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DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA16SEC4810007
3. Project Title: Living Marine Resources Cooperative Science Center	
4. Award Period of Performance Start Date: 09/01/2016	5. Award Period of Performance End Date: 08/31/2022
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
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9. Email: pchigbu@umes.edu	10. Phone Number: 410-621-3034
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13. Title: Director of Research	
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REPORTING INFORMATION	
Signature of Submitting Official: Joshua Shockley	
16. Submission Date and Time Stamp: 09/30/2022	17. Reporting Period End Date: 08/31/2022
18. Reporting Frequency: ○ Annual ◉ Semi-Annual ○ Quarterly	19. Report Type: ◉ Not Final ○ Final
RECIPIENT ORGANIZATION	
20. Recipient Name: UNIVERSITY OF MARYLAND EASTERN SHORE	
21. Recipient Address: 11868 ACADEMIC OVAL, PRINCESS ANNE, MD 21853-1295 USA	
22. Recipient UEI: LNUBJQ26R2M5	23. Recipient EIN: 526002033

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

Education Goals:
1. Prepare the future workforce for marine and fisheries sciences through the relevant degree programs.
2. Strengthen collaborations across partner universities and professional networks to enhance academic programs in marine and fisheries sciences

Research Goal:
1. Develop an exemplary capacity for scientific collaborations among partner institutions in the NOAA relevant fields of marine and fisheries sciences

Administration Goals:
1. Organizational excellence for effective and efficient management of the programs and activities of the Center
2. Effectively communicate the activities and accomplishments of the Center
3. Assess and evaluate the Center's goals and objectives

25. What was accomplished under these goals?

Students Recruited and trained: A total of 113 students have been recruited to the Center. Twenty-five (25) students have been identified/recruited to the Center as members of Cohort 1 (2016 – 2017), including 6 Ph.D., 6 M.S., and 13 B.S. Of these Cohort 1 students, nineteen (19) have graduated, including 4 Ph.D., 6M.S., and 9 B.S. students. Twenty-five (25) students have been identified/recruited as members of Cohort 2 (2017-2018) including 8 Ph.D., 8 M.S., and 9 B.S. students. Of the Cohort 2 students, 18 have graduated, including 5 Ph.D., 7 M.S., and 6 B.S. students. Twenty-two (22) students have been identified/recruited as members of Cohort 3 (2018-2019) including 4 Ph.D., 7 M.S. and 11 B.S. students. Ten (10) students from Cohort 3 have graduated so far including 1 Ph.D., 4 M.S. and 5 B.S. Seventeen (17) students including 3 Ph.D., 8 M.S., and 6 B.S. students have been recruited into Cohort 4. Of the Cohort 4 students three (3) have graduated including 2 M.S. and 1 B.S. student. Twenty-three (24) students have been recruited into Cohort 5 including 5 Ph.D., 8 M.S., and 11 B.S. students. One B.S. student from Cohort 5 has graduated.

Six (6) active collaborative research projects (Table 25.1) were underway after selection for funding by the LMRCSC after reviews by the Technical Advisory Board (TAB). Other research projects supported with leveraged funds from agencies such as NOAA, NSF, USDA, are on-going at the LMRCSC.

The Center continued to hold monthly Executive Committee meetings during which plans to execute student development and professional activities were discussed.

Further details can be found in the attached document.

ACCOMPLISHMENTS *(cont'd)*

26. What opportunities for training and professional development has the project provided?

The Center provided direct support during this period for training of 44 students (14 B.S., 19 M.S., 11 Ph.D.). Sixteen graduate students participated in the Data Carpentry for Ecologists workshop in November 2021. Graduate and undergraduate students are required to take part in Scientific Ethics Training by completing the CITI Responsible Conduct of Research online training course. Graduate students at RSMAS, UMES, and UMCES are also required to complete a semester long course in ethics. The education committee continued to deploy asynchronous training modules for undergraduate students in Social Science and Data Management. Undergraduate students will continue to complete these modules in coming reporting periods. All of these activities are captured through the completion of the Student Development Plan form, which is completed by the students in consultation with their advisors each semester. A list of supported students and their completion of these activities is available in Table 26.1 in the attached document.

During this period, eighteen (18) students completed NERTO internships. A list of these students, their mentors, and their projects is available in Table 26.2 in the attached document.

27. How were the results disseminated to communities of interest?

• Center Scientists produced 10 journal articles, 2 of which included student authors, and 1 chapter in a book.
• Four additional journal articles, including one additional student author, were in press or under review at the end of this reporting period.
• Center Scientists delivered 27 oral and 16 poster presentations at professional meetings, of which 25 and 16 were by student presenters, respectively.
• To date, Center publications since September 2016 have been cited 1,313 times (188 from directly funded publications, 1125 from leveraged publications).
• The Center continues to update its website regularly and publish newsletters. During this period, a newsletter was published in June 2022.

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

Education Goals: As examples, the Center will:
• Continue to engage NOAA Scientists in order to enhance research collaborations and identify scientists to serve on graduate student thesis and dissertation committees; work with students to identify sites for NERTO.
• Continue to mentor students and encourage them to present research results at professional meetings, and publish their work in peer-reviewed journals.
Research Goals: As examples the Center will:
• Continue to seek leveraged funds to support students
• Continue research on TAB funded projects and projects supported through leveraged funds
• Continue efforts to publish results from prior awards and present at scientific meetings.
Administrative Goals: As examples, the Center will:
• Continue Executive Committee meetings monthly.
• Continue to collect data for evaluation of the Center's activities.
• Continue to disseminate information about the Center to the public, including producing Newsletters.
• Continue to monitor student development plans to ensure completion of Center Milestones.
• Continue to collect post-graduation information on the students.

