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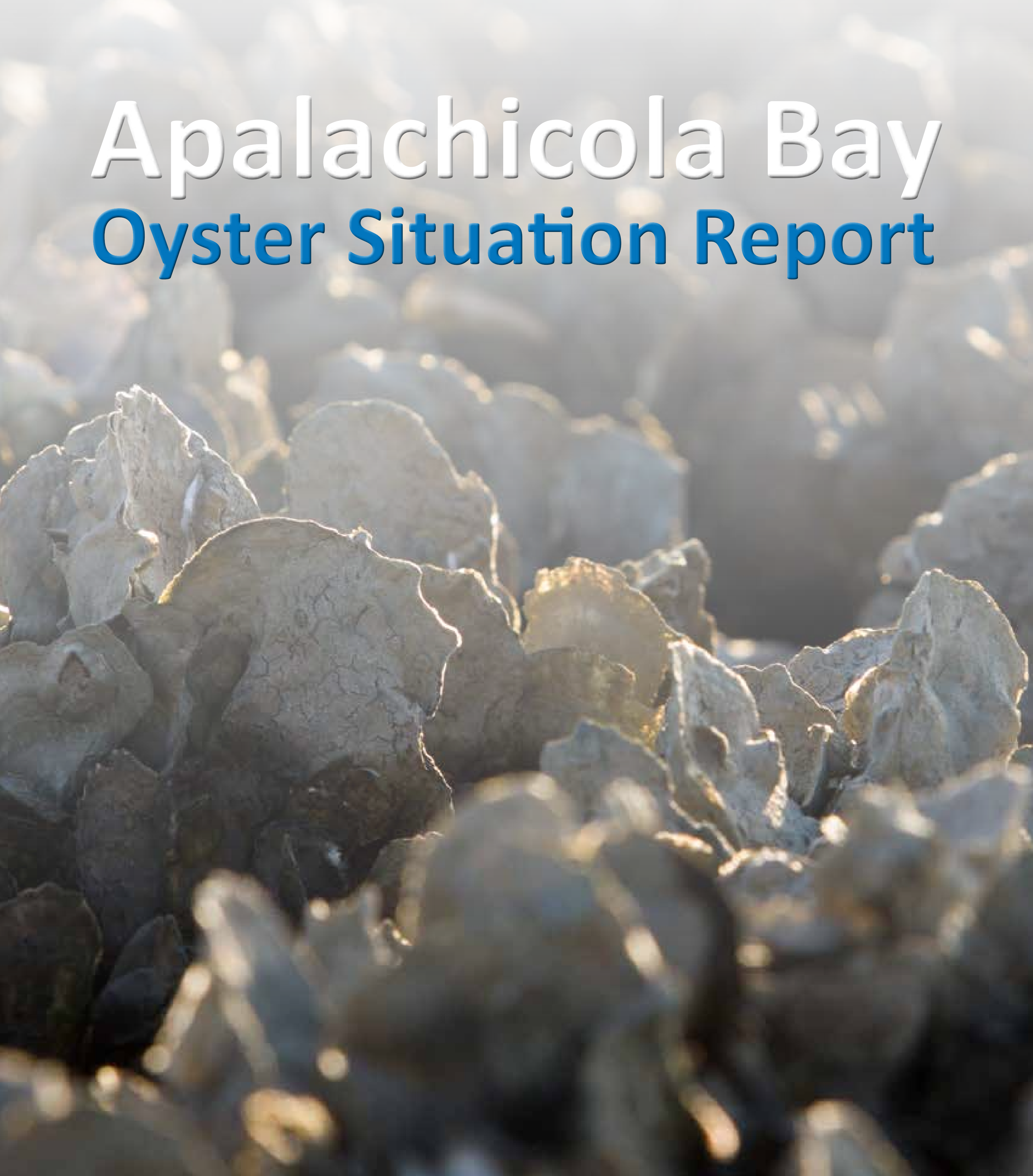

Apalachicola Bay

Oyster Situation Report

Apalachicola Bay Oyster Situation Report

APRIL 24, 2013

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Apalachicola Bay Oyster Situation Report

APRIL 24, 2013

EXECUTIVE SUMMARY

This report summarizes efforts conducted through the University of Florida Oyster Recovery Team, in collaboration with various stakeholders, to describe conditions in Apalachicola Bay prior to and after a historic collapse of the oyster fishery. The report characterizes conditions in the bay, reviews possible causes for the fishery collapse, and outlines a plan for future monitoring, research and fishery management. Conclusions in this report are based on analyses of data collected in historical monitoring programs conducted by the Florida Fish and Wildlife Conservation Commission, Florida Department of Agriculture and Consumer Services, Apalachicola National Estuarine Research Reserve (Florida DEP) and Northwest Florida Water Management District, as well as field, experimental, and community data collected by the authors, who are reporting in their capacity as members of the UF Oyster Recovery Team.

Findings

- Apalachicola River discharge levels are strongly influenced by rainfall over the Apalachicola-Chattahoochee-Flint River Basin. The lower part of this basin was frequently classified by the National Integrated Drought Information System as in an 'exceptional drought' during the last three years.
- Water quality data indicate that 2012 was a year of high salinity at all monitoring stations in the bay likely caused by low river flows and limited local rainfall in most months.
- A large decline in oyster landings was reported after August 2012 in the bay, and the number of reported oyster harvesting trips also dropped off each month during the second half of that year.
- The 2012 decline in oyster landings and recruitment of juvenile oysters is unprecedented during the period of data analyzed and has likely involved recruitment failure or high mortality of small oysters.
- Fisheries independent monitoring data, collected by state agencies, indicates a general downward trend in abundance of legal-sized (3 inch or larger) oysters in the bay in recent years and a large decline in sub-legal (smaller than 3 inches) oysters present in 2012.
- Because of the low abundance of sub-legal oysters in 2012 there is a high likelihood that legal-sized oysters will be in low abundance in 2013 and likely in 2014 as well.
- The current size limit of 3 inches appears to be effective at reducing the risk of "growth overfishing" where yield (pounds of meat harvested) is reduced because oysters are harvested at too small a size. However, it is essential that this size limit be accepted by the community, adopted by the industry, and enforced by regulatory agencies and the county judicial system. Substantial future harvesting of sub-legal oysters could have negative effects not only on oyster populations but also a serious impact on the national reputation of Apalachicola oysters as a high-quality seafood product.
- Oysters, white shrimp, brown shrimp, blue crab and multiple finfish species have been analyzed for the presence of oil residue. All samples were either below the limits of detection or below quantifiable limits. Thus, based on analyses conducted so far, there is no evidence of chemical contamination from the Deepwater Horizon oil spill in the seafood sampled from Apalachicola Bay.
- A large percentage of oysters in the bay have some degree of shell parasitism by clams, polychaete worms, sponges or other organisms. This parasitism negatively affects the integrity and aesthetics of the oyster shell, the overall growth and productivity of the oysters, and the economic value of product bound for the half-shell market. There are no historic data to compare degree of shell parasitism observed in 2012-2013.

Recommendations

Monitoring

- There is a need to continue the monitoring of oysters in Apalachicola Bay, both in terms of tracking landings reported by oystermen, and in the sampling done by state agencies.The fisheries independent monitoring program needs to be expanded in its spatial extent to include all of the bay where oyster bars occur, including areas that are closed to fishing, because these may represent important sources of oyster spat.
- Oysters should be included on the list of invertebrate species routinely assessed by Fish and Wildlife Research Institute (FWRI) stock assessment staff. These assessments can identify persistent uncertainties in oyster ecology or population status and help guide research such as the relationship between Apalachicola River flows and juvenile oyster survival rate or culling mortality.

Management and Restoration

- Acceptance by the community and industry, and enforcement and adjudication of rules regarding size limits, spatial restrictions, and weekly and seasonal closures is essential for these measures to be effective in sustaining the oyster population.
- Throughout our work on this project there were persistent reports of high levels of unreported harvest and illegal harvest from closed areas. While tangible evidence of illegal activity is not available, it is clear from our simulation models that lack of compliance with current regulations could greatly reduce the likelihood of Apalachicola Bay oyster populations returning to historic population levels, regardless of management action taken.
- Oyster leases should be explored as a possible alternative to open-access fisheries. The concept of TURF (Territorial User Rights Fisheries) as a lease arrangement could be appealing to oyster fishermen and help promote restoration actions such as re-shelling because the fishermen would benefit directly from the restoration activities they were engaged in by having a "share" of the restored area (the lease) to manage and harvest from.
- The total current area of oyster bar in Apalachicola Bay that is not open to fishing is unknown, and the degree to which this area is the source of the oyster spat for the entire bay also is unknown. If this area is small or declining, then large-scale oyster relay from these closed areas to areas open to fishing may reduce the total spat available throughout Apalachicola Bay, increasing the risk of "recruitment overfishing" where harvests of adults could influence availability of future spat.
- Therefore, the practice of 'relaying' should be carefully evaluated in regard to its short-term benefits versus potential longer-term negative impacts to the fishery—in other words, whether or not it is depleting a substantive portion of the source population of oyster spat.
- Management actions such as shell planting could expedite the recovery of Apalachicola Bay oyster resources. However, a new modeling tool called ECOSPACE, brought forward by the UF Oyster Recovery Team, suggests that shell planting needs to be conducted at a considerably greater scale than current levels to be effective—approximately 200 acres per year for a 5-year period. A very important uncertainty is whether shell planting should concentrate large amounts of shell in small areas to create thick layers of shell or whether shell should be spread over larger areas but not in as thick a shell layer. Restoration should be done in a manner that provides information on efficacy and cost-effectiveness of different shelling strategies, including evaluating different densities of shelling and different kinds of shell material.
- A participatory decision-making process, involving SMARRT (the Seafood Management Assistance Resource and Recovery Team), relevant state agencies and experts from the state university system is needed to support long-term management of the oyster fishery in a more robust manner. The ECOSPACE model could further support members of SMARRT and management agencies to screen different policy or restoration alternatives.

Research

- Research is needed to identify an optimal approach for monitoring long-term settlement, juvenile and adult survival, productivity, health, mortality, oyster diseases, and product quality of oysters. Subsequently this information could be used to inform changes in the oyster monitoring program.
- Research is needed to quantify how oyster population dynamics, product quality and the fishery are affected by interactions between river flow, nutrients, salinity, harvesting intensity and restoration methods.
- There is a need to assess the harvesting practices of the oystermen and how they respond to changes in oyster abundance.
- The ECOSPACE model has additional functionality to identify effects of varying flow regimes and to screen flow alternatives, relative to Apalachicola Bay oyster population dynamics and harvest potential when the model is linked with the Apalachicola Basin River Model currently being used by the Apalachicola-Chattahoochee-Flint River Stakeholders Group.

Outreach and Education

- A community-based outreach and education program is needed to foster actions consistent with supporting a sustainable bay ecosystem and economy.
- Involvement of oyster harvesters and processers in research and restoration projects can aid in educating the entire community about bay stewardship.

The Future

The situation in Apalachicola Bay, as outlined in the pages of this report, highlights a series of interwoven ecologic, fisheries, and community concerns. The bay is a national treasure, and its demise would sever critical links among our modern society, nature and our heritage. Work to date is a starting point toward understanding the processes underlying the current crisis, and includes steps that can and should be taken in initial efforts to restore the bay. However, if we are truly committed to bringing the bay back to a point even close to its former productivity, a great deal of work is still required. These studies and analyses were conducted on a shoestring budget with internal funds from UF/IFAS, and limited support from Florida Sea Grant and from the National Institute of Environmental Health Sciences. If we are truly committed to the restoration of the bay, we can't stop here.There is a critical need for follow-up work, bringing together state and federal agencies, academic researchers, and the community, to look out over a 5-, 10-, and 20-year time scale, to conduct interventions, do the necessary research, and monitor outcomes. This will require a strong leadership structure and it will cost money. The question remains as to whether we, as a society, are willing to make this investment of time, and money, to preserve this priceless natural resource for our lifetime, and the lifetimes of our children.

BACKGROUND

Apalachicola is a heritage fishing community located in the Big Bend Gulf coast region of Florida. For decades, it has been the state's prime production estuary for oysters prized for their outstanding quality and taste. Today this unique oyster fishery may be on the verge of collapse. This collapse is associated with multiple environmental and human factors.

Apalachicola Bay traditionally has been a great place for oysters to grow. Freshwater inflows from the Apalachicola River are retained in Apalachicola Bay by a series of barrier islands fringing the coast. This retention of fresh water lowers the salinity level in Apalachicola Bay creating preferable salinity conditions that favor good oyster growth, survival, and low disease occurrence, but unfavorable conditions for marine predators that feed on oysters such as conchs and whelks. Apalachicola Bay has other natural geologic features such as ancient hard bottom areas that provide nucleation sites for oysters to grow forming oyster bars. In addition to lowering the salinity, fresh water flows from Apalachicola River also deliver nutrients from upstream areas that are essential for the entire Apalachicola Bay ecosystem.

During the last two years, a severe drought in the southeast U.S., including Georgia, where much of the water in the Apalachicola River originates, has dramatically reduced freshwater inflows to Apalachicola Bay. Adding to this problem are withdrawals of water from upstream reservoirs for use by metropolitan Atlanta and water withdrawals in the basin for Georgia and Alabama agriculture. Oystermen and other concerned citizens in the Apalachicola area have pointed to declines in abundance of a wide range of aquatic animals in the bay, including economically and ecologically valuable oysters and other seafood products. This situation could reflect a variety of stressors, including increased disease and predation as salinity in the bay has increased without the typical rate of freshwater inflow, perhaps nutrient limitation of the food web, and a historically high level of oyster harvesting.

The number of oysters harvested and the number of oyster fishermen in Apalachicola Bay has increased in recent years due to several factors including high oyster prices because of reduced oyster availability in other areas following the Deepwater Horizon oil spill in 2010. There also were temporary changes in harvest regulations immediately following the oil spill, due to concerns that oysters might be lost to oil contamination. This led to increased harvest rates – yet the oil did not reach the bay, and no evidence of oil contamination has ever been found in Apalachicola Bay. In 2011 and 2012 oyster prices again remained high and the number of oyster harvesting trips reported by fishermen reached the highest levels observed since the mid-1980s. Additionally, fishermen raised concerns about large harvests of sub-legal (less than 3 inch) oysters over this same time period—all while Apalachicola River flows reached some of their lowest points recorded and salinity levels increased within the bay to higher and higher levels. In essence, the period from 2010 to 2012 may have been a perfect storm for the oyster fishery in Apalachicola Bay with low river flows and higher salinity creating poor environmental conditions and several years of low juvenile survival and naturally low populations. At the same time, oyster demand, prices, and fishing effort, combined with insufficient fishery management enforcement and adjudication, led to a large portion of the oysters being harvested. Unfortunately, the storm may not be over as surveys of juvenile oysters suggest that legal oyster abundance will be low in 2013 and likely 2014 as well. Now is the time to address key long-term uncertainties related to managing and restoring oyster resources in Apalachicola Bay, in order to create and maintain a resilient oyster fishery.

RESPONSE

University of Florida/IFAS responded to this situation in fall 2012, when Senior Vice President Jack Payne formed the UF Oyster Recovery Team, and appointed Karl Havens, director of Florida Sea Grant, to serve as chair. The team includes UF researchers with a broad range of experience and knowledge about oysters and coastal ecosystems in Florida. Also included are researchers from Florida State University and Florida Gulf Coast University, state regulatory agencies, the Northwest Florida Water Management District, and representatives from the oyster industry and other fishing-related businesses in Apalachicola. The work reported here was funded primarily by internal funds from the Institute of Food and Agricultural Sciences at UF, Florida Sea Grant, and with some components funded by the National Institute of Environmental Health Sciences (Grant U19ES020683) as part of the Deepwater Horizon Research Consortium.

The team met in Apalachicola for public meetings in October 2012 and January 2013, and researchers have met with agency scientists on a number of occasions throughout this period to obtain and jointly evaluate historical and contemporary data on oysters, water quality and other features of the bay. The focus of research has been on looking for signs of increased infection, signs of oil or dispersant from the Deepwater Horizon oil spill, evidence of over-harvesting and harvesting of sub-legal oysters, and predation impacts on oysters and how it relates to salinity at different locations in the bay. The team has also worked with members of the industry and community to develop approaches for increased community resiliency, and evaluated options for diversification of seafood products.

While researchers were doing this work, a group of oystermen, oyster dealers and other members of the community formed a citizen action group called SMARRT (Seafood Management Assistance Resource and Recovery Team) that aims to work with the state regulatory agencies to develop a process to ensure that the oyster industry has long-term sustainability. UF/IFAS faculty supported this effort, by developing a process for participatory decision making and by developing a tool (an interactive and visual computer model of the bay) that can be used by SMARRT to screen restoration and policy alternatives.

ABOUT THIS REPORT

This report summarizes the findings of natural and social science research and outreach conducted by members of the UF Oyster Recovery Team since October 2012. It focuses on questions related to “what happened?” in the bay (i.e., research dealing with presence/absence of oil or dispersant, disease, predators, apparent responses to reduced salinity and the effects of fishing of sub-legal oysters on recovery of the population) and “what can be done?”

This is a report of efforts to understand the bay, its ecology, and optimal approaches to protecting its resources. It should be emphasized that this is only a start. Bringing the bay back to a point even close to historical oyster production levels will require restoration actions and long-term research and monitoring, in a second phase plan, to assess the outcome of new programs, and to continually refine our understanding of the bay and its operation. This will need to include further development and implementation of the ECOSPACE model with validation efforts and river flow analyses to determine effects of mitigating management strategies. Future work will also need to include continued oyster health and productivity assessments, and examination of alternative seafood products and seafood product production practices.

RESULTS

Environmental Conditions *Bill Pine and Karl Havens*

To assess physical conditions in the bay during 2012, we examined recent patterns in freshwater inputs, rainfall, water temperature, and dissolved oxygen in Apalachicola Bay using data from U.S. Geological Survey gauge stations on the Apalachicola at Chattahoochee and preliminary 2012 water quality data from the Apalachicola National Estuarine Research Reserve.

