Performance Report for Cooperative Agreement No: NA06OAR4810163
for the Period from September 1 2011 – February 28, 2012

University of Maryland Eastern Shore
Living Marine Resources Cooperative Science Center

Paulinus Chigbu, Ph.D. (Principal Investigator & Director, LMRCSC)
Bradley Stevens (Co-Principal Investigator & Distinguished Research Scientist)
University of Maryland Eastern Shore (Lead Institution)

Stacy Smith, Ph.D. (Co-Principal Investigator)
Delaware State University

Deidre Gibson, Ph.D. (Co-Principal Investigator)
Hampton University

Dionne Hoskins, Ph.D. (Co-Principal Investigator)
Savannah State University

Rosemary Jagus, Ph.D. (Co-Principal Investigator)
University of Maryland Center for Environmental Science, IMET

David Die, Ph.D. (Co-Principal Investigator)
RSMAS/University of Miami

Table of Contents

List of Tables

Executive Summary

The mission of the Living Marine Resources Cooperative Science Center (LMRCSC) is to conduct research congruent with the interests of NOAA Fisheries and to prepare students for careers in research, management, and public policy that support the sustainable harvest and conservation of our nation's living marine resources. Established in October, 2001, the LMRCSC was created as a cooperative agreement between NOAA Educational Partnership Program (NOAA EPP), the University of Maryland Eastern Shore (UMES), Delaware State University (DSU), Hampton University (HU), Savannah State University (SSU), the University of Miami (UM/RSMAS) and the University of Maryland Center for Environmental Science Institute of Marine and Environmental Technology (UMCES-IMET). UMES is the lead institution.

The mission of the LMRCSC is accomplished by addressing the following goals:

Goal 1: Enhance Marine Research and Academic Program Capacities of the Center MSIs
Goal 2: Enhance Research Programs in the Marine Sciences at Participating Institutions
Goal 3: Generate a Pool of Scholars Entering the Field of Marine Sciences and Fisheries

The Center continues to be guided by two management tracks, A) Administrative and B) Programmatic. The Administrative component includes the Center Director, Program Manager, Executive Committee, Center Core Administration and the Board of Visitors.

To accomplish Goal 1, the Center used the Virtual Campus for curriculum development and seminars and expanded it to include courses which were offered online between Center partners and to a NOAA NEFSC contractor and a NOAA employee located in Woods Hole, MA who are enrolled in the Professional Science Master's (PSM) degree program at UMES. Seminars and several courses offered through the University of Maryland interactive video network (IVN) were made available to Center students during this reporting period. NOAA scientists, including Dr. Howard Townsend (NOAA Cooperative Oxford Lab, MD), Dr. Larry Alade (NOAA NEFSC), and Jason Link (NOAA NEFSC) will teach a new course "**Ecosystem Modeling Applied to Fisheries**" at UMES in January 2012. The course was to be offered in summer 2011 but did not meet minimum enrollment requirements. Three courses (Multivariate Statistics, Stock Assessment, and Marine Population Dynamics) that are part of the "essential curriculum" recommended by NOAA Fisheries for training fisheries scientists were offered to students at the Center during spring semester. In addition, Fisheries Survey Sampling, Fish Ecology, and Risk and Decision Analysis are being offered this fall (2011). The Articulation Agreement document signed by all LMRCSC partners led to cross registration between partners for these courses. Five graduate students in the PSM program interned at NOAA Science labs in summer 2011.

In support of the programmatic component of the LMRCSC designed to accomplish Goal 2, twelve (12) collaborative projects were funded by the LMRCSC for 2010-2011 project year were completed by December 31, 2011. Eighteen proposals were submitted in response to the 2011-12 LMRCSC RFP on October 14, 2011 with twelve being approved for funding following review by the Technical Advisory Board. The on-going and future research projects at the Center are intended to meet the mission of NOAA Fisheries: "*Stewardship of living marine resources through science-based conservation and management and the promotion of healthy ecosystems*". The TAB and NOAA scientists' involvement also ensures that the LMRCSC has a strong linkage with the mission of NOAA: "*To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs*".

Highlights of the results obtained for some of the completed TAB projects are presented below. Additional information on the projects is presented on pages 11 to 26 of the report. The development of in-situ assessment and observation methods for black sea bass, a commercially important species, will allow for better understanding of the meaning of trap CPUE and how it relates to fish abundance, which will allow managers to interpret CPUE and landings data with greater accuracy. A major objective of NMFS is to develop alternate feeds for aquaculture. The study dealing with taurine as an ingredient in the development of fish free diets is helping to establish the minimum taurine requirement and its effects at different inclusion levels for many commercially important fish species. Taurine plays a major role in allowing the reduction and elimination of fishmeal from fish diets. Thus results from this study are useful for greatly enhancing the ability of the aquaculture industry to increase global fish production. Finally, the study on temperature preferences of Atlantic croaker under normoxic and hypoxic conditions has yield some preliminary data

that are useful for evaluating the effects of anthropogenic stressors and habitat degradation on habitat use and residency of scianids.

In the current reporting period, LMRCSC students and faculty made 59 presentations (oral and poster) at scientific meetings (46 of which were made by students), and published 13 articles in refereed journals, 6 of which were authored or co-authored by students or graduates of LMRCSC. An additional 9 articles were accepted for publication or are in press (6 co-authored by students). Through its research activities in living marine resources the Center is addressing NOAA Fisheries mission goal, to: "*protect, restore, and manage the use of coastal and ocean resources through an Ecosystem Approach to Management*".

A total of $2,591,029.14 was collectively awarded in grants to the LMRCSC institutions during this reporting period, which has directly impacted and will continue to have positive impacts on Center activities. These funds enhanced LMRCSC research through support of its faculty and students and by development/enhancement of infrastructure. Ten grant proposals totaling $7,886,158.92 were submitted to funding agencies during the current reporting period.

In support of Goal 3, to generate a pool of scholars entering the field of marine science, 35 students (16 BS, 13 MS, 6 Ph.D students) were supported and received training in NOAA core sciences during this reporting period, and 5 students graduated (3 BS, 1 MS, 1 Ph.D.). Students participated fully and actively in faculty-directed research projects on their home campuses or at Center partners. Many received training directly at NOAA facilities. Students were also provided travel awards to conferences to present their research and network with their peers and with professional scientists.

In order to create a pipeline of students into the marine sciences, the Center conducted activities for students in grades K-12 which collectively impacted more than 1000 students. These included specific training and research experiences such as the Coast Camp for Youth at Savannah State University, CREST SEEL program at UMES, and the SciTech program at IMET in which 1000-2000 Baltimore area high school students participate annually, the Upward Bound Marine and Estuarine Science Program at UMES that reaches 25 high school students and activities in marine science conducted at local schools by LMRCSC faculty and graduate students.

LMRCSC educational, research and outreach activities are, therefore, addressing three of the five essential activities NOAA has identified as being important for the success of its mission: (i) "*developing, valuing, and sustaining a world-class workforce*", (ii) "*ensuring sound, state-of-the-art research*", and (iii) "*promoting environmental literacy*". This table summarizes some of the LMRCSC accomplishments during this reporting period.

Summary of LMRCSC Performance Measures of Success Relative to 2010-11 Implementation Plan

Activities	Proposed in the Implementation Plan (2010-11)	Accomplished (Sept. 1 2011– Feb. 28, 2012) 6 months
1. # of proposals funded by the Center after TAB reviews	12 (10 – 14)	12
2. # of proposals submitted to programs other than NOAA EPP	20	10
3. # of scientific presentations at conferences (including students')	35 (30 – 60)	59 (46*)
4. # of theses & dissertations produced	12	2
5. # of peer-reviewed publications/book chapters	18 (10 – 25)	13 (6*)
6. Amount of leveraged funds ($)	$1.3 million (500,000 to 1.5 million)	$2,591,029.14
7. # K-12 students trained in NOAA related sciences	500	> 1000
8. # of B.S. students trained in NOAA related sciences	50	26
9. # of B.S. students graduated in NOAA core sciences	25	3
10. # of M.S. students graduated in NOAA core sciences	9	1
11. # of Ph.D. students graduated in NOAA core sciences	3	1
12. # of interns at NOAA/other labs.	10	5

With students

INTRODUCTION

Established in October 2001, the Living Marine Resources Cooperative Science Center (LMRCSC) was created as a cooperative agreement between NOAA Educational Partnership Program, the University of Maryland Eastern Shore (UMES), Delaware State University (DSU), Hampton University (HU), Savannah State University (SSU), the University of Miami (UM/RSMAS) and the University of Maryland Center for Environmental Science Institute of Marine and Environmental Technology (UMCES-IMET). UMES is the lead institution. The mission of the Center is to conduct research congruent with the interests of NOAA Fisheries and to prepare students for careers in research, management, and public policy that support the sustainable harvest and conservation of our nation's living marine resources.

The following are the goals and objectives of the LMRCSC:

Goal 1: Enhance Marine Research and Academic Program Capacities of Center MSIs

Goal 1 is accomplished through the following objective:

Objective 1: **Build upon Existing Academic and Organizational Infrastructure to Develop Strong Interactive Academic Programs in Marine Sciences**

Goal 2: Enhance Research Programs in the Marine Sciences at Participating Institutions

Goal 2 is accomplished through the following objectives:

Objective 1: **Continue Current and Develop New Research Programs Congruent with NOAA Fisheries Research Priorities**

Objective 2: **Fully Integrate Research Programs with NOAA Fisheries to Ensure Long Term Funding and Programmatic Stability**

Goal 3: Generate a Pool of Scholars Entering the Field of Marine Sciences and Fisheries

Goal 3 is accomplished by the following objectives:

Objective 1: **Enhance Recruitment of Students from Underrepresented Groups into Marine Science Disciplines**

Objective 2: **Strengthen Outreach & Education Programs to Students and the Public**

Objective 3: **Develop Programs that Enhance the Practical Education of Undergraduate and Graduate Students in the Marine Sciences**

SECTION I – STATUS OF AWARD ACTIVITIES (Goals and Objectives)

For the period **March 1 to August 31, 2011**, the following tasks were accomplished in support of the goals and objectives of the LMRCSC:

Goal 1: Enhance Marine Research and Academic Program Capacities of Center MSIs

Objective 1: **Build upon Existing Academic and Organizational Infrastructure to Develop Strong Interactive Academic Programs in Marine Sciences**

In the current reporting period, the Center institutions achieved this objective through:

i. **Increased use of the Virtual Campus for a) curriculum development and b) meetings,**

ii. **Strengthening collaborations among center partners, and**

iii. **Strengthening administrative and programmatic components of the Center**

i) Increased use of the Virtual Campus: The Virtual Campus was used to provide courses to students, hold student committee meetings, Executive Committee meetings, and thesis and dissertation defenses. Details on these activities are shown below. The Virtual Campus concept has been expanded to include not only courses offered through videoconferencing, but also in an online format. Three of the nine essential courses cited by NOAA NMFS as critical to training stock assessment scientists were offered online in Fall 2011 by LMRCSC researchers during the current reporting period and are listed below. Bayesian Statistics (another of the nine essential courses) was offered online to LMRCSC students for the first time.

ia) Academic Courses:

- **Bayesian Statistics**: This course was developed and offered online in Spring 2012 by Dr. Elizabeth Babcock at RSMAS and made available to students at LMRCSC partners via GoToMeeting. In addition to those at RSMAS, six students at UMES were able to participate in the course.

- **Business and ethics of fisheries management:** This course was instructed by Dr. Nicole Buzzetto-More (UMES). Six Professional Science Masters program students are enrolled in the course.

Several University System of Maryland MEES courses were offered in Fall 2011 to LMRCSC students and others at UMES. Courses offered or are currently being offered, and students who enrolled or are currently enrolled in them are shown in Tables 1 and 2, respectively. SSU, HU, RSMAS and DSU students were not enrolled in MEES courses for credit during the reporting period, however, the Center has developedan Articulation Agreement to make it possible for students at non-University System of Maryland institutions to enroll in the courses via IVN. The document has been signed by all LMRCSC partner institutions. Courses that are being offered online as part of the PSM degree program in quantitative fisheries and resource economics are presented in Table 3.

Table 2. MEES Courses Offered in Fall Semester 2011 Using Interactive Video Network (IVN).

Course Number	Course	Instructor	Students Enrolled
MEES 608B	Climate Change and Biosphere (Seminar)	Kilbourne	Dan Cullen Heather Wolfer
MEES 608K	Fluid Dynamics	Koch and Sanford	
MEES 610	Land Margins	Fisher	
MEES 682.	Fish Science & Management	Secor et al.	
MEES 698E	History of Ecology	Kangas	
MEES 698R	Stable Isotopes	Nelson and Cooper	
MEES 698X	Remote Sensing	Elmore	
MEES607	Quantitative Methods	Harris	
MEES608C	Diseases in the Chesapeake Bay	Schott	
MEES608D	Scientific Writing & Communications	Kennedy	Bhae Jin Peemoeller Whitney Dyson
MEES608L	Genomic Seminar	Hill & Chen	
MEES621	Biological Oceanography	Hood et al.	Belita Nguluwe
MEES698C	Cell and Molecular Biology	Place & Jagus	Bhae Jin Peemoeller
MEES698G	Microbial and Env.	Chen and Hill	

MEES698M	Practical Protein Chemistry	Ahmed	

Table 3. Courses Offered Online during Fall Semester 2011

Course number	Course Title	Instructor	Students (online)
AGSC 605	Agricultural Statistics	Harter-Dennis	Cornelius Chilaka (UMES/PSM) Evan Lindsay (UMES/PSM) Andrew Turner (UMES/PSM) Leonardo Matthews (UMES/PSM) Jeffrey Kipp (UMES/PSM) Kristen Lycett (UMES/CREST)
MEES688	Fishery Survey Sampling	Stevens	Andrea Stoneman (DSU) Jessica Blaylock (NOAA/UMES/PSM) Michele Traver (NOAA/UMES/PSM)
MEES688P/ORLD617	Personnel Development	Costello	Joseph Drummond (UMES/PSM) Cornelius Chilaka (UMES/PSM) Evan Lindsay (UMES/PSM) Leonardo Matthews (UMES/PSM) Andrew Turner (UMES/PSM) Jeffrey Kipp (UMES/PSM)
MEES 688	Fish Ecology	Chigbu & May	Jessica Blaylock (NOAA/UMES/PSM) Andrea Stoneman (DSU) Courtney McGeachy (UMES) Whitney Dyson (UMES)
MEES643	Risk and Decision Analysis	Ali	Jessica Blaylock (NOAA/PSM) Joseph Drummond (UMES/PSM) Evan Lindsay (UMES/PSM) Leonardo Matthews (UMES/PSM) Andrew Turner (UMES/PSM) Jeffrey Kipp (UMES/PSM)

Table xxx. MEES Courses Offered in Spring Semester 2012 Using Interactive Video Network (IVN).

Course number	Course Title	Instructor	Students
MEES 631	Fish Ecology	Miller	Whitney Dyson (LMRCSC/UMES) Emily Tewes (LMRCSC/UMES)
MEES 688	Surface Water Quality Monitoring	Xia	Dan Cullen (LMRCSC/UMES)
MEES 698F	Fisheries Oceanography	North	Emily Tewes (LMRCSC/UMES) Heather Wolfer (CREST/UMES)
MEES 698G	Zooplankton Ecology	Pierson	Kristen Lycett (LMRCSC/UMES)
MEES 688J	Fisheries Biology and Management	May	Michele Traver (PSM/UMES)

Table xx. Courses Offered Online during Spring 2012

Course number	Course Title	Instructor	Students (online)
MEES608N	Special Topics: Fisheries Management and Policy	Stevens	Courtney McGeachy (UMES/LMRCSC) Dan Cullen (UMES/LMRCSC) Emily Tewes (UMES/LMRCSC) Eric Evans (UMES/LMRCSC)

MEES 640	Intro to Resource Economics		Cornelius Chilaka (UMES/PSM) Joseph Drummond (UMES/PSM) Evan Lindsay (UMES/PSM) Andrew Turner (UMES/PSM) Leonardo Matthews (UMES/PSM) Jeffrey Kipp (UMES/PSM)
MEES688	Bayesian Statistics	Babcock	Dan Cullen (UMES/LMRCSC) Evan Lindsay (UMES/PSM) Andrew Turner (UMES/PSM) Leonardo Matthews (UMES/PSM) Jeffrey Kipp (UMES/PSM) Jessica Blaylock (NOAA/UMES/PSM))
MEES688	Business of Fisheries Mgmt & Ethics	Buzzetto-More	Cornelius Chilaka (UMES/PSM) Joseph Drummond (UMES/PSM) Evan Lindsay (UMES/PSM) Andrew Turner (UMES/PSM) Leonardo Matthews (UMES/PSM) Jeffrey Kipp (UMES/PSM)
MEES688	Marine Population Dynamics	Die/Chigbu	Leonardo Matthews (UMES/PSM)

The courses listed in Tables 1 to 3 above address various aspects of the study of living marine resources and their environments, hence, they were offered to students to strengthen their backgrounds in the LMRCSC thematic areas: Quantitative Fisheries, Essential Fish Habitat, and Aquaculture. LMRCSC students are not required to enroll in all the courses listed above, but instead they take only the course(s) that they need for graduation which are not offered at their home institutions.

Seminars and Workshops

The LMRCSC Seminar Series continued in this reporting period. The presentations were made available at all LMRCSC partners via the Virtual Campus. Three sessions (Table 5) were held in the current reporting period.

Table 5. LMRCSC Seminar Series 2011-2012.

