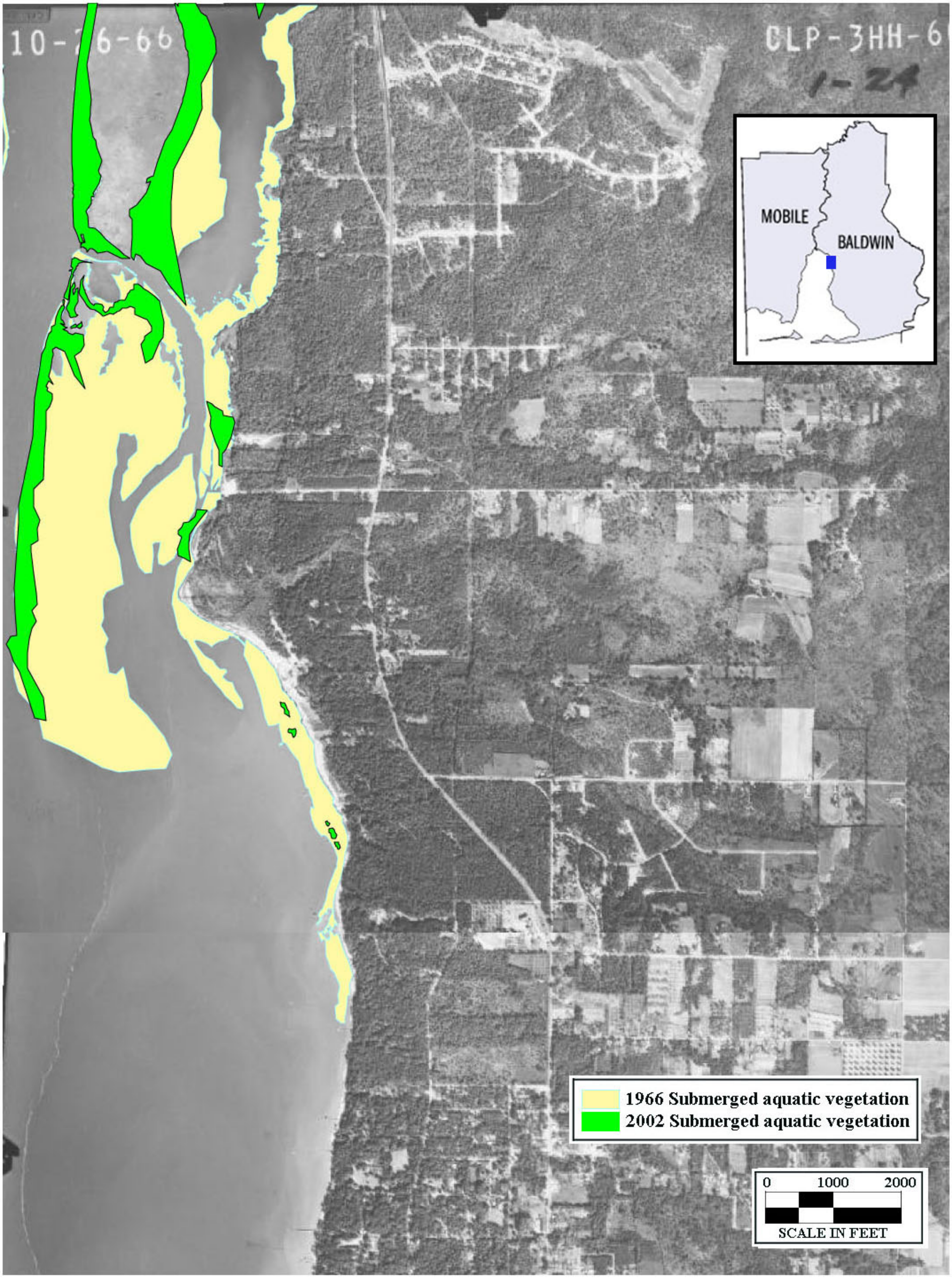
Attachment 2 – Historic SAV Occurrence Maps