Flow patterns in the Apalachicola River

The Apalachicola River is formed by the confluence of the Chattahoochee and Flint Rivers approximately 112 miles upstream of the town of Apalachicola, Fla. This Apalachicola-Chattahoochee-Flint River Basin (ACF) drains a watershed of about 19,500 miles^2 in three states: Georgia (74% of watershed), Alabama (15%), and Florida (11%). Within this basin, 16 in-stream reservoirs are present which modify and attenuate river flows in various ways. River flows are also modified via surface and subsurface water withdrawals for agricultural, municipal, and industrial use. How these flow modifications alter the hydrology and ecology of the ACF basin and Apalachicola Bay is an area of ongoing debate and research by numerous federal, state, and citizens groups.

The Apalachicola River has seasonally variable flows with the highest flows generally occurring during winter and spring and lowest flows occurring in summer and fall. The Apalachicola River is the primary source of freshwater input into Apalachicola Bay, and as such flows from the river have a very strong influence on the salinity, nutrient dynamics, and other aspects of the Apalachicola Bay ecosystem. We assessed recent flow patterns in the Apalachicola River measured at the Chattahoochee USGS gauge 02358000 by calculating modified box plots of monthly river flows from 1950-2006, as shown in **Figure 1**. These box plots can be interpreted as follows: the x-axis represents the month of the year and the y-axis represents the average daily flow volume for that month from 1950-2006; the thick horizontal line for each month is the median value (middle value for historic daily flows for that month); the box is the interquartile range which spans the first quartile (the 25th percentile) to the third quartile (the 75th percentile); the whiskers extend 1.5 times beyond the interquartile range, and the circles extending beyond the whiskers are the most outlying largest or smallest values. In simplest terms this can be interpreted as saying that in a given month between 1950 and 2006, most of the average daily flows would be observed within the box for each month. We then used colored dots to plot the mean monthly flows in each year from 2007-2012 to assess what the flows over the last 6 years looked like compared to the previous 56 years. This graph demonstrates that for most months over the last 6 years, the flows in the Apalachicola River have been exceptionally low with average daily winter/early spring flows (January–April) generally falling in the lower 25% of measured flows for that month

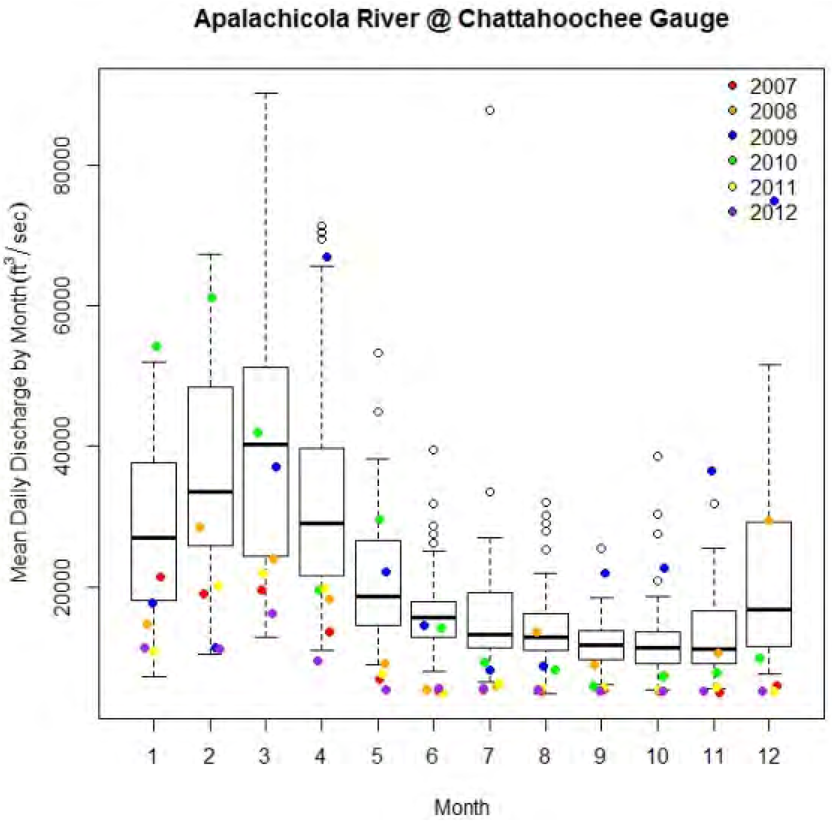

Figure 1 Modified box plot of mean daily discharge (ft^3/sec) by month from 1950-2006 (box plots) and from 2007-2012 (individual colored dots by year, see legend) for the Apalachicola River measured at the USGS Chattahoochee gauge.

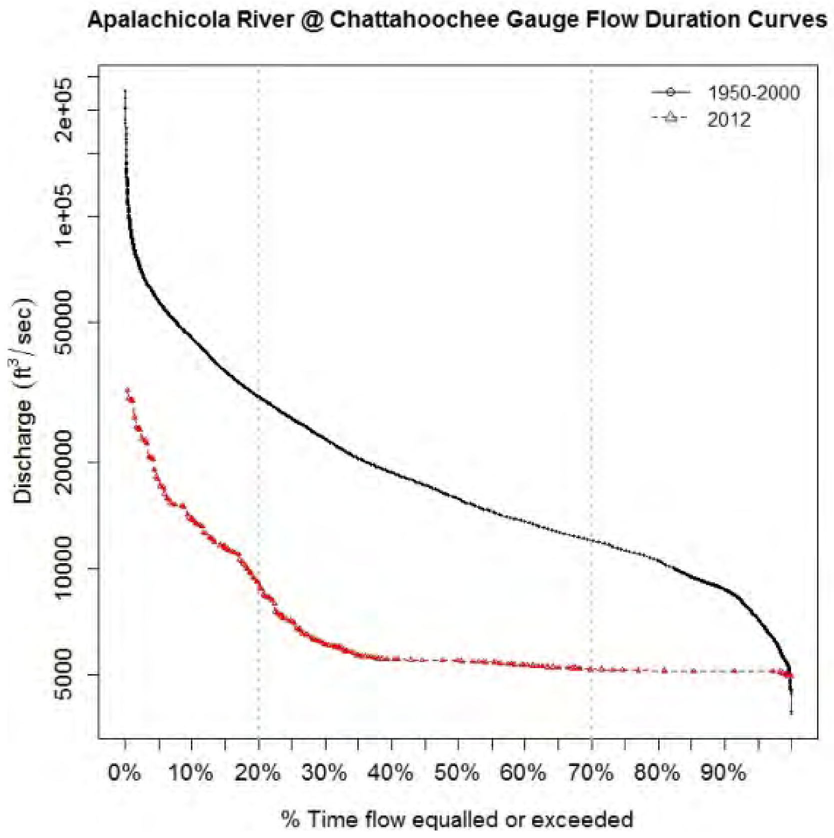

Figure 2 Flow duration curve for the Apalachicola River measured at the USGS Chattahoochee gauge. Black line represents the average flow values that were equal to or exceeded from 1950-2012 and the red line represents the observed 2012 flows.

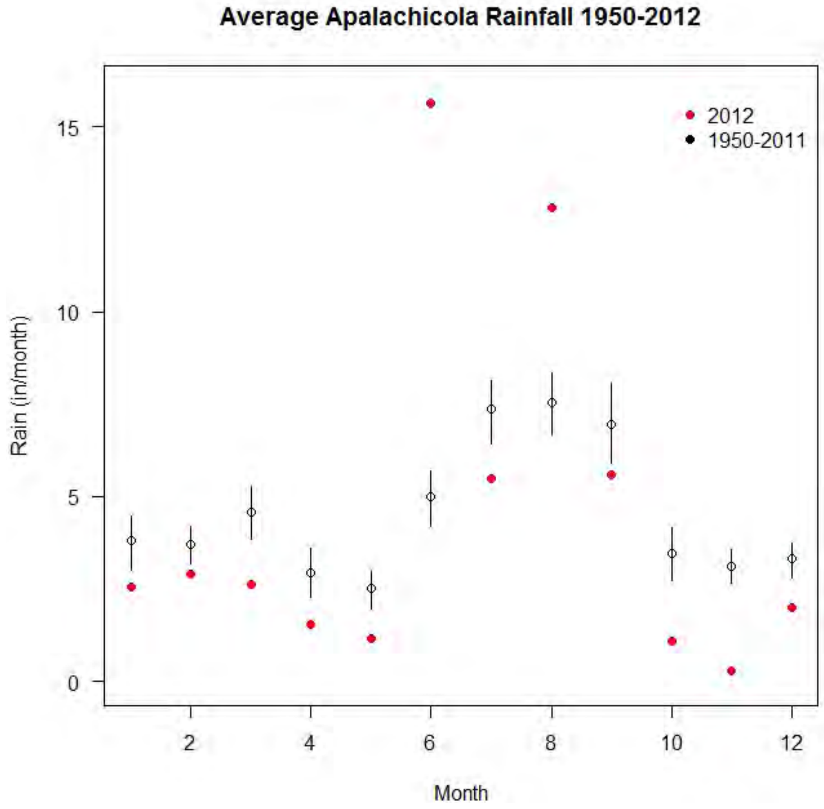

Figure 3 Average monthly rainfall and boot-strapped 95% confidence limits for Apalachicola from 1950-2011 (black circles with error bars) and 2012 (red dots) obtained from the Prism Climate Group *(http://prism.oregonstate.edu)*.

and the flows during the rest of the year (May–December) generally at the lowest levels measured for any year during the period of record. The general exception to this pattern over the last six years is 2009 when flows were generally normal through the winter and above normal range during fall and winter.

To more closely examine the river flow for 2012 compared to most of the period of time (1950-2000) we created a river stage duration curve (**Figure 2**) which shows the percent of time the Apalachicola River flow equaled or exceeded a given flow value in a particular year. This graph shows that in 2012 the Apalachicola River mean daily discharge (ft^3/sec) equaled or exceeded a discharge level of about 10000 ft^3/sec about 20% of the time, whereas during the time period between 1950-2000 this same flow level was exceeded more than 80% of the time (**Figure 2**). Combined, **Figures 1 and 2** demonstrate how low the Apalachicola River flows have been in recent years, particularly in 2012 compared to the period of record.

Apalachicola area rainfall

Apalachicola River stage and discharge levels are strongly influenced by rainfall within the Apalachicola-Chattahoochee-Flint River Basin. According to briefings hosted by the National Integrated Drought Information System (NIDIS) and a variety of cooperating agencies and research groups, the lower part of the ACF basin, particularly the Flint River drainage within southwest Georgia has frequently been in "exceptional drought" conditions for much of the past three years (see materials archived at *http://www.drought.gov/drought/regional-programs/acfrb/acfrb-home*) including most of 2012.

At the local level, 2012 rainfall levels in the Apalachicola Bay area show that rainfall during 2012 was well below average (**Figure 3**), even below the lower 95% confidence interval (e.g., rainfall was higher on average 95% of the time based on the 1950-2011 record compared to rainfall observed in 2012). The two exceptions are June and August 2012, both months with significant tropical rain events resulting in above average rainfall.

Apalachicola Bay water quality 2012

We looked for anomalous patterns (high or low events) in the water quality data available from data sondes maintained by the Apalachicola NERR lab (downloads available, *http://cdmo.baruch.sc.edu*) for locations at Dry Bar, Cat Point, and a surface and bottom sonde in East Bay. We made plots of temperature (C), salinity (ppt), dissolved oxygen percent saturation (DO%), and dissolved oxygen in milligrams/l. Water quality data suggests that 2012 was a year of generally high salinity (for Apalachicola Bay) at all stations (**Figures 4-7**) likely because of low river flows and limited local rainfall in most months (**Figures 1-3**). Summer conditions of high heat and salinity changed abruptly following large rain events related to Tropical Storm Debby in late June and other rain events in August. While these rain events were locally significant and did cause short-term changes in salinity, temperature, dissolved oxygen, and likely other water quality parameters, these rain events were mostly coastal and were not accompanied by large changes in river flow from basin level inputs.

Nutrient inputs to the bay

In addition to delivering fresh water, the Apalachicola River is a major source of nutrients to the bay, fueling a food web that supports oysters, shrimp, fish and other marine organisms. When flows decline, so do inputs of nutrients, and if this phenomenon lasts for a long period of time, the abundance of all of the organisms mentioned above may decline.

There are no continuous measurements of nutrient input to the bay, only water flow volume. However in the early 2000s the Northwest Florida Water Management District conducted several years of simultaneous measurement of flows, nutrient concentrations and nutrient inputs (loading rate). This was done for three nutrient elements that are important for marine food webs – nitrogen, phosphorus and organic carbon. Regression analysis of those data indicated that concentrations did not vary with flow. This allowed a simple loading model to be developed based simply on the regression of flow vs. load. That model was used to approximate what the loads have been in the more recent years (**Figure 8**). The data clearly show a decline in the inputs of nitrogen, phosphorus and carbon to the bay in the last two years. Low nutrient inputs also occurred in some earlier drought years, including 2006 and 2007. Additional work is required to identify possible linkages between the reduced nutrient inputs and changes in the marine organisms. This relationship is complicated by time lags between loading reduction and biological responses, and the timing of response depends on the life cycle of each organism.

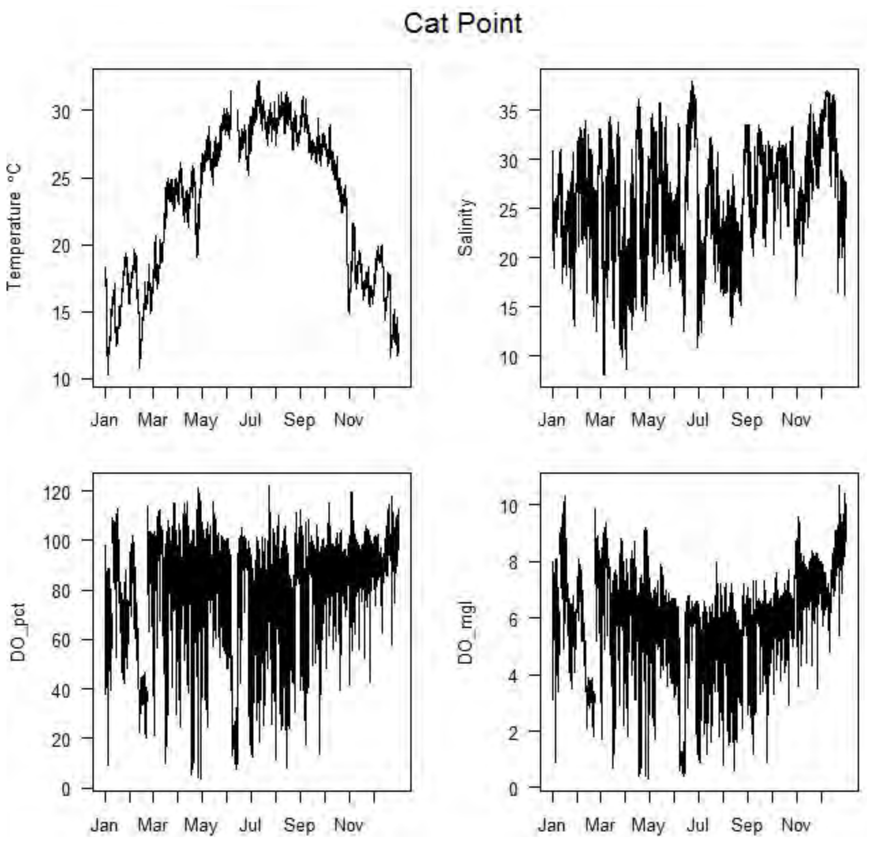

Figure 4 Temperature (C), salinity (ppt), and dissolved oxygen (% saturation, DO_pct and mg/L, DO_mgl) for the Cat Point data sonde in Apalachicola Bay maintained by Apalachicola-NERR staff for 2012. Data are considered preliminary until finalized by NERR staff.

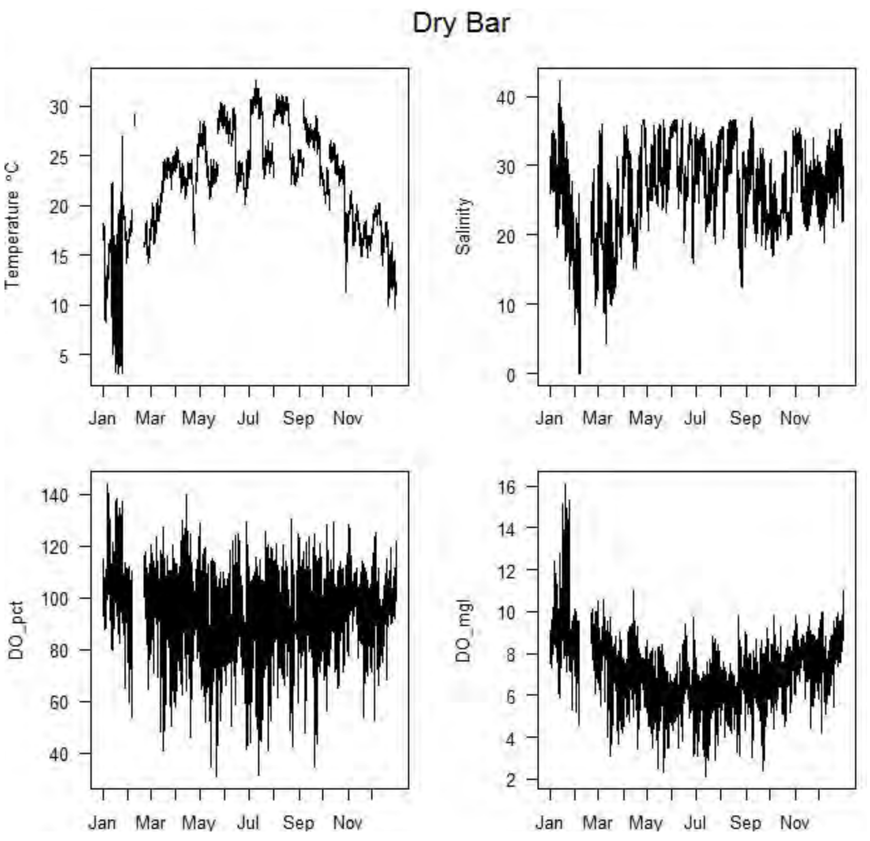

Figure 5 Temperature (C), salinity (ppt), and dissolved oxygen (% saturation, DO_pct; and concentration in mg/L DO_mgl) for the Dry Bar data sonde in Apalachicola Bay, maintained by Apalachicola-NERR staff for 2012. Data are considered preliminary until finalized by NERR staff.