DATE	SPEAKER	TITLE
October 7, 2011	Dr. Bradley Stevens (UMES)	Discovering the Kad'yak, Alaska's oldest known shipwreck
November 4, 2011	Dr. Andrij Horodysky (HU)	Sensory ecophysiology of mid-Atlantic fishes: towards a mechanistic understanding of form-function-environment relationships
December 2, 2011	Dr. Jessica Miller (OSU)	A biogeochemical approach to fisheries ecology, conservation, and management

Teaching Assistant Workshop: LMRCSC sponsored a workshop from September 16-17, 2011 at UMES aimed at providing graduate students with the leadership and instructional skills needed to be effective Teaching Assistants. The workshop was led by Dr. Philliph Mutisya, Professor of Education at North Carolina Central University. Approximately 30 students attended the workshop.

ib) Executive Committee (EC) Meetings: Because of budget reductions, EC meetings have been held via teleconference rather than by the Virtual Campus. Teleconferences were held monthly from September, 2011 to February, 2012. One in-person EC meeting was held in conjunction with the American Fisheries Society meeting in Seattle, WA on Sept 3, 2011.

ic) Student meetings: No student meetings were held using the Virtual Campus during the reporting period.

ii) Strengthening collaborations among center partners: A strong collaboration is continuing between HU and UMES as a result of a funded TAB project (see TAB reports). HU and UMES students spent 10 weeks at the VIMS Eastern Shore Laboratory in Wachapreague, VA, investigating the Sensory ecology of tautog: ecophysiological auditory and visual performance measures, and Temperature preferences of Atlantic croaker under hypoxic and normoxic conditions.

iii. Strengthening administrative and programmatic components of the Center: The Center continued to be guided by two management tracks, A) Administrative and B) Programmatic.

A. The Administrative component includes the Center Director, Program Manager, Executive Committee, Center Core Administration and the Board of Visitors.

Center Director and Staff: There were no changes in Center staff during this reporting period.

Executive Committee **(EC):** The EC consists of the Distinguished Research Scientist (DRS), Project Directors from each Center institution and Center Director; Dr. Chigbu serves as chair of the EC. The EC met via conference call monthly from March to August, 2011.

Center Core Administration **(CCA):** The CCA, consisting of UMES' Vice President for Academic Affairs, UMES' Vice President for Administrative Affairs, a representative from the office of the President, UMES' Dean of the School of Agriculture and Natural Sciences, Chair of Department of Natural Sciences, LMRCSC Director, DRS, and Program Manager last met on March 14, 2011. CCA members were briefed by Dr. Chigbu on Center accomplishments, challenges, and about the re-competition proposal for the CSCs.

LMRCSC Board of Visitors **(BOVs):** The BOV, consisting of the Presidents of the LMRCSC partner institutions or their designees, last met on November 2, 2011 at University of Miami-RSMAS.

Center Faculty and Staff Positions**:** Dr. Matthew Ogburn left Savannah State University in Fall 2011 but continues to collaborate with LMRCSC in his new position at Smithsonian Environmental Research Center. Dr. Shari Wiley joined the Mathematics Department at Hampton University in Fall 2011, bringing strong quantitative modeling and stock assessment skills to the Center.

B. Programmatic:

Technical Advisory Board **(TAB):** Twelve proposals recommended for funding for the 2010/11 project year (Table xxx) were completed by December 2011. Results are shown in section xxxx below.

A revised Request for Proposals for the 2011-12 project year was circulated to all partners as well as to NOAA Fisheries personnel on August 30, 2011. Eighteen proposals were submitted to UMES by October 14, 2011. Twelve were approved for funding in December 2011.

The TAB comprises the following individuals:

- Dr. Kristy Wallmo (TAB Chair; NOAA Office of Science & Technology)
- Dr. Tom Noji (Director, J.J. Howard Marine Science Lab., Sandy Hook, NJ)
- Dr. Mike Rust (NOAA NWFSC, Seattle, WA)
- Dr. Ayeisha Brinson (NOAA NEFSC, Woods Hole, MA)
- Dr. Richard Brill (NOAA SEFSC, VIMS)
- Dr. James Berkson (NOAA SEFSC, Virginia Tech)
- Dr. Meka Laster (NOAA EPP Representative), as an observer

Monitoring and Evaluation: Online evaluation forms designed to assess LMRCSC programs have been in place since 2005. Four updated online evaluation forms for: 1) graduates, 2) cruise participants, 3) student interns, and 4) internship mentors exist.

LMRCSC Exit Evaluation: A total of 23 undergraduate and graduate students from at least four LMRCSC partners have completed and submitted the exit evaluation during their final semester. Two were submitted during this reporting period.

LMRCSC Cruise Evaluation: An evaluation form aimed at assessing the students' experience aboard LMRCSC research cruises is distributed to participants following each research cruise. Fourteen surveys have been completed, including 4 in the current reporting period.

Evaluation Forms for interns and mentors: To date, 37 students have provided evaluations of their internship experiences at various NOAA facilities, LMRCSC partners and other institutions, including six submitted during the current reporting period. Similarly, a total of 17 supervisors have provided evaluations of the LMRCSC students who participated in internships in their labs. The data provided are utilized by the Center to ensure the best possible internship experiences for both students and their supervisors. No surveys were submitted during this reporting period.

Goal 2: **Enhance Research Programs in the Marine Sciences at Participating Institutions**

Objective 1: **Continue Current and Develop New Research Programs Congruent with NOAA Fisheries Research Priorities**

RSMAS graduate students and faculty funded by the LMRCSC continued their research work in the areas of essential fish habitat, aquaculture, and quantitative fisheries. The work in essential fish habitat is being conducted by graduate students Xaymara Serrano and Rolando Santos. Xaymara is working with Dr. Andrew Baker on impacts of climate change on coral reef communities. Her dissertation will be entitled "Population Genetics of Scleractinian Corals in the Tropical Western Atlantic (Caribbean). Dwight Ebanks continued his work on the effects of climate change and acidification on early life history of cobia. This project has both applications to aquaculture and essential fish habitat. *Quantitative fisheries* is the main area of research of the RSMAS P.I. who during this period focused on work to support the assessment of International Commission for the Conservation of Atlantic Tunas (ICCAT) and billfish species. Dr. Die has continued his work of technical support of the Center for Independent Experts that provides NMFS with independent peer review of science products.

The LMRCSC is fully integrated into the support structure of the B.S. and M.S. degree programs in Marine Science at Savannah State University. SSU has provided research vessels (3), teaching and research space (3 research labs, 4 faculty offices, one academic building with classrooms, a dry lab, and computer lab), and some technical (boat captain) and administrative (clerical) support. Because SSU already had some research capacity, the LMRCSC has been able to enhance the quality of instrumentation and technical needs.

Existing NOAA collaborations with NOAA's Gray's Reef National Marine Sanctuary continue through current projects to monitor utilization of the reef by commercially important species. This work is now being continued by new M.S. student, Noelle Hawthorne.

TAB Approved Projects for 2010/11: Twelve projects recommended for funding by the Technical Advisory Board were completed by December 31, 2011 (Table xxx).

Table 6. Projects approved by TAB for 2010/2011

Principal Investigators	Proposal Title	Amount Approved
1. Joe Pitula (UMES), Feng Chen (IMET), Eric May (UMES), Courtney Schupp (NPS)	Correlation of biotic and abiotic factors in environmental presence of *Hematodinium*	$28,842.00
2. Sook Chung (IMET), Joe Pitula (UMES), Gretchen Messick (NOAA)	Determining critical stages of *Hematodinium* infection and measuring environmental and physiological stress impact on infection	$31,179.00

3. Brad Stevens (UMES), Beth Babcock (RSMAS), Gary Shepard (NOAA)	Development of in-situ assessment and observation methods for black sea bass	$13,420.00
4. Adam Tulu (UMES-Student), Ali Ishaque (UMES), Rosemary Jagus (IMET), Chris Chambers (NOAA)	Development of molecular tools and methodologies to evaluate the effect of marine pollutants on Atlantic tomcod, *Microgadus tomcod*	$27,002.00
5. Matt Ogburn (SSU), Dionne Hoskins (SSU), Howard Schnabolk (NOAA)	Evaluation of restored intertidal oyster reefs using lidar	$22,060.00
6. Dionne Hoskins (SSU), Susan Abbott-Jamison (NOAA), Michael Jepson (NOAA)	Piecing together the historical role of African-Americans in Georgia's coastal fisheries using oral histories	$7,600.00
7. Andrij Horodysky (HU), Andrea Johnson (HU), Richard Brill (NOAA)	Sensory ecology of tautog: ecophysiological auditory and visual performance measures	$21,108.00
8. Al Place (IMET), Tom Rippen (UMES), James Morris (NOAA)	Taurine – the missing ingredient for development of fish free diets for aquaculture?	$34,297.00
9. Andrea Johnson (UMES), Andrij Horodysky (HU), Richard Brill (NOAA)	Temperature preferences of Atlantic croaker under hypoxic and normoxic conditions	$41,614.00
10. Carla Curran (SSU), Paul Pennington (NOAA)	The effect of structure on predation rates of parasitized and unparasitized grass shrimp	$30,500.00
11. Eric Schott (IMET), Dennis McIntosh (DSU), Gretchen Messick (NOAA)	Tracking pathogens of blue crabs along a climatological and latitudinal gradient	$41,217.00
12. Belita Nguluwe (UMES-Student), Andrea Johnson (UMES), Al Place (IMET), Anne Richards (NOAA)	Use of mitochondrial DNA markers to evaluate US Fishery management areas and effective population size of monkfish	$9,000.00

TAB Project Reports

Project Title: *Hematodinium* and Dinoflagellates in Coastal Bays

Investigators: Joseph Pitula, Feng Chen Co-PI
Scope of work: To investigate the diversity and biogeographic distribution of blue crab pathogen *Hematodinium* spp. in the Maryland coastal waters, and to correlate this with dinoflagellate populations coincident in these waters.
Project Description: Although dinoflagellate pathogen *Hematodinium* has been detected in various samples associated with blue crab tissues, we know very little if and how the pathogen transmits between crabs via water or sediment. Very few studies have been conducted to detect *Hematodinium* in the free living stages. We applied PCR based technology to detect the *Hematodinium* spp. in the natural environments. Water and sediment samples have been collected for two years along the Maryland coastal waters (the Delmarva Bay). The goal is to detect the blue crab pathogen in the water samples and understand their genetic diversity and population dynamics using molecular tools such as the cloning and sequencing method or DGGE fingerprinting method.
Thematic Area Addressed: Essential Fish Habitat
NOAA Collaborator(s): Frank Morado, Ph.D, Fisheries Pathobiologist , NOAA NWFSC, Seattle, Washington
LMRCSC Collaborator(s): Dr. Joseph Pitula
LMRCSC Research Student(s) trained: Ihuoma Njoku (UMBC), Whitney Dyson (UMES)
Start Date: Jan 2011 **Planned End Date:** December 2011

Planned and actual results of project: We conducted a two year survey, from 2010-2011, in which 48 of 546 (8.8%) of environmental samples from the Maryland and Virginia coastal bays were positive for *Hematodinium* sp. between April and November, as based upon endpoint PCR analysis specific to blue

crab isolates. Detection in both water and sediment was roughly equivalent, and there were no obvious seasonal patterns. However, there was a high detection in April water samples, which was unanticipated owing to the fact that sporulation events from infected crabs would not be expected in this early month of the seasonal disease cycle. Focusing on three sites of high prevalence (Sinnickson, VA; Tom's Cove, VA; and Newport Bay, MD) *Hematodinium* sp. population diversity was analyzed using standard cloning methods. Of 131 clones, 109 (83.2%) were identical, 19 displayed a single nucleotide substitution, and 4 contain two nucleotide substitutions.

Our data suggests a continuous presence of *Hematodinium* sp. in both water and sediment of a combined Maryland and Virginia coastal bay ecosystem. The detection of *Hematodinium* sp. in the water column in April is an earlier manifestation of the parasite than predicted, pointing to an as yet unknown stage in its development prior to infection. Its presence may be due to a sporulation event in adult blue crabs harboring infection and emerging from winter hibernation, or release of active dinospores from overwintering cysts. That the population is relatively homogenous ranging from April to November, at three distinct sites, supports a hypothesis that one species of *Hematodinium* is responsible for infections within the ecosystem.

As a result of this study, we have submitted the following manuscript for publication:

Temporal distribution of genetically homogenous 'free-living' *Hematodinium* sp. in Delmarva coastal waters and sediments Joseph S Pitula, Whitney D Dyson, Habibul B Bakht, Ihuoma Njoku, and Feng Chen.

It is currently under review in the Journal BMC Bioaquatic Systems. In addition, Dr. Pitula will be presenting the results at the 2012 Eastern Fish Health Workshop in Lake, Placid. The title of the invited talk is: Population Structure Of Environmental-Derived *Hematodinium* sp. In Chincoteague Bay. It will be presented in the session dedicated to the detection of parasites in aquatic systems. Finally, the data generated in this work has enabled Drs. Pitula and Chen to submit a grant with Frank Morado, of the Northwest NOAA Fisheries, to the North Pacific Research Board 2012. It is entitled: "Environmental investigations and population genetics of the parasitic dinoflagellate, *Hematodinium* sp., the causative agent of Bitter Crab Syndrome in North Pacific Tanner crabs, *Chionoecetes* spp. " This grant is currently under review.

How will results be incorporated into NOAA Fisheries operations? The outcome of this data is predicted to lead to better management strategies related to *Hematodinium* disease in crustaceans.

How will results be incorporated into LMRCSC research and curriculum?

Course Material: Dr. Pitula is currently teaching a genetics course for graduate students at UMES in 2012. The data can be incorporated into the curriculum as: genetic methods for identification purposes, and for comparative phylogenetic analysis. In addition, we will be offering an updated version of an environmental microbiology course, which in the past has focused on bacteria. Now, we can incorporate protistan studies into the curriculum.

PCR-DGGE training to LMRCSC students: On June 1-3, 2011, a PCR-DGGE training workshop was held in Dr. Feng Chen's lab. Dr. Jinjun Kan, an expert on DGGE provided a lecture and laboratory demonstration to a group of 10 students. This short workshop was mainly set up to train the summer intern, Ihuoma Njoku, an undergraduate student from UMBC who was supported by LMRCSC. In addition, Ammar Hanif and Whitney Dyson, the two other minority graduate students supported by LMRCSC also participated the training.

Outreach activities: Dr. Chen devoted a significant amount of time for mentoring and training high school students, high school teacher, undergraduate and graduate students in the past 6 months. The technician and graduate students in Dr. Chen's lab provided tremendous help for training the interns. The Chen lab trained eight high school students and one high school teacher from spring to summer 2011. They are Bilal Moiz (Mount Hebron HS, Fall 2010-Spring 2011), Daniel Kevin (Howard HS, Fall 2010-Spring 2011), Autumn Cadogan (Baltimore Polytechnic Institute, Fall 2010-Spring 2011), Benjamin Lao (Wild Lake HS, Summer 2011), Nicole Rusconi (River Hill HS, Summer 2011), Robert Luo (Poolesville HS, Spring-present 2011), Kenneth Hepburn (Parkdale HS, Biology/Chemistry teacher, Summer 2011),

Deja Duncan (Polytechnic Institute, Fall 2011-Spring 2012), and Tomas Richard (Howard County HS, Fall 2011-Spring 2012). These students learned how to perform basic research, deliver scientific reports and present their research to the public. Four of them are minority students. The high school teacher, Ken Hepburn was working on the *Hematodinium* project which is supported by LMRCSC. Ken was able to update his knowledge on molecular biology which will be beneficial to many high school students.

Project Title: **Determining critical stages of *Hematodinium* sp. infection, and measuring environmental and physiological stress impact on infection of the blue crab, *Callinectes sapidus***

***Project Description*:** Decapod crustaceans (blue, snow, and tanner crabs and lobster) experiencing environmental stress compromise their physiological capacity for survival, hence increasing molt- and life stage- dependent disease susceptibility (bacterial and parasitic infections and epizootic shell disease) and mortality. To understand the direct effects of stress on the animals' susceptibility to disease(s), we aim to identify critical stages to *Hematodinium sp* infection and to measure their stress responses, using hatchery raised naive blue crabs as a model organism. These data allow us to extrapolate stress-induced infection and mortality and to simulate the levels of environmental stress on animals for predicting possible future disease outbreaks and mortality in various coastal areas in the U.S.

Thematic Area Addressed*: Essential Fish Habitat*, *Aquaculture*

Lead Scientist(s): J. Sook Chung, UMCES@IMET

NOAA Collaborator(s): G. Messick, NOAA Oxford Lab

LMRCSC Collaborator(s): J. Pitula, UMES

LMRCSC Research Student(s): Z. Sankoh, Morgan State University, and Meagan Bratcher, UMES.

Start Date: Jan. 03, 2011

How will results be incorporated into NOAA Fisheries operations? The outcome of this project will allow us to extrapolate stress-induced infection and mortality and to simulate the levels of environmental stress on animals for predicting possible future disease outbreaks and mortality in various coastal areas in the U.S.

How will results be incorporated into LMRCSC research and curriculum? Research training was provided to undergraduate intern Z. Sankoh, Morgan State University (Sept. 1-Dec. 17, 2010) and Meagan Bratcher, UMES (June 1-Aug 5). J. Sook Chung incorporated the findings of this research into MEES 698M: Comparative and Molecular Endocrinology, Spring 2011.

Project Title: Development of in-situ assessment and observation methods for black sea bass, *Centropristis striata*

Project Description: Black sea bass (*Centropristis striata*) support an important commercial and recreational fishery in the Mid Atlantic Bight. Fish live offshore near the continental shelf edge during winter, migrate to inshore habitats in the spring for spawning, and return offshore in fall. Trawl surveys conducted by NOAA are not effective in sampling the heterogeneous inshore habitats, so there is no acceptable index of abundance for adult black sea bass. We propose to develop methods for surveying abundance of black sea bass in inshore waters using in-situ video technology. The goals of the study will be to understand how fish utilize habitat, and determine if we can assess abundance in a quantitative manner. In Year 1, we tested video observation systems to count and observe fish around traps. In Year 2, we will refine techniques for assessment and develop standard video sampling procedures.