PRODUCTS

29. Publications, conference papers, and presentations

• Center Scientists produced 10 journal articles, 3 of which included student authors, and 1 chapter in a book. Full citations are available in the attached document in Tables 29.1a and b.
• Four additional journal articles, including one additional student author, were in press or under review at the end of this reporting period. A detailed citation is available in the attached document in Table 29.2.
• Center Scientists and students delivered 27 oral and 16 poster presentations at professional meetings, most by student presenters. A detailed list is available in the attached document in Table 29.3.

PRODUCTS *(cont'd)*

30. Technologies or techniques

Nothing to Report

31. Inventions, patent applications, and/or licenses

Nothing to Report

Attach a separate document if more space is needed for #6-10, or #24-50.

PRODUCTS *(cont'd)*

32. Other products

In addition to the products listed above, the Center also produced three theses/dissertations (Table 32.2).

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Sixty-one (61) individuals have worked on the project, including scientists (16), graduate students (28), undergraduate students (13) and professional staff (4). Their details can be found in Table 33.1 of the attached document.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Key personnel reported changes to 3 sources of support including one renewed sources of support. Details can be seen in Table 34 in the attached document.

35. What other organizations have been involved as partners?

Thirteen (13) organizations including six state agencies, three NGOs and one private organization were involved as collaborators in the project. The details of these collaborations can be seen in Table 35 of the attached document.

Attach a separate document if more space is needed for #6-10, or #24-50.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

Thirty-nine (39) NOAA Scientists and thirteen (13) scientists from other institutions have been involved in the project as collaborators during this period. Their names and involvement are listed in Tables 36.1 and 36.2 in the attached document.

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

During this period, the Center directly supported work that resulted in 2 peer reviewed journal articles in NOAA-mission sciences.

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

LMRCSC students at RSMAS are active in improving Diversity, Equity, and Inclusion at the University level.
The SSU MSCI program is the pacesetting program for the other STEM graduate degrees at SSU because of the LMRCSC. Even the liberal arts graduate programs note best practices from the MSCI degree program.

39. What was the impact on the development of human resources?

Students and faculty are receiving the financial support needed to stay in school, to be trained in research, to enter graduate programs, and to be gainfully employed to conduct NOAA research after graduation. Six students earned degrees in NOAA relevant sciences and have secured or are seeking employment in the field. Details can be seen in Table 39 in the attached document.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

Students across the Center have access to courses at other Center institutions. This access broadens the diversity of courses available to our students. The Cohort Experience Workshop and other Center training and professional development further enhance our students' experience, making it more relevant to future NOAA mission careers.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

At HU, institutional impact was achieved by providing additional funding to support faculty and student research, via upgrading lab space and equipment.
At RSMAS, support increases the critical mass of fisheries scientists at RSMAS, improving our ability to do NOAA relevant work and train students.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

Research results have been published, and presented at scientific meetings and stock assessment working groups.
SSU is partnering with the SEFSC to develop greater sUAS capacity in support of fisheries research. Methods developed in faculty and student research on the effects of ocean acidification is being used to propose a model system for the Galveston laboratory.

43. What was the impact on society beyond science and technology?

Training offered to students at the LMRCSC is helping to diversity the workforce in marine and fisheries science.
At HU, faculty and students are being invited to give talks, serve on panels, and work with K-12 students on Center related research.
Aquaculture and the aquaculture facility at DSU have contributed to student outreach activities.
At RSMAS, one PhD student is working on a web-based data interface that will be open to the public.
At SSU, Center activities have created HBCU capacity to perform oyster reef restoration for shoreline stabilization and fisheries productivity. These activities were the basis for a larger habitat restoration proposal submitted by the Gullah Geechee Cultural Heritage Corridor Commission to perform oyster reef restoration throughout the National heritage Area.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , At RSMAS, PhD student research on lane snapper age, growth and connectivity includes samples gathered in Belize, and may inform management of this species in Belize.
At UMCES, collaboration between Schott lab and crab researchers in Brazil brought the Brazilians a level of 'Omics expertise that improved their research going forward.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Pandemic restrictions have required that traditionally in-person activities such as the Cohort Experience Workshop and NERTO be conducted virtually.
At SSU, the institutional PI was on mandatory telework through part of this period and was not in the building. Students who were in the building were managed by Dr. Victoria Young.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to Report

47. Changes that had a significant impact on expenditures

Personnel changes in DSU CAST caused difficulties in summer supply ordering.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to Report

49. Change of primary performance site location from that originally proposed

Nothing to Report

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

The Implementation Plan identifies four Education outcomes and two Research outcomes. The details of these outcomes are provided in the attached document. Highlights from this reporting period include:

- 57 total students, 51 Underrepresented Minority (URM) students trained in the Center
- 51 URM students pursuing higher education in NOAA mission fields
- 3 Seminars offered
- 6 students graduated, of which 6 are URM students
- 37 collaborations with NOAA Scientists
- 6 collaborative research projects

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

Attach a separate document if more space is needed for #6-10, or #24-50.

Supplemental Text to the LMRCSC Semi-annual Report (March 1, 2022 – August 31, 2022)

Text and tables are arranged using the same numbering system in the RPPR form:

25. What was accomplished under these goals?

a. Major Activities:

i. Education Activities:

Student Recruitment Activities: Recruitment activities for this award have ended.