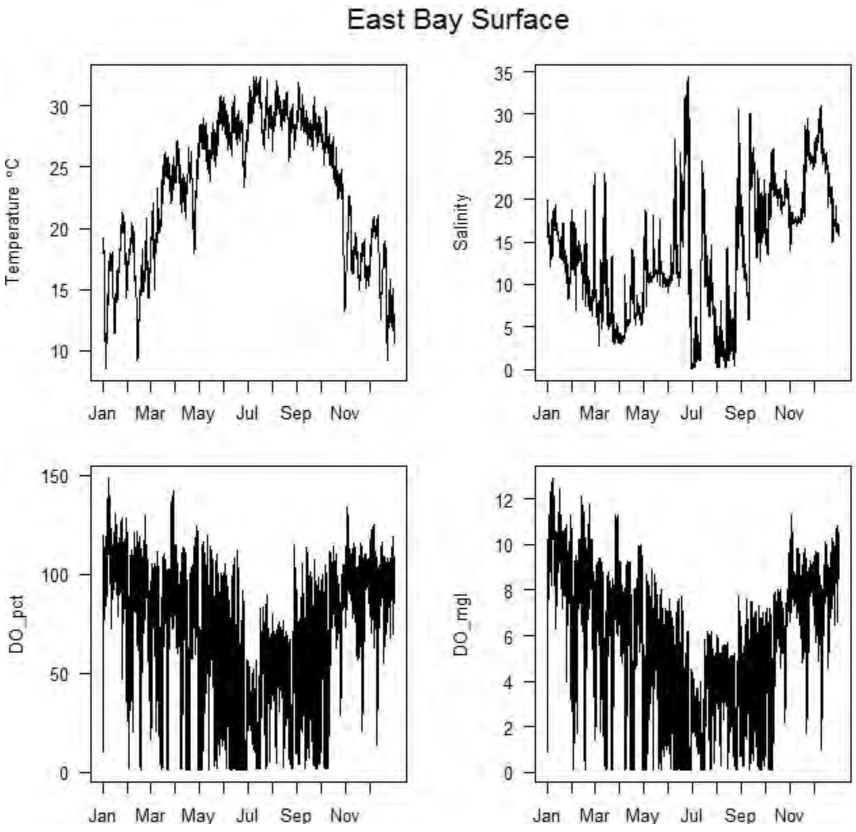

Figure 6 Temperature (C), salinity (ppt), and dissolved oxygen (% saturation, DO_pct and concentration in mg/L, DO_mgl) for the East Bay data sonde near the surface of Apalachicola Bay, maintained by Apalachicola-NERR staff for 2012. Data are considered preliminary until finalized by NERR staff.

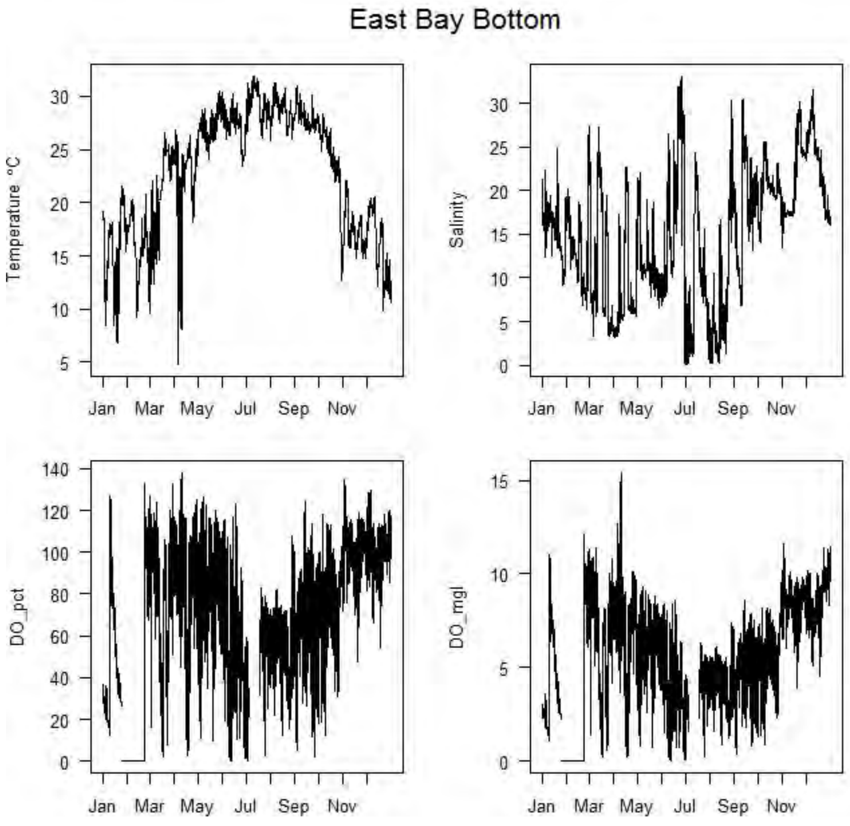

Figure 7 Temperature (C), salinity (ppt), and dissolved oxygen (% saturation, DO_pct and concentration in mg/L, DO_mgl) for the East Bay data sonde maintained at depth in Apalachicola Bay, maintained by Apalachicola-NERR staff for 2012. Data are considered preliminary until finalized by NERR staff.

Future work

The types of variables reported—river flow, rainfall, various water quality metrics—can all be easily (and cheaply) measured via automated equipment. However, our understanding of how these different variables may (or may not) impact oyster populations is not as well known. Various studies have documented that oyster disease and parasite risks increase under high temperature and salinity conditions in lab and field trials. Because of very limited monitoring of disease and pathogens that affect oysters in Apalachicola Bay (and not necessarily their human consumers) we do not have a good understanding of exactly when these types of outbreaks occur, what the outbreaks are, or even whether these outbreaks have population level impacts on oysters in terms of mortality or growth. Similarly, higher salinity environments are thought to support higher abundance of potential oyster predators such as whelks, drills, and conch. However, we do not have data available on trends in these species related to environmental conditions so we do not know what the time lag of any increase in predator populations may be, nor again do we know the population level effects on oysters. Linking water quality and flow monitoring data with information on the occurrence and spatial distribution of key diseases, pathogens, and predators is a key area of future work to develop an understanding of the linkages between environmental conditions and oyster population responses.

Status and Trends in the Oyster Fishery

Mike Allen, Bill Pine, Carl Walters and Ed Camp

We assessed the current status and recent trends in the oyster fishery in Apalachicola Bay. This was done first through simple graphical assessments of fisheries dependent data that are reported by the fishers and dealers to the Florida Fish and Wildlife Conservation Commission, as well as fisheries independent data of surveys of juvenile and adult oysters collected by Florida Department of Agriculture and Consumer Services. We then used these data, along with information on oyster growth rates, spawning patterns, maturity schedules, mortality rates, and other biological data obtained from previous studies to conduct a stock assessment of the Apalachicola oyster fishery. A stock assessment is a compilation of biological and fishery data that is used to determine the status of the "stock" or management unit of interest, in this case, oysters in Apalachicola Bay. In Florida, stock assessments are routinely conducted by FWC for a large variety of fish species such as redfish and gag grouper, but only for a few invertebrates—lobster, stone crab, blue crab and queen conch. No previous stock assessment exists for oysters in Florida. We used an array of mathematical and statistical techniques to develop a variety of models that described the relationship between the oyster population in Apalachicola Bay, observed through the fishery independent data, and the oyster harvests, observed through the fishery dependent data, based on our knowledge of oyster biology. The basic approach in these models is known as a statistical catch-at-age model where we estimated the relative recruitment (spat) and juvenile mortality rates in each month from 1986-2012 that likely would have been required to produce the reported monthly adult oyster landings. The models were developed over a series of three meetings with FWC, FDACS, the Florida Department of Environmental Protection, and Northwest Florida Water Management District personnel. The assessments assume complete reporting of harvest by oystermen over the time frame of the examined data. It is uncertain whether this is a valid assumption, and it should be examined in future work.

Fisheries dependent data summary

We used monthly oyster landings data from FWC with 1986 as our starting year because of uncertainty in the voluntary reporting program prior to 1986. As shown in **Figure 9**, reported oyster landings in Apalachicola Bay have ranged from about 1-2.5 million pounds over this time period with higher catches observed in 1987, and in 2007 and 2009 of 2.7-2.8 million pounds. Low landings occurred in 1995 and 1996 (<1 million pounds each year) and also following Hurricane Elena in 1985 (about 0.5 million pounds) when the bay was closed to harvest for nearly a year. Reported landings for 2012 are still preliminary as not

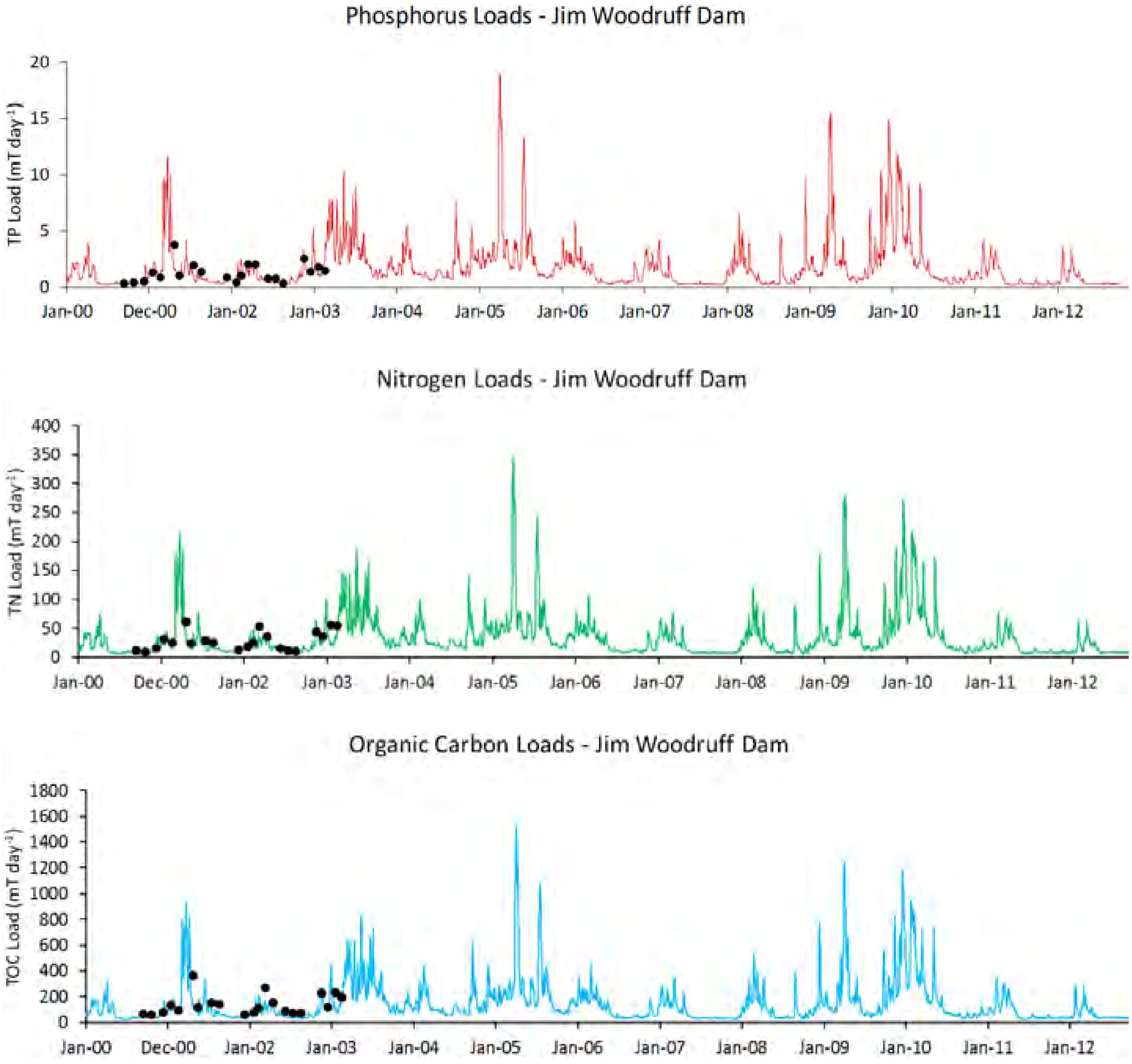

Figure 8 Loading rates of total phosphorus (TP), total nitrogen (TN) and total organic carbon (TOC) at the Jim Woodruff Dam in the Apalachicola River. The black symbols are actual measured loads and the colored lines are estimated loads from the regression model described in the text.

all dealers have reported their final totals from the year. However, total landings for Apalachicola Bay to date are about 2.3 million pounds for 2012. When landings data for each month are analyzed individually, a large decline in reported oyster landings is observed for Apalachicola Bay during 2012. **Figure 10** plots the monthly landings from January 2007-December 2012 and shows the large decline in landings that occurred in August-December 2012.

We then examined trends in Apalachicola Bay (AB) license holders from 1986-2012. The number of license holders peaked in the late 1980s at about 1200 license holders, declined to 400-500 license holders from about 1995-2005, and then begin to increase steadily with about 900 fishermen holding AB licenses in 2012 (**Figure 11**). Reported Apalachicola oyster fishing trips (**Figure 12**) since 1986 have varied widely from about 5,000 trips in 1985 (the year of Hurricane Elena) to more than 40,000 trips reported in 2012 (the highest on record). However, in 2012 most of this effort was during the first half of the year as the number of oyster fishing trips by month since 2007 shows that the number of trips in Apalachicola Bay declined sharply in each month during the second half of 2012 (**Figure 13**).

Figure 9 Annual reported oyster landings in pounds provided by FWC from Apalachicola Bay, Florida 1986-2012. Note that 2012 landings are preliminary.

Figure 10 Monthly reported oyster landings in pounds provided by FWC from Apalachicola Bay, Florida 1986-2012. Note that 2012 landings are preliminary.

Figure 11 Total number of Apalachicola Bay license holders from 1986-2012 provided by FWC.

Fisheries independent data summary

We obtained surveys of oyster counts by size (sub-legal and legal categories) from FDACS over a wide spatial area of Apalachicola Bay from 1990-present. In general these surveys are completed by counting the number of oysters of different size classes inside standard quadrats on different oyster reefs throughout Apalachicola Bay. We used data on the number of legal and sub-legal oysters from different locations to compile a composite average of oyster abundance throughout the bay through time. These results (**Figure 14**) suggest a slow downward trend in the abundance of legal oysters for harvest in the bay in recent years and a dramatic decline in the number of sub-legal oysters present in 2012. Because of the low abundance of sub-legal oysters in 2012 there is a high likelihood that legal-sized oysters will be in low abundance during at least 2013 and likely 2014 as well.

Stock Assessment Modeling Efforts

Yield-per-recruit analysis

There is concern in the Apalachicola oyster fishing community related to the effects of harvesting sub-legal oysters on the long-term population viability of the Apalachicola oyster fishery. To assess this, we built a simple mathematical model to evaluate the impacts of harvesting oysters at different sizes. A common objective in commercial fisheries is to maximize yield (i.e., pounds per harvest). This objective is generally achieved by a specific combination of harvest rate and size at harvest. If animals are harvested at too small a size, potential gains in yield that would have occurred by allowing animals to grow to a larger size are lost. This situation is referred to as growth overfishing. Similarly, if harvest rates on animals are too high, potential gains in yield that could have occurred by allowing more animals to survive to larger sizes prior to harvest are lost. To recommend optimal harvest rates that avoid growth overfishing, the equilibrium yield has to be determined under a range of harvest rates and minimum size limits.

We constructed a simulation model to determine the optimal size at harvest for oysters in Apalachicola Bay and assess how harvest of smaller sizes could increase the risk of growth overfishing and subsequently reduced harvests in terms of smaller yield of oysters harvested. Our model simulates how yield in the fishery would change under different harvest rates and size regulations. This simulation requires estimates of oyster growth, survival, and recruitment which we derived from earlier studies in Apalachicola Bay or from ongoing research. Our findings suggest that the current size limit of oysters (3 inches, 76.2-mm) is quite close to that which would produce maximum yield (**Figure 16**) over a range of harvest rates. The results suggest that a 3-inch minimum size limit would protect against growth overfishing over a relatively large range in harvest rates, and thus, the 3-inch size limit is likely a good minimum size limit for use in Apalachicola Bay. This model is sensitive to the parameters used in the model such as growth such that if growth rates change, then the model should be updated with different growth rates as the optimal minimum size regulation would likely change. Additionally, this assessment assumes that the prices received by fishermen are constant relative to the size of oysters at harvest. If price for larger oysters is substantially higher (due perhaps to sales for the restaurant "on the half shell" market relative to the processing market), the optimal harvest size of oysters would likely be greater and more sensitive to minimum size at harvest (**Figure 17**). These caveats notwithstanding, this assessment shows that the current size limit is generally sufficient for maximizing yield. While our results suggest that this size limit would be effective, there is evidence of harvesting of sub-legal oysters (< 3 inches). If large harvests of sub-legal oysters are occurring, then it is likely that potential yield is being lost to the fishery because of oysters being harvested at too small a size, basically increasing the risk of growth overfishing. Basically the current harvest regulations are only going to be effective if they are accepted by the community and industry, and enforced and adjudicated.

Figure 12 Annual number of reported oyster fishing trips in Apalachicola Bay, Florida from 1986-2012. Note that 2012 numbers are preliminary.

Figure 13 Reported oyster fishing trips by month for Apalachicola Bay from January 2007-December 2012 provided by FWC. Note that 2012 are preliminary.