Thematic Area Addressed: Quantitative Fisheries; Essential Fish Habitat

Lead Scientist(s): Bradley G. Stevens bgstevens@umes.edu

NOAA Collaborator(s): Gary Shepherd, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA. Gary.Shepherd@noaa.gov ; Vincent Guida, NEFC, J.J. Howard Research Laboratory, Sandy Hook, NJ Vincent.guida@noaa.gov

LMRCSC Collaborator(s): Elizabeth Babcock, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Rickenbacker Causeway, Miami, FL ebabcock@rsmas.miami.edu

LMRCSC Research Student(s): Dan Cullen (PhD Student) University of Maryland Eastern Shore; Courtney McGeachy (MS – UMES).

Start Date: 1 Jan 2011 **End Date:** 31 December 2011

Results of project: **T**his project supported a PhD student (Dan Cullen) and an M.S. student (Courtney McGeachy). Year 1 goals were 1) Build and test a video observation platform for assessing the abundance of BSB and compare baited vs. unbaited deployments (Cullen); and 2) Observe, classify, and quantify behavior of fish relative to traps and other fish in order to determine the effect of behavior on trap catches (McGeachy).

Field Sampling – Sampling occurred on 11 dates between 14 June and 4 August, 2011 at six sites off the Maryland coast near Ocean City, MD, between 25 and 35 m depth. Sampling was conducted from the chartered *F/V Andrew G* using two modified habitat traps (107 x 53 x 31 cm; 3.8 cm wire, with 3 escape vents). Five GoPro® HD Hero (720p resolution, 170º angle of view; Woodman Labs, Inc., California) cameras were attached to a steel frame 38 cm above each trap. For Subproject 1 (Trap 1), four cameras were placed on the sides facing outward while a fifth faced inward to record fish/trap interactions; sampling consisted of 60 minute continuous video and photos at 5 or 10 s intervals. Four deployments were made per day, alternating baited (squid) and unbaited traps. For Subproject 2 (Trap 2), four cameras were faced inward to observe fish in traps, and one faced outward; deployments were continuous for up to 4 hr in order to avoid disturbing fish. During all deployments, angling was conducted to capture fish near the traps for size comparison. The total length of fish caught by hook-and-line and traps was measured to the nearest centimeter. Over 97 hrs of video have been collected of which only about half have been examined to date. In August, 2011, additional observations were made at the NMFS J.J. Howard Lab in Sandy Hook, NJ, in a controlled-environment mesocosm (tank) containing a resident population of BSB. Trap 2 was placed in the tank, and fish behavior recorded for 4-5 hr on 5 consecutive days, with an additional camera set to observe the trap from the side of the tank.

Subproject 1 Results: Assessment of BSB abundance – Relative abundance of fish was estimated using the "MeanCount" method to estimate the average number of fish. Single frames were sampled systematically at 30 s intervals for the first 30 min of video, and the number of fish from all frames was used to calculate the MeanCount or average. The average number of fish counted was compared between baited and unbaited samples. Preliminary analyses indicate that more fish were observed over live bottoms, than on sandy bottoms, and presence of bait made little difference. Future analyses will be stratified by substrate type (sand/mud, shell) and/or the presence of structure (rock, coral, artificial) in the field of view. Over 40 hr of video were collected at sea using the inward-facing cameras on Trap 2, during which 7 fish were caught by the trap, and over 24 hr of video were collected in the mesocosm, during which 5 fish were caught. The proportion of approaching fish that entered the traps was 1.5% in the field and 3.2% in the mesocosm; these are significantly different from 1, but not from each other. Large male fish exhibited a greater proportion of agonistic behaviors in the mesocosm than in the field. During recording on Aug 23, 2011, an earthquake occurred which afforded a unique behavioral observation - all fish schooled into one corner of the tank 30 s prior to humans feeling any vibrations.

Presentations at regional, national, and international meetings: PhD Student Dan Cullen presented preliminary results of his work on assessment of fish abundance at the 2011 MEES Colloquium held at the Appalachian Laboratory in Frostburg, in October, 2011.

How will results be incorporated into NOAA Fisheries operations? We expect to achieve several goals with applicable results: 1) We hope to determine if video-based estimates are feasible, and if they are correlated with habitat and trap catches; if so, they can be used as a quantitative measure of abundance, and add to the available data base for stock management. 2) Understanding how fish behave in and around traps will allow better understanding of the meaning of trap CPUE, how it relates to fish abundance, and the natural progression of catch rates over time. This will allow managers to interpret CPUE and landings data with greater accuracy.

How will results be incorporated into LMRCSC research and curriculum? We expect that one PhD dissertation and one MS Thesis will be based partially on the results of this research. Data collected during the project will also be used in the class "Survey Sampling" taught by Dr. Stevens for training students to analyze fish stock assessment data.

Project Title: Development of molecular tools and methodologies to evaluate the effects of marine pollutants in the Atlantic tomcod, *Microgadus tomcod*

***Project Description*:** The Ishaque/Chambers laboratories are studying the effects of polycyclic aromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCB) contaminants in the estuarine species, *Microgadus tomcod*. As part of this project, UMES graduate student Adam Tulu has collaborated with Dr. Rosemary Jagus of UMCES-IMET to develop molecular tools and methodologies to assess the effects of PAH and PCB on the transcript levels of cytochrome 1A1 (CYP1A1) and cytochrome CYP19A (CYP19A). Under Dr. Jagus' guidance, Mr. Tulu has been successful in purifying RNA from tomfish samples generated in Dr. Chambers' laboratory, in cloning the cDNA for CYP1A1 and generating and cloning a partial cDNA sequence for CYP19A. To finalize his graduate studies, Mr. Tulu proposes to: a) complete the cloning of cDNA for CYP19A; b) generate in vitro transcripts of CYP1A1 and CYP19A for standard curves; and c) evaluate CYP1A1 and CYP19A transcript levels in fish exposed to PAH, PCB, or both, using RT-qPCR. A summer undergraduate intern will be recruited to assist in the processing of the many samples in need of analysis. The data gathered will be analyzed in the context of data already accumulated in this project including histological, biochemical and morphological response to the toxins. The 3'-end of the sequence was completed by 3' rapid amplification of cDNA ends (RACE)-PCR.
Thematic Area Addressed*: Quantitative Fisheries*
Lead Scientist(s):Adam Tulu, UMES; Dr. Rosemary Jagus, UMCES-IMET and Dr. Ali Ishaque, UMES
NOAA Collaborator(s): Dr. Chris Chambers, NOAA Fisheries Service (NMFS)
LMRCSC Research Student(s): Adam Tulu, UMES
Start Date: 01/03/11
Results of project*:* 3' rapid amplification of cDNA ends (RACE)-PCR has been successfully applied to construct the full length cDNA sequence of CYP19a aromatase. *In vitro* transcripts of CYP1A1 and CYP19A have been generated for standard curves and conditions for RT-qPCR determination have been optimized. CYP1A1 and CYP19A transcript levels have been determined in fish exposed to PAH, PCB, or both, using RT-qPCR. The study has demonstrated that PCBs alone, but not PAHs, have a significant effect on hepatic CYP1A and ovarian CYP19A. Furthermore, there is a significant interaction between the effects of PAH and PCB on ovarian CYP19A transcript levels, but not on hepatic CYP1A transcript levels. Morphological analysis assay quantify the morphological effects of PAH and PCB on Gonadosomatic Index (GSI), Hepatosomatic index (HIS), and Condition Factor (CF) as a biomarker. The structure and promoter sequences of CYP19A have been characterized in many different fish species and conserved protein domain of aromatase CYP19A, including I helix, heme-binding and oxygen-bindings has identified. The result of morphological assay indicate that adult tomcods of length (7.13±0.77 cm), and weight (7.53±2.72 g) did not differ significantly by sex or reproductive condition. When gonadosomatic index (GSI) was analyzed by ANOVA, both high-PCB and high-PAH concentration treatment groups have observed significant ($P<0.05$) gonadal loss. Hepatosomatic index (HSI) of reproductively matured females was indicated both levels of PCB and both levels of PAH have a significant effect on liver average weight compared with the control group. There was no significant PAH-PCB drug-drug interaction observed in any treatment group.

More accomplishments: In December 5, 2011 Adam Tulu successfully defended his dissertation. In November he made a poster presentation at the 41st annual AFS meeting in Seattle, WA. Currently he is in the process of compiling his dissertation and writing two manuscripts for publication. He is continuing to work on the cloning stage of identifying the 5' UTR region of aromatase CYP19A using rapid amplification of cDNA ends (RACE) cloning method. By the end of 2012 physical year, he expects to submit a complete amino acid and mRNA sequence of tomcod aromatase CYP19A to the NCBI sequence database. At least two papers will be published on aquatic toxicology in scientific journals and his dissertation will be submitted to the graduate office.

How will results be incorporated into NOAA Fisheries operations? The research will provide unique information on the relatedness of bioindicators, including measures of adult reproductive performance, and it will explicitly analyze the interactions among contaminants. These results extend beyond local species and systems to studies with similar concerns in other marine and estuarine ecosystems. The work has also provided a useful tool to investigate tomcod aromatase, CYP19A.
How will results be incorporated into LMRCSC research and curriculum? This funding is supporting the research of Mr. Adam Tulu towards completion of his Ph.D. thesis. The funds were also used to support a summer undergraduate intern, Jordan Gomes.

Project Title: Evaluation of restored intertidal oyster reefs using lidar

Project Description: Restoring Essential Fish Habitat (EFH) is a critical aspect of Ecosystem-Based Management, leading to the rebuilding and sustaining of healthy fish stocks in areas that have been heavily impacted by human activities. Habitat restoration projects using the eastern oyster *Crassostrea virginica* provide an exceptional model system for studying restoration outcomes because they are conducted across a wide geographic range and with a variety of materials and techniques. Efforts to restore oyster reefs have varied in their outcomes, but outcomes beyond the first year are rarely documented due to lack of funding for long-term monitoring. Oyster density and reef area are relatively straightforward to quantify, but such measures alone are insufficient to determine whether restoration projects provide similar ecosystem services to natural reefs. Restoration outcomes related to biological components of reef structure and food webs such as oyster growth, community development, and use by important fishery species can be particularly difficult to measure, with high variability among natural reefs preventing comparison between restored and natural reefs (e.g. Walters and Coen 2006). Assessment of improvements in water quality is advancing with the development of in situ measurements of phytoplankton uptake, but results differ depending on differences in oyster size and density relative to water flow and depth (Grizzle et al. 2006; Grizzle et al. 2008). Clear, quantifiable and inexpensive measures of restoration success are needed to evaluate the outcomes of oyster restoration projects. These could include rapid field assessments or remote sensing such as lidar, which has the potential to greatly enhance our ability to study emergent coastal ecosystems (Brock and Purkis 2009). In Georgia, as in other US Atlantic and Gulf Coast states, the oyster is a keystone species and dominant ecosystem engineer that has been an important fishery species and provides structure and foraging habitat for a wide range of commercially and recreationally important fisheries (NOAA 1998a, 1998b).

The purpose of this study was to develop rapid, inexpensive measures of intertidal oyster restoration success that could be assessed in the field or remotely using lidar. We recognized the importance of choosing clear goals for evaluating restoration success (Coen and Luckenbach 2000). For this study, we chose to use the percent cover of oysters and physical structure of the reef as our criteria for evaluating restoration success. Restoration was considered to be successful when the biological and physical characteristics of restored reefs were similar to those of naturally-occurring reefs.
Thematic Area Addressed: Essential Fisheries Habitat
Lead Scientist(s): Dr. Matthew Ogburn, SSU
NOAA Collaborator(s): Howard Schnabolk, NOAA Office of Habitat Conservation
LMRCSC Collaborator(s): Dr. Dionne Hoskins, NOAA Fisheries and SSU
LMRCSC Research Student(s): Eric Ransom, SSU (Undergrad); Tiffany Ward, SSU (Graduate)
Other collaborators: Dr. Jeb Byers (UGA), Daniel Harris (UGA Marine Extension), Brian Corley (UGA Marine Extension), Gabe Gaddis (GA DNR)
Start Date: January 2011 **End Date**: December 2011
Results of project:
Methods: To evaluate the vertical structure of natural intertidal oyster reefs, seven natural reefs and non-reef (control) areas were studied along the Wilmington River and other tributaries of Wassaw Sound in Chatham County, GA (Table 1, Fig. 1). These reefs were distributed along a salinity gradient in the Wilmington River estuary that varied from 35 to 20 at low tide. No natural oyster reefs occurred at lower salinities in this estuary. At each site, three transects each in reef and adjacent non-reef areas were established perpendicular to shore. Shoreline slope was determined from relative elevation measurements

taken at 1 m intervals along each transect from the marsh surface to the water's edge at low tide. Relative elevations was determined by placing a laser level on a PVC post at the marsh edge and measuring the distance from the laser beam to the sediment surface. Rugosity was measured at each 1 m interval using a modification of the chain-length method (Rogers et al 1983) by laying a 2-m chain parallel to shore so that it follows the vertical structure of the reef and measuring the actual horizontal distance covered. Rugosity was calculated using the equation $R = 1 - d/l$, where d is the horizontal distance covered by the chain and l is the length of the chain when fully extended (Aronson and Precht 1995). In the reef areas, seven additional rugosity measurements were made at the lower (approximately 0.5 m above low water) and upper (approximately 0.5 m below the edge of the marsh) reef resulting in a total of 10 rugosity measurements each on the lower and upper reef. Reef height was measured as the distance from the sediment surface to the tallest point along the chain used for rugosity measurements. One reef height measurement was taken for each rugosity measurement.

Twelve restored reefs (or sections of restored reefs constructed in different ways) were sampled for comparison with natural reefs (Table 1, Fig. 1). These restored reefs varied in age from a rock reef at SSU that was at least 30 years old to a shell bag reef at the GA DNR Coastal Resources Division headquarters that was in its first year. Biological and physical characteristics were measured using the same methods as for natural reefs except that the 7 additional rugosity and height measurements were not taken on all restored reefs. Differences among natural and both young (3 years or less) and old (5 years or more) restored reefs were determine using non-parametric Kruskal Wallace One Way Analysis of Variance Among Ranks due to the relatively low sample size (n = 10) for the upper and lower section of each reef.

Biological data

Percent cover estimates were recorded to compare reef structure data with the presence and oysters and other reef organisms. Percent cover estimates were made visually in 1 m^2 quadrats along each transect. Cover was estimated to the nearest 5% (due to the limited accuracy of visual estimates) for five dominant cover classes which were 1) live oyster, 2) dead oyster shell, 3) barnacles, 4) sand/mud, and 5) *Spartina alterniflora*.

Oyster density, mortality, and size distribution were recorded on the upper and lower reef to provide additional biological data for comparison with vertical structure. Oyster density was recorded as the number of live oysters in three 0.25 m^2 quadrats placed randomly along the upper and lower reef of each site. The ribbed mussel (*Geukensia demissa)* and hard clam (*Mercenaria mercenaria*) were also counted. Percent mortality was estimated by counting the number of recently dead oysters (clean shell with pearly-white interior) and dividing by the sum of live and recently dead oysters. The size distribution of oysters was estimated by measuring the shell height of 30 randomly selected oysters within each quadrat. Comparisons between the upper and lower sections of natural and restored reefs were made using Two-Way Analysis of Variance.

Remote sensing

Lidar data collected in 2009 (0.3 m minimum point density) were analyzed using LP360 in ESRI ArcMap. A challenge of using the lidar data for this study was that water covered approximately the lower half of the intertidal oyster reefs at most sites, limiting the extent to which comparisons could be made between field and lidar data. Shoreline slope of reef and non-reef areas was estimated by converting point measurements to 2-D creekbank profiles (Stockdon et al. 2009) for 6 of the 7 natural reef sites sampled in the field and determining the change in elevation that occurred over the 2 m of horizontal distance immediately adjacent to the water level. The Herb River site could not be analyzed using lidar data because it was nearly entirely submerged. Rugosity and height were estimated from the lidar data by extracting point data for an approximately 1 m wide by 5 m long strip parallel to shore and just above the water line. The standard deviation of point elevations was used as a proxy for rugosity and the difference between the maximum and minimum point elevations was considered to be reef height.

Lidar data were also used to aid in the estimation of the loss of marsh due to erosion in places where there were gaps in the fringing oyster reef. The horizontal distance and area eroded were determined for a total of 20 locations (the 7 reefs that were sampled in the field and 13 reefs sampled using lidar only) by using the measuring tools available in ArcGIS. Distance and area were measured

from the at -0.3 m elevation because this most closely approximated the lowest extent of Spartina. Distance and area of erosion were compared to stream width using linear regression.

Results:

Biological characteristics of oyster reefs differed between restored and natural reefs; however restored reefs appeared to become similar to natural reefs as they aged (Fig. 2). Oyster density was on the whole significantly higher ($p < 0.001$) in restored reefs (overall mean, ± S.D.; 281 ± 203 m^{-2}) than in natural reefs (216 ± 140 m^{-2}). Important differences were observed in the location of high oyster densities between natural and restored reefs. Natural reefs had significantly higher ($p < 0.001$) densities of live oysters in the upper reef (329 ± 82 m^{-2}) than in the lower reef (172 ± 152 m^{-2}), whereas restored reefs (especially reefs in their first or second growing season) had low densities in the upper reef (156 ± 119 m^{-2}) and very high densities in the lower reef (368 ± 202 m^{-2}) including a mean density of 716 m^{-2} on a shell bag reef in its third growing season. Percent mortality was 3-4% and did not vary among natural and restored reefs or upper and lower reef sections. Oyster size increased with restored reef age, with the size distribution approaching that of natural reefs within 3-8 years.