Experiential Training – The Center has continued to enhance its engagement with NOAA scientists in order to identify mentors for LMRCSC graduate and undergraduate students during the NERTO program and as members of their thesis or dissertation committees.
During this period, many facilities began to open after Covid 19, thus NERTO internships ranged from remote to fully in-person depending on the specific circumstances of each facility. Several NERTO internships were conducted remotely with the assistance of the students' NOAA mentors.

ii. Research Activities – The following table describes 6 TAB projects that were active during the reporting period that were investigated by students and scientists at the LMRCSC partner institutions. One of these projects began in 2019, three in 2020, and 2 were initiated in 2021.

Table 25.1: TAB Projects During this Reporting Period*

Project Number	Principal Investigator	Title	Thematic Research Area
19-07	Adrianne Wilson	Population structure and growth of lane snapper, a data limited species	SASI
20-03	Kyarii Ramarui	Proteomic analysis of two *Haematococcus pluvialis* strains as aquaculture feedstock	SNAP
20-04	Eric Schott	Life history and disease ecology of the blue crab, a key benthic-pelagic link in tropical and temperate American estuaries	SASI
20-06	Janelle Layton	Investigating the effects of climate change on heat shock proteins and development in the early life history stages of Nassau grouper	CLIME
21-01	Tunde Adebola	Developing a Coupled Human Ecological System for Chesapeake Bay Shellfish Fisheries	SASI
21-02	Nicholas Coleman	Sonar Censusing and Habitat Use by Spawning Run Atlantic and Green Sturgeon, *Acipenser oxyrinchus* and *A. medirostris*	SASI

**Only currently active projects are included. CLIME: Climate Impacts on Marine Ecosystems;*

HaBS: Habitats and Biological Systems; SASI: Stock Assessment Support and Information; SNAP: Seafood, Nutrition, Aquaculture, and Pathology; FESS: Fishery Economics and Social Sciences

In addition, several projects supported with leveraged funds from various agencies including NOAA, NSF, and USDA are on-going at the Center, and new proposals were developed and submitted to various funding agencies.

Data Management and QA/QC: Based on feedback from students and the recommendation of the External Evaluation team, the Education Committee has elected to replace the Data Management for Scientists course, which graduate students took for credit. Instead, the Center contracted an organization called Data Carpentry to conduct a two-day workshop entitled "Data Management and Visualization in R for Ecologists." The workshop was held November 13 and 14, 2021 and was required for all graduate students who had not already fulfilled the Data Management training requirement.
Graduate students who had already completed the requirement and advanced undergraduates were also invited to participate as space allowed. Students who joined the Center after November 2021 will complete this training in Fall 2022, if they are approved for transfer to the new award.

Ethical Conduct of Research Training for Students and Faculty:
All center students are required at a minimum to complete online CITI Responsible Conduct of Research courses. The certificate of completion is submitted through the ISpring Learning Management System (LMS). In addition, graduate students at RSMAS, UMES, and UMCES are required to take a course in scientific ethics.

iii. Administrative activities:
   1. The Center conducted its monthly Executive Committee, Education Committee, and Science Committee meetings.

b. Specific Objectives
   i. **Education Goal 1.** Prepare the future workforce for marine and fisheries sciences
      1. Objective 1.1: Recruit students from under-represented groups into marine and fisheries science disciplines
      2. Objective 1.2: Increase retention and degree completion rates for students in marine and fisheries sciences programs
      3. Objective 1.3: Assess the value-added outcomes of degree programs in marine and fisheries sciences at the partner institutions
   ii. **Education Goal 2.** Strengthen collaborations across universities and professional networks to enhance academic programs in marine and fisheries sciences
      1. Objective 2.1: Use relevant research-based curricula to provide students with the highest quality education in marine and fisheries sciences
      2. Objective 2.2: Use Virtual Campus technology to provide students with the opportunity to learn from some of the nation's leading scholars in marine and fisheries sciences
      3. Objective 2.3: Ensure that curricula of degree programs at partner institutions address current challenges and emergent needs within the profession
      4. Objective 2.4: Link students to professional networks and employment opportunities in marine and fisheries sciences
   iii. **Scientific Research Goal 3.** Develop an exemplary capacity for scientific collaborations among partner institutions in the NOAA relevant fields of marine and fisheries sciences
      1. Objective 3.1: Integrate the Center's research agenda with NOAA Fisheries research priorities in four key thematic areas: ecosystem change and prediction,

stock assessment support, habitat research and protection, and safe seafood and aquaculture

2. Objective 3.2: Foster collaborative research programs to strengthen the research capacities of partner institutions by leveraging the significant strengths and resources of research universities as infrastructure for capacity building
3. Objective 3.3: Develop faculty recruitment and retention practices that ensure that the collective capacity of scholars affiliated with the Center represents significant concentrations of strength in the four key research thematic areas

iv. **Administration Goal 4.** Organizational excellence for effective and efficient management of the programs and activities of the Center

1. Objective 4.1: Establish an Administrative Structure to enhance center operations and provide supportive environment for training and mentoring of students, and for research in marine and fisheries sciences
2. Objective 4.2: Monitor and ensure compliance with Center Award Conditions

v. **Administration Goal 5.** Effectively communicate the activities and accomplishments of the center

1. Objective 5.1: Develop infrastructure for effective and efficient internal and external communication
2. Objective 5.2: Develop an effective strategy for communication with students, faculty and administrators within the center, and increase visibility of the center through enhanced communication of its accomplishments to external stakeholders

vi. **Administration Goal 6.** Assess and evaluate the center's goals and objectives