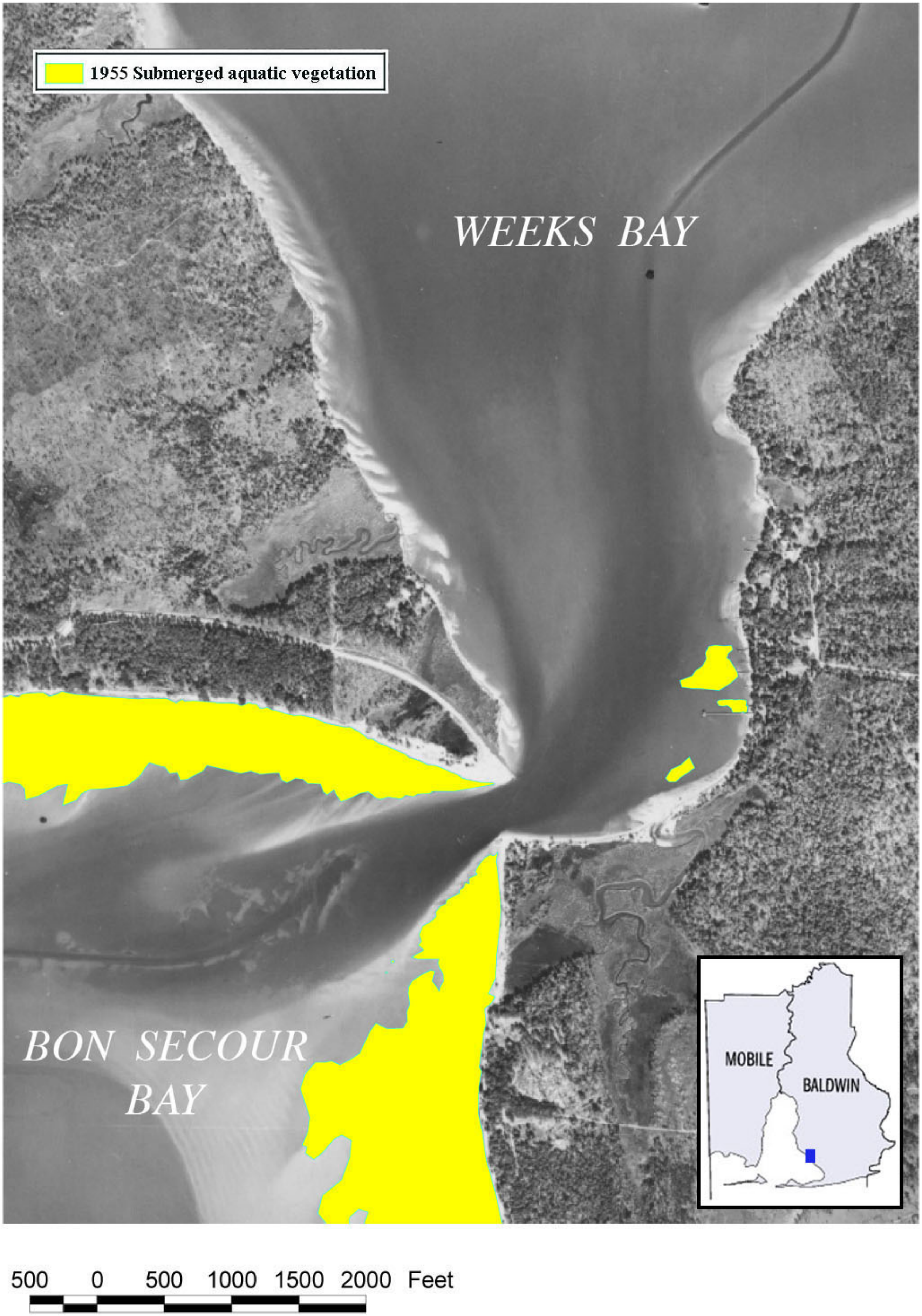
MOBILE
BALDWIN
BAYOU LA BATRE
MISSISSIPPI SOUND
1940 Submerged aquatic vegetation
2002 Submerged aquatic vegetation
500 0 500 1000 1500 2000 Feet


MOBILE
BALDWIN
MOBILE BAY
FOWL RIVER
1940 Submerged aquatic vegetation
500 0 500 1000 1500 2000 Feet


DOG RIVER
MOBILE BAY
1940 Submerged aquatic vegetation
2002 Submerged aquatic vegetation
0
1000
2000
SCALE IN FEET
MOBILE
BALDWIN



10-26-66
CLP-3HH-6
1-24
MOBILE
BALDWIN
1966 Submerged aquatic vegetation
2002 Submerged aquatic vegetation
0
1000
2000
SCALE IN FEET


1955 Submerged aquatic vegetation
WEEKS BAY
BON SECOUR
BAY
MOBILE
BALDWIN
500 0 500 1000 1500 2000 Feet