The rugosity and height of reefs was typically greater at the upper elevations of natural reefs and lower elevations of restored reefs (Fig. 3). Rugosity varied from 0.03 – 0.59 on natural reefs and from 0.01 – 0.51 on restored reefs. Reef height varied from 1 – 26 cm on natural reefs and 1 – 36 cm on restored reefs. There were statistically significant differences in rugosity and height among the upper and lower sections of reefs, with reef type (natural vs. restored) and reef age being important factors. The rugosity of natural reefs was significantly higher at upper elevations (0.35 ± 0.09) as compared to lower elevations of natural reefs (0.21 ± 0.11) and upper and lower elevations of both young and old restored reefs (Fig. 4). The upper elevation of young restored reefs had significantly lower rugosity (0.10 ± 0.06) than any other reef type or elevation. Reef height was greatest for lower elevations of young restored reefs (19 ± 9 cm) and lowest for the lower elevations of natural reefs (9 ± 4 cm) (Fig. 5). There was also some variability among reefs within each of these groups.

Natural reefs had steeper slopes than non-reef areas and restored reefs. The slope of natural reefs (0.23 ± 0.07) was significantly greater than that of non-reef areas (0.10 ± 0.04) and restored reefs (0.23 ± 0.23), and the slope of restored reefs was greater than that of non-reef areas ($p < 0.001$). However, nine of the restored reefs had relatively low slopes (0.12 ± 0.08), whereas three (Clam Creek, Tybee 2004, and Tybee 2009) had relatively steep slopes (0.56 ± 0.23).

Comparison of field and lidar data:

There was no relationship between rugosity or reef height when field and lidar methods were compared. Field measurements of rugosity and reef height varied from <0.01 to 0.58 and 0 to 21 cm respectively at elevations with comparable measurements whereas lidar estimates of rugosity (standard deviation of elevation in m) and reef height varied from <0.01 to 0.31 m and 3.6 to 96 cm. Linear regression did not reveal a significant relationship between field and lidar measurements of rugosity ($r^2 = 0.008$, $p = 0.609$) or reef height ($r^2 < 0.001$, $p = 0.99$). Field data used for the method comparison allowed for the detection of differences between natural reefs and non-reef areas for both rugosity ($U < 0.001$, $p < 0.001$) and reef height ($U = 7.5$, $p < 0.001$), whereas no differences were detected using lidar data (rugosity: $U = 112$, $p = 0.117$; height: $U = 108$, $p = 0.090$).

Estimates of slope using field and lidar methods were reasonably comparable and both methods could be used to distinguish between natural and control areas. Field measurements of slope at elevations with comparable measurements varied from 0.03 to 0.37, whereas lidar measurements varied from 0.03 to 0.42. There was a significant linear relationship between field and lidar measurements ($r^2 = 0.66$, $p < 0.001$). Significant differences between natural reefs and non-reef areas were detected using both field ($U = 4.5$, $p < 0.001$) and lidar data ($U = 32$, $p < 0.001$). However, there was greater overlap of observations for lidar (44.4%) than for field measurements (16.7%).

Discussion:

Restored intertidal oyster reefs in Georgia largely appear to be undergoing successful development into functioning reefs that are similar to natural reefs. Restored reefs that are at least 5 years

old appeared to be approaching, but were not yet identical to, the physical and biological structure of natural reefs for most characteristics measured in the field. However, the older reefs sampled in this study were very small (<20 m^2) and may not be representative of larger restoration projects. Walters and Coen (2006) reported that faunal community differences between natural and restored reefs were still apparent after 7 years, which is generally consistent with our findings that the physical and biological characteristics of restoration projects was still dramatically different from natural reefs after three years and somewhat different after 5-8 years. We will be conducting long-term monitoring of several large restored reefs to follow their development over time to gain a clearer understanding of the timeline of reef development.

An interesting and unexpected aspect of reef development has been that recently restored reefs (<5 growing seasons) had the highest densities of live oysters in the lower reef, whereas natural reefs and older restored reefs typically had higher densities in the upper reef. Natural reefs also had higher rugosity and taller vertical structures in the densely colonized upper reef than the lower reef. Many restored reefs had the highest rugosity and greatest height at the lower reef. This appeared to be because wave energy prevented sedimentation from burying lower sections of restored reefs (especially shell bag reefs), whereas upper sections of some restored reefs were mostly covered in sediment after only a few months. Oyster recruitment is also likely to be greater at lower elevations of the reef. Further research is needed to determine the causes of these differences, but development of habitat structure similar to that of natural reefs is likely critical for restoration projects to develop natural ecosystem functions (e.g. Soniat et a. 2004, Grabowski et al 2008).

Oyster restoration projects constructed using shell bags (sometimes placed on pallets) and bundles of oak branches outperformed reefs constructed using rock or coated PVC. We evaluated these materials against the criteria that restored reefs resemble natural reefs in both the percent cover of live oysters and the physical structure of the reef (rugosity and height). Shell bag and oak bundle reefs both closely resembled natural reefs, whereas rock and PVC had much lower percent cover of oysters and taller, more rugose structures than natural reefs. The results of this study suggest that it is unlikely that rock or coated PVC reefs will develop to resemble natural reefs, especially given that the rock reef on which we collected data had been in place for at least 30 years. Thus, shell bag or oak bundle reefs are most likely to create self-sustaining oyster reefs that grow to resemble natural reefs. It should also be noted that we visited (but did not sample) a reef constructed of coated bamboo that appeared as though it would perform similarly to the oak bundle reef.

Although airborne lidar appeared to be a compelling tool for monitoring restoration projects (e.g. Brock and Purkis 2009), it did not turn out to be useful for measuring the physical structure of intertidal oyster reefs. One challenge was that the lidar system used to collect the data analyzed in this study does not penetrate water and the tide was high enough to cover much of the oyster reef in most areas. In areas where sufficient reef was exposed for analysis, variability in the elevation data was equal to or greater that the differences in elevation measured in the field. Thus, the precision of the lidar data at the marsh edges was insufficient to detect differences in reef rugosity and height. Similar issues with elevation data at the marsh edge have been noted by others using the same lidar dataset (Mike Robinson, pers. comm.). The lidar data did turn out to be useful for determining the area of marsh lost to erosion in gaps between intertidal oyster reefs. The area of marsh lost was proportional to creek width, suggesting that oyster restoration may be most effective at preventing marsh habitat loss in wider creeks and rivers.

Future Plans:

A draft educational module on oyster reef ecology has been developed for use in K-12 classrooms. The module focuses on the ecosystem services provided by oyster reefs and the importance of restoring reefs to the coastal ecosystem. Scheduling conflicts prevented the teaching of the module during the fall semester. However, an SSU graduate student who is a NSF K-12 is in the process of coordinating the teaching of the module in the class that she is assigned to. We anticipate that the module will be taught in early 2012.

How will results be incorporated into NOAA Fisheries operations?

This project addresses NOAA's targeted research area of Essential Fisheries Habitat. NOAA has funded a number of habitat improvement projects in GA that were evaluated in this project. Our results indicate that some oyster restoration projects in Georgia appear to be meeting our criteria for success which are re-establishing the structural complexity and percent cover of live oysters of natural reefs. Oyster reefs constructed with both shell bags and oak bundles appear to be successful, although shell bag reefs are susceptible to sedimentation at upper reef elevations. One way to address this issue may be to construct a reef with shell bags at lower elevations and oak bundles or bamboo spat sticks at upper elevations. Alternatively, a reef could be constructed in two phases, with the lower reef constructed first and the upper reef constructed later after sediment has filled in behind the lower reef, thus raising the elevation of the upper portions of the restored reef. Rock and concrete-coated PVC do successfully recruit some oysters, but these structures do not appear to result in reefs that resemble natural oyster reefs either in physical structure or percent cover of live oysters. While reefs constructed with these materials may provide some of the ecosystem services of natural reefs (e.g. habitat structure, foraging habitat for nekton), we think that restoration efforts should focus on constructing reefs that restore habitat that is as close to the natural habitat as possible.

We also anticipate that the study will inform restoration monitoring programs. Our results suggest that airborne lidar is not currently adequate for assessing the physical structure of oyster restoration projects. Thus, continued field monitoring of project will be needed to determine if projects are meeting restoration goals. To this end, we have initiated long-term field monitoring of three NOAA OHC funded restoration projects in Georgia. This long-term monitoring program will provide critical data for evaluating best practices in intertidal oyster restoration, especially considering that funding is rarely available for long-term monitoring of restoration projects.

How will results be incorporated into LMRCSC research and curriculum?

This research has provided a summer internship for an undergraduate student, Mr. Ransom. He wrote up his results as part of his senior research thesis class and presented a poster at the 2011 Coastal and Estuarine Research Federation meeting in Daytona Beach, FL. Ms. Ward has completed her first semester of the SSU Marine Sciences graduate program and also presented the results of this study in an oral presentation at the CERF meeting. She is using the results of this study as preliminary data for her M.S. thesis proposal. In addition, the project is part of a partnership between SSU and NOAA's Office of Habitat Conservation to conduct long-term monitoring of oyster restoration projects. This project allowed us to set up several long-term monitoring sites and collect the initial data. Our initial oyster monitoring in fall 2010 (prior to the receipt of this award) was conducted by a graduate research methods course taught by Dr. Ogburn. Ms. Ward will lead the monitoring effort and will coordinate with SSU faculty to incorporate the monitoring program into their courses.

Project Title: Sensory ecology of tautog: ecophysiological auditory and visual performance measures

Project Description: The ecophysiological abilities of coastal fishes to cope with environmental variability and anthropogenic stressors have received little attention. We therefore seek mechanistic insights into the influence of biotic and abiotic processes on the auditory and visual systems of tautog as a companion project to our earlier study of the sensory systems of black sea bass. We will evaluate these ecophysiological performance measures as assays of essential fish habitat, predator-prey interactions, and anthropogenic stressors. This proposal responds directly to research priorities delineated in the LMRCSC RFP, and directly supports the mission of NOAA-Fisheries, and provides research experience for undergraduate students.

Thematic Area Addressed: Essential Fish Habitat

Lead Scientist(s): Dr. Andrij Z. Horodysky, HU

NOAA Collaborator(s): Dr. Richard Brill, NMFS-NEFSC

LMRCSC Collaborator(s): Dr. Andrea K. Johnson, UMES

LMRCSC Research Student(s): Elizabeth Seagroves, HU undergraduate; Krysten Rybyzynske, UMES undergraduate

Start Date: 01/11 **End Date:** 12/11

Planned and actual results of project:

Project Objectives and Achievements: Tautog were obtained by hook and line and vented at the time of capture to avoid barotrauma. Two fish that exhibited exopthalmia at the time of capture expired before venting could be completed. Fish were transported by Dr. Horodysky to the VIMS Eastern Shore campus and maintained in temperature controlled, filtered, sterilized, and oxygenated recirculating 1000 L aquaria maintained at 32 ppt and 16 ^{o}C. Tanks were assayed 1-5 times daily for temperature, salinity, oxygen, and ammonia levels.

A) AUDITORY ECOPHYSIOLOGY

1. Characterize the frequency sensitivity and pressure and particle motion thresholds of Tautog, and 2) Using auditory thresholds, calculate theoretical auditory ranges as a function of depth.

- Auditory brainstem response experiments were conducted for nine tautog (530-1310 g), resulting in six complete datasets. For each fish, experiments included stimuli from (i) a speaker that presented both pressure and particle motion components of sound (range: 100-2000 Hz), and (ii) a vibration mini-shaker that presented predominantly particle motion (range: 100-1000 Hz). The large nuccal hump and extremely tough skin of tautog presented issues for proper placement of fine wire electrodes, and their copious mucus made the recording of auditory evoked potentials very challenging (mucus causes reference and recording electrodes to short to each other, damping the recorded signal). These issues were overcome via the use of implanted stainless steel needle electrodes and by adjusting the duration of stimulus presentation and increasing the number of recorded signal averages by an order of magnitude, which unavoidably lengthened the duration of experiments. Tautog demonstrated auditory brainstem responses from 100-600 Hz when stimulated with the shaker apparatus and 100-1200 Hz when stimulated by the speaker; in both cases, the species exhibited greatest sensitivity to low frequency stimuli (200-300 Hz). At all frequencies, tautog exhibited fairly high thresholds to speaker stimuli, demonstrating poorer auditory performance than black sea bass (Horodysky et al., unpublished data) or other coastal fishes surveyed with the same technique (Horodysky et al., 2008a; Horodysky, in preparation). These results suggest that tautog survey the auditory scene of the temperate reef environment at low frequencies, and that sensitivity to faint sounds and to higher frequencies (e.g., high frequency invertebrate stridulation noises) may not provide a selective advantage to the species. Analyses of tautog hearing data are ongoing. Auditory thresholds have been calculated. Pressure and particle motion fields of the stimuli in experimental tanks are being calculated from the data obtained in summer 2011.

B) VISUAL ECOPHYSIOLOGY

3. Characterize the luminous (intensity) sensitivity, flicker fusion frequency (speed of vision), and chromatic (color) sensitivity of tautog.

- We used whole-animal corneal electroretinography (ERG) to examine potential circadian changes in the response of tautog (*Tautoga onitis*) visual systems to light stimuli varying in wavelength (spectral sensitivity), intensity (luminous sensitivity), and temporal properties (flicker fusion frequency, FFF). Experiments were conducted for nine individuals (1140-2250 g), resulting in nine complete datasets. Tautog demonstrated fairly high and diel-invariant sensitivity to dim light (dynamic range of 2.2 log cd m^{-2}) and moderate speeds of vision (FFF_{day} 38 Hz; FFF_{night} 34 Hz), consistent with patterns observed in other deeper-dwelling and temperate reef-associated fishes with which they co-occur. The eyes of tautog are comparatively more sensitive and slower than those of most shallow-dwelling coastal sciaenids (Horodysky et al., 2008b) and epipelagic coastal piscivores (Horodysky et al., 2010). Tautog exhibited broad spectral sensitivities from 400-560 nm, with peak sensitivity circa 490 nm (blue-green wavelengths). Rhodopsin templates fitted to the photopic spectral sensitivity data via maximum likelihood suggest the presence of a two cone pigments: one centered in short blue wavelengths (464 nm) and another at longer green wavelengths (525 nm). These results are consistent with seasonal migration patterns from the shallow green-yellow coastal waters in cooler months to the deeper blue-green coastal waters during spawning in warmer months, and correlate well to results from other coastal fishes (Horodysky et al., 2008; 2010). Collectively the visual systems of tautog and other temperate reef fishes thus correlate well with the photoclimate and light niches they inhabit. Analyses of tautog vision data are complete.

4. Provide intensity thresholds for the lower and upper limits of visual function

- The dynamic range (5-95% of maximum intensity response) of tautog was 2.2 log cd m^{-2}, indicating a lower (5%) threshold of -1 log cd m^{-2}. The upper threshold resides between 1-2 log cd m^{-2}. It was beyond the scope of this study to measure the minimum intensity above threshold that causes retinal damage, or to measure the scope and permanence of that damage with increasing intensity above the upper threshold. Analyses of tautog vision data are complete.

5. Determine whether visual and auditory responses of tautog are correlated with gender (male, female, and intersex) and gonadal development.

- On the basis of macroscopic gonadal assessment, there is no evidence that visual functions differs among sexes. Histological assessment of gonadal development is ongoing at UMES.

6. Provide recommendations to aquaculture and management agencies involved with habitat issues and production of tautog in the mid-Atlantic region.

- Although the role of audition in the ecology of tautog is not well understood, their nearly exclusive sensitivity to low frequency sounds suggests that low frequency noise pollution associated with marine construction and the operation of offshore wind farms and oil platforms may present particular challenges to the species. Tautog are presently overfished, and overfishing is occurring. Given these concerns, we recommend that future work investigates the potential sublethal effects of high background noise conditions on potential losses in yield due to stress, growth performance, and/or fecundity.
- Tautog visual systems are well adapted for foraging during daylight hours in coastal waters of the mid Atlantic. Increased turbidity due to eutrophication, development/runoff, or siltation-producing activities such as coastal and marine construction present likely impediments to foraging and/or reproduction in the species. Visual ecophysiology experiments and husbandry experience through this project suggest that tautog culture operations strongly consider (i) shading holding/grow tanks from mid-day light intensities and (ii) providing refugia within holding or grow tanks for tautog to inhabit. Attempts to feed tautog pelleted or freeze-dried food were repeatedly unsuccessful – live bivalves illicited the strongest feeding responses in captivity.

How will results be incorporated into NOAA Fisheries operations? The overall goals of this project are to provide sensory data relevant to the habitat use and resiliency, to anthropogenic stressors and habitat degradation of a managed fisheries resource consistent with the missions of LMRCSC and

NOAA-Fisheries. Such data form baselines to better quantify potential impacts of habitat changes on spatial and temporal use of nursery habitats. This project builds upon previous studies on fish sensory ecology in the Mid-Atlantic region that have been published in the scientific literature. The results of this study will be reported to local, state, and federal constituents as well as at national scientific meetings.
How will results be incorporated into LMRCSC research and curriculum?
Elizabeth Seagroves, the HU undergraduate student on the project, attended the 2011 national American Fisheries Society Meeting with funds from this project in September 2011, to learn and observe Ms. Kendyl Crawford present our 2010 TAB-funded black sea bass vision data. Ms. Seagroves subsequently presented the our summer 2011 tautog vision data at the 2012 Ocean Sciences Meeting in Salt Lake City, Utah in February 2012. Ms. Seagroves reported having a very good experience, and as a result of the research and training experiences, and the 'acceptance' of her work by the scientific community, she is now interested in pursuing graduate training in fisheries/marine science.

Dr. Horodysky presented a talk entitled 'Sensory ecophysiology of temperate reef fishes in coastal Mid-Atlantic waters: form-function-environment syntheses' at the 6th Biennial NOAA EPP Forum. The talk combined the tautog and sea bass vision and hearing datasets. Students Kendyl Crawford and Elizabaeth Seagroves were listed as coauthors.