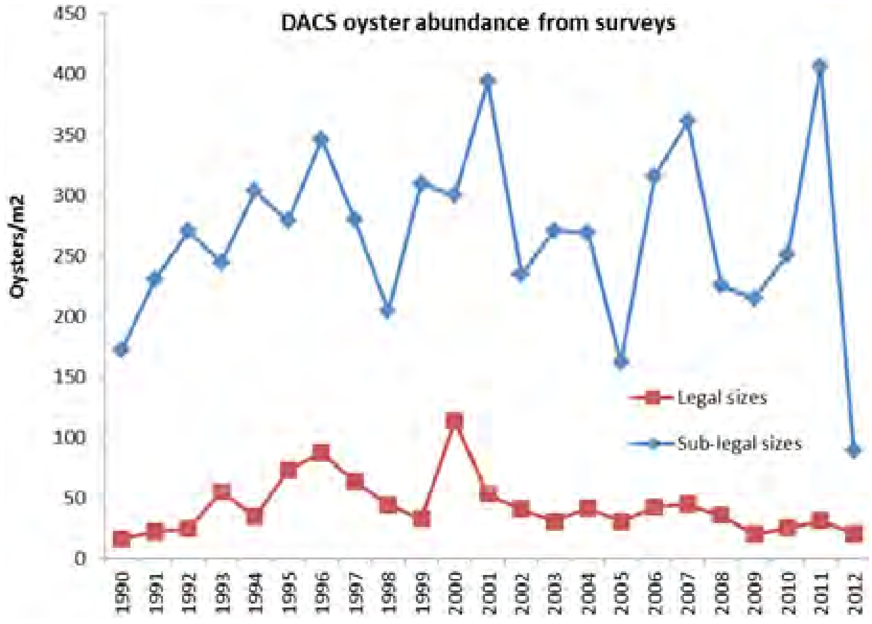

Figure 14 A composite of oyster density per m^2 of habitat in Apalachicola Bay from data collected by FDACS from 1990-2012 across a large number of oyster bars. Legal-sized oysters (> 3") are shown by the red line and sub-legal (< 3") are shown by the blue line.

Statistical Catch-At-Age Model

We developed a detailed population dynamics model to aid in interpretation of past harvest and FDACS survey data for the Apalachicola oyster population, and in particular to determine how natural mortality, recruitment, and exploitation rates have varied since the mid-1980s. Key aims of this work have been to determine whether there has been overharvesting (in particular due to take of sub-legal oysters) and whether we can detect mortality and recruitment effects of Apalachicola River flow that are not clearly evident in simple comparisons of harvest and flow data.

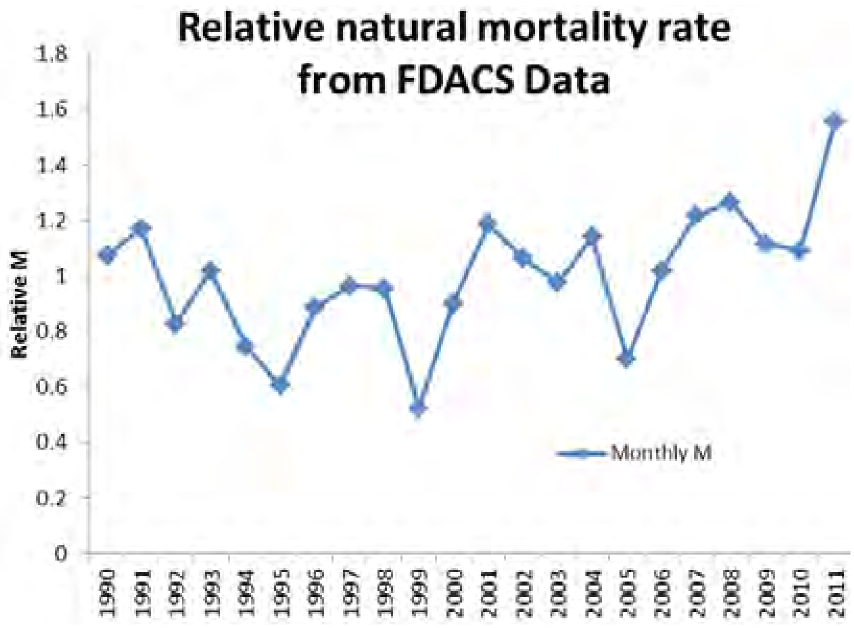

Figure 15 Natural mortality (M) for juvenile oysters in Apalachicola Bay estimated from the stock assessment model based on surveys of juvenile oysters by FDACS.

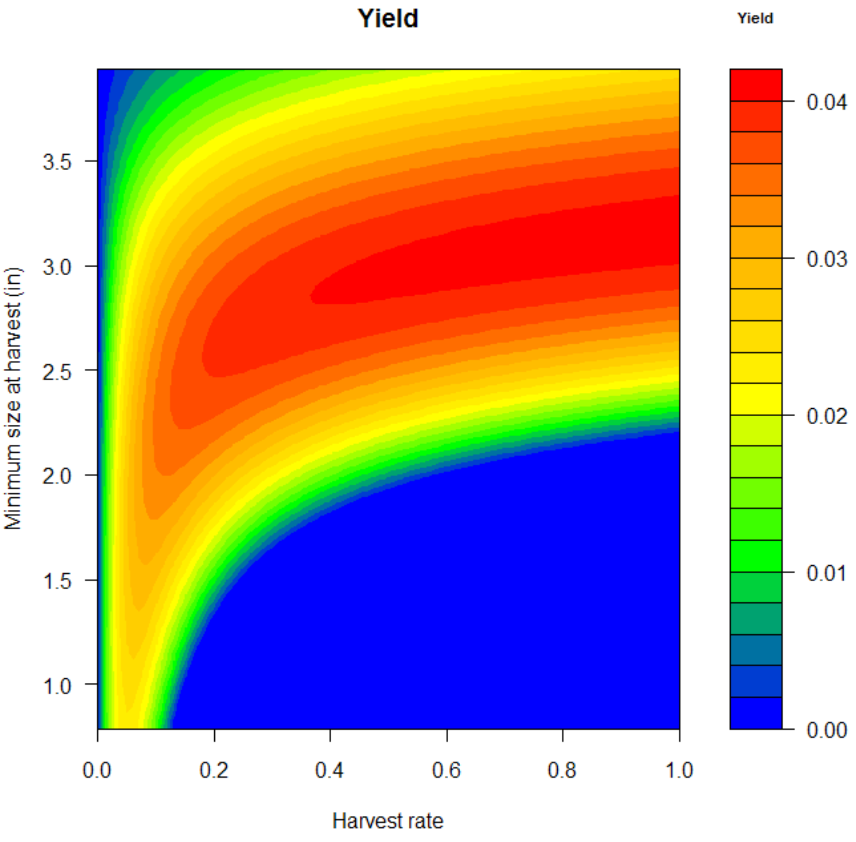

Figure 16 Relative amount of value (represented by colors) of the Apalachicola Bay oyster fishery attained at various harvest rates (x-axis) and minimum size limits (y-axis), when price per pound of oyster increases by two-fold for larger oysters (greater than 3 in), representing potentially greater price paid for larger oysters for the "half shell" market.

We calibrated the model by fitting it to reported oyster landings and FDACS survey data. As indicated in **Figure 18**, the model fits the data very well, and indicates complex trends in mortality and recruitment rates over the past two decades. Almost all of the variation in catches can be explained by variation in fishing effort, and there is no indication of a persistent downward trend in abundance of sub-legal oysters preceding the severe decline evident in DACS data for 2012 (**Figure 14**). Declines in harvest of legal-sized oysters the last few months of 2012 are likely due to lack of recruitment from juveniles to the legal-sized because of low abundance of juveniles. However, the decline in sub-legal abundance, sudden as it was, cannot be attributed to reduced spawner abundance (i.e., adult population) and/or larval supply based on the available data we have examined. Without more data, we cannot reach a conclusion about what proximal factor(s) contributed to the decline.

The main findings from the stock assessment model fitting exercise can be summarized by four main points. First, the 2012 decline in landings and juvenile abundance is unprecedented during the period of data we examined (1986-2012 fishery dependent data, 1990-2012 fishery independent data), and has likely involved a recruitment failure that we have not been able to completely explain with the available data. Possible reasons for this recruitment failure include very high natural mortality rate of small oysters from predators or some type of episodic disease or pathogen.

Second, both direct analysis of survival patterns (from sub-legal to legal-sizes, **Figures 19 and 20**) in the FDACS data and the model fitting exercise indicate that natural mortality rates appear to be increasing over time (**Figures 15, 19, 20**). The exact reason is uncertain, but two hypotheses that could be tested through future work include assessing whether natural mortality on juvenile oysters increases during periods of higher salinity from either predators or disease and determining whether the discard mortality rate of culled, sub-legal oysters has potential population level consequences. The role of culling mortality may be different under a range of population sizes (more significant at lower population sizes than high) or that culling mortality may be higher under situations where natural mortality is already high.

Third, the severe decline in sub-legal abundance in 2012 FDACS surveys (**Figure 14)** suggests that the legal harvests in 2013 and possibly 2014 will again be very low and likely not better than the 2012 season. These low abundance levels of legal oysters lead managers to close major fishing areas to protect remaining populations and reef habitat or, alternatively, the populations may be so low that it is not economical for fishermen to harvest from these efforts even without a closure. For example, in response to the FDACS reports, the FWC closed the commercial oyster harvest on weekends from November 16, 2012 to May 31, 2013.

Fourth, there is no evidence that harvest of sub-legal oysters has or would lead to overfishing, if current regulations are followed. It is unlikely that occurrence of sub-legal oysters in the catch has caused the trends we see in the data unless the sub-legal harvest has been unregulated and extremely high.

Restoration actions, caution, and future work

Much uncertainty exists as to what approaches are best for restoration. Modeling efforts suggest linkages between the available shell habitat and recruitment in Apalachicola Bay. If essential shell substrate habitats have been lost in Apalachicola Bay from storm events or reduced production of natural shell (accumulated as oysters grow then die in the bay leaving their shell) then the risk of the oyster fishery having effects on the oyster population likely increases. In oyster populations the carrying capacity of the population could be related to the substrate available for oyster spat to settle and grow. Both substrate and the number of oyster spat available may be influenced by the number of oysters harvested each year. In this way feedbacks are created between the oysters that are harvested, the shell that is available for spat to settle, and the spat that are produced each year. While these feedbacks may not be strong in years with high oyster abundance, in years with low abundance, the interactions between spat, substrate, and adult harvests may be strong. If shell habitat is lost due to high harvest rates, storm events, or other causes, this could reduce the available habitat for juveniles and ultimately reduce adult populations.

One area of uncertainty is our understanding of whether juvenile oyster mortality rates do increase under high salinity conditions and from what cause. This could have policy implications related to a variety of issues such as using techniques adopted from the clam culture industry of using netting to reduce predator abundances (likely only possible on leases) or modifying fishing intensity. Another area of uncertainty is the scale, in terms of size, depth, and spatial location, of any restoration efforts related to shelling. A variety of culching programs have been carried out in Apalachicola Bay over several decades that can provide

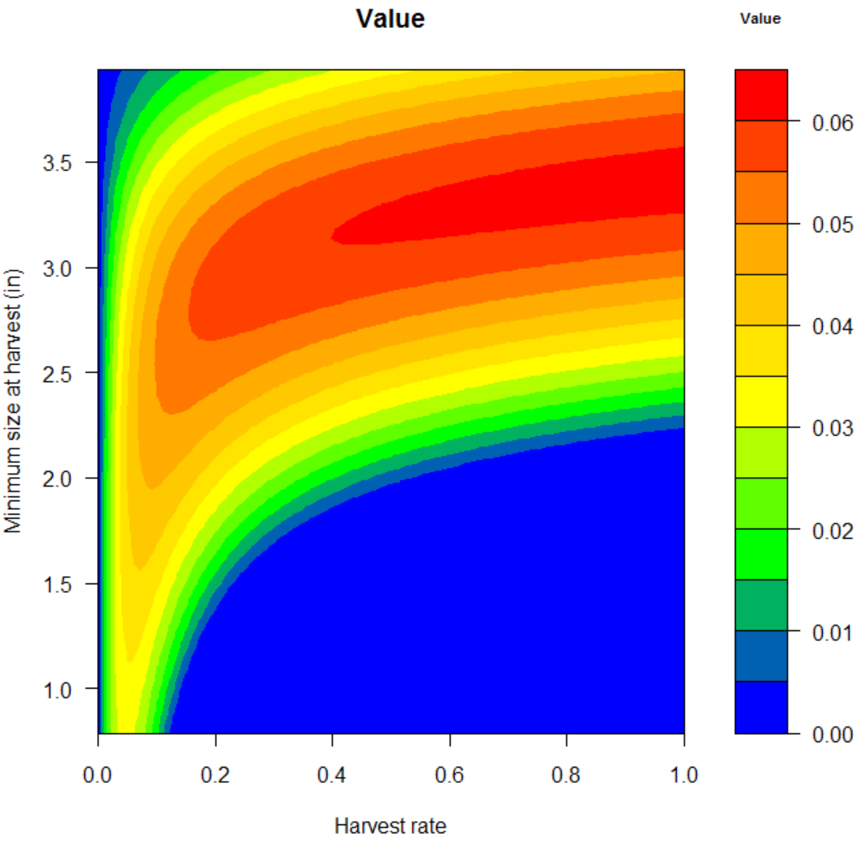

Figure 17 Relative amount of value (represented by colors) of the Apalachicola Bay oyster fishery attained at various harvest rates (x-axis) and minimum size limits (y-axis), when price per pound of oyster increases by two-fold for larger oysters (greater than 3 in), representing potentially greater price paid for larger oysters for the "half shell" market.

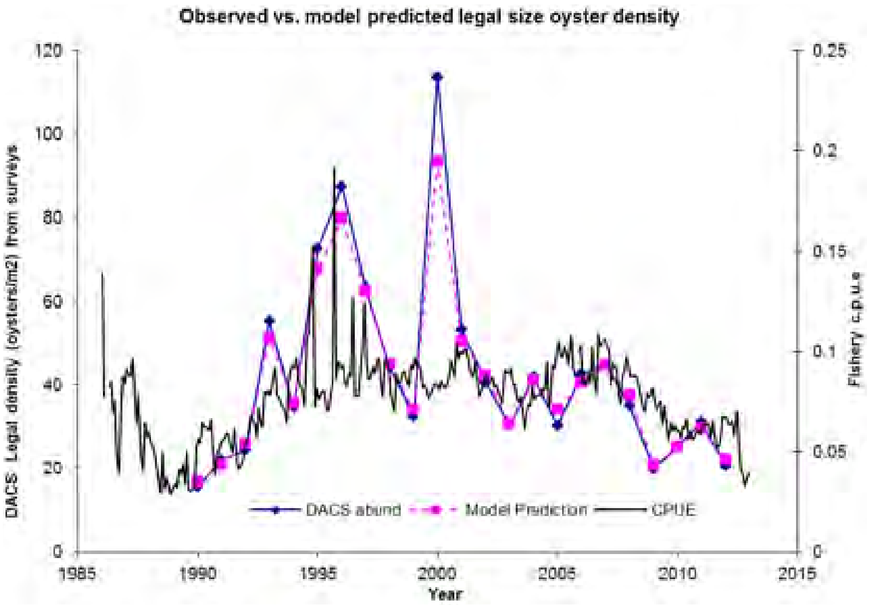

Figure 18 An example of the stock assessment model fit of predicted density of legal-sized oysters (dashed, light blue line) with the observed density of legal oysters from the FDACS data (dark blue solid line) and fishery CPUE (solid black lined, measured on secondary Y-axis) to data from 1986-2012.

some guidance on this activity. However, additional work could be done to better identify the best approach to re-culching oyster bars, particularly under variable flow conditions. In simplest terms, culching as a restoration tool is likely to require large volumes of shell because essentially the culching is trying to replace the shell material that would have been produced naturally by oysters as they grow and die. This shell material is instead transported out of the bay when the oysters are harvested. Given the high costs of culching activities, in terms of buying the shell and planting the shell in the bay, determining the culching strategy that most efficiently helps in restoring oyster bars in Apalachicola Bay is essential.

We are also concerned that the recovery of Apalachicola Bay oyster resources may take longer than many people assume. As an example, to estimate the amount of time it is likely to take Apalachicola Bay oyster reefs to recover, we modified our assessment model to evaluate what the Apalachicola Bay oyster fishery might look like over the next 10 years (until 2023) under different policy options for restoration (**Figure 21**). Under the "no closures" scenario, we assumed that fishing effort (number of trips) would remain at about the same levels as observed in recent years into the future. For the "reduced effort" scenario, we assumed a 50% reduction in effort during 2013-2014 (because of low oyster abundance) and then resumption to the same effort as the no closures level for the remaining years. For the "shelling" scenario we assumed that there is about 1-2 km^2 of productive oyster bar in the bay and evaluated a cultching program that would cover about 40-50 ha (about 100 acres) per year for five years. This simple projection model does not include depensatory predation (higher proportional losses to predators due to low oyster abundance), any disease outbreaks, etc. We evaluated three scenarios and compared the time to recovery for each (**Figure 21**). Our results suggest that even under the best case scenario, recovery is likely to take 3-5 years to reach the harvest levels observed through most of the 1990s and 2000s.

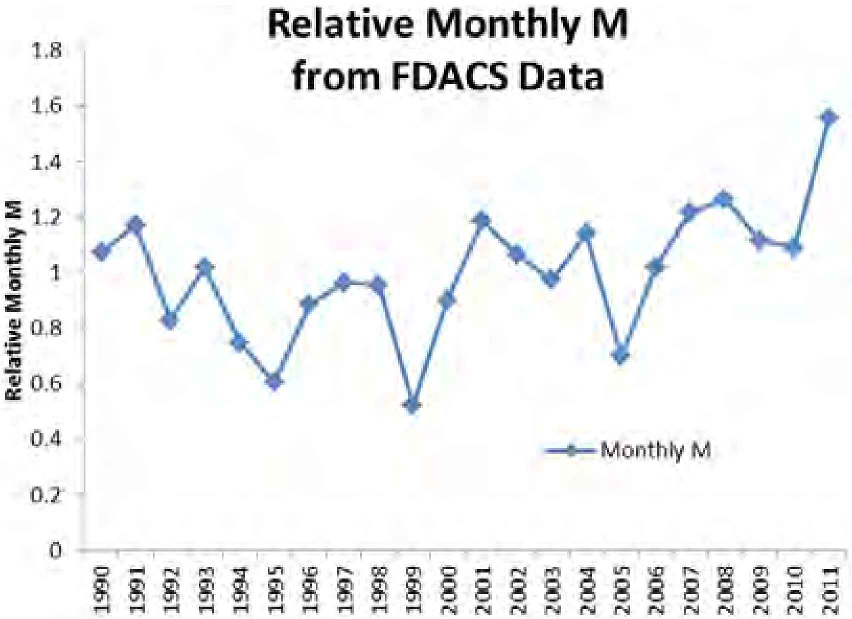

Figure 19 Relative monthly natural mortality rate (M) of juvenile oysters from the FDACS collected in Apalachicola Bay from 1990-2011.