1. Objective 6.1: Assess and evaluate center educational programs
2. Objective 6.2: Assess and evaluate center research
3. Objective 6.3: Assess and evaluate center administration

c. Significant results:
    i. Education goals: Students recruited and trained: A total of 113 students have been recruited to the Center. Twenty-five (25) students have been identified/recruited to the Center as members of Cohort 1 (2016 – 2017), including 6 Ph.D., 6 M.S., and 13 B.S. Of these Cohort 1 students, nineteen (19) have graduated, including 4 Ph.D., 6 M.S., and 9 B.S. students. Twenty-five (25) students have been identified/recruited as members of Cohort 2 (2017-2018) including 8 Ph.D., 8 M.S., and 9 B.S. students. Of the Cohort 2 students, 18 have graduated, including 5 Ph.D., 7 M.S., and 6 B.S. students. Twenty-two (22) students have been identified/recruited as members of Cohort 3 (2018-2019) including 4 Ph.D., 7 M.S. and 11 B.S. students. Ten (10) students from Cohort 3 have graduated so far including 1 Ph.D., 4 M.S. and 5 B.S. Seventeen (17) students including 3 Ph.D., 8 M.S., and 6 B.S. students have been recruited into Cohort 4. Of the Cohort 4 students three (3) have graduated including 2 M.S. and 1 B.S. student. Twenty-three (24) students have been recruited into Cohort 5 including 5 Ph.D., 8 M.S., and 11 B.S. students. One B.S. student from Cohort 5 has graduated.
        a. A new tool has been added to the LMRCSC Virtual Campus: the Learning Management System (LMS) ISpring Learn. The new LMS represents a significant upgrade from the previously used LMS, Schoology. During this period, we continued building content and developing reports through the system as well as training students in its use. It has already begun to enhance the engagement of students in Center activities as well as improve tracking of student progress and assessment of activities.
    2. Building a Strong Center Cohort Community:
        a. Two installments of the LMRCSC Fellow Forum were held during this period (March and May 2022).
        b. A training webinar regarding Personal Time Management for Students was held in March.
        c. Professional Development workshop was offered by Dr. Maggie Sexton biweekly for undergraduate students and monthly for graduate students during the academic year at UMES.
        d. PIs at HU, OSU, SSU, and UMCES report holding regular lab meetings with Center students.
        e. Center staff and students participated in the 10th Biennial Science and Education Forum in Tallahassee, Florida. Center Director Dr. Paulinus Chigbu sat on the Steering Committee. Center Assistant Director sat on the Sponsorship and Exhibitors Committee. Dr. Dan Cullen represented LMRCSC on the Technical Program Committee. Center Faculty served as moderators for four technical sessions and judged at least 30 student oral and poster presentations. Center Students presented 13 talks and 9 posters. Center staff and students also took the opportunity to gather for dinner during the forum.
    ii. Research goals: 6 collaborative research projects (Table 25.1) were underway after selection for funding by the LMRCSC after reviews by the Technical Advisory Board (TAB). Reports on the TAB projects are included in Appendix II. Other research projects supported with leveraged funds from agencies such as NOAA, NSF, USDA, are on-going at the LMRCSC. A list of leveraged funds can be found in Appendix III.
    iii. Administrative goals:
        1. The Center held its monthly Executive Committee meetings during which plans to execute student development and professional activities were discussed.
        2. The LMRCSC External Evaluators submitted to the Center their findings from

assessment activities during this period. The report is available in Appendix IV.

3. OSU LMRCSC Program Director hosted a special session sponsored by the LMRCSC at the 2022 Annual American Fisheries Society Meeting. The session focused on collaborative research that advances our understanding and management of marine and estuarine fisheries and the habitats that support them. Center students and scientists submit abstracts. Four students and 2 Center staff contributed presentations.

b. Key outcomes or other achievements:
   i. A total of 113 students (25 in Cohort 1, 25 in Cohort 2, 22 in Cohort 3, 17 in Cohort 4, and 24 in Cohort 5) have been recruited to the Center
   ii. Twelve (12) additional non-degree students were trained through internships.
   iii. External Evaluation of the LMRCSC is continuing.
   iv. New proposals have been submitted to various agencies to leverage funding in order to support additional students.

26. What opportunities for training and professional development has the project provided?

The project has provided students several training and professional development opportunities including the NERTO, and training in Ethical Conduct of Research and Data Management (Table 26.1, 26.2).

Table 26.1: Supported students, training opportunities and milestones. URM (Underrepresented Minority)

First	Last	URM (y or n)	Cohort #	Degree	Partner	Cohort Experience	NERTO	Ethical Conduct of Research Training	Data Management Course	NOAA Mentor
Maria	Henson	Y	1	B.S.	HU	NA	NA	Fall 21	Spr. 21	NA
Adrianne	Wilson	Y	2	Ph.D.	RSMAS	Spr. 19	Fall 18	Fall 15	Fall 18	Yes
Joe	Day	Y	2	M.S.	SSU	Fall 22	Sum. 22	Fall 20	Fall 22	Yes
Sena	Tay	Y	2	M.S.	SSU	Spr. 21	NA	NA	Fall 21	Yes
Nicholas	Coleman	Y	2	M.S.	UMCES	Spr. 21	Sum. 22	Spr. 22	Fall 17	Yes
Kasondra	Rubalcava	Y	2	Ph.D.	UMES	Spr. 18	Sum. 19	Fall 19	Fall 19	Yes
Arona	Bender	Y	3	M.S.	HU	Spr. 21	Sum. 21	Spr. 20	Fall 20	Yes
Benjamin	Frey	Y	3	M.S.	UMCES	Spr. 19	Spr. 19	Fall 19	Fall 19	Yes
Teemer	Barry	Y	3	B.S.	UMES	N/A	N/A	Fall 18	Spr. 21	N/A
Caitlyn	Czajkowski	N	3	M.S.	UMES	2021	2022	2020	2021	Yes
Ashley	Silver	Y	3	Ph.D.	UMES	Spr. 21	Sum. 21	Fall 20	Fall 20	Yes
Emily	Andrade	Y	4	M.S.	DSU	2023	2022	2021	2021	Yes
PaShun	Hawkins	Y	4	B.S.	HU	NA	NA	Spr. 21	Spr. 21	NA
Jaelyn	Leslie	Y	4	M.S.	HU	Spr. 21	Sum. 21	Fall 20	Fall 20	Yes