Drs. Horodysky, Johnson, and Brill are building a comparative database of sensory function in temperate reef-associated fauna that remain highly susceptible to overfishing due to their typically slow growth, complex life-history and reproductive habits, and high exploitation rates due to the ease of location of reef habitats where these species aggregate. Other threats to these fauna include marine construction and development of oil-drilling and wind farm operations proposed along the Mid-Atlantic seaboard.

Project Title: Taurine – the missing ingredient for development of fish free diets for aquaculture?

***Project Description*:** Develop and evaluate commercially viable husbandry technologies for new candidate species in both near-shore, offshore, and land-based aquaculture systems. (NMFS Objective 4.5) and b.) Develop alternative feeds for aquaculture (NMFS Objective 4.4).
***Thematic Area Addressed**: Aquaculture*
***Lead Scientist(s)*:** Dr. Allen R. Place, University of Maryland Center for Environmental Science, Institute of Marine and Environmental Technology
***NOAA Collaborator(s)*:** Ronald B. Johnson NOAA, NWFSC, Seattle, WA 98112, USA
***LMRCSC Collaborator(s)*:** Thomas E. Rippen, Seafood Technology Specialist, UMES, Princess Anne, MD 21853
***LMRCSC Research Student(s)*:** An LMRCSC summer intern will be hired for the summer of 2012
Start Date 1/1/2011

Results of project: So far on this project we have completed taste testing of gilthead sea bream, *Sparus aurata*, Striped Bass, *Morone saxitilis,* and cobia, *Rachycentron canadum*. The taste testing panel examined whether differences could be determined between fish raised on fishmeal based diets and those raised on plant protein based diets. The tests for each species were conducted separately, so comparisons between the species were not conducted, only within each species between the diet types. The results of the taste testing showed that the panel members could not tell a difference in taste with any species between the diet types, an encouraging result meaning that raising fish on plant proteins does not negatively affect their taste when compared to fish raised on more traditional, fishmeal based diets. There were however differences in the shear force of both fresh and cooked fillets for each species with the fillets from fish raised on plant proteins consistently requiring less force to shear, which corresponded to a higher water content of those fillets (Table 7). The work with striped bass and gilthead sea bream was presented in a 15 minute presentation at the Aquaculture America conference in Las Vegas, NV in March of 2012 by Aaron Watson, and poster featuring the work done with all three species was presented at the NOAA EPP meeting in Tallahassee, FL in March of 2012.

Table 7. Peak shear force required to shear fillets from gilthead sea bream and striped bass, both cooked and fresh, raised on fishmeal or plant protein based diets.

Species	Diet	Fresh/Cooked	Peak Shear Force (g)
Gilthead Sea Bream	Fishmeal	Fresh	11,641.0
Gilthead Sea Bream	Plant Protein	Fresh	10,819.5
Gilthead Sea Bream	Fishmeal	Cooked	19,297.6
Gilthead Sea Bream	Plant Protein	Cooked	7,294.8
Striped Bass	Fishmeal	Fresh	17,299.2
Striped Bass	Plant Protein	Fresh	12,922.5
Striped Bass	Fishmeal	Cooked	45,532.0
Striped Bass	Plant Protein	Cooked	22,689.4

Leveraged funding: We are currently in the process of extending this work with Mike Rust and Ron Johnson (NOAA) with sable fish. Also, there is potential for getting some extra funding working with Shin Kwon Kim from Korea and the Soy industry to support our work if we can put together a joint project which would include IMET, NOAA and Shin Kwon's lab.

How will results be incorporated into NOAA Fisheries operations? Results of this work are helping to establish the minimum taurine requirement and its effects at different inclusion levels for several commercially important species in aquaculture. We believe that taurine plays a major role in allowing the reduction and elimination of fishmeal as the aquaculture industry seeks fishmeal replacements from more sustainable, plant protein based sources. Aiding the ability to reduce fishmeal and possibly fish oil through taurine inclusion and the use of sustainable products will greatly enhance the ability of the aquaculture industry to increase global production to meet the ever increasing global demand for high quality, safe seafood. Organoleptic testing of fillets from fish raised on fish product free diets is a necessity in this process to ensure customer acceptability, and thus far our work in this area has shown with three separate, high value species that there are no negative effects on taste, odor, or texture as perceived by a taster, with the use of plant based, fishmeal free diets. This end point data is critical to continuing the push throughout the industry to transition away from the use of fshmeal and other fish products in diets for aquaculture

How will results be incorporated into LMRCSC research and curriculum? This project is 25 % support and graduate training to Aaron Watson and provided training to a summer undergraduate intern. An LMRCSC summer intern will again be hired in the summer of 2012 to help us continue to explore the effects of taurine addition to plant based feeds for aquaculture species.

Project Title: Temperature preferences of Atlantic croaker under hypoxic and normoxic conditions

Project Description: Atlantic croaker (*Micropogonias undulatus*), an economically and ecologically important demersal species common in Chesapeake Bay, was used as a model species to assess the mechanistic influence of normoxic and hypoxic conditions on temperature preference and movements using a custom videography behavioral preference system. The results of this study complement currently funded work (NSF-CREST) that assesses croaker movement in Chesapeake Bay via telemetry. Our intent is to provide a model approach which can be applied to other fish species. Coupled with habitat mapping of the Chesapeake Bay, we provide important information on how essential fish habitat (EFH) is affected by increases in the spatial extent and duration of seasonal hypoxia in Chesapeake Bay.

Thematic Area Addressed: Essential Fish Habitat
Lead Scientist(s): Dr. Andrea K. Johnson, UMES

NOAA Collaborator(s): Dr. Richard Brill, NMFS-NEFSC
LMRCSC Collaborator(s): Dr. Andrij Z. Horodysky, HU
LMRCSC Research Student(s): Elizabeth Seagroves, HU undergraduate; Krysten Rybyzynske, UMES undergraduate
Start Date: 01/11 **End Date:** 12/11

Planned and actual results of project:
Project Objectives and Achievements: Atlantic croaker were obtained from commercial fishing contacts and transported to the VIMS Eastern Shore Laboratory. Fish were maintained in temperature controlled, filtered, sterilized, and oxygenated recirculating 1000 L aquaria maintained at 18 ppt and 25^{o}C. Tanks were assayed 1-5 times daily for temperature, salinity, oxygen, and ammonia levels.
At the time of a trial, a single croaker was removed from the holding tank and implanted with a small plastic sample identifying tag (Hallprint Ltd) that was affixed with high gain reflective tape. Each fish was then transferred to a ~ 50L behavioral Shuttlebox tank maintained at normoxia at 22-24^{o}C and 18 ppt salinity that was illuminated with a single white 23W fluorescent bulb. The system consists of two round chambers (39 cm in diameter) connected by a short (10 x 6 mm) raceway and includes two recirculation pumps, four dosage pumps (for inflow from warm and cold baths), two temperature mixing towers, a CCD video camera, and two temperature probes to monitor temperature continuously. Custom ShuttleSoft software (Loligo Systems) tracked the movements of the animal throughout the Shuttlebox tank sections and controlled temperature accordingly. Changes in temperature were controlled by a DAQ instrument that regulates the activity of sets of pumps, depending on the position of the fish. Passage of the fish into the warmer side of the tank prompted the dosage pumps to increase the temperature in both tanks; the reverse occurred if the fish swam into the low temperature tank. A 2^{o}C temperature difference was constantly maintained between the two circular tank sections, regardless of the direction of change. Oxygen saturation was monitored via a galvanic oxygen electrode which measured the content of water returning from the right hand (decreasing) circular section. Custom data acquisition software (DasyLab) controlled the addition of oxygen or nitrogen to the system to attain the desired experimental setpoint. Experiments were conducted for 24 hrs each at normoxia (> 90% O_2 saturation), moderate hypoxia (50% O_2 saturation), and severe hypoxia (25% O_2 saturation). Full normoxia-hypoxia protocol data were obtained for eight croaker; normoxia-only data were collected for an additional three croaker to establish baseline behavior. At the conclusion of each Shuttlebox experiment, all fish were euthanized and blood, liver, and gonad tissues were sampled from seven individuals for histological and biochemical assays.

1. Determine the temperature preference of Atlantic croaker under normoxic conditions and two levels of hypoxic exposure.

- Atlantic croaker used in these experiments were fairly small (192-236 mm TL, 84-145g), approaching sexual maturity (Gonadosomatic index: 0.29-1.02). Croaker exhibited fairly broad time-at-temperature distributions at normoxia (range 13-32^{o}C); selected temperatures generally decreased with oxygen content . At normoxia, croaker exhibited a broad affinity for temperatures ranging from 19-25%. At 50% oxygen saturation, fish exhibited a bimodal affinity pattern for 19^{o}C and 23-24^{o}C, which may be indicative of fish moving between the 'warm' and 'cold' sections of the experimental tank sections searching for more optimal oxygen conditions. It is worth noting that the temperature distribution of croaker at 50% oxygen saturation was constrained relative to normoxia-croaker spent less time at the extremes of the temperature distribution. At 25% saturation, croaker decreased general activity levels in the Shuttlebox tank, strongly preferring cold water (mode: 16^{o}C). These results are consistent with general inferences into croaker physiology, as 25% oxygen saturation levels roughly correspond to the inflection point between aerobic metabolism and anaerobic debt (R. Brill, J. Peyton, and A. Johnson, personal observation). Minimized activity and selection of colder water are common mechanisms fishes use to endure hypoxia (Schurman et al., 1991). Statistical analyses of the complex autocorrelated behavioral data are underway. We are investigating mechanisms to model the within-individual autocorrelation and covariance in using both frequentist and information theoretic approaches.

2. Evaluate the effects of temperature and hypoxia treatment on Atlantic croaker general health.

- Based on size ranges, gonadosomatic index (GSI), and macroscopic assessment of gonad stage, croaker in these experiments were late juveniles and early adults approaching sexual maturity (GSI: 0.29-1.02). Spleno-somatic index (SSI) ranged from 0.05-0.07, and hepatosomatic index (HSI) ranged from 0.4-1.0. Histological analyses of these tissues and microscopic analysis of blood cell counts are on-going.

3. Integrate observed physiological and behavioral responses determined in laboratory (this project) to telemetered field movements (horizontal and vertical; NSF-CREST-funded research), and to changes in water quality and other environmental variables measured in the field.

- On the basis of this initial investigation of croaker behavioral thermoregulation, and to codify laboratory-field integration, we wish to expand the project in 2012 as part of Dr. Johnson's UMES graduate student's doctoral dissertation (H. Wolfer). The use of a larger Shuttlebox tank will allow behavioral experiments to be conducted on the larger size class of adult croaker that are being tracked in the NSF-CREST project. Additionally, adjustments to videography via infrared illumination, rather than the white-light illumination we used, will allow the future assessment of potential diel differences in thermoregulation. These combined modifications would improve mechanistic insights into croaker behavioral thermoregulation and allow stronger integration between laboratory and field inferences.

4. Provide recommendations to management agencies involved with habitat issues in the mid-Atlantic region.

- This project provides preliminary insights relevant to the habitat use and resiliency to anthropogenic stressors and habitat degradation of Atlantic croaker consistent with the missions of LMRCSC and NOAA-Fisheries. Results of this project will be made available to state, regional, and federal fisheries and management agencies.

How will results be incorporated into NOAA Fisheries operations? This project provided preliminary insights relevant to the habitat use and resiliency to anthropogenic stressors and habitat degradation of a managed fisheries resource consistent with the missions of LMRCSC and NOAA-Fisheries. Such data form baselines to better quantify potential impacts of habitat changes on spatial and temporal use of nursery habitats. This project provides a critical laboratory behavioral link to codify leveraged laboratory and field research (NSF-CREST). The results of this project support an ecosystem-based approach to the ecophysiology of fisheries resources that use coastal mid-Atlantic waters**.**

How will results be incorporated into LMRCSC research and curriculum? Data from this project will be included in lectures in Dr. Johnson's Fish Physiology Course and Dr. Horodysky's Ichthyology course. Drs. Horodysky, Johnson, and Brill wish to build a comparative database of ecophysiological function in benthic fisheries resources.

Project Title: Tracking pathogens of blue crabs (*Callinectes sapidus*) along a climatological and latitudinal gradient

***Project Description*:** In collaboration with the DE NERR staff and a DSU graduate student, trawling will be conducted in the lower St. Jones River and nearby DE Bay NERR in June and October. Graduate student Ammar Hanif is overseeing subsequent crab sample processing and pathogen analyses with Dr. Schott. A summer undergraduate intern from a minority serving institution will also participate in sample collections (June-July) in the DE NERR. Additional crabs will be collected by partners in NJ, CT, and MA, and shipped to IMET for pathogen analyses. DNA and RNA will be extracted from crab samples (Schott, Hanif, Torres) and subjected to PCR analyses for the pathogens, *Hematodinium* sp. and blue crab reovirus. Prevalence of each pathogen will be calculated. These will be the first assessments of these two diseases in the Northeast. A specific objective of the project is to establish relationships with partners throughout the Northeast to allow the long term monitoring of blue crab health. The goal is to 1)

establish sampling and shipping protocols, and 2) have these new collaborations continue and improve, with the result that the consortium of partners will be in a position to apply for funding from other external sources to continue blue crab diseases monitoring beyond the term of the LMRCSC grant. One additional benefit of the multi-partner collaboration is the exposure this will provide to graduate and undergraduate LMRCSC students.
Thematic Area Addressed*:* Quantitative Fisheries, Essential Fish Habitat
Lead Scientist(s)**:** Eric J Schott, UMCES-IMET
NOAA Collaborator(s)*:* Gretchen Messick, NOAA NCCOS Cooperative Oxford Lab, Ron Goldberg, NOAA NMFS Milford Lab
LMRCSC Collaborator(s)*:* Dennis McIntosh, DSU
LMRCSC Research Student(s)*:* Ammar Hanif (graduate student, Univ of MD), Laura Torres (summer intern, UTPA).
Start Date: Jan 1, 2011

Scope of work:
1. Determine the early and late season *Hematodinium* sp. and RLV prevalence in blue crabs within the DE NERR. [Schott and McIntosh]
2. Measure *Hematodinium* sp. and RLV prevalence in blue crabs of mixed age/size classes along a climatic and latitude gradient from DE Bay to southern Massachusetts. This entails coordinating the collection and shipment of crabs from partners within MA Division of Marine Fisheries (B. Estrella), NOAA Milford Lab (R. Goldberg), NJ NERR (P. Jivoff, Rider University), and the DE NERR (R. Scarborough). [Schott]
3. Establish a process and network to conduct long term crab disease monitoring in the region, to enable correlations between disease, crab abundance, and climate change. [Schott and McIntosh]

Planned and actual results of project: The project will measure prevalence of the protozoan parasite, *Hematodinium*. sp. and the viral pathogen, RLV, in blue crabs from DE Bay to Southern Massachusetts. This will establish the first data on these two diseases of blue crab in this geographic region. As the regional climate warms, blue crab populations may increase, as may the pathogens that afflict crabs. With the exception of DE Bay, the majority of crab sampling is occurring this month, and pathogen analyses will not be completed until November.
Early season crabs were trawled from the DE Bay NERR by graduate student Ammar Hanif and summer intern Laura Torres (from Univ. of Texas, Pan American). Hanif and Torres analyzed over 50 crabs for pathogens, finding no prevalence of either in the June-July samples.

In late August, an opportunity arose to capture blue crabs in a salt pond of Long Island, adding a 5th location to the regional survey. These salt ponds are unusual, closed, settings, in which crabs are recruited in the early summer when the ponds are opened to the sea for several weeks. After the barrier to the sea rebuilds, there is no transport of blue crabs to or from the sea. Presumably, crab pathogens also do not enter after the closure. Analysis of these crabs is underway.

In the Northeast, with the decline of the lobster harvests, and the possible expansion of blue crab populations, there is a growing interest in the health and abundance of blue crabs. As a result of our partnership with NOAA Milford lab, we were asked to analyze crabs from a mass mortality that occurred in Long Island Sound in May and June. We did not find evidence that either pathogen was at work; we also understand that the deaths could be explained by sudden changes in temperature and salinity.

Correlations of disease prevalence with latitude and water temperatures will be investigated, and will be more meaningful if extended over a 3-5 year period. Developing preliminary data to apply for external support for a multi-year prevalence survey is an objective. Aside from developing a baseline or establishing whether these two lethal pathogens of blue crab are present in the NE, these analyses will address the question of whether crab pathogens will expand into Northern waters along with the host species. We have a suggestion from 2008-2009 data that both RLV and *Hematodinium* sp. are undetected in the northernmost range, in Southern MA.

2012 update:

Crabs have been received from all the partners as of October 2011: a minimum of 40 crabs from DE, NJ, CT and MA (approximately 105 crabs were received from MA). Crabs from DE, MA, and NY have been processed, so that RNA and DNA are now stored at -80 C. Pathogen assays for *Hematodinium* and Reovirus have been performed on nucleic acids of crabs from MA and DE. As expected, both pathogens were detected in a small percentage of crabs from DE, and no pathogens were observed in crabs from MA. Still to be analyzed are the late season samples from DE Bay National Estuarine Research Rserve, Barnegate Bay NJ, and Milford CT.

We have accessed temperature data records at NOAA buoys in the vicinity of the collection sites in southern MA, Milford CR, DE Bay and the NJ coast. If the project continues for another 3 years as hoped, then annual crab disease data can be compared with water temperature data at these long term monitoring stations.

One set of data that we are now acquiring is crab abundance for the various states in the region. DE and NJ have fishery independent data, while it is not known if CT, NY and MA have such information. We will work with managers in those states to obtain best estimates.