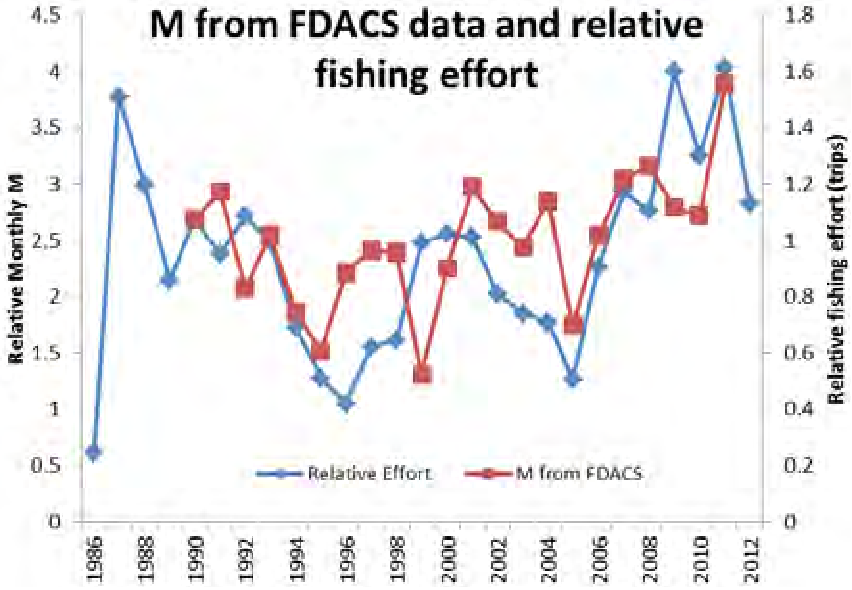

Figure 20 Natural mortality rate (M, red line, primary y-axis) and relative monthly fishing effort (trips, blue line, secondary y-axis) of juvenile oysters from the FDACS collected in Apalachicola Bay from 1990-2011.

We have also developed preliminary versions of two spatial modeling systems to help identify future impacts of water management on oysters, and management options for the oyster fishery. The FLABAY model simulates hydrodynamics and water chemistry (nutrients and salinity) over Apalachicola Bay, and its results can be written to files as input for the ecological/fishery model, ECOSPACE. The ECOSPACE model is based on an ECOPATH/ ECOSIM food web model that simulates changes in primary production, oyster population structure (age-size composition) and growth based on available production, and oyster predator dynamics in responses to changes in oyster abundance and salinity. ECOSPACE has a comprehensive policy interface allowing specification of spatial fishery operations (e.g. seasonal closures) and habitat restoration (cultch planting) policies, and it is also capable of doing economic impact assessments (fishery and regional economic values, employment).

FLABAY uses an extremely simple hydrodynamic model to quickly compute monthly average water movement and mixing rates over a grid of spatial cells (0.6km x0.6km) using river flow, wind, and rainfall data. It can "reconstruct" monthly historical patterns of nutrient loading and salinity for the

1986-2012 period in just a few minutes of personal computer processing time, and can also simulate future scenarios for seasonal and inter-annual variation in Apalachicola River flow. As shown in **Figure 22**, a screen capture from the model interface, the model reconstructed salinities at key locations in the bay (Cat Point, Dry Bar) based on observed river discharge, wind, and rainfall patterns are reasonably close to the measured values from the NERR program, which is critical for predicting salinity-related changes in oyster production (i.e., growth, predation impacts from freshwater-intolerant predators) in the ECOSPACE model. This type of hydrodynamic model can easily be demonstrated and used in workshop settings with fishermen and other interested stakeholders.

As an example of how FLABAY and ECOSPACE can be used for policy comparison and screening, we assessed the amount of time it would take for oyster populations to recover over a 20-year time period (2013-2033) for Apalachicola Bay oysters assuming (1) a decline in 2012 similar to the one observed (2) freshwater flow patterns from 2013-2023 similar to those observed since 2000 (i.e., periods of high, low, and average flows) and (3) reduced oyster fishing effort in 2013 and 2014 (80-90% reduction in 2013, about 50% reduction in 2014). We used the model to compare two different policies, one without cultching and one with cultching, and how the estimated time it takes oyster populations to recovery differed between these. The first policy test of no cultching and reduced fishing effort in 2013 and 2014 (**Figure 23**) the ECOSPACE model predicts disturbingly slow recovery from the 2012 decline, even if fishing effort is severely reduced in 2013 and 2014. The slow recovery time is due to a combination of reduced recruitment due to reduced natural shell (larval settlement substrate) abundance and predicted "depensatory" high impacts of oyster predators on the reduced population (e.g., predators are removing a larger portion of the population than normal because the abundance of oysters is low).

We then evaluated a policy where a large cultching effort of about 200 ha per year from 2013-2017 is implemented to speed up recovery of

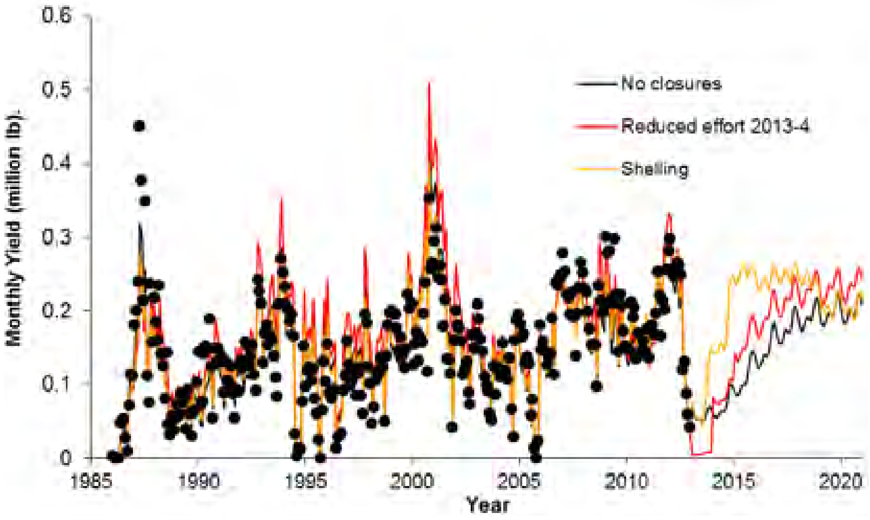

Figure 21 Observed (black dots) and predicted (solid lines, one for each policy evaluated) monthly oyster yield for Apalachicola Bay.

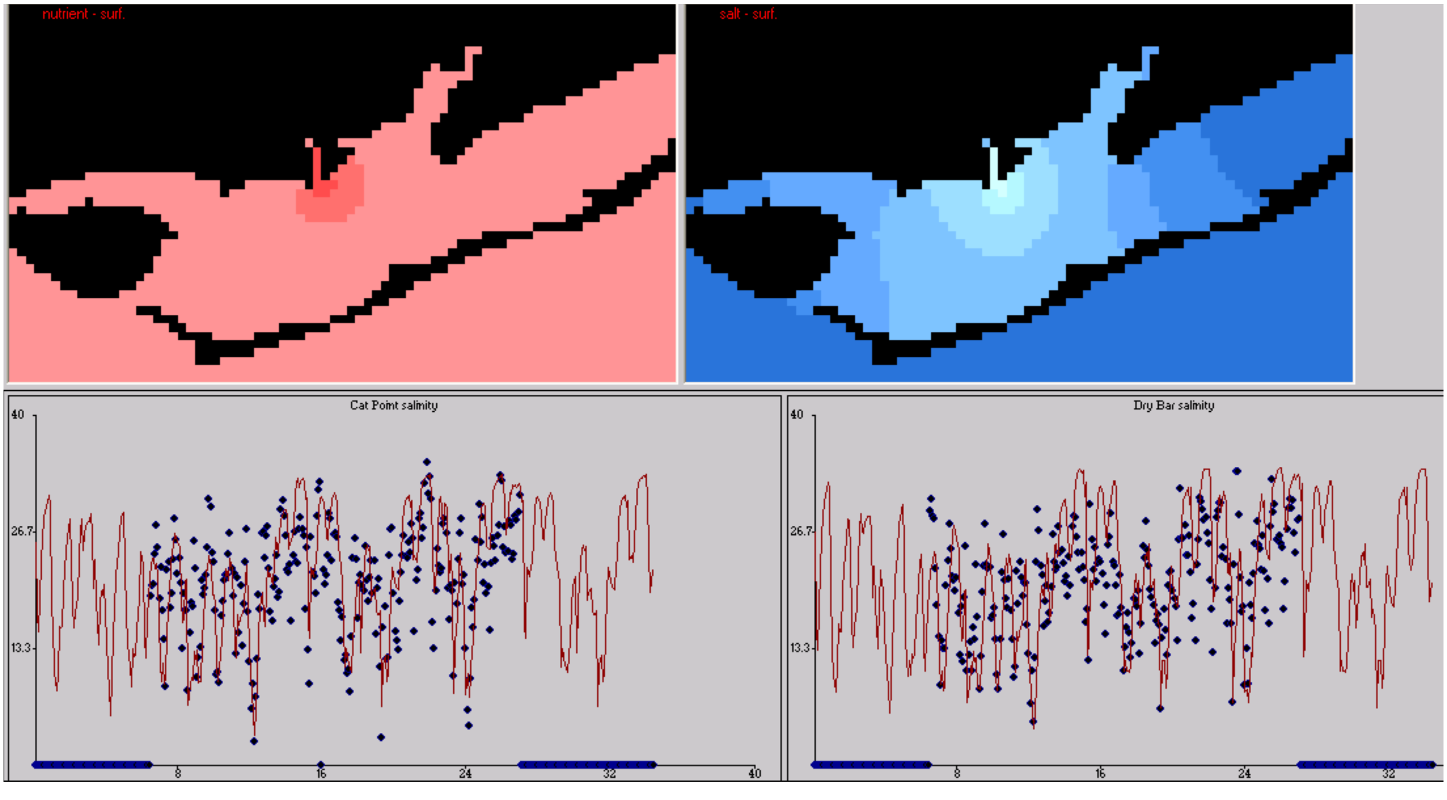

Figure 22 Screenshot from the FLABAY model, showing predicted nutrient and salinity maps for one simulated month, and fit to historical data on mean monthly salinities at Cat Point and Dry Bar.

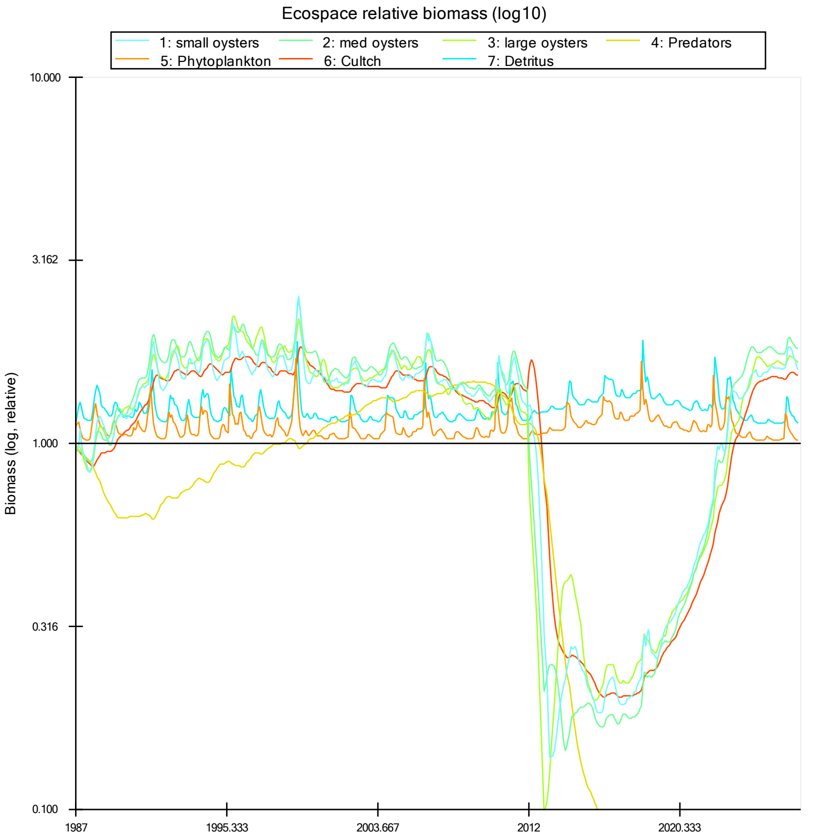

Figure 23 Time plot of simulated relative abundances of ecosystem components using the ECOSPACE model. Note long time predicted for oyster population recovery (about 10-12 years) following decline in 2012, despite reduced fishing effort in 2013 and 2014.

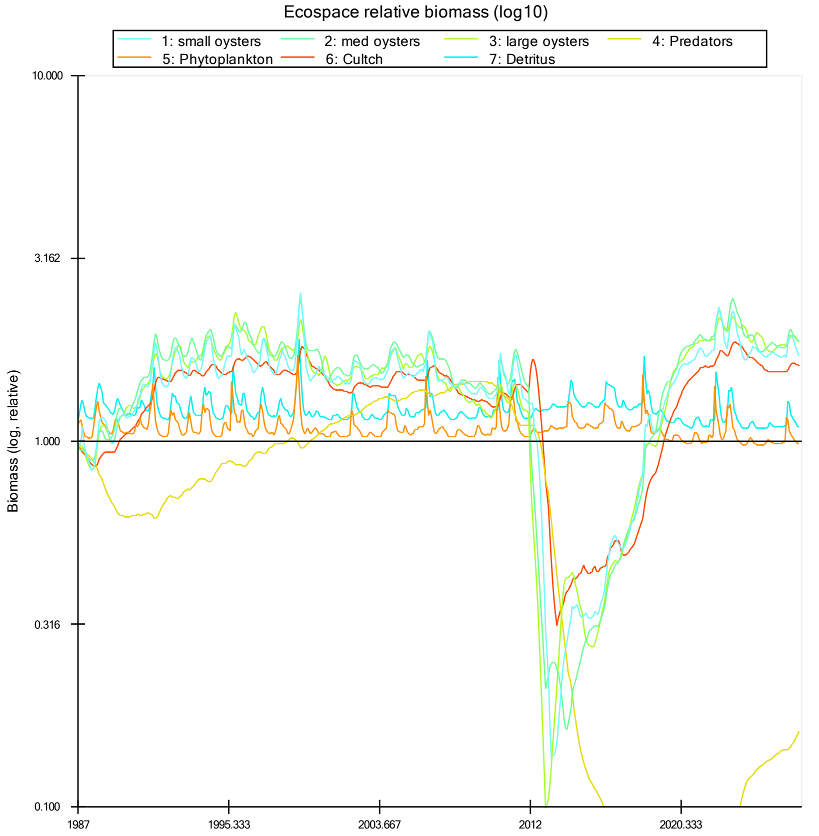

Figure 24 ECOSPACE predicted time trends for oyster recovery for a scenario where 200-ha per year of cultch is added for the 2013-2017 period and fishing effort is reduced during 2013 and 2014. Note more rapid oyster recovery than predicted in the baseline scenario Figure 23 where only effort is reduced.

oyster recruitment and to spread fishing effort over a larger area in addition to the fishing effort reduction evaluated above (**Figure 24**). When compared to the first scenario where no cultching took place, only effort reduction (**Figure 23**), the time to recovery is reduced from 10-12 years (**Figure 23**) to 8-10 years (**Figure 24**).

Note that both **Figures 23 and 24** assume severe reduction in fishing effort for 2013, and moderate (50%) reduction for 2014. Scenarios without these effort reductions lead to even longer recovery periods. Further, the scenarios in **Figures 23 and 24** all assume reasonably favorable Apalachicola River flows, i.e. with some drought years but some wet years as well (a future pattern similar to the flow pattern since 2000). A key concern during oyster population recovery is latent effort response by oyster fishermen. In this situation as oyster populations begin to recover, oyster fishermen may quickly locate these oysters and quickly harvest the recovering population as they begin to rebound. If this happens, it is likely to perpetually keep the oyster populations low and extend the recovery time or keep the oyster population from recovering at all. Therefore, there is a need for new resource management tools, procedures and regulations.

While these models show promise, there is substantial work still required to calibrate the models to available data. We think that a variety of population and ecosystem models should be developed for Apalachicola Bay to help screen policy options that managers are faced with when looking at fishing regulations, restoration approaches or river flow alterations.

There are major uncertainties in any model predictions and it is only through an iterative process of model building, prediction, and rigorous testing in the field that we are able to improve the model's abilities. A key experiment is also naturally occurring right now in that the periods of extremely low Apalachicola flows during 2012 are replaced with high flows during the winter of 2013 and potentially into the spring/summer season of high mortality for juvenile oysters. Are existing monitoring programs able to detect any change in mortality rates during 2013 compared to earlier, low-flow conditions? How will the oyster resources and the oyster fishery respond to the 2012 decline? We do not know whether drought conditions (low river flow) will return following the currently wet winter, nor do we know how rapidly and strongly predator populations will respond to reduced oyster availability, leading to further severe mortality events. Perhaps most important, we do not know the effective productive area of Apalachicola Bay for oysters, and because of this we do not know how much area really needs to be cultched. Additionally, we do not know whether restoration efforts could and should be applied to the much larger bar area that may have supported higher historical catches in the voluntary reporting data prior to 1986. Many of these needs could be addressed through field studies and the results used to update these types of models for assessing trade-offs in policy options.

Contaminants *Andrew Kane*

In response to community concerns about environmental health impacts associated with the Deepwater Horizon oil spill, and concerns about the health of the Apalachicola Bay oyster fishery, studies were initiated to discern the presence of oil spill-related contaminants in Apalachicola Bay seafood products. These costly efforts were incorporated into a larger, ongoing regional study to discern the safety of inshore-harvested seafood, particularly for coastal residents who regularly consume portions of their catches.[1]

Seafood sampling in Apalachicola Bay included oyster, white shrimp, brown shrimp, blue crab and multiple finfish species. Sampling was accomplished with the assistance of the Franklin County Seafood Workers Association, and fishers who were assigned specific tasks to contribute to the effort. Oysters were collected by tonging from four east-west distributed sites in the bay. White and brown shrimp were collected by trawling from two distinct sites in the bay. Blue crab were collected using crab pots from two separate sites in the bay, and finfish were collected by hook and line from multiple bay sites.