Layton	Janelle	Y	4	M.S.	OSU	Apr-21	Jun. 22-Aug. 22	Fall 2020	Fall 2021	Yes
Hillary	Thalmann	N	4	Ph.D.	OSU	Mar/April -2019	Mar. 22-Jun. 22	Fall 2021	Fall 2021	Yes
Cristin	Mayes	Y	4	Ph.D.	RSMAS	NA	Sum 22	Fall 19	NA	Fall 20
Kyarii	Ramarui	Y	4	Ph.D.	UMCES	Spr. 21	Spr. 21	Fall 19	Fall 20	Yes
Glen	Collins	Y	4	B.S.	UMES	N/A	N/A	Spr. 21	Spr. 21	N/A
Shakira	Goffe	Y	4	M.S.	UMES	Spr. 21	Sum. 21	Fall 19	Fall 20	Yes
Tahirah	Johnson	Y	4	M.S.	UMES	Spr. 21	Sum. 21	Spr. 21	Fall 20	Yes
Imani	Wilburn	Y	4	M.S.	UMES	Spr. 21	Sum. 21	Spr. 20	Fall 20	Yes
Jonathan	Nash	Y	5	B.S.	HU	NA	NA	Spr. 21	Spr. 21	NA
T'Kiyah	Reeves	Y	5	B.S.	HU	NA	NA	Spr. 21	Spr. 21	NA
Derrick	Richardson	Y	5	B.S.	HU	NA	NA	Spr. 21	Spr. 21	NA
Noah	Tait	N	5	M.S.	HU	Fall 2022	Sum. 22	Spr. 22	Spr. 22	Yes
Leann	Cohn	Y	5	MS	OSU	TBD	Jun. to Sept. 21	Fall 2022	Fall 2021	Yes
Jennifer	Wong-Ala	Y	5	PhD	OSU	TBD	Jun. 22-Aug. 22	Fall 2022	Fall 2021	Yes
Chryston	Best-Otubu	Y	5	PhD	RSMAS	Spr. 21	Fall 22	Fall 20	Fall 20	Fall 21
Michon	Shaw	Y	5	B.S.	SSU	NA	NA	NA	NA	Yes
Alexandria	Tennant	Y	5	B.S.	SSU	NA	NA	NA	NA	Yes
Kristafer	Howard	Y	5	M.S.	SSU	Spr. 21	Spr. 21	Fall 20	Fall 21	Yes
Cloe	Lemaire	N	5	M.S.	SSU		Sum. 22	Fall 21		Yes
David	Garcia	Y	5	Ph.D.	UMCES	Fall 22	Sum. 22	Spr. 23	Fall 22	Yes
Olivia	Pares	Y	5	Ph.D.	UMCES	Spr. 21	Spr. 21	TBD	Fall 20	Yes
Mikaela	Blackwood	Y	5	B.S.	UMES	N/A	N/A	Spr. 22	N/A	N/A
Malika	Brown	Y	5	B.S.	UMES	NA	NA	Fall 21	NA	N/A
Nina	Clovis	Y	5	B.S.	UMES	N/A	N/A	Spr. 22	N/A	N/A
Kayla	McKinley	Y	5	B.S.	UMES	N/A	N/A	2022		N/A
Kendall	Metz	N	5	B.S.	UMES	N/A	N/A	2021		N/A
Angel	Delgado	Y	5	M.S.	UMES	Fall 2022	Sum. 22	Fall 21	Fall 21	Yes
Marcus	Teat	Y	5	M.S.	UMES	2023	2022	2020	2021	Yes
Kaithlynn	Wade	Y	5	M.S.	UMES	Fall 2022	Sum. 23	Fall 21	Fall 21	Yes
Jasmine	Smalls	Y	5	Ph.D.	UMES	Fall 22	Sum. 22	Spr. 22	Fall 22	Yes
Savannah	Clax	Y		Non-Degree	OSU	NA	NA	NA	NA	NA
Keons	Adams	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Dajaa	Ajhar	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A

Kevin	Armstrong	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Eymani	Barias	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Myah	Bowie	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Daryl	Bullock	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Chaney	Galloway	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Xavier	Harrell	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Leianna	Jones	N		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Moses	Nwakwuo	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Anazi	Pharrams	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A
Kayla	Winn	Y		Non-Degree	UMES	N/A	N/A	N/A	N/A	N/A

Table 26.2: NERTO internships completed during this reporting period.