How will results be incorporated into NOAA Fisheries operations? Blue crabs are not a federally managed species. However, interactions with state and federal scientists in MD, DE, CT, and MA reveal how relevant this research is to the management of blue crabs, which support a $160 million fishery in the US. It is reasonable to expect that in the Northeast, a growing recreational and commercial harvest of blue crabs is on the horizon, especially if lobster harvests remain at historically low levels.
Contacts have been made with state agents in NJ and

How will results be incorporated into LMRCSC research and curriculum? Results will be used to support applications for external funding from NOAA and state agencies to continue the monitoring of blue crab health throughout the Northeast.
The effort to extend the duration of this study to 3-5 years has included extensive outreach. In February, Dr. Schott and Ammar Hanif travelled to the Milford Aquaculture Seminar to meet with extension agents and other scientists in the Northeast. Dr. McIntosh and Dr. Schott developed a 1 page flyer that asks for collaborations in the blue crab project, either through joint fundraising or through reporting of blue crab health/mortality observations. This 1 page has been provided to extension agents and others (see attached PDF). Dr. Schott presented (oral) the goals and progress of this study at the 2012 Shellfisheries Association meeting in Seattle WA, and Ammar Hanif presented (poster) the goals to colleagues at the 2012 NOAA-EPP conference in Tallahassee FL. Contacts made through outreach efforts include state agents and Sea Grant staff in MA, NJ, CT, DE.

DE-11-01 NOAA LMRCSC Scientific and Educational cruise aboard the NOAA Ship Delaware II

SCHOLARLY PRODUCTIVITY

In the current reporting period, LMRCSC students and faculty made 59 presentations (26 oral and 33 poster) at scientific meetings, published 13 articles in refereed journals with another 9 in press or accepted. The articles presented and published are listed below.

Oral Presentations (*Students, Presenter in **bold** if not first author)

Babcock, E. Using marine reserves to inform fishery management. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Bowen-Stevens, Sabrina R.*, Cox, T. M**.,** Curran, M. C., Sayigh, Laela S., Fun facts: Using cetacean research to teach students about science and ocean literacy, Society of Marine Mammalogy, Tampa, FL (November 2011)

Brady, M.*, Conn, P., Bailey, L., Fox, D. A., Shertzer, K. Why did the eel cross the creek: Understanding American eel behavior in an estuarine setting. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Breece, M.*, Fox, D.A., and T. Savoy. Factors influencing the coastal movements of Atlantic sturgeon in the Mid-Atlantic and along the eastern seaboard of the US. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Crawford, K.E.C.*, Horodysky, A, Brill, R., and A.K. Johnson. Ontogeny of visual ecophysiology in black sea bass (Serranidae: *Centropristis striata*). 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Curran, M.C., Aultman, T*., and H. Schaffner. Developing ocean literate students using data from flounder research. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Curran, M. C., Aultman, T. V.*, Hoover, Krista M., Gerido, Leona, Sukkestad, Kathryn E.*, Gunzburger, Lindsay, Keeping science alive: Collaborations with K12 teachers and marine educators, CERF Dayton Beach, FL (November 2011)

Curran, M. C., Yozzo, K. L.*, Ebanks, S. C.*, Partridge, M. J.*, Modeste, Tracey*, John, J. M.*, Paul L. Pennington, Does the bopyrid parasite Probopyrus pandalicola affect the density, behavior, and reproductive success of the daggerblade grass shrimp *Palaemonetes pugio*, CERF Dayton Beach, FL (November 2011)

Curran, M. C, Solow, A. R., and Allen, D. M., Does temperature play a role in long-term patterns in use of an intertidal salt marsh basin by flatfishes in South Carolina? International Flatfish Symposium IJmuiden, The Netherlands (November 2011)

Edwards, Kelli L*; Cox, T. M.; Frischer, Marc. Composition of bacterial communities from the spleen of stranded bottlenose dolphins *Tursiops truncatus* from the Atlantic coast of the United States. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011

Fleming, K.M.*, Fox, D.A., and S. K. Bolding. Can humans and sturgeons coexist? Linking Gulf sturgeon habitat utilization and human development in Choctawhatchee Bay, FL. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Gonsalves. L*. Jacobs, J.M., Johnson, A.K., and E.B. May. Predicting the impact of poor nutritional status on immune function in striped bass, *Morone saxatilis*. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Horodysky, A., Brill, R., Bushnell, P., Musick, J. A., and R. J. Latour. Comparative metabolic rates of common western North Atlantic Sciaenid fishes. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Hoskins, D. Stocking the pond: NOAA Living Marine Resources Cooperative Science Center's Coast Camp engages diverse youth. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Hoskins, D. Ecosystem Function and Management on the Georgia Coast. IGEL, Sapelo Island,GA. 15Sept11

James, J.* and Pride, C., Seasonal extremes of oxygen profiles for winter and summer months in the Savannah River and implications for future harbor deepening. PSLSAMP Fall National Symposium and Research Conference, Savannah, GA, (Oct. 14-15, 2011).

Miller, J. A. and R.A. DiMaria. Factors influencing otolith elemental incorporation: Implications for field applications. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Miller, J. A., and L. Tomaro. Early marine residence of spring-run Chinook salmon: A comparison of growth and migration in two interior Columbia River populations. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Meadows, A. W.,, Ward, J., Post, B.,, Norwood, C., Moak, J., Flite, O., Curran, M. C., Using sturgeon migration and habitat use data to determining opportunities for fish passage, defining ecosystem flow needs, and informing changes in dam operation, American Fisheries Society, Seattle, WA Sept 2011.

Ogburn, M. B., Toward ecosystem-based management of the blue crab fisheries in the South Atlantic Bight. Smithsonian Environmental Research Center (November 2011).

Saul, S.* Die, D.J., Brooks, E., and J. Abbott. Modeling the effect of fisher behavior on CPUE in the Gulf of Mexico reef fish fishery. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Sherman, M.* and Curran, M. C., How does temperature affect the starvation rate of the daggerblade grass shrimp Palaemonetes pugio infected with the bopyrid isopod *Probopyrus pandalicola*? CERF Dayton Beach, FL (November 2011)

Seagroves, E.*†, A.Z. Horodysky, RW. Brill, & A.K. Johnson. Visual ecophysiology of tautog (*Tautoga onitis*). 2012 Ocean Sciences Meeting, Salt Lake City, UT. February, 2012.

Stevens, B.G. Sexual maturity of deep-sea red crabs *Chaceon quinquedens* in the Mid-Atlantic Bight. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Tulu, A.*, Chambers, R.C., Ishaque, A.B., and R. Jagus. Development of molecular tools, cDNA cloning and sequence analysis of aromatase Cytochrome P450/19A in Atlantic tomcod, *Microgadus tomcod*. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Watson, A.* Taurine, the missing ingredient for fish-free diets for aquaculture. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Poster Presentations (*Students, Presenter in **bold**, if not first author)

Bedu, P.* Using molecular methods to search for *Hematodinium* sp and Reolike virus of blue crab *Callinectes sapidus*. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Bowen-Stevens, Sabrina R.*; **Cox, T. M.,** Foraging behaviors of common bottlenose dolphins *Tursiops truncatus* in the salt marsh estuary near Savannah, Georgia, USA. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011.

Cannon, A.,* Ozbay, G. 2011. Monitoring aquatic health in wastewater discharge point source in Delaware Inland Bays Tidal Canal: a case study on heavy metal contaminants. 21st Biennial Conference of the Coastal and Estuarine Research Federation, Nov. 2011. Daytona, FL.

Crawford, K.C.*, S. Harper, D. Zeller. Reconstruction of Marine Fisheries Catches for Tuvalu (1950-2009), 2012 Ocean Sciences Meeting, Salt Lake City, UT. February, 2012.

Davis, J.* Bacterial symbionts of a marine invertebrate, *Elysia rufescens*. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Dyson, W.E*., Pitula, J.S., Schott, E., and A. Hanif. A PCR-based assay for detection of *Hematodinium* sp in sediment and water from the Maryland Coastal Bays. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Dyson, W.E*., Pitula, J.S., Schott, E., and A. Hanif. A PCR-based assay for detection of *Hematodinium* sp in sediment and water from the Maryland Coastal Bays. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Gaynus, C.* Isolation and Characterization of Bacteria Samples from Assateague Island, 2012 Ocean Sciences Meeting, Salt Lake City, UT. February, 2012.

Gibson, D., Crawford, K.C.*, Burns, K.P. Students, educators, researchers and the community unite! 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Gilligan, M., Cox, T. M., Hintz, C. Collaborative, Early-undergraduate-focused REU Programs at Savannah State University Have been Vital to Growing a Diverse Ocean Science Community, AGU Fall 2011 meeting, San Francisco, December 5-9, 2011.

Hanif. A*. Using molecular methods to monitor pathogens in early life history of blue crabs (*Callinectes sapidus*). Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Hazelkorn, R. *; **Cox, T. M.**; Perrtree, Robin*, Indication of aggression in *Tursiops truncatus* through dorsal fin rake marks between begging and non-begging dolphins in Savannah GA. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011.

Jackson, K. *Scales, a Nonlethal Alternative to Muscle Tissue for Observing δ13C and δ15N Stable Isotopes of Atlantic Croaker, 2012 Ocean Sciences Meeting, Salt Lake City, UT. February, 2012.

Johnson, S.* and R. Brill. Investigation of the Hypoxia Tolerance of Blue Crab (Callinectes sapidus), 2012 Ocean Sciences Meeting, Salt Lake City, UT. February, 2012.

Johnson, A.K., Bediako, B.*, and E. Wirth. Metal concentrations in American goosefish. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Kiser, R., and M.C. Curran. Distribution and abundance of flatfishes in Wylly Creek, GA. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Kovacs, Carolyn*; Perrtree, Robin*; **Cox, T. M.,** Are common bottlenose dolphin (*Tursiops truncatus*) interactions with shrimp trawlers resulting in social segregation in Savannah, Georgia?, 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011.

Lindsay, E.*, Depass, C.*, Johnson, A.K. and R. McBride. Fecundity estimation of American goosefish *Lophius americanus* in the western North Atlantic. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Love, Lance*; **Cox, T. M**; Perrtree, Robin*; Kovacs, Carolyn*; Doyle, Kate; Bowen-Stevens, Sabrina*. Distribution of the Common Bottlenose Dolphin (*Tursiops truncatus*) in the Savannah River; Savannah, Georgia. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011.

Pavel, C*, Curran, M.C., Carroll, C.J., Meadows, A.W., Post, B., Norwood, C., Moak, J., and O. Filte. Movement patterns of shortnose sturgeon *Acipenser brevirostrum* in the Savannah River, GA. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Peemoeller, B.* and B.G. Stevens. Improving conservation of New England whelks, *Busycoptypus canaliculatus*: Size at maturity. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Peemoeller, B.* and B.G. Stevens. Improving conservation of New England whelks, *Busycoptypus canaliculatus*: Size at maturity. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Perrtree, Robin M.*; **Cox, T. M**. Begging behavior by the common bottlenose dolphin (*Tursiops truncatus*) near Savannah, Georgia: prevalence, spatial distribution, and social structure. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011.

Reyes, Ana*; **Cox, T. M**; Doyle, Kate ; Kovacs, Carolyn*; Perrtree, Robin*; Bowen-Stevens, Sabrina*. Spatial Variation in the Predominant Behavior of Common Bottlenose Dolphins (*Tursiops truncatus*) in the Estuaries of Savannah, GA. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November 2011

Reckenbeil, B.* and Ozbay, G. 2011. Successful Spat Survival on Shell in the Delaware Inland Bays. 2011 Annual Meeting of the Mid-Atlantic Chapter of the American Fisheries Society, Nov. 2011. Manahawkin, N.J.

Smith, D.*, Curran, M.C., C. N. Belcher. The distribution of shark species in relation to macrohabitat features off the coast of Georgia, USA. 141st Annual Meeting of the American Fisheries Society, September 4-8, 2011. Seattle, WA.

Smith, S., Cherrier, J, Caffrey, J. Sarkodee-Adoo, J.* 2011. Dissolved Inorganic Carbon Dynamics in Two Subtropical Estuaries: Apalachicola Bay, FL, and St. Joseph Bay, FL. 96th Ecological Society of America Conference, August 7-12. Austin, TX.

Smith, S.L. Economic impact of Deepwater Horizon oil spill on the FL Gulf Coast oyster industry. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Stoneman, A.,* Kocovsky, P., Kraus, R., Lee, C., and Plumb, R. 2011. Diet, Age, and Reproduction of Trout-perch in the Western Basin of Lake Erie. 141st Annual Meeting of the American Fisheries Society, Sept. 2011. Seattle, WA.

Stoneman, A.,* and Smith, S. 2011. Effects of ocean acidification on otolith growth on the mummichog (*Fundulus heteroclitus*) and other Atlantic fish species. 2011 Annual Meeting of the Mid-Atlantic Chapter of the American Fisheries Society, Nov. 2011. Manahawkin, N.J.

Tulu, A.*, Chambers, R.C., Ishaque, A.B., and R. Jagus. Development of molecular tools, cDNA cloning and sequence analyusis of aromatase Cytochrome P450/19A in Atlantic tomcod, *Microgadus tomcod*. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Vicente, J*. Bacterial Community Analysis of the Symbionts in Two Coexisting Cryptic Sponges *Xestospongia deweerdtae* and Plakortis sp. Marine-Estuarine-Environmental Science Program Annual Symposium. October 14-15, 2011. Appalachian State University.

Wolfer, H.* Physiological effects of sublethal hypoxia on Atlantic croaker in Chesapeake Bay. 141st Annual Meeting of the American Fisheries Society. September 4-8, 2011. Seattle, WA.

Publications (*Students)

Published

Bowen-Stevens, S. R.*, Cox, T. M., and Curran, M. C. 2011. What are bottlenose dolphins doing on land? An activity teaching the scientific method through the unique behavior of strand feeding. The American Biology Teacher 73(7):407-411.

Chiou TH, Place AR, Caldwell RL, Marshall NJ, Cronin TW. 2012, A novel function for a carotenoid: astaxanthin used as a polarizer for visual signalling in a mantis shrimp, J. Exp. Biol. 215:584-9.

Graves, J.E., A.Z. Horodysky, and D.W. Kerstetter. (2012). Incorporating circle hooks into Atlantic pelagic fisheries: case studies from the commercial tuna/swordfish longline and recreational billfish fisheries. Bull. Mar. Sci. vol 88.

Love, L.*; Cox, T. M.; Perrtree, Robin*; Kovacs, Carolyn*; Doyle, Kate; *Bowen-Stevens, Sabrina*. Distribution of the Common Bottlenose Dolphin (Tursiops truncatus) in the Savannah River; Savannah, Georgia. 19th Biennial Conference on the Biology of Marine Mammals. Tampa, FL, November* 2011.

Kapareiko, D., Hyun Jeong Lim, Eric J. Schott, Ammar Hanif* and Gary H. Wikfors, 2011, Isolation and Evaluation of New Probiotic Bacteria for use in Shellfish Hatcheries: II. Effects of a *Vibrio* sp. Probiotic Candidate Upon Survival of Oyster Larvae (Crassostrea virginica) in Pilot-Scale Trials, J. Shellfish Res. 30: 617-625.

Lim, H.J., D. Kapareiko, E. J. Schott, A. Hanif* and G. H. Wikfors, 2011, Isolation and Evaluation of New Probiotic Bacteria for use in Shellfish Hatcheries: I. Isolation and Screening for Bioactivity, J. Shellfish Res. 30:609-615.

Mace, M.M.* and Curran, M. C., 2011. Prey selection by the blue crab *Callinectes sapidus* feeding on the sand fiddler crab *Uca pugilator* and the mud fiddler crab *Uca pugnax.* Crustaceana 84(11): 1281-1293

Montalvo NF*, Hill RT. 2011, Sponge-associated bacteria are strictly maintained in two closely related but geographically distant sponge hosts, Appl Environ Microbiol, 77:7207-16.

Ogburn, M., Hall, M, and R. B. Forward, Jr., 2012. Blue crab (*Callinectes sapidus*) larval settlement in North Carolina: environmental forcing, recruitment-stock relationships, and numerical modeling, Fisheries Oceanography, vol. 21:20-32 .

Siler, A. and Curran, M. C., 2011. The learning cycle: engaging children in the scientific method. Current: The Journal of Marine Education 27(3):24-32.

Smith SM, Morgan D, Musset B, Cherny VV, Place AR, Hastings JW, Decoursey TE. 2011, Voltage-gated proton channel in a dinoflagellate, Proc Natl Acad Sci. 108:18162-7.

Wang K, Wommack KE, Chen F. 2011, Abundance and distribution of *Synechococcus* spp. and cyanophages in the Chesapeake Bay. Appl Environ Microbiol. 77:7459-68.

Williams EP, Peer AC, Miller TJ, Secor DH, Place AR. 2012, A phylogeny of the temperate seabasses (Moronidae) characterized by a translocation of the mt-nd6 gene, J. Fish Biol. 80:110-30.

In Press or Accepted

Submitted

Aultman, T.* and M.C. Curran. Move over! Studying flatfish travel patterns to profile fish behavior. The American Biology Teacher.

Forrestal F., M. Coll, D.J. Die and V. Christensen. (in review). Ecosystem effects of Bluefin Tuna (*Thunnus thynnus thynnus*) aquaculture in the North-Western Mediterranean Sea. *Marine Ecology Progress Series*.

Graves, J.E., A.Z. Horodysky, and D.W. Kerstetter. In review. Incorporating circle hooks into pelagic longline and recreational billfish fisheries: bottom-up versus top-down control. Bull. Mar. Sci.

Hammerschlag, Neil, Lazarre, Dominique M*, Rumbold Darren, Wasno Robert, Hammerschlag-Peyer Caroline M and Slonim Curt. In Review. Summer movement patterns of tiger sharks satellite-tagged off the Gulf Coast of Florida. Marine Ecology.

Kalinowsky, C.A.,* M.C. Curran, and J. Smith. Fall 2010. Age and growth of the Cobia (Linnaeus 1776), in Port Royal Sound and adjacent waters of Beaufort County, South Carolina. Fishery Bulletin.