Analytical results at the time of this report include oyster PAH, or polycyclic aromatic hydrocarbons data (see **Table 1**). Data focus on PAHs with known relative carcinogenic risk factors, allowing for the development of risk assessment based on: (a) the levels of contaminants present in seafood, (b) and frequency and portion sizes of seafood meals consumed, and (c) consumer body weight. Further, these PAHs are the same chemicals that were analyzed by federal and state agencies throughout the Gulf. Focus on these chemicals, therefore, may also allow for comparison of analytical results throughout the region. Samples processed for additional organic analyses, metal analyses, and seafood types are underway.

Table 1 shows analytical results for sixteen parent PAHs for individual oyster samples collected from AP Bay in 2012. In addition to parent PAHs, alkyl homologues were also analyzed. These data provide quantitative information about the presence and concentrations of these PAHs in oyster meats, as well as inter-individual variability of potential contaminant levels between oysters sampled from the same site. Such variability data is lost when samples are “pooled”, i.e., the meats of three to twelve oysters from a site are homogenized together, subsampled, and processed to generate an “average” from those oysters (typical method used by state and federal laboratories). Although sample pooling greatly reduces effort and cost (analyzing one sample rather than

PAH Concentraton, ng/g

wet sample wt. (g)	**5.342**	**5.496**	**4.954**	**5.155**	**5.211**	**5.059**	**5.344**	**5.336**	**5.227**	**4.989**	**5.204**	**5.327**
Sample ID	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
Naphthalene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acenaphthylene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acenaphthene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fluorene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Phenanthrene	0.15	nd	BQL	nd	nd	nd	nd	BQL	nd	nd	BQL	nd
Anthracene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fluoranthene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pyrene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chrysene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benz[a]anthracene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo[b]fluoranthene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo[k]fluoranthene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo[a]pyrene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Indeno[1,2,3-cd]pyrene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibenz[a,h]anthracene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo[g,h,i]perylene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table 1 Analytical results for PAHs from 12 Apalachicola Bay oyster samples. The different PAHs analyzed are listed in the left-hand column (labeled “Sample ID”); results for individual PAHs from 12 individual oyster samples are in the next 12 columns to the right. Results are presented in ng/g (nanograms per gram wet weight oyster homogenate; parts per billion); nd=not detected; BQL=below quantifiable limits. Refer to text on next page for additional details.

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[1] This study was supported by the National Institutes of Environmental Health Sciences, as part of the Deepwater Horizon Research Consortium. The UF component of the award supports research groups through the University of Florida Emerging Pathogens Institute (Dr. J. Glenn Morris, Principal Investigator). This study, called “Healthy Gulf Healthy Communities,” supports three separate projects developed to support Gulf coast community health in the wake of the oil spill. These projects are led by Dr. Lynn Grattan, focusing on individual psychological health and well-being; Dr. Brian Mayer, focusing on community resiliency; and Dr. Andy Kane, focusing on seafood safety. The seafood safety team brings together expertise in aquatic biology and toxicology, analytical toxicology, food science and human nutrition, risk assessment, and risk communication.

12, for example), there is no data to detect animals from a site that can accumulate higher amounts of contaminants that might pose greater risk to consumers.

The data presented in **Table 1** are similar to other oyster data analyzed thus far from Apalachicola Bay. Most results in this table are noted as “nd,” meaning not detected (i.e., below level of detection). Several samples are noted as “BQL,” meaning Below Quantifiable Limits.” The chemical detection limit for most of these PAHs is approximately 1-2 part per billion, and may vary among analytes (chemicals detected). The level of quantification, often close to the level of detection, is based on our ability to confidently provide a numerical value for the concentration present. In the subset of data presented in the table above, there is one result that was quantified, phenanthrene, with a concentration of 0.15 parts per billion.[2] The FDA’s level of concern for phenanthrene in oysters is 2,000 parts per million (over 7 orders of magnitude, i.e., 10 million times higher, than was detected in an Apalachicola Bay oyster sample).

Oyster Condition and Health *Andrew Kane*

To address concerns about declining oyster harvests, and the sustainability of the Apalachicola Bay oyster fishery, we have begun to examine environmental parameters that can affect the condition, health and growth of oysters regionally throughout the bay. A variety of environmental stressors can affect the health and growth dynamics of oysters in the Apalachicola Bay system, including sub-optimal water quality, contamination, oyster density, tonging-induced mortality, and the presence of parasites and pathogens. This section outlines the primary efforts contributed through the UF Aquatic Pathobiology Laboratories, with support from the Contaminants and Pathogens Work Group, others contributing to the UF Oyster Recovery Team, and the University of Florida Institute of Food and Agricultural Sciences.

Sampling efforts were initiated to address the questions: “How healthy are Apalachicola Bay oysters?” “What factors might be associated with altered health status?” and “Are there regional differences in condition, health or population dynamics?” To begin answering these questions, oysters were harvested from multiple sites in Apalachicola Bay across an east-west transect of the bay. These sites are shown in **Figure 26**.

Oysters were sampled by tonging using two approaches. One approach allowed for more rapid collection of a larger number of specimens for health assessment that also permitted assessment of relative density, catch per unit effort, and size distribution including spat on cultch (**Figures 27 and 28**). This method closely reflects typical harvesting methods.

The second sampling method used a depletion sampling approach as illustrated in **Figure 29**. Briefly, an area of known size (demarcated by maximally open tong rakes) on an oyster bed is repeatedly sampled in the same spot (depleting that small spot completely, or close to completely). Theoretically, if sufficient samples are randomly taken over a reef, density of harvest-size oysters can be estimated, along with a different metric for catch per unit effort.

Health studies

Oysters have been sampled throughout Apalachicola Bay to discern the condition index of the meat, and the relative condition of the oyster shell based on the degree of shell parasitism associated with boring polychaete worms, boring clams, and boring sponges.

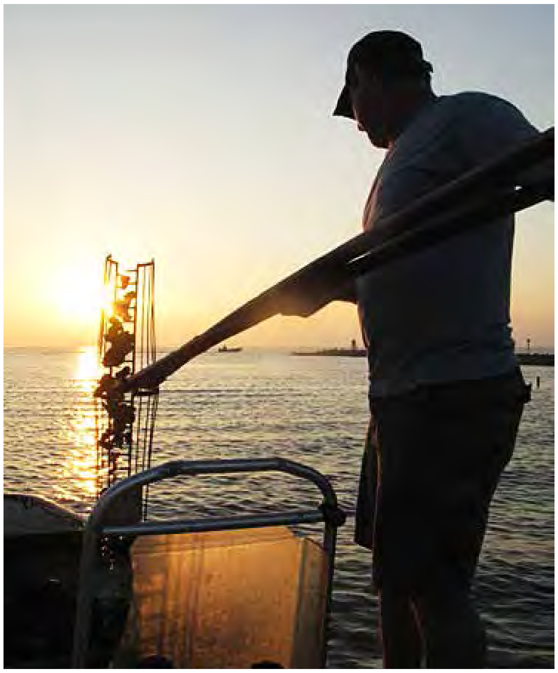

Figure 25 *Left photo* Technicians process freshly harvested seafood in a field laboratory.

Right photo Starting at sunrise, Shannon Hartsfield tonged for oysters with Andy Kane to make collections for chemical analyses. Multiple watermen provided time and input to facilitate these sample collections. Each waterman collected specimens with data on GPS coordinates, time of collection and species.

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[2] Some real-world examples of part per billion comparisons include: one penny in 10 million dollars, 1 second in 32 years, 1 foot of a trip to the moon, a blade of grass on a football field, or one drop of water in an Olympic-size swimming pool.

Meat condition index is related to the overall health and well-being of the animal, and reflects potential impact of multiple environmental stressors such as food availability, parasites and disease, water quality, and reproductive status. The condition index of the oyster meat is particularly important to Apalachicola Bay oysters that are prized for both flavor and appearance (**Figure 30**).

Shell parasites and condition indices analyzed as part of this effort include the prevalence and severity of boring shell parasites. These parasites include the sponge, *Cliona*; the boring clam, *Diplothyra smithii*; and the polychaete worm *Polydora* (**Figure 31**). The presence and severity of these parasites in the oyster shells can have detrimental effects on the well-being of the oysters. Heavy shell parasite infestations divert oyster energy away from growth and health, and shift energetics toward self-preservation and secretion of more nacre to wall-off the invaders from the inside of the mantle cavity. Further, shells that are weakened by shell parasites are less "water tight" and more susceptible to predators such as whelks that use slow, steady pressure to pry open the shell and eat the oyster inside. Shell condition also affects the half-shell appearance of the oyster that is critical for the Apalachicola Bay oyster product.

Shell parasites also affect the internal shell appearance, as parasites bore close to the animal inside. Multiple internal shell indices associated with shell-boring parasites are also being observed and recorded as part of these studies (**Figure 32**). Typically, the vast majority of all Apalachicola Bay oysters has some degree of shell parasitism (i.e., high prevalence) that affects the aesthetics of the shell as well as overall growth of the oyster. The severity of shell parasitism, however, varies greatly among individuals and location. The shell parasite observations described in **Figure 32** contribute to an overall shell rank index (developed as part of this project).

Dermo infections. One of the most widespread diseases that affects American oyster is Dermo. This disease is caused by a microscopic, single-celled parasite that lives within the oyster meat tissues. The scientific name (genus and species) of the parasite is *Perkinsus marinus*. The common name of the disease (Dermo) came from an older genus name, *Dermocystidium marinum*, thought at the time to be a fungus.

Dermo disease is endemic to Apalachicola Bay oyster populations. In other words, it exists historically throughout the bay and

Figure 26 Apalachicola Bay map showing East-West sampling areas outlined in blue. All sites were sampled with replication to discern within-site variability.

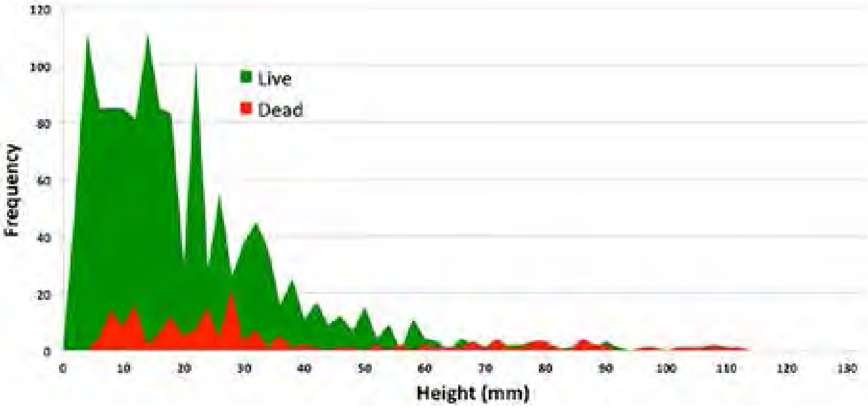

Figure 27 Size distribution (numbers) of live and dead oysters from a single sampling site on an oyster reef. The sampling strategy was to determine the number of tong "licks" and number of minutes it took to collect 32 harvest size (3 inch) oysters. At this site there are numerous spat (although not uncommon, always reassuring to see) analyzed from cultch or intact oysters. The number of live (green) oyster greater than 75 mm height however, is low in this sample. This is associated with environmental, disease or predator factors that thin the 40-60 mm portion of the area's population, and/or removal by harvesters. Replicate sampling sites on the same oyster reef revealed notable variability in abundance and size distribution.

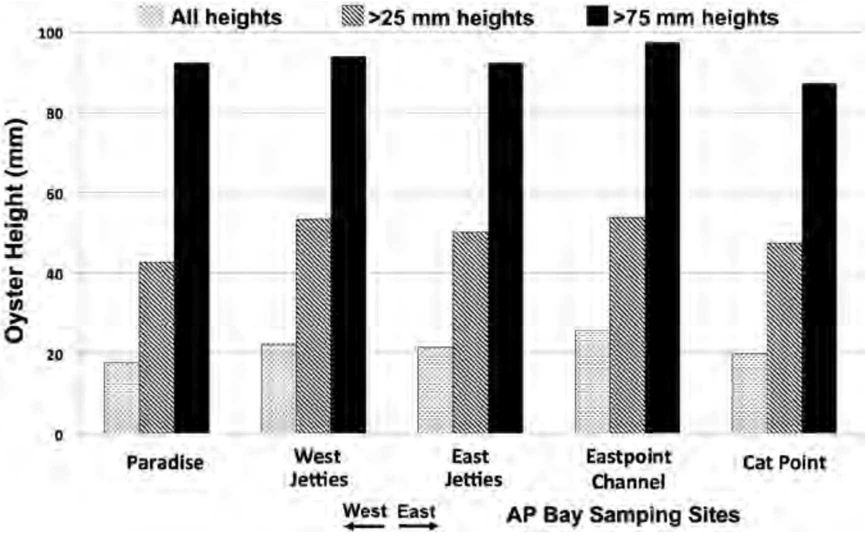

Figure 28 Relative size distribution of oysters sampled in November 2012 from five sites across an east-west transect of Apalachicola Bay. For each site, the light colored bar represents the average oyster height for all oysters examined, including all spat. The middle diagonally hatched bars represent the average height for all oysters greater than 25mm height. The black right-most bar for each site shows the average oyster height for all harvest size oyster. There are no differences in oyster height between sites examined during this sampling period. Approximately 2,000 oysters from each site were evaluated.

Figure 29 Depletion sampling methods to estimate oyster density per square meter.

Left Tongs are carefully lowered down onto the oyster bed, guided by a piece of PVC pipe to maintain location. This allows the same spot to be resampled until the number of oysters depletes close to zero for that spot. From these data, we can determine the number of oysters per square meter. *Right* Water height is determined by the water line on the tong poles. Based on the operator's measured "wing span," the width of the particular tongs, and the water depth, we can determine the area that was sampled on the bottom at each sampling site.

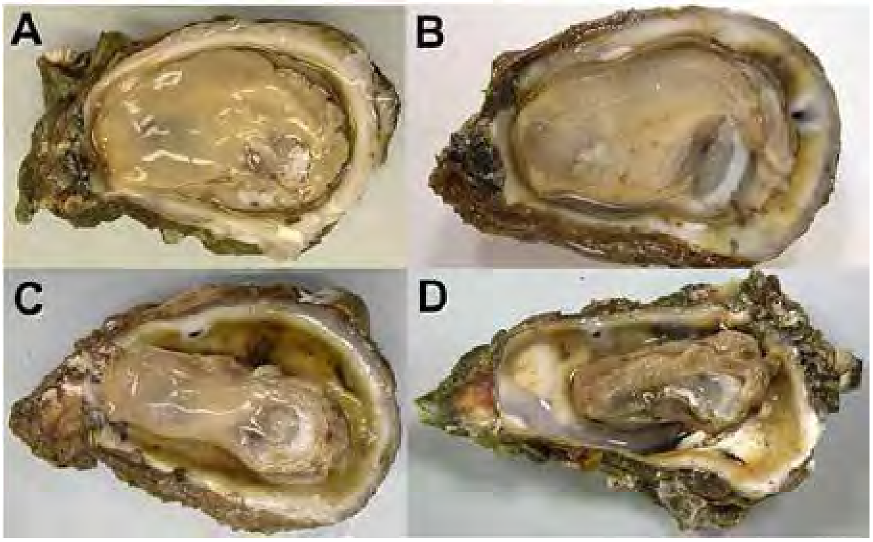

Figure 30 The meat condition index is ranked on a scale of 1-5, where 5 is a "perfect oyster," with plump, not watery or translucent meat that fills out the shell, with a uniform tan-creamy appearance. Images shown in this figure taken from Apalachicola Bay samples show a range of meat ranks. The oyster pictured in image A, had a meat index of 4.5. The oysters in image B, C, and D had indices of 3.5, 2.0 and 1.0, respectively.

is widespread. The severity of the disease, however, is typically relatively low such that it does not commonly overtly harm the oysters. When severe, however, Dermo can devastate and wipe out oyster populations. In general, elevated salinity and temperatures are associated with increased Dermo prevalence (percentage of infected oysters) and infection severity.

This project has initiated monitoring of the prevalence and severity of Dermo at multiple sites across Apalachicola Bay. To do this, tissues from fresh, live oysters are incubated in a special growth medium, and then stained with iodine to visualize the Dermo spores (**Figure 33**). The number and distribution of spores in tissue samples seen under the microscope are used to rank the presence and severity of infection in each oyster examined.

Data from Cat Point (**Figure 34**) and other Apalachicola Bay locations reveal a high prevalence of Dermo in oysters (typically >90% of all oysters sampled are positive for the parasite), albeit with a relatively low infection severity (approximately 1.00 on a scale ranging from 0-5).

Dermo data derived from samples taken in November 2012 and February 2013 indicate that:

- "Early" versus "late" winter samples did not reveal significantly different weighted prevalence of Dermo between these two sampling time points (from animals taken from the same oyster bar);
- Sampling along different oyster bars (Cat Point, East Point Channel, East and West Jetties, Paradise) did not reveal significantly different weighted prevalence of Dermo within bars;
- Dermo infections may be higher throughout the bay now than previously estimated, based on other studies conducted through the Oyster Sentinel program[3] and Petes et al. (2012).[4]

Additional efforts

Continued sampling and analyses for Dermo disease (and other health indices) are planned as part of this study to discern Dermo prevalence and severity in summer months, when infections are typically higher. This type of sampling and data analysis is important in order to discern trends that may be relevant to fishery management strategies that can account for seasonality, oyster density and harvest pressure, water flow, water quality, and other stressors.

Application of additional oyster health indices and analyses to examine associations between environmental conditions and oyster health are also planned. Of great importance will be to discern relationships between Apalachicola Bay conditions, harvest pressure, and the health, condition and distribution of oysters relative to implementation of near- and long-term management strategies.

Outreach and community partnerships

Efforts have also included outreach through the Franklin County Seafood Workers Association, and support for the newly formed SMARRT. Support for SMARRT has been based on developing common goals to support a sustainable and healthy Apalachicola Bay system in partnership with federal and state managers and regulators. To that end, collaborative efforts have also extended to working with other stakeholders including Franklin's Promise Coalition, Gulf Coast Workforce Board, Florida Department of Agriculture and Consumer Services, Florida Fish and Wildlife Conservation Commission, and Apalachicola National Estuarine Research Reserve Service. Thanks are due to the many contributing Apalachicola Bay fishers and all parties engaging in this constructive partnership.