Student Name	Activity/Project Title	NOAA Personnel Involved	Location
Angel Reyes Delgado	Diet variation and trophic impact of weakfish (*Cynocion regalis*) within multiple marine habitats of the Eastern U.S.	Brian Smith	NEFSC, Woods Hole, MA
Chryston Best-Otubu	Spatial modeling of diets, predation, and the pelagic food web of the California Current	Isaac Kaplan	NWFSC, Seattle, WA
Cloe Lemaire	Position, monitoring pH in south Texas estuaries as a measure of microhabitat variability	Jennifer Doerr	SEFSC, Galveston, TX
Cristin Mayes	Advanced predictive modeling, assessment, and web development for coastal Restoration	Joe Serafy	SEFSC, Miami, FL
David Garcia	A temporal analysis of microbes in the Salish Sea using 16S rRNA	Matt Galaska and Sean McAllister	Genetics and Genomics Group (G3) and in the Ocean Environment division at the NOAA PMEL, Seattle, WA
Emily Andrade	Antimicrobial assessment of microalgae species for use as aquaculture feed additives for sablefish	Joseph Dietrich	NWFSC, Newport, Oregon

Hillary Thalmann	Assessing Pacific Cod metabolic rate under variable temperature scenarios using otolith stable isotopes and microchemistry	Ben Laurel	AFSC, Newport, OR
Imani Wilburn	Quantifying microplastics in Maryland Coastal Bay fish and sediments	Ashok Deshpande	NEFSC, JJ Howard Marine Science Laboratory
Janelle Layton	Species distribution modeling of climate vulnerable West Coast Groundfishes	Chris Harvey	NWFSC, Seattle, WA
Jasmine Smalls	Prevalence of *Vibrio parahaemolyticus* and *Vibrio vulnificus* in Blue Crabs (*Callinectes sapidus*) and Seawater Harvested from the Maryland Coastal Bays.	John Jacobs and Howard Townsend	NOAA/NCCOS/NMFS/ST/ Ecosystems Cooperative, Oxford Lab
Jennifer Wong-Ala	Transport of *Toxoplasma gondii* oocysts in coastal areas inhabited by the Hawaiian monk seal	Johnanna Wren	NOAA PIFSC, Honolulu, HI
Joe Day	Genetic analysis of Common Bottlenose Dolphins *Tursiops truncatus*	John Carlos Garza and Eric Archer	NWFSC, La Jolla, CA
Kaitlynn Wade	Low recruitment in US South Atlantic Reef Fish	Kevin Craig and Kyle Shertzer	SEFSC, Beaufort, NC
Kia Ramarui	Flow cytometric investigation of the high-light stress response of a heterotrophically grown mutant *Haematococcus pluvialis* strain.	Gary Wikfors	NEFSC, Milford, CT
Marcus Teat	Microplastics in River Otters	Ashok Deshpande	NEFSC JJ Howard Lab, Sandy Hook, NJ
Noah Tait	Developing a coupled human ecological system for Chesapeake Bay shellfish fisheries	Howard Townsend	Oxford, MD
Olivia Pares	Systematic review of the disease ecology and conservation & management strategies of stony coral tissue loss disease	Helena Antoun	SEFSC, Puerto Rico
Tahirah Johnson	Prevalence and environmental determinants of *Shewanella* spp. in Chesapeake Bay and Maryland's Coastal Bays	John Jacobs and Howard Townsend	NOAA/NCCOS/NMFS/ST/ Ecosystems Cooperative, Oxford Lab

29. Publications, conference papers, and presentations

Table 29.1a: LMRCSC Publications in peer reviewed journals. Center students are identified with asterisk (*). Center scientists' names appear in bold**.**

Publications in journals	Justification	Status
Lawrence* A, Green* S, Wang T, Bachvaroff T, **Chung JS**. 2022. Seasonal changes in the expression of insulin-like androgenic hormone (IAG) in the androgenic gland of the Jonah crab, *Cancer borealis*. PloS One 17(2).	Cohorts 1 and 2 students	Published
Secor DH, O'Brien MHP, **Coleman* N**, Horne A, Park I, Kazyak DC, Bruce DG, Stence C. 2022. Atlantic Sturgeon Status and Movement Ecology in an Extremely Small Spawning Habitat: The Nanticoke River-Marshyhope Creek, Chesapeake Bay. Reviews in Fisheries Science & Aquaculture 30(2):195-214.	TAB	Published
Adebola T, Hart D, **Chigbu P**. 2022. Bathymetric trends in the body size, and diet of *Astropecten americanus* in the northwest Atlantic Ocean. Estuarine Coastal and Shelf Science 269.	Leveraged	Published
Lin HZ, Li YT, **Hill RT**. 2022. Microalgal and bacterial auxin biosynthesis: implications for algal biotechnology. Current Opinion in Biotechnology 73:300-307.	Leveraged	Published
Liu CL, Dasi EA, Watson AM, **Place AR, Jagus R**. 2022. eIF2 alpha phosphorylation in response to nutritional deficiency and stressors in the aquaculture fish, *Rachycentron canadum*. Journal of Marine Science and Engineering 10(5).	Leveraged	Published
Secor DH, O'Brien MHP, **Coleman* N**, Horne A, Park I, Kazyak DC, Bruce DG, Stence C. 2022. Atlantic Sturgeon status and movement ecology in an extremely small spawning habitat: The Nanticoke River-Marshyhope Creek, Chesapeake Bay. Reviews in Fisheries Science & Aquaculture 30(2):195-214.	Leveraged	Published
Tavares CPD, Zhao ML, Vogt EL, Model JFA, Vinagre AS, da Silva UDT, Ostrensky A, **Schott EJ.** 2022. High prevalence of CsRV2 in cultured *Callinectes danae*: Potential impacts on soft-shell crab production in Brazil. Journal of Invertebrate Pathology 190.	Leveraged	Published
Tizabi D, Bachvaroff T, **Hill RT**. 2022. Comparative analysis of assembly algorithms to optimize biosynthetic gene cluster identification in novel marine actinomycete genomes. Frontiers in Marine Science 9.	Leveraged	Published
Wang T, He K, Blaney L, **Chung JS**. 2022. 17 beta-Estradiol (E2) may be involved in the mode of crustacean female sex hormone (CFSH) action in the blue crab, *Callinectes sapidus*. Frontiers in Endocrinology 13.	Leveraged	Published
Zhao ML, Xu L, Bowers H, **Schott EJ**. 2022. Characterization of Two Novel Toti-Like Viruses Co-infecting the Atlantic Blue Crab, *Callinectes sapidus*, in Its Northern Range of the United States. Frontiers in Microbiology 13.	Leveraged	Published