Montalvo, N. F.* and R. T. Hill. Bacterial speciation in the marine sponges *Xestospongia muta* and *Xestospongia testudinaria*. Submitted to Applied and Environmental Microbiology. (In revision).

National Research Council of the National Academies[1]. 2011. Approaches for ecosystem services valuation for the gulf of Mexico after the deepwater horizon oil spill. The National Academies Press. 128 pp. ([1]D.J. Die is a member of the NRC committee that authored this document.)

Saul S.*, D.J. Die. (in review). An individual-based model of ontogenetic migration in reef fish using a biased random walk. *Transactions of American Fisheries Society.*

Sukkestad, K*. and M.C. Curran. Noodling for mollusks: Who knew that some mussels were endangered? The American Biology Teacher.

LMRCSC in the news

Dr. Tara Cox http://www.wtoc.com/story/15328454/pygmy-sperm-whale-washes-ashore-on-tybee-island
http://www.wtoc.com/story/15335281/ssu-students-help-with-beached-whale

Dr. Sue Ebanks http://ccr.mcgraw-hill.com/2011/11/01/biologist-marine-biologist/

Dr. Matthew Gilligan http://www.smithsonianmag.com/science-nature/Top-10-Real-Life-Body-Snatchers.html
http://forums.nasioc.com/forums/showthread.php?t=2277564
http://brightstrangethings.com/tag/biology/

Dr. Dionne Hoskins http://www.savannahtribune.com/news/2011-09-21/Social_%28and%29_Community_News/The_People_Of_Pin_Point_Documentary_to_be_Screened.html
http://savannahnow.com/news/2011-09-15/dionne-hoskins-appointed-replace-floyd-adams-savannah-chatham-school-board
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CD4QFjAB&url=http%3A%2F%2Fwww.savannahtribune.com%2Fnews%2F2011-09-21%2FSocial_(and)_Community_News%2FDionne_Hoskins_Appointed_District_Two_School_Board.html&ctbs=cdr%3A1%2Ccd_min%3A9%2F1%2F2011%2Ccd

_max%3A12%2F31%2F2011&ei=AvdhT9rxFsbetgerwIj9Bw&usg=AFQjCNHhJJpyoBFVOTZ0GDvQgh9BpwQHiQ

SSU Marine Sciences Creating degrees for future jobs
http://www.connectsavannah.com/news/article/104859/

Grantsmanship: A total of $2,591,029.14 (Tables 8a and 8b) was collectively awarded to the LMRCSC partner institutions during the current reporting period which directly or indirectly impacted Center activities. Among the stakeholders that provided the awards included the US Department of Agriculture, US Environmental Protection Agency, US Department of Education, National Science Foundation, US Department of Commerce through the National Marine Fisheries Service, Foundations, and the Departments of Natural Resources in each partnering institution's home state. Of the total amount of funds awarded to LMRCSC, $776,721.07 came from NOAA, whereas $1,814,308.07 was obtained from other agencies.

The funds provided by these agencies impacted LMRCSC research through support of its faculty and students and by development/enhancement of infrastructure. Ten proposals that total $7,886,158.92 (Table 9) were submitted to various agencies during this reporting period.

Table 8a. Current leveraged funding from NOAA to LMRCSC institutions

Author	Funding Agency	Title of Project	Start/End Date	Amount	Current 6 month period
Zohar, Y. (IMET)	NOAA	The blue crab *Callinectes sapidus*: an integrated research program of basic biology, hatchery technologies, and potential for replenishing stocks	12/01/06-11/30/11	$4,095,099	$409,509.90
Chen, Feng (UMCES-IMET)	NOAA	Metagenomic analysis of microalgae in the Chesapeake Bay	8/1/10-7/31/11	$19,975	9987.5
Hill, Russell (UMCES-IMET)	NOAA	Metagenomic analysis of microalgae in the Chesapeake Bay	8/1/10-7/31/11	$52,150	26075
Schott, E. (UMCES-IMET)	NOAA Sea Grant	Effects of toxic algae blooms on health and disease of blue crab: Defining thresholds for exposure	2/1/11-1/31/12	$22,463	11231.5
Stevens, B.G.(UMES)	NOAA	Improving conservation of New England Whelks	2010-2012	$75,688	12614.67
Hoskins, D. (SSU)	GA Sea Grant	Marine Resources Utilization in GA	2009-11	$16,830	$4,207.50
Gilligan, M. (SSU)	NOAA	Replacement of University's Major Marine Science Vessel	2010-11	$449,550	$224,775.00
Johnson, A.K (UMES) and R.A. Richards (NOAA)	NOAA NMFS-Monkfish Set Aside Program	Influence of temperature on the distribution and catch rates of monkfish, *Lophius americanus*.	5/1/11-4/30/12	$ 79,899	$39,949.50
Ozbay, G. (DSU)	NOAA ECSC	Benthic diatom assemblages as environmental indicators in Blackbird Watershed, Delaware	6/1/2008-5/2011	$146,895	$24,483
Place, A.R. (IMET)	NOAA	Metagenomic Analysis of Microalgae in the Chesapeake Bay	08/01/10-07/31/11	$27,775	$13,887.50
TOTAL					**$776,721.07**

Table 8b. Current leveraged funding to LMRCSC institutions from sources and agencies other than NOAA (*Students)

Author	Funding Agency	Title of Project	Start/End Date	Amount	Current 6 month period
*Serrano, X. (RSMAS-Student)	McKnight Fellowship	Ecophysiology of corals	8/2008-7/2011	$30,000	$5,000.00
*Santos, R. (RSMAS-Student)	McKnight Fellowship	Multi-scale spatial variation of nearshore submerged aquatic vegetation seascapes at Biscayne National Park	8/2009-7/2012	$30,000	$5,000.00
Die, D.J. (RSMAS)	NTVI (*)	Center for independent experts	9/2007-8/2011	$122,176	$33,125.00
Chung, J.(COMB), Zmora, O.(COMB), & Sagi, A.	US-Israel BARD	Endocrine and Molecular Manipulations of the Crustacean Molt to Control Growth and Synchronize Ecdysis	2009-2011	$150000	$37,500.00
Jagus, R. (COMB)	NSF-MCB	Interferon-upregulated eIF2alpha kinases in fish	06/15/07-05/31/11	$612,209	$76,526.13
Schreier, H. (COMB) & Tal, Y.	US-Israel BARD.	Using a "Sulfide Loop" to control fish pathogens in marine recirculating aquaculture systems	2009-2011	$150000	$37,500.00
Schott, E. (UMCES-IMET)	Barbor FTD	Blue crab reo-like virus transmission study	3/25/11-3/35/12	$12,568	$6284
Schott, E. (UMCES-IMET)	FWRI	Impact of Hematodinium	9/1/10-8/31/11	$3,975	$1987.5
Frischer, M. (SKIO), Gibson, D.(HU) G. Paffenhöfer	NSF	Doliolid Blooms: What are the Driving Variables? Investigations of Trophic Interactions	1/1/09-12/21/12	$75,688	$12,614.67
Halverson, C., Gibson, D.(HU) and C. Witherspoon	NSF OCE ISE	Communicating Ocean Sciences to Informal Education Network (COSIEN)	10/1/10 – 9/1/12	$32,281	$8,070.25
Smith, S. (DSU), Ozbay, G. (DSU)	USDA-NRCS	The efficacy of heavy use area protection (HUAP) pads to decrease runoff of nonpoint source pollution into the Chesapeake Bay watershed.	8//1/2011-8/1/2012	$99,435.92	$49717.96
Ozbay, G. (DSU)	USDA-CBG	"Enhancing Geographic Information System Education and Delivery through Collaboration: Curricula Design, Faculty, Staff, and Student Training and Development, and Extension Services.	9/1/2010-8/30/2013	$299,996	$49,999.33
Ozbay, G. (DSU)	USDA-AFRI	Inactivation of enteric foodborne viruses in high risk foods by non-thermal Processing technologies.	2/1/2011-1/31/2016	$2,000,000	$200,000
Ozbay, G. (DSU)	USDA Evans-Allen program	Monitoring aquatic health and habitat value of oyster (Crassostrea virginica) gardening and restoration through community-based oyster enhancement efforts.	9/1/2010-8/31/2012	$209,750	$52,437.50
Ozbay, G. (DSU)	DuPont Clear into the future Env stewardshi	Oyster restoration efforts at Delaware's inland bays	7/1/2010-6/30/2011	$25,000	$12,500

	p grant				
Ozbay, G. (DSU)	DSU Center for School Change	Diverse Pathways to Success: Women in the Sciences and Social Sciences, Part 2	1/1/2010-12/30/2011	$750	$375
Ozbay, G. (DSU)	NSF	Research Experience for Undergraduates Site: Undergraduate Research in Molecular Genetics & Genomics at DSU	5/2010-9/2012	$250,000	$62,500
Ozbay, G. (DSU)	USDA-NRI	Persistence of Enteric Viruses in Oysters (*Crassostrea virginica)*	10/1/2008-9/30/2011	$100,000	$16,666.67
Ozbay, G. (DSU)	EPA	Mid-Atlantic Drinking Water Program: Drinking Water and Human Health. National Integrated Water Quality Program (NIWQP)	12/1/2009-11/30/2012	$48,000	$8,000
Ozbay, G. (DSU)	NSF SMILES	Monitoring Aquatic Health and Habitat Value of Oyster (*Crassostrea virginica*) Gardening and Restoration through Community Based Oyster Enhancement Efforts	TBD	$10,000	10000
Ozbay, G. (DSU)	USDA-FSIS	Microbial and Chemical Contaminants in Processed Catfish for Food Safety.	09/25/09-09/24/11	$555,550	$138,887.50
Hoskins, D.(SSU	COL	National Ocean Science Bowl (GA-SC) competition	2010-11	$15,000	$7,000.00
Hoskins, D. (SSU)	Ocean Leadership	Diversity Initiative	2010-11	$10,000	$5,000.00
Hintz, C. (SSU)	United Negro College Fund	Production of High Fidelity Lunar Stimulants for Exploration Risk Reduction and Systems Analysis Year 2	2009-11	$66,000	$16,500.00
Mayor Otis Johnson, Ph.D., Maria Procopio, Dionne Hoskins, and Horace Magwood, III	GA DNR	Sidewalk to the Sea Program	2009-11	$191,580	$47,895.00
Curran, C.(SSU)	USDOE	Training and research grant	2009-15	$3,000,000	$250,000.00
Gilligan, M.(SSU)	NSF	Research Experience for Undergraduates	2009-12	$292,434	$48,739.00
Pride, C.(SSU)	NSF	New GK12: Building Ocean Literacy in a Coastal Community Through Science	2009-14	$2,214,884	$221,488.40
P. Chigbu & J. Love (UMES)	NSF	University of Maryland Eastern Shore REU in Marine and Estuarine Science	6/1/09 – 5/31/12	$231,521	$38,586.83
P. Chigbu, J. Pitula, E. May, M. Mitra, & A. Johnson (UMES)	NSF	CREST Center for the Integrated Study of Coastal Ecosystem Processes and Dynamics	8/1/10 – 7/31/15	~$5,000,000	~$500,000
P. Chigbu, K. Wallmo (NOAA), J. Okoh, J. Keane-Dawes, S. Tubene (UMES)	NSF	Professional Science Master's degree in Quantitative Fisheries and Resource Economics	5/1/10 – 4/30/13	~$700,000	$116,666

E. May, A. Allen (UMES)	USDA Capacity Bldg Grant	Capacity Building Grants Program, Watershed Level Examination of Urea Use as Fertilizer and the Production of the Biotoxin Domoic Acid	10/1/10 – 9/30/13	$499,950	$83,325.00
A, Allen, E. May (UMES	USDA Capacity Bldg Grant	Development of A Subsurface Application Technology for Dry Poultry Litter to Protect Air and Water Quality	10/1/10 – 9/30/13	$599,000	$99,833.33
Gibson, D., Horodysky, A., Cuker, B.	NSF (HRD-HBCU-UP)	Targeted Infusion Project: Educational Partnership in Climate Change and Sustainability (EPiCCS)	9/1/11 – 8/31/14	$163,749	$54583
TOTAL					**$1,814,308.07**

Table 9. Grants submitted by LMRCSC during this reporting period (September 1, 2011 to February 28, 2012)

Author	Funding Agency	Title of Project	Amount
Smith (DSU), Ozbay (DSU)	USDA-NRCS	The efficacy of heavy use area protection (HUAP) pads to decrease runoff of nonpoint source pollution into the Chesapeake Bay watershed.	$99,435.92
Gibson, D. (HU)	NIST Construction Grants program	Atmospheric and Coastal Sciences Research Building (ACSRB)	$5,000,000
Chung, J.S. (IMET)	US EPA	Uptake and effects of dispersed oil droplets and emulsified oil by estuarine crust	$139,393
Chung, J.S. (IMET)	GRI	LSU Research Consortium: Effects of oil droplets	$393,824
Chung, J.S. (IMET)	NSF	Functional roles of a novel crustacean female sex hormone in sex differentiation and developing secondary sex features of crustaceans	$635,507
Place, A.	NOAA	ECOHAB: Integrating cell and toxin cycles of karlodinium veneficum with key environmental regulators: In situ studies of predictive determinants for bloom toxicity	$74,375
Place, A.	NOAA	ECOHAB: Sorting the fatty acid chaff from the toxin wheat or is it all wheat? – Assigning dinoflagellate PKS genes to toxin synthesis.	$434,608
Place, A.	BARD	Taurine: A potential key ingredient to reduce the dependence on fish meal in aquaculture	$158,400
Place, A.	NIH	The chemistry and biology of the karlotoxins	$392,488
Place, A.	NSF	Diversification along a salinity gradient: Genetic mechanisms and functional consequences	$558,128
TOTAL			**$7,886,158.92**

Objective 2: Fully Integrate Research Programs with NOAA Fisheries to Ensure Long Term Funding and Programmatic Stability. All research projects funded through the LMRCSC have substantial involvement by NOAA scientists. Details on these projects are included on pages 11 – 26 above.

SECTION II – EDUCATION AND OUTREACH EFFORTS

LMRCSC Education and Outreach efforts are addressed through the following goal and objectives:

Goal 3: **Generate a Pool of Scholars Entering the Field Of Marine Sciences and Fisheries**
The objectives which accomplish this goal include:

Objective 1: **Enhance Recruitment of Students From Underrepresented Groups into Marine Science Disciplines**

Objective 2: **Strengthen Outreach & Education Programs to students and the public**

Objective 3: **Develop Programs that Enhance the Practical Education of Undergraduate and Graduate students in the Marine Sciences**

Objective 1: **Enhance Recruitment of Students From Underrepresented Groups into Marine Science Disciplines**

Total student support for the current reporting period was $168,715.20 (Table 10). Total student support for project year 2010-11, including the first six months of the No Cost Extension period was $1,051,742 (47%).

Thirty five (16) B.S., 13 M.S., and 6 Ph.D. students were supported during the current reporting period through fellowships, scholarships, stipends and travel awards. Students who received support during the current reporting period are shown in Table 11.

Table 10. Student funding by LMRCSC institution

	Budget	9/1/10-2/28/11	3/1/11-8/31/11	9/1/10-2/28/11	3/1/11-8/31/11	9/1/11-2/28/12	TOTAL
UMES	$987,353	$173,273	$121,707	18%	12%	$81,051.78	38%
SSU	$316,828	$79,741	$43,693.90	25%	14%	$22,121.44	46%
RSMAS	$114,402	$33,439	$35,078.00	29%	31%	$8,827	68%
HU	$197,757	$42,716	$37,035	22%	19%	$30,300	56%
DSU	$229,794	$38,000	$53,268.55	17%	23%	$26,415.48	51%
IMET	$375,726	$121,491	$103,584	32%	28%		60%
TOTAL	$2,221,860	$488,660	$394,367	22%	18%	$168,715.20	47%

Table 11. Students who received support during the funding period September 1, 2011 to February 28, 2012.

First Name	Last Name	Academic Institution	Degree	Type	Amount
Daniel	Cullen	UMES	Ph.D	Stipend, Tuition, Travel	$11,971.33
Jhamyllia	Rice	UMES	Ph.D	Stipend, Tuition	$10,010.89
Adam	Tulu	UMES	Ph.D	Stipend, Tuition	$12,146.51
Whitney	Dyson	UMES	M.S.	Travel	$213.96
Courtney	McGeachy	UMES	M.S.	Stipend, Tuition	$12,395.89
Belita	Nguluwe	UMES	M.S.	Stipend, Tuition	$1,636.38
Jamila	Payton	UMES	M.S.	Stipend, Tuition	$4,167.75
Candace	Rodgers	UMES	M.S.	Stipend, Tuition	$11,600.89
Emily	Tewes	UMES	M.S.	Stipend, Tuition, Travel	$13,667.18
Cy'Anna	Scott	UMES	B.S.	Stipend, Tuition	$3,241.00
Dontrece	Smith	SSU	M.S.	Stipend	$6,999.96
Jeremy	Mitchler	SSU	M.S.	Stipend	$1,567.28
Tiffany	Ward	SSU	M.S.	Stipend	5166.64
Noelle	Hawthorne	SSU	M.S.	Stipend, tuition	$7,359.14
Amarria	Phillips	SSU	B.S.	Stipend, Travel	$1,028.42
Xaymara	Serrano	RSMAS	Ph.D	Travel	$1,095
Rolando	Santos	RSMAS	Ph.D	Stipend, Travel	5707

Dominique	Lazarre	RSMAS	Ph.D	Stipend, Travel	$2,025
Maryse	Leandre	HU	M.S.	Stipend	$6,000
Jonathan	Garing	HU	B.S.	Stipend	$1,000
Matthew	Dill	HU	B.S.	Stipend	$1,000
Symone	Gyles	HU	B.S.	Stipend	$1,000
Matthew	Taylor	HU	B.S.	Stipend	$2,200
Kendyl	Crawford	HU	B.S.	Stipend	$2,200
Brittany	*Carmon	HU	B.S.	Stipend	$3,000
Coleman	*Ewell	HU	B.S.	Stipend	$1,200
Symone	Johnson	HU	B.S.	Stipend	$2,200
Keya	Jackson	HU	B.S.	Stipend	$1,000
Elizabeth	Seagroves	HU	B.S.	Stipend	$4,250
Joyah	Watkins	HU	B.S.	Stipend	$2,000
Daniel	Ingman	HU	B.S.	Stipend	$2,000
Camile	Gaynus	HU	B.S.	Stipend	$1,250
Cory	Janiak	DSU	M.S.	Stipend, Tuition, Travel	$9,352.20
Andrea	Stoneman	DSU	M.S.	Stipend, Tuition, Travel	$16,563.28
Amy	Cannon	DSU	B.S.	Travel	$500.00
TOTAL					$168,715

Table xxx. Students recruited into LMRCSC from Sept 1, 2011 to February 28, 2012

First Name	Last Name	Academic Institution	Degree
Jonathan	Garing	HU	B.S.
Matthew	Dill	HU	B.S.
Symone	Gyles	HU	B.S.
Matthew	Taylor	HU	B.S.
Briana	Jones	UMES	B.S.
Tiana	Jones	UMES	B.S.