Developing Cost-Effective Monitoring for the Oyster Fishery and an Experimental Assessment of Predator Impacts

David Kimbro

The collapse of the Apalachicola Bay oyster fishery has been detected through the combined efforts of the FDACS monitoring program and the commercial landings records of the FWC. Although these data are adequate to monitor the decline in market size oysters, they do not provide sufficient information to determine the precise cause of this decline. As part of the oyster task force, my team is developing tools to supplement the current FDACS monitoring program so that future data include key demographic information: recruitment, growth, mortality, and size structure. By re-sampling the data we collect, we will determine the minimum sampling effort and operational cost required to obtain reliable demographic predictions.

Using Florida Sea Grant program development funds, we developed a spatially stratified sampling design for reefs in which 16 0.25 m^2 quadrats were collected from 18 different reefs (**Figure 35a**). As the current protocol used by FDACS does, we harvested all material in a quadrat and then processed

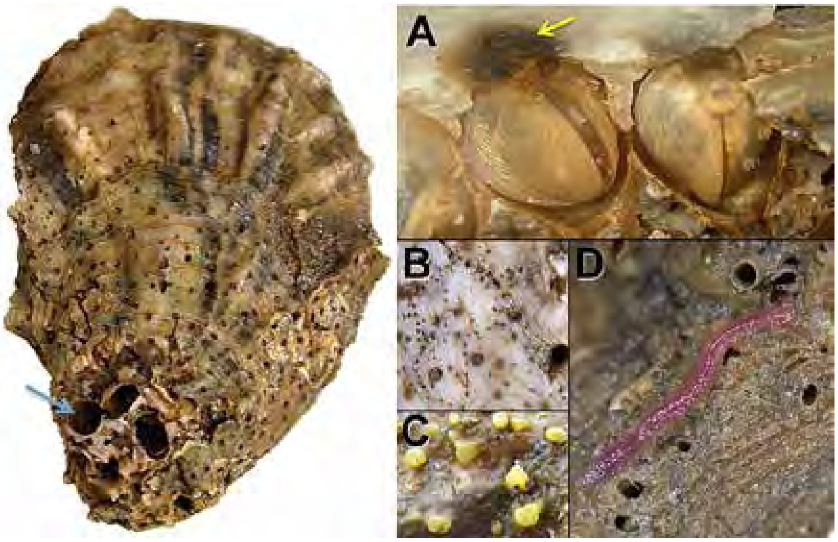

Figure 31 Shell parasites observed in Apalachicola Bay oysters 2012-2013. The whole oyster shell on the left shows evidence of several types of parasite damage. The blue arrow points to one of several larger holes formed by boring clams (*Diplothyra smithii*). Also evident are numerous smaller holes associated with the boring sponge, *Cliona spp*. Panel on the right shows close up images of common Apalachicola Bay oyster shell parasites. Panel A shows two boring clams seen at the edge of a shell that was fractured to reveal the parasites. Note the black spot (yellow arrow) associated with the clam's activity on the inner nacreous layer of the shell. Panel B shows close up of exterior shell holes bored by *Cliona* sponge. In life, this sponge organism is yellow and protrudes from the shell holes (Panel C). Panel D shows one of two types of polychaete worms, *Polydora*. This worm forms tubes within the shell, and can cause the oyster host to wall off this invader by forming mud blisters on the inside of the shell.

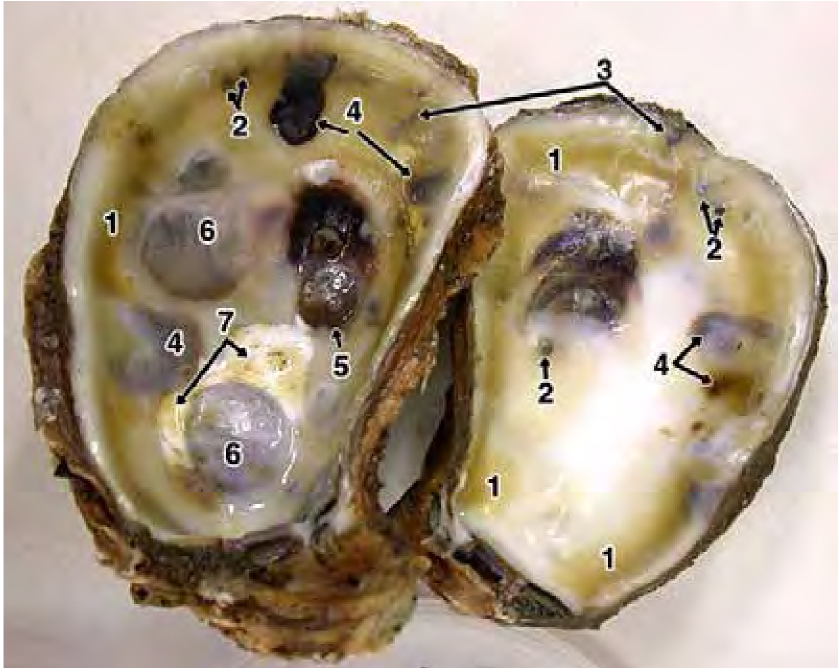

Figure 32 Internal shell observations associated with parasites from Apalachicola Bay oysters. Observations are described by number.
1 Yellowing. This discoloration in the nacreous layer is deposited by the mantle under stressful conditions.
2 Black spots associated with *Diplothyra* clams living within the shell.
3 Burrowing tubes at periphery of shell. These are points of access of boring *Polydora* worms.
4 Enlarged Polydora burrows within shell.
5 Mud blister. This "blister" is formed when *Polydora* worms penetrate the nacreous layer of the shell. The oyster host expends energy to secrete more nacre to wall-off the invader.
6 Long-standing mud blisters with thicker layer of nacre walling off the worm.
7 Chalky deposits. These white deposits are also laid down by the mantle under stressful conditions.

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[3] Oyster Sentinel, Ray and Soniat (http://www.oystersentinel.org)
[4] Petes LE, Brown AJ and Knight CR. 2012. Ecol. Evol. 2(7)1712-1724

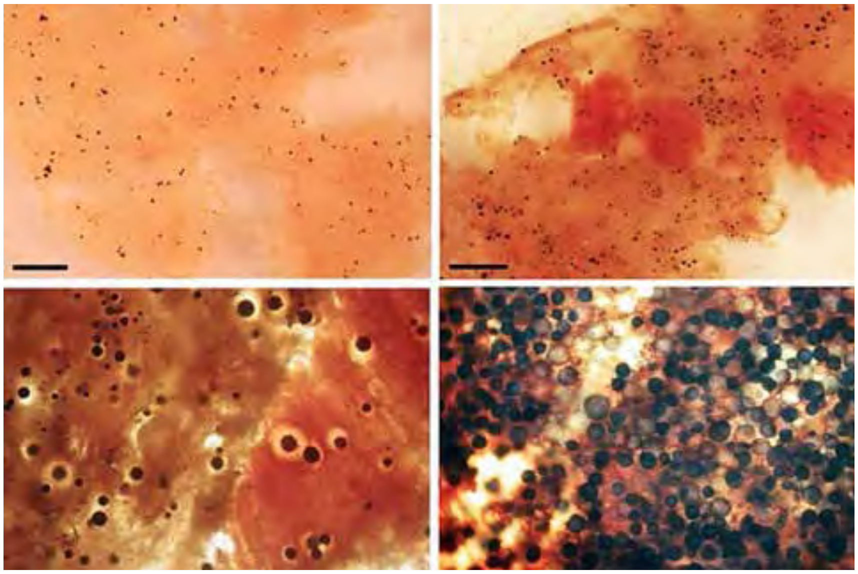

Figure 33 Photomicrographs showing varying degrees of Dermo infection in oyster mantle tissue. The number and distribution of *Perkinsus* spores allows a trained observer to derive a weighted prevalence for a sampling site and time point. The weighted prevalence is based on the percentage of oysters with any detectable Dermo multiplied by the mean severity rank (0-5) on a Mackin Scale.

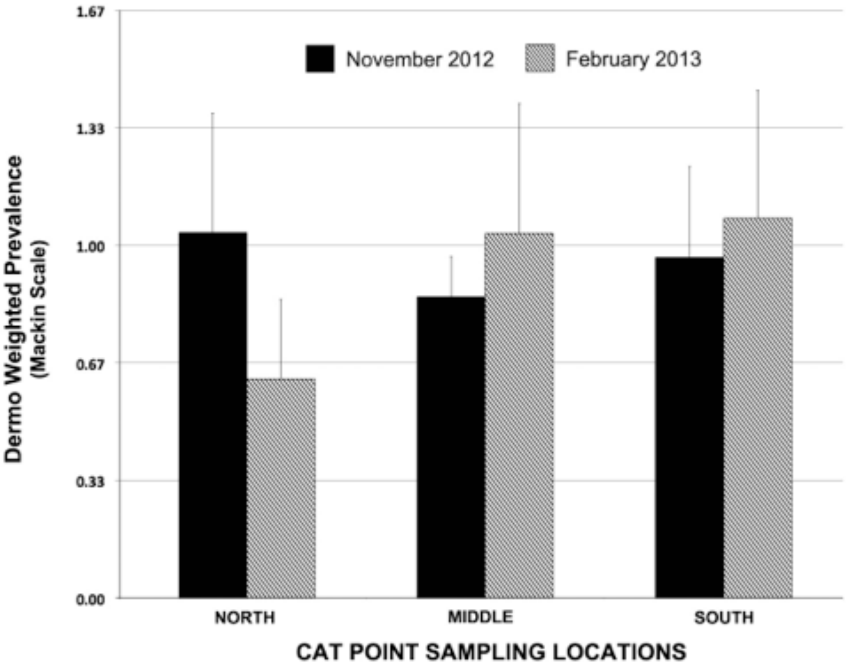

Figure 34 Spatial and temporal distribution of Dermo in oysters sampled along Cat Point bar in November 2012 and February 2013.

it to estimate number, biomass, and size structure of oysters and predatory gastropods and decapods. However, we processed each sample three different ways. Each method differs in quality of data production and operational cost. The first sampling event was completed in January 2013 and involved working with Franklin's Promise to hire local oystermen for vessel transportation ($2,000). Below, we present preliminary findings on the condition of oyster reefs.

Oyster reef structure

Based on model-selection analysis, the amount of reef structure throughout Apalachicola Bay differs in two important ways. First, reefs in east Apalachicola have nearly double the amount of oyster structure when compared to reefs in west Apalachicola (**Figure 35b**). Second, and with respect to eastern reefs, reef structure increases in a linear fashion with distance from freshwater input (**Figure 35c**). In contrast, in the west, reef structure increases minimally from Region 1 to Region 3.

Oyster abundance

According to the same statistical procedures, the abundance of adult oysters (oysters > 25 mm) differs between the east and west portions of Apalachicola Bay (**Figure 36b**). Similar to the pattern of reef structure, adult oysters on eastern reefs increased in abundance with distance from freshwater input. However, the presence of adult oysters is highly variable in Region 3 (i.e., larger error bars). The distribution of juvenile oysters (i.e., individuals < 25 mm) parallels the adult spatial pattern (**Figure 36c**).

Oyster size

In the January 2013 survey, we found that oyster size on eastern reefs decreased with increasing distance from freshwater input. In contrast, oyster sizes collected from western reefs increase with increasing distance from freshwater input (**Figure 37b**). Because spatial differences in the supply of oyster larvae could skew the average size of oysters, we re-plotted these data only for oysters > 25 mm length, thereby minimizing the influence of recruitment variation. This subset of data showed larger oysters sizes on both sides of the bay, yet the spatial patterns from Regions 1-3 mirrored those of the full data set (**Figure 37cv**).

Oyster predator abundance

In January 2013, the primary macro-invertebrate predator was the southern oyster drill (*Stramonita haemostoma*). The abundance of this predator was significantly less than the abundances we observed in preliminary sampling during October 2012. But for both the eastern and western portions of Apalachicola, the winter abundance of this predator peaks in Region 2 (**Figure 38b**). Because of the expected effects of the winter season, we found few individuals of crown conchs.

In our pending research, we will:

- **A.** Monitor oyster recruitment and individual growth throughout the bay on a monthly basis beginning in March 2013.
- **B.** Conduct an oyster mortality experiment throughout the bay to assess mortality of adult and juvenile oysters as a function of predation and environmental conditions.
- **C.** Establish correlative relationships between these oyster response metrics by deploying salinity, temperature, and tidal loggers throughout the bay.
- **D.** Collect monthly samples from each reef on nutrient and phytoplankton (Chl-a) concentrations in the water column.
- **E.** Repeat the aforementioned oyster survey in order to characterize the distribution and abundance of oysters and their predators during the summer.
- **F.** Use computerized re-sampling of our data to simulate less intensive sampling effort (e.g., measuring only a fraction of adult oysters in a quadrat) and to determine how much effort is required for reliable model analysis.

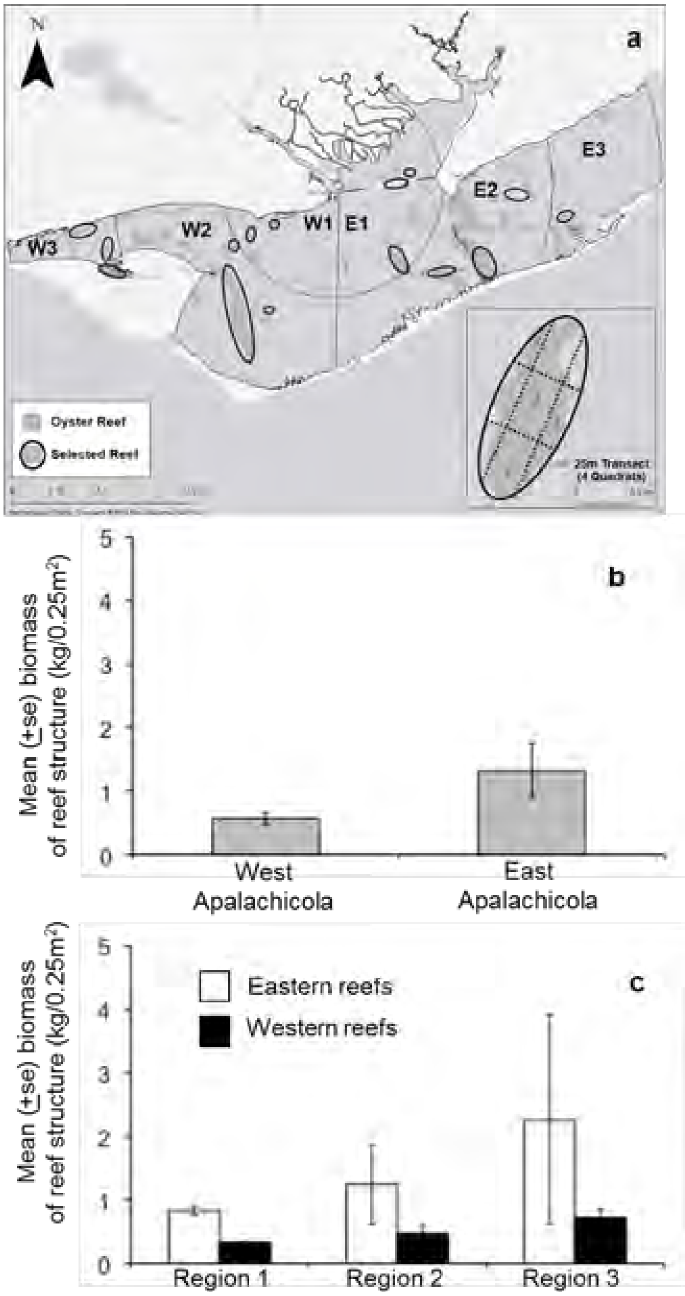

Figure 35 Map of oyster reefs in Apalachicola Bay (a), biomass of reef structure in the western and eastern portions of the bay (b) and biomass of reef structure in three different regions of the bay (c).

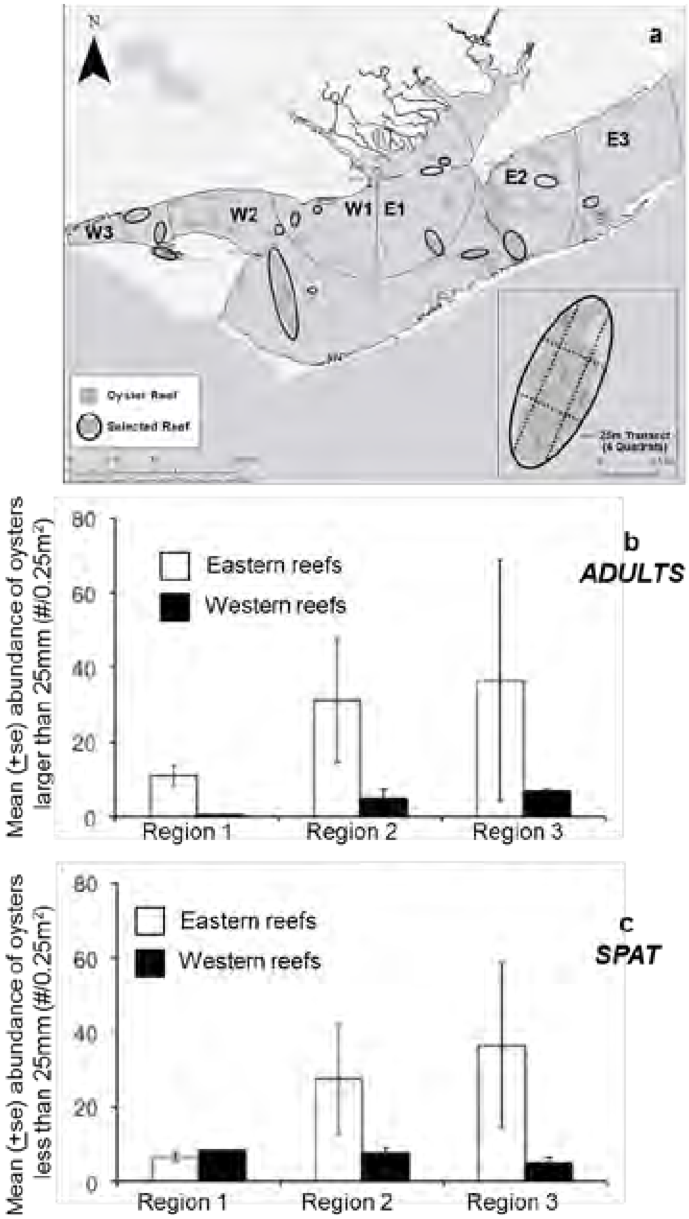

Figure 36 Map of oyster reefs in Apalachicola Bay (a), abundance of adult oysters (b) and spat (c) in different regions of the bay.