Table 29.1b: LMRCSC Publications as book chapters. Center students are identified with asterisk (*). Center scientists' names appear in bold**.**

Book chapters	Justification	Status
Horodysky AZ, C. Schweitzer, and R.W. Brill. *In Press*. Applied Sensory Physiology and Behaviour, Ch 2 *In*: Fangue N, Cooke SJ, Cech JJ, Eliason E, Brauner C and Farrell AP (eds). Fish Physiology Volume 39A: Conservation Physiology for the Anthropocene – A Systems Approach.	Leveraged	Published

Table 29.2: Publications that were in press or under review at the end of the reporting period. Center students are identified by asterisk (*). Center scientists' names appear in bold.

Publications in journals	Justification	Status
Holladay, P., **Hoskins-Brown, D**., Mandala, L., Mitchell, K. Gullah Geechee, appropriation and cultural heritage tourism. Tourism Geographies.	Leveraged	Under Review
López-Figueroa, N.B.*, Walters, T.L., Rodríguez-Santiago, A.E., Laureano-Rosario, A. E., DiGeronimo, S., Hallock, P., Frischer, M.E. and **Gibson, D.M**. Zooplankton community variability in the South Atlantic Bight (2015–2017)	Leveraged/LMRCSC Acknowledged	In Revision
Schultz, Emma A., Kemit-Amon Lewis, **Dionne L. Hoskins-Brown**. Summary of green sea turtle, *Chelonia mydas*, nesting data from the East end beaches of St. Croix, U.S. Virgin Islands from 2003-2015. Caribbean Journal of Science.	Other LMRCSC Activity	Under Review
Wade, K.J.*, Shertzer, K.W., Craig, K.J. & Williams, E.H. (2022). Correlation in recruitment patterns of Atlantic reef fishes off the southeastern United States. Regional Studies in Marine Science.	Cohort 5 Student	In Review

Table 29.3a: Oral presentations at professional meetings (virtual and in-person). Center students are identified by asterisk (*). Center scientists' names appear in bold.

Oral presentations at professional meetings	Justification
Barry*, T. 2022. Spatial data compilation for anadromous fishes protected under the Endangered Species Act. NOAA EPP/MSI Annual Forum. April 5-8, 2022. Tallahassee, FL.	Cohort 3 Student
Bender*, A.N., Krause, D., Goebel, M., **Lewallen, E., Bonin, C.** 2022. Estimating effective population size and historical demography of leopard seals (*Hydruga leptonyx*) in the Antarctic Peninsula. Association for the Sciences of Limnology and Oceanography (ASLO), Ocean Sciences Meeting (OSM); Virtual Feb 24- Mar 4 2022. Oral Presentation.	Cohort 3 Student
Bender*, A.N., Krause, D., Goebel, M., **Lewallen, E., Bonin, C.** 2022. Genetic approaches to monitor effects of climate change on leopard seals in the Antarctic Peninsula. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022. Oral Presentation.	Cohort 3 Student
Best-Otubu*. C. 2022. Estimating food web structural responses to water alterations in the Biscayne Bay using Ewe Models. American Fisheries Society Annual Meeting. Spokane, WA 8/21/2022- 8/25/2022.	Cohort 5 student

Chigbu, P., **Babcock, E**., **Gibson, D**., **Hoskins-Brown, D**., **Jagus, R**., **Miller, J.**, **Smith, S.**, **Sexton, M**., **Young, V**. 2022. Contributions of NOAA LMRCSC in enhancing workforce diversity in the marine science. Presented at the AFS meeting, August 20-25, 2022, Spokane, WA.	LMRCSC PIs
Coleman*, N.C., Lankowicz, K.M., O'Brien, M.H.P., Secor, D.H. 2022. Using Adaptive Resolution Imaging Sonar (ARIS) to estimate the fall spawning run of Atlantic sturgeon in the Nanticoke River-Marshyhope Creek. Oral Presentation at American Fisheries Society Tidewater Division. March 24-26. Nag's head, North Carolina.	Cohort 2 Student
Coleman*, N.C., O'Brien, M.H.P., Lankowicz, K.M., Secor, D.H. 2022. ARIS Sonar imaging of adult Atlantic Sturgeon in the Nanticoke-Marshyhope System. American Fisheries Society 152nd Annual Meeting. August, Spokane, Washington.	Cohort 2 Student
Cohn*, L., Feist, B., Whitmire, C., and Conway, F. 2022. Using GIS to illustrate rockfish conservation area closure impacts on the US West Coast from 2008-2021. Society for Applied Anthropology Conference Presentation, March 2022.	Cohort 5 Student
Czajkowski*, C., **McIntosh, D.** 2022. Efficacy of two disinfectant technologies for use in post-harvest treatment of oysters, Presented at NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022	Cohort 3 Student
Haughton*, S. 2022. Evaluating physiological and immune responses of Tanner crab to *Hematodinium* sp. Infection. NOAA EPP/MSI Annual Forum. April 5-8, 2022. Tallahassee, Fl.	Cohort 3 Student
Henson*, M., Schweitzer, C., **Horodysky, A.** 2022. Linking metabolic rate to growth rate in fishes of the Mid-Atlantic region. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022. Oral	Cohort 1 Student
Johnson*, T., Almuhaideb, E., Meredith, J., Rosales, D., **Chigbu, P., Dasilva, L., Parveen, S.**, Richards, G. 2022. Prevalence of *Shewanella* spp. in Chesapeake Bay Oyster and Seawater. NOAA EPP/MSI Annual Forum. April 5-8, 2022. Tallahassee, FL.	Cohort 4 Student
Johnson*, T., Almuhaideb, E., Meredith, J., Rosales, D., **Chigbu, P., Dasilva, L., Parveen, S.,** Richards, G. 2022. Prevalence of *Shewanella* species in Chesapeake Bay Oyster and Seawater. Association of Research Directors (ARD) meeting. April 2-5, 2022. Atlanta, GA.	Cohort 4 Student
Johnson*, T., Parveen, S., Meredith, J., Almuhaideb, E., Rosales D., **Chigbu, P., Dasilva, L**. 2022. Incidence and Pathogenic Potential of *Shewanella* species in oysters and seawater collected from the Chesapeake and Maryland Coastal Bays. IAFP annual meeting, July 30-August4, 2022. Pittsburgh, PA.	Cohort 4 Student
Johnson*, T., Parveen, S., Meredith, J., Almuhaideb, E., Rosales D., **Chigbu, P., Dasilva, L.** 2022. Occurrence of *Shewanella* species in oyster and seawater collected from the Chesapeake Bay. AFS annual meeting. August 21-25, 2022. Spokane, WA.	Cohort 4 Student
Leslie*, Jaelyn, Krause, Douglas. 2022. Assessing the changes in mass and body condition of Antarctic leopard seals (*Hydrurga leptonyx*) using aerial images. Association for the Sciences of Limnology and Oceanography (ASLO), Ocean Sciences Meeting (OSM); Virtual Feb 24- Mar 4 2022. Oral Presentation.	Cohort 4 Student
Leslie*, Jaelyn, Collier, Jahia, Morris, Halia, Barco, Susan, Adebola, Tunde, and **Bonin, Carolina**. 2022. The potential long-term impacts of the 2013 morbillivirus outbreak on common bottlenose dolphins (*Tursiops truncatus*) stranding frequency and body condition from Virginia, NOAA EPP/MSI Education and Science Forum; Tallahassee, Florida, April 6-8 2022. Oral Presentation.	Cohort 4 Student

Miller, J. A., Almeida, Z. A., **Thalmann*, H.,** Rogers, L., Laurel, B. 2022. Thermal effects on early life stages of Gulf of Alaska Pacific Cod: shifts in phenology 2022 American Fisheries Society Meeting, Spokane, WA	Cohort 4 Student
Nash*, J. 2022. Quantifying the distribution of gelatinous invertebrates and their habitat conditions on the Northeast US Shelf through imagery and associated environmental Data. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022. Oral	Cohort 5 Student
Reeves*, T., Schweitzer, C., **Horodysky, A.** 2022. Effect of environment on pigmentation in the grass shrimp, *Palaemonetes pugio*. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022.	Cohort 5 Student
Rubalcava*, K. Chigbu P. 2022. Abundance and distribution of Brown Shrimp (*Farfantepenaeus aztecus*) in Maryland Coastal Lagoons. 2022 American Fisheries Society Meeting, Spokane, WA	Cohort 2 student
Smith, S., Elliott, C., Gissandaner, C. 2022. Blue carbon sequestered in Delaware Tidal Marsh Soils. Presented at the Association of 1890 Research Directors Research Symposium, Atlanta, GA, April 2022	Leveraged
Teat*, M., Bland, A., Maina*, J., Venello, T., Ozbay, G. 2022. Oyster restoration, species diversity, and water quality in Rehoboth Bay, Delaware. Presented at NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022 - RCCE - 3rd Place Oral ($250)	Cohort 5 Student
Teat*, M., Bland, A., Maina*, J., Venello, T., **Ozbay, G.** 2022. Oyster restoration, species diversity, and water quality in Rehoboth Bay, Delaware. Presented at the American Fisheries Society Meeting, Spokane, WA, August 2022	Cohort 5 Student
Teat*, M., Bland, A., Maina, J., Venello, T., **Ozbay, G**. 2022. Oyster restoration, species diversity, and water quality in Rehoboth Bay, Delaware. Presented at the Association of 1890 Research Directors Research Symposium, Atlanta, GA, April 2022	Cohort 5 Student
Thalmann*, H., Laurel, B., **Miller, J.** A. 2022. ICES PICES Early Career Science Conference: Effects of thermal variability on juvenile Pacific Cod diet and trophic position in Gulf of Alaska nursery habitats, St. John's, NL, CA	Cohort 4 Student
Thalmann*, H., Laurel, B., Rew, M. B., Almeida, Z. A., **Miller, J. A.** 2022. Quantifying Pacific Cod metabolic rate using otolith carbon isotopes and microchemistry. 2022 American Fisheries Society Meeting, Spokane, WA	Cohort 4 Student