Recruitment into Marine Science Programs: Recruitment has been facilitated through increased outreach of LMRCSC using the following modalities: 1) LMRCSC web site, 2) LMRCSC newsletters and brochures, 3) Participation in meetings of AFS, ASLO, ERF and other organizations which provide wide exposure, 4) Visits to universities/colleges and personal contact, and 5) Internships at Center partner institutions. Contact between Center students and faculty at events such as the LMRCSC Student Weekend and ASLO has led to increased interest among students in pursuing advanced degrees within the Center. In addition, the LMRCSC's reputation nationwide has resulted in an increase in applications to Center partners. The students who graduated at the LMRCSC institutions are in Table 12, whereas those who interned at NOAA or at LMRCSC partner institutions are in Tables 13 and 14.

- Program Manager Todd Christenson has taken an increased role in recruitment for LMRCSC program. During this reporting period, Mr. Christenson staffed the LMRCSC table at the meetings of the American Fisheries Society (Seattle, WA, Sept 4-8. 2011), Hispanic Engineering, Science and Technology Conference (Sept 27-28, Edinburgh, TX), Society for the Advancement of Chicanos and Native Americans in Science (San Jose, CA, Oct

27-29, 2011), and American Society of Limnology and Oceanography (Salt Lake City, UT, Feb 20-14, 2011) . During these conferences he met and collected contact information from more than 50 students, several of which plan to apply to LMRCSC institutions. He also discussed graduate programs with current LMRCSC students from Hampton University and past participants in UMES' REU program.

- Using leveraged funds, the LMRCSC has hired two new staff to assist in recruitment of students. Ms. Judy Rose, Professional Science Master's Program Coordinator, was hired in fall 2011. She visited Spelman College (October 27, 2011) and Morehouse College, GA (October 28, 2011) and made presentations on the LMRCSC and leveraged programs: NSF CREST-CISCEP and PSM. Ms. Kerrie Bunting, CREST-CISCEP Program and Outreach Coordinator was hired in fall 2011 and has begun recruiting graduate and undergraduate students, as well as K-12 students and teachers for summer 2012 workshop and internship at the Center.
- For the third year, SSU coordinated the Georgia-South Carolina Ocean Sciences Bowl competition with Dionne Hoskins and Greg Hunter as regional coordinators. During fall 2011, both worked with three predominately African American high schools (Groves, Johnson, and Beach) to develop a diversity team to compete at the February, 2012 event.
- SSU Marine Science faculty and students manned a display in the SSU Open Campus Day (Oct. 15, 2011) and the Garden City Fall Festival (Oct. 22, 2011).
- Dr. Matthew Gilligan transitioned to partial retirement and took on the duties of recruitment for externally funded Marine sciences Programs at SSU. He visited HBCUs in Georgia and surrounding states.
- Dr. Ogburn has recruited three students in Fall semester 2011 for undergraduate and graduate research on LMRCSC projects.
- Drs. Ogburn and Curran met with students at the fall SEERS meeting. Drs. Hoskins and Ogburn also served as EDGE intern mentors.
- Dr. Stacy Smith (DSU) became a participant in the Connecting Generations Creative Mentoring Program at Dover High School. She works weekly with students. Dr. Smith is also working with mentor program leaders on developing a week-long Environmental Justice science camp for high school students.

Table 13. Students who worked at NOAA labs or LMRCSC partners (September 1, 2011 to February 28, 2012).

First Name	Last Name	Academic Institution	Degree	Facility	Time period
William	Gardner	UMES	Ph.D	NEFSC, Sandy Hook Lab	October, 2009 to present
Kate	Fleming	DSU	M.S.	NMFS lab-Panama City, FL	Jan 2010 to present.
Shari	Mullen	UMES	MEES	NOAA AFSC (NOAA GSP)	June 2010 to present
Lonnie	Gonsalves	UMES	MEES	NOAA COL, MD (NOAA GSP)	June 2010 to present
Noelle	Hawthorne	SSU	M.S.	Grays Reef NMS	

Objective 2: **Strengthen Outreach & Education Programs to students and the public**

Accomplishments – In this reporting period, LMRCSC faculty worked on a wide range of projects, strengthening outreach and education programs to students and the public. This, in turn, resulted in additional grant awards (Table 8a&b), proposals that have been submitted to an agency for funding (Table 9) and collaborative projects, which are summarized below.

K-12 Education**:** In this reporting period, LMRCSC offered the following activities for K-12 students.

- ***Upward Bound Marine and Estuarine Science Program*****:** This program offers lessons in marine science and coastal ecology to 20 – 25 students in grades 10-12 from Somerset, Worcester and Wicomico Counties, MD. The program draws on the expertise of UMES-LMRCSC faculty and staff as well as MD Coastal Bays Program, National Park Service and MD Department of Natural Resources at the UMES Paul S. Sarbanes Coastal Ecology Laboratory. In the past, the program has been conducted for 6 sessions during the summer and on four selected Saturdays (4

sessions) during the academic year. LMRCSC graduate Nick Clemons, a National Park Service employee, led or participated in sessions during the summer or academic year.

- Dr. Gibson (HU) and her COSIA colleague, Karen Burns at the Virginia Aquarium are working with the Marine Science Club, since fall 2011, to organize the Retro Green, Youth Environmental Conference. HU students are planning multiple environmental and marine science topics to Virginia Middle and High School students. The conference will take place April 21st, 2012.

- HU Marine Science, Biology and Atmospheric and Planetary Science departments are working together to plan the Virginia Space Grant Consortium Summer GEAR UP Institute at HU. This program will provided hands on activities to 150 high school students and parents.

- Dr. Burbanck continues his presentations to high school classes and civic groups on the topics of health of the Bay and effects of sea level rise on coastal and estuarine Mid-Atlantic marshes.
- To better manage the demand for outreach, the outreach coordinator focused activities to the NOSB this fall. Part of the national NOSB's goal is to develop more teams and more DIVERSE teams in its regions. SSU is the regional host for the GA-SC bowl. However, there are no public school teams and only one coastal Georgia team. The fall and winter is the time that teams form and study for the February competition, so concentrated effort was dedicated to cultivating local teams in 3 high schools.
- The LMRCSC at SSU worked with the Savannah Ocean Exchange, an internal initiative being hosted in Savannah that encourages global leaders to disseminate working solutions to ocean-related problems. www.savannahoceanexchange.com. Dr. Hoskins was a co-chair of Culture and Cuisine while Dr. Gilligan developed an internship prototype with President Dozier and the Exchange leadership.
- Twelve African American children from Jack and Jill of America Inc., and elite education and leadership organization for children were hosted at SSU for a field trip and dissection at the Marine Sciences Building in October.
- Working with Crowe and Associates, SSU scheduled the public debut of the documentary on Pin Point, Georgia, the fishing community Supreme Court Justice Clarence Thomas grew up in. That event was held on 28Sept11.

***American Fisheries Society*:**

- LMRCSC student Lonnie Gonsalves has been nominated for President-elect of the AFS Equal Opportunity Section. If confirmed he will assume the two-year post in 2012.

- UMES-PSM student and NOAA contractor Michele Traver continues to serve as Chair for the AFS Equal Opportunity Section's Mentoring for Professional Diversity award committee.

- The AFS UMES Student Subunit contributed funds to support the Equal Opportunity Section student travel award.

Outreach

- **Newsletter**: The Center publishes a newsletter, *The Living Sea,* to highlight Center research and educational activities. No issues were produced during the current reporting period.

- **Website**: A major redesign of LMRCSC web site (www.umes.edu/lmrcsc) intended to make the site more comprehensive and centralized was initiated during this reporting period with completion anticipated by April 2012. The new site will highlight Center accomplishments and make them more accessible to the user, and will be modified to include information on faculty and students at all partners. Each of the LMRCSC partner institutions also has its own website that is directly linked to the LMRCSC main web page. The web sites for the respective institutions are: DSU (http://cars.desu.edu/aqua-sci/index.htm); SSU (http://www.ssufisheries.com/); HU

(http://www.hamptonu.edu/academics/schools/science/marine/); UMCES-IMET (http://www.umces.edu/imet) and RSMAS (http://cufer.rsmas.miami.edu/index.php?page_id=31).

- **Facebook**: LMRCSC Technical Monitor Jeanine Cody created an LMRCSC page on Facebook which went live on July 20, 2009. It provides students and others a forum to network and discuss marine and fisheries issues, funding and identify job opportunities, current events in marine science, etc. Two hundred forty-eight (248) individuals, including many students, have signed up as 'fans' of the site. The site is co-managed by Jeanine Cody and Todd Christenson.

- DRS Dr. Brad Stevens serves on the editorial committee for the Journal of Shellfish Research.

- LMRCSC Director, P. Chigbu has been appointed to serve as a Technical Advisor to the Advisory Committee to the U.S. National Section to International Committee for the Conservation of Atlantic Tunas (ICCAT).

- HU's LMRCSC and Marine Science Club students organized the Teen Environmental Conference for Middle, High and HU College students in the City of Hampton. This event was leveraged by Dr. Gibson's NSF COSIA grant in Partnership with the VA Aquarium. The results of this event were presented at the AFS meeting in Seattle, WA on September 4-8, 2011.

- Dr. Stacy Smith volunteered and participated in the annual Delaware Bay Horseshoe Crab Spawning Survey, conducted by the Delaware National Estuarine Research Reserve. Overharvesting of horseshoe crabs depleted the population, but spawning surveys from recent years show their numbers are rebounding.

- Aaron Watson (M.S. IMET) was interviewed and filmed for a documentary on the current state of the oceans and aquaculture sustainability. The resulting documentary, *Oceans: Turning the Tide*, video, 26:40, created for national broadcast by LinkTV, San Francisco, was aired September 2011.
- Dr. Eric Schott serves as board member of Blue Water Baltimore, a 501c3 organization that works to revitalize Baltimore's streams and harbor, and thence the Chesapeake Bay and is a member of the Scientific and Technical Advisory Committee. Dr. Schott also serves on the Maryland Oyster Advisory Commission, appointed by Governor O'Malley. This body advises the Maryland Department of Natural Resources on oyster management in the state. Dr. Schott also serves on the Maryland Sea Grant Ecosystem Based Fisheries Management Blue Crab team.

***Objective 3*: Develop Programs that Enhance the Practical Education of Undergraduate and Graduate Students in the Marine Sciences:**

Workshops/Seminars:

- The LMRCSC Seminar Series continued during this reporting period (see Tables 4 & 5). Drs. Brad Stevens (UMES), Andrij Horodysky (HU) and Dr. Jessica Miller (OSU) presented their seminars, respectively on October 7, November 4 and December 2, 2011, respectively.

Cruises:

- The LMRCSC winter cruise was held aboard the R/V Delaware II from January 17 – 27, 2012. Students who participated are shown in Table xxx below. Sarah Bornhoeft of NOAA's Cooperative Oxford Laboratory also participated.

Table xxx. Participants in the LMRCSC winter cruise 2012.

First Name	Last Name	Degree	Institution	Vessel	Date

Andrea	Stoneman	M.S.	DSU	R/V Delaware II	Jan 17 - 27, 2012
Candace	Rodgers	M.S.	UMES	R/V Delaware II	Jan 17 - 27, 2012
Sarah	Bornhoeft	N/A	NOAA COL	R/V Delaware II	Jan 17 - 27, 2012
Emily	Tewes	M.S.	UMES	R/V Delaware II	Jan 17 - 27, 2012
Courtney	McGeachy	M.S.	UMES	R/V Delaware II	Jan 17 - 27, 2012
Evan	Lindsay	PSM	UMES	R/V Delaware II	Jan 17 - 27, 2012
Whitney	Dyson	M.S.	UMES	R/V Delaware II	Jan 17 - 27, 2012

SECTION III – SUCCESS STORIES

- LMRCSC's Professional Science Masters program in Resource Economics accepted several additional students for Fall, 2011 including Joseph Drummond and Cornelius Chilaka. The first cohort of 3 students is expected to graduate in May, 2012.

- In order to accommodate the two NOAA employees in the PSM program, online versions of several quantitative fisheries courses were developed and offered during the Spring 2011 semester: 1) Stock Assessment, co-taught by Dr. Chigbu and Dr. Albert Chi (UMES) and Dr. Larry Alade (NOAA NEFSC). 2) Multivariate Statistics, taught by Dr. Albert Chi (UMES), and 3) Marine Population Dynamics, taught by Dr. David Die (RSMAS). The Stock Assessment and Multivariate Statistics courses are being offered in real time using Blackboard and Wimba. GoToMeeting is used to offer the Marine Population Dynamics course. Three additional classes from the list of nine essential courses for fisheries are being offered online in Fall Semester, 2011 (Fish Ecology, Fisheries Survey Sampling, and Risk and Decision Analysis). The development of these courses is a significant step toward a full online program which can ultimately be made available nationwide.

1. What specific contributions have the projects made to the Center, NOAA and partners?

- The LMRCSC educational, research and outreach activities have resulted in several contributions during this reporting period. Thirty five (35) students from B.S. to doctoral levels were supported and trained in NOAA core sciences. One M.S. and one Ph.D student graduated. Twelve projects funded through the TAB are underway for 2010-11 were completed in December, 2011; $2,591,029.14 in external funding is supporting Center-related activities.

- The Center's doctoral graduates, Larry Alade, Ayeisha Brinson and Jose Reyes-Tomassini, all NMFS employees, are continuing to collaborate with the Center particularly in teaching courses in support of its mission.

2. How many students participated in Center projects or activities? Fifty-nine (59) students participated in the Center projects. The names of some of the students, their research projects and presentations they made during this reporting period are presented in the section on "scholarly productivity" on pages 26 through 30. More than 1000 K-12 students participated in the Center educational and outreach activities.

3. What specific benefits were accrued to students, faculty members and the institution(s) by participating in the program? Students benefited from their participation in the projects through hands-on research experience, completion of theses in partial fulfillment of their degree requirements, stipend, and travel awards to conferences. Besides, some students secured employment after completion of their degree programs, or received scholarships for graduate studies. Some of the students' awards and benefits are mentioned below:

Student Awards:

Maryse Leandre (HU) receives a VA Space Grant Award as a result of her M.S. research at HU.

Students who Received Employment as a Result of their Work at the Center:

Matthew Taylor (HU) is in the Observer Program at the Alaska Fisheries Science Center
Maryse Leandre is currently employed as Environmental Supervisor at Northrup Grumman aerospace.

Students who Received Scholarships for Graduate Degree Programs as a Result of their Work at the Center:
Xaymara Serrano and Rolando Santos (RSMAS) continued to receive support during this period from the McKnight Fellowship to support their PhD work.
Kasim Ortiz received a graduate research assistantship from the Institute for Partnerships to Eliminate Health Disparities at the University of South Carolina's Health Sciences Policy and Management Program and LaTrisha Allen is an ECSC fellow at FAMU.

The following students have applied to scholarship opportunities through NOAA or other agencies
Jeanette Davis (Ph.D, UMCES IMET): Dr. Nancy Foster Scholarship program.
Ammar Hanif (M.S., UMCES IMET): NOAA-EPP Graduate Sciences Program
Eric Evans (Ph.D. UMES): NOAA-EPP Graduate Sciences Program
Jhamyllia Rice? (Ph.D, UMES): NOAA Graduate Sciences Program
Jan Vicente (Ph.D, UMCES IMET): EPA-Star (10/11), Ford Foundation (01/12), and Dr. Nancy Foster Scholarships.
Tiana Jones (B.S., UMES) applied for the NOAA Undergraduate Scholarship Program
Briana Jones (B.S., UMES) applied for the NOAA Undergraduate Scholarship Program

Students who received Training at NOAA Laboratories or at Center Institutions
a) William Gardner has been conducting research in collaboration with Dr. Ashok Deshpande at the NOAA J.J. Howard Marine Science Lab at Sandy Hook continuously from April, 2009 to the present. William is analyzing the PCB content of Atlantic coast and Chesapeake Bay striped bass. He will complete this research project in December, 2011 and is expected to graduate in May, 2012.

4. To what extent have the projects or activities enhanced and improved outreach, education, training and NOAA related research at the institutions?
Students supported under the LMRCSC have access to tools and training they would not have were it not for the LMRCSC. Several students at the Center institutions who are not directly funded by the LMRCSC are benefiting from the infrastructure and equipment made available to the institutions by the LMRCSC. Moreover, the LMRCSC has resulted in leveraged funding that has enabled the Center institutions to recruit and support more students than they would otherwise be able to support.

SECTION IV – REVISIONS TO TASKS AS DESCRIBED IN GRANT AWARD AMENDMENTS AND THE IMPACT TO THE AWARD: There were no amendments to the award.