Fostering Community Resiliency and Stewardship *Traci Irani and Angela Lindsey*

Social vulnerability and resiliency theory are approaches that have been used to look at communities' responses to both natural and man-made disasters. For communities dependent on natural resources for their livelihoods, environmental and natural disasters are particularly salient, since these communities are vulnerable to negative changes in the environment. Social scientists define social vulnerability as a group of factors that make the system more or less able to cope with change. Social vulnerability can be understood as a characteristic within the system that affects how much harm from external factors the system is likely to experience. Within a community system, increasing the resiliency of the community and involving its members in the decision-making process can be an important way to prepare members to handle future disasters and remain strong. In addition, access to more resources helps people adapt to living in an environment with regular environmental vulnerability. Increasing information and awareness is also a strategy to decrease vulnerability and increase resilience. While scientific information is absolutely essential in working through environmental disasters and issues, it should be coupled with knowledge from those communities impacted.

During the past seven years, Franklin County, Fla. has endured hardships, including hurricanes, tropical storms, red tide, the Deepwater Horizon oil spill and drought. Due to these hardships, local resources have been impacted, which has directly impacted the economic and social stability of Franklin County's communities. University of Florida researchers and community outreach specialists have been working with these communities to help mitigate the socio-psychological as well as environmental effects. Through these pre-established relationships with community leaders in Franklin County, UF was able to

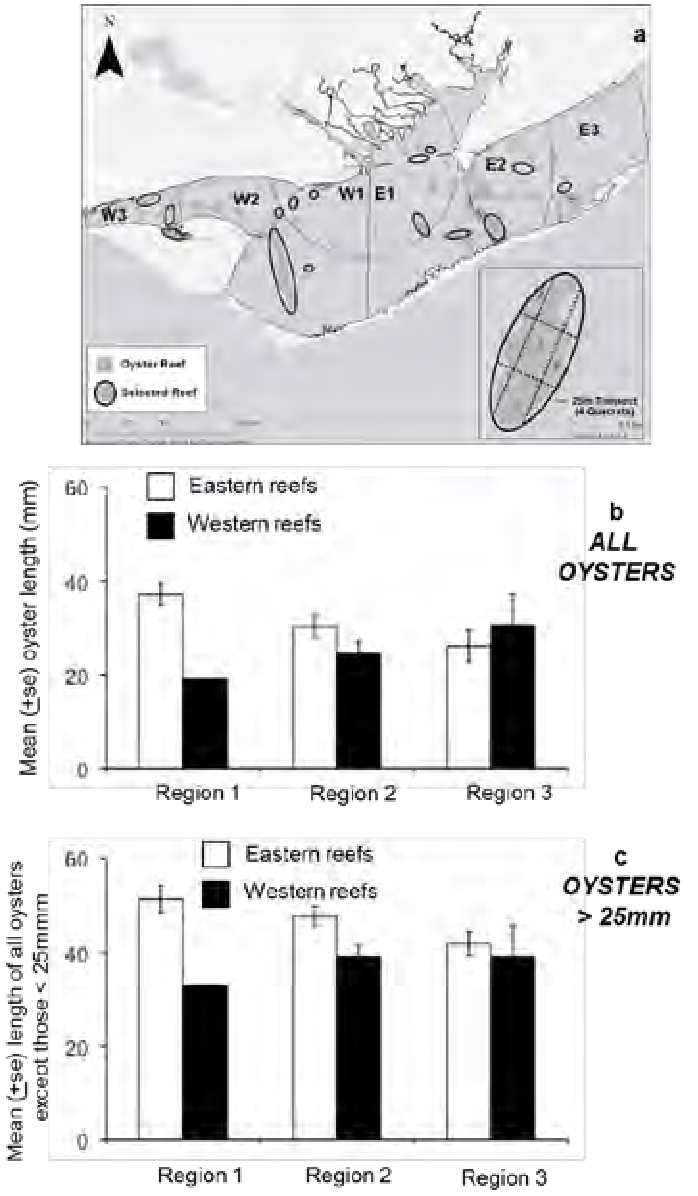

Figure 37 Map of oyster reefs in Apalachicola Bay (a), average length of all oysters (b) and average length of only adult oysters in different regions of the bay (c).

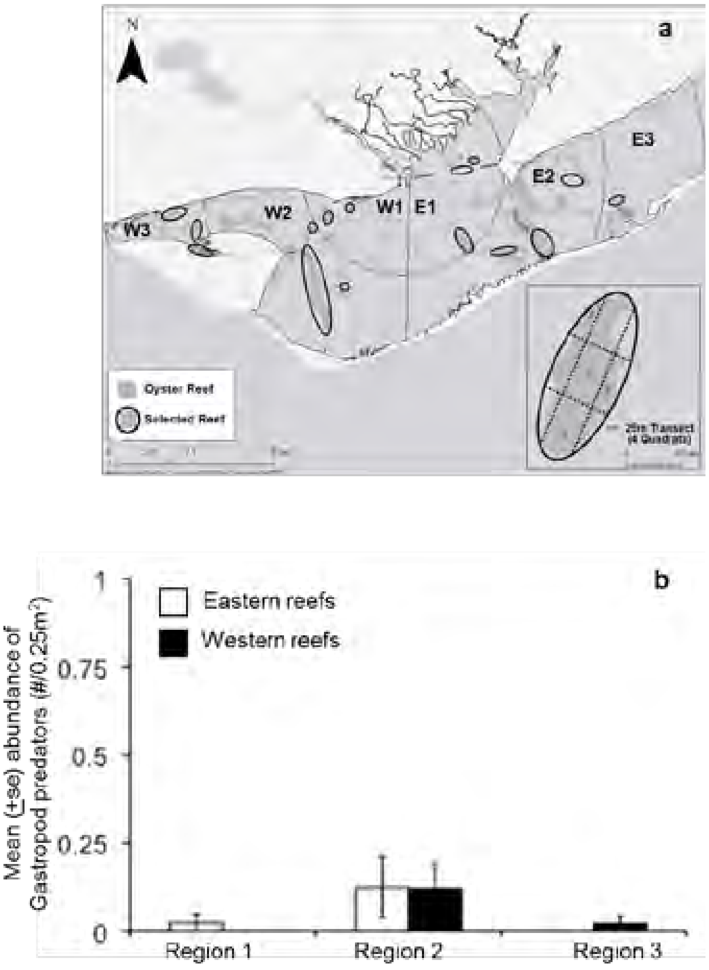

Figure 38 Map of oyster reefs in Apalachicola Bay (a), and abundance of gastropod predators in different regions of the bay (b).

continue to assist with resilient strategies and outreach efforts to combat recent economic downturns caused by the oyster harvesting crisis. These efforts included organizing and guiding community listening sessions and public forums, as well as collaborating with stakeholders on efforts to minimize damage and better prepare for future disasters.

Since the 1990s, there has been a change in development projects and processes in which researchers have focused on community participation as a formative research technique. This shift has brought about a host of different social science research methods, including participatory rural appraisal, appreciative inquiry, and community capitals framework, that all include a focus on more participatory methods when working with the community. Within these approaches, community participation has been used as a way to increase community empowerment and resilience.

Using the community participation method, a listening session and public forum meeting were held to hear the concerns of the community. The goal of these events was to understand community perceptions of the problems facing these communities. The first community meeting was an informal community listening session held on October 9, 2012. The purpose of this session was to bring interested parties together to address the oyster industry decline in Apalachicola Bay, FL. The session was divided in two different phases including: (1) what is happening, and how (are these events) affecting you? And (2) what are potential solutions to the situation? For this event, there were about 30 participants in attendance and these included representatives from the Franklin County Seafood Workers Association, Franklin's Promise Coalition, Florida Sea Grant, UF/IFAS Extension, and the university's Oyster Recovery Task Force. In addition, more than 15 community members were in attendance.

It was during this session that community members described their idea of forming a stakeholder-based community initiative that focuses on the sustainability and resilience of the local seafood industry. The proposed effort, identified as Seafood Management Assistance Resource and Recovery Team (SMARRT), would work collaboratively to tackle current hardships and create sustainable plans that ensure future preparedness. Partners in this program would be about 15 members representing law enforcement/regulators, government officials, seafood businesses, nonprofit organizations, social services and academic institutions. The inclusion of diverse partners and stakeholders was evidence of the goal to develop a sustainable solution for the bay.

The community development of the SMARRT initiative is an example of Empowerment Theory within a community. Empowerment Theory describes how changes in beliefs and attitudes influence changes in behavior leading to social change. It argues that by first developing a critical consciousness about one's (or a community's) situation and abilities, that collective action toward the social or collective good will occur. Empowerment can be considered either a process or an outcome, and can be analyzed at the individual or community level. As a process, empowerment increases power so that actors can take control of and act upon their own situations. Perceived control over the situation can account for varying levels of community participation, with communities who perceive that they have more control over their situations more apt to participate in community meetings and community organizing events.

Following the theory, once the idea of SMARRT was initiated, the community was open to working with UF to further develop the idea and meet the goals. Therefore, once SMARRT was identified and defined, UF began efforts to work with the community to further develop this important initiative. A public forum was subsequently held on October 16, 2012 to identify next steps in the development of the SMARRT Task Force. This forum aimed to support this collaborative effort by bringing community members together with vested stakeholders to discuss potential solutions and action plans to address the challenges of the oyster decline. The sessions focused on stakeholder input regarding the future direction of the SMARRT initiative. Outputs of this meeting included the development of an ad hoc committee to assist in the development. UF was asked to sit on this task force and has since been actively involved in the development of SMARRT.

This meeting provided the opportunity for community members to interact both internally and externally, which can also lead to open communication, higher feelings of empowerment, and resilience. The theory of communicative action explores the role of communication in creating social bonds. This theory argues that for groups to work together they must first understand one another, particularly in their interpretations of the world and social norms. Language, therefore, is a way to understand one another on a deeper level. Open communication, without resorting to power or persuasion, is crucial to reveal truth about situations and issues and is the only way to reach true consensus. It was the aim of these initial meetings to learn from the community and to be thoroughly transparent in efforts in which to assist them. Efforts were therefore developed collaboratively and strategically.

One example of the collaborative effort between the community and UF was the development and presenting of a grant workshop to Franklin County, FL in February 2013. The focus of this workshop was collaboration among community resource organizations in order to have the largest impact within the community. For this event, there were 13 participants from extension and 15 with nonprofit or public organizations. Participants had diverse and overlapping program interests, including gardening, health, nutrition, natural resources, youth, the arts, financial literacy, and disaster preparedness. The grant workshop covered topics including (1) developing the right idea, (2) creating logic models, (3) building a grant writing team, (4) collaborating as a team, (5) creating a budget, and (6) final submission. The overall goal of the workshop was to the increase capacity of community leaders and organizations to collaborate together to secure resources for their programs focused on community development and resiliency.

Moving ahead, UF will continue to look for opportunities to collaborate with the community in order to meet needs.

In addition, we will continue to be active in our efforts to work with the community to further the development of SMARRT. The theory of empowerment discusses new ways of approaching development intervention collaborations. Suggestions have been made on how to facilitate the empowerment process when working with groups. This includes (1) enhancing experience and competence, (2) enhancing group structure and capacity, (3) removing social and environment barriers, and (4) enhancing environmental support and resources. In order to integrate the pieces of empowerment theory into SMARRT, UF will continue to advise SMARRT developers on next steps and organizational structure. We have been present at all meetings and work diligently to become a bridge between the community organization and the resources available at the University of Florida.

The use of participatory methods when working with communities, whether for research or development projects, can be used to open communication lines among people to express concerns and priorities for their communities. This is important in developing new strategies for handling current and future crises and natural disasters in resource-dependent communities like those in Franklin County.

Alternative Seafood Products *Steve Otwell*

A new modest, periodic fishery appears probable and potentially useful in terms of partial predator control. Initial studies are assessing the potential for harvest and utilization of the crown conch, *Melongena corona*, which is one of the primary predators on oysters. These small mollusks can appear in substantial numbers relative to salinity regimes in Apalachicola Bay as well as other similar coastal/estuarine areas about Florida and the Southeast U.S. region. Development of the fishery will proceed with caution due to the lack of information pertinent to a fishery. Preliminary assessments have been favorable regarding necessary processing to recover edible portions and market acceptance of the product in cooked forms. Commercial retail interest is strong mindful of the limited availability of the traditional queen conch, *Strombus gigas*, which currently is under formal consideration as an endangered species (NOAA/2013). Since December 2012, crown conch has been harvested from Florida waters and processed to recover substantial volumes for secondary production of food items. The cooked forms have been successfully evaluated by the seafood sensory expertise at the Food Science and Human Nutrition Department at the University of Florida, and through trials in established retail/food service chains based in Florida. Further work is necessary to assess attributes involving appropriate resource availability and utilization, food safety and quality, including frozen storage and shelf-life, and markets for by-products including empty shells and live crown conch that are too small for processing. As a new seafood item, request for appropriate terminology for product identity and labels as Crown Conch have been formally initiated with the required federal authorities in the Food and Drug Administration and respective resource authorities in the FWC. This work is proceeding with commercial assistance through Florida Sea Grant staff without financial support from grant funds.

SUGGESTIONS FOR MONITORING, MANAGEMENT, RESTORATION AND RESEARCH

Monitoring

- There is a need to continue the monitoring of oysters in Apalachicola Bay, both in terms of tracking landings reported by oystermen, and in the sampling done by state agencies.The fisheries independent monitoring program needs to be expanded in its spatial extent to include all of the bay where oyster bars occur, including areas that are closed to fishing, because these may represent important sources of oyster spat.
- Oysters should be included on the list of invertebrate species routinely assessed by Fish and Wildlife Research Institute (FWRI) stock assessment staff. These assessments can identify persistent uncertainties in oyster ecology or population status and help guide research such as the relationship between Apalachicola River flows and juvenile oyster survival rate or culling mortality.

Management and Restoration

- Acceptance by the community and industry, and enforcement and adjudication of rules regarding size limits, spatial restrictions, and weekly and seasonal closures is essential for these measures to be effective in sustaining the oyster population.
- Throughout our work on this project there were persistent reports of high levels of unreported harvest and illegal harvest from closed areas. While tangible evidence of illegal activity is not available, it is clear from our simulation models that lack of compliance with current regulations could greatly reduce the likelihood of Apalachicola Bay oyster populations returning to historic population levels, regardless of management action taken.
- Oyster leases should be explored as a possible alternative to open-access fisheries. The concept of TURF (Territorial User Rights Fisheries) as a lease arrangement could be appealing to oyster fishermen and help promote restoration actions such as re-shelling because the fishermen would benefit directly from the restoration activities they were engaged in by having a “share” of the restored area (the lease) to manage and harvest from.
- The total current area of oyster bar in Apalachicola Bay that is not open to fishing is unknown, and the degree to which this area is the source of the oyster spat for the entire bay also is unknown. If this area is small or declining, then large-scale oyster relay from these closed areas to areas open to fishing may reduce the total spat available throughout Apalachicola Bay, increasing the risk of “recruitment overfishing” where harvests of adults could influence availability of future spat.
- Therefore, the practice of ‘relaying’ should be carefully evaluated in regard to its short-term benefits versus potential longer-term negative impacts to the fishery—in

other words, whether or not it is depleting a substantive portion of the source population of oyster spat.

- Management actions such as shell planting could expedite the recovery of Apalachicola Bay oyster resources. However, a new modeling tool called ECOSPACE, brought forward by the UF Oyster Recovery Team, suggests that shell planting needs to be conducted at a considerably greater scale than current levels to be effective—approximately 200 acres per year for a 5-year period. A very important uncertainty is whether shell planting should concentrate large amounts of shell in small areas to create thick layers of shell or whether shell should be spread over larger areas but not in as thick a shell layer. Restoration should be done in a manner that provides information on efficacy and cost-effectiveness of different shelling strategies, including evaluating different densities of shelling and different kinds of shell material.
- A participatory decision-making process, involving SMARRT (the Seafood Management Assistance Resource and Recovery Team), relevant state agencies and experts from the state university system is needed to support long-term management of the oyster fishery in a more robust manner. The ECOSPACE model could further support members of SMARRT and management agencies to screen different policy or restoration alternatives.

Research

- Research is needed to identify an optimal approach for monitoring long-term settlement, juvenile and adult survival, productivity, health, mortality, oyster diseases, and product quality of oysters. Subsequently this information could be used to inform changes in the oyster monitoring program.
- Research is needed to quantify how oyster population dynamics, product quality and the fishery are affected by interactions between river flow, nutrients, salinity, harvesting intensity and restoration methods.
- There is a need to assess the harvesting practices of the oystermen and how they respond to changes in oyster abundance.
- The ECOSPACE model has additional functionality to identify effects of varying flow regimes and to screen flow alternatives, relative to Apalachicola Bay oyster population dynamics and harvest potential when the model is linked with the Apalachicola Basin River Model currently being used by the Apalachicola-Chattahoochee-Flint River Stakeholders Group.

Outreach and Education

- A community-based outreach and education program is needed to foster actions consistent with supporting a sustainable bay ecosystem and economy.
- Involvement of oyster harvesters and processers in research and restoration projects can aid in educating the entire community about bay stewardship.

The Future

The situation in Apalachicola Bay, as outlined in the pages of this report, highlights a series of interwoven ecologic, fisheries, and community concerns. The bay is a national treasure, and its demise would sever critical links among our modern society, nature and our heritage. Work to date is a starting point toward understanding the processes underlying the current crisis, and includes steps that can and should be taken in initial efforts to restore the bay. However, if we are truly committed to bringing the bay back to a point even close to its former productivity, a great deal of work is still required. These studies and analyses were conducted on a shoestring budget with internal funds from UF/IFAS, and limited support from Florida Sea Grant and from the National Institute of Environmental Health Sciences. If we are truly committed to the restoration of the bay, we can’t stop here. There is a critical need for follow-up work, bringing together state and federal agencies, academic researchers, and the community, to look out over a 5-, 10-, and 20-year time scale, to conduct interventions, do the necessary research, and monitor outcomes. This will require a strong leadership structure and it will cost money. The question remains as to whether we, as a society, are willing to make this investment of time, and money, to preserve this priceless natural resource for our lifetime, and the lifetimes of our children.

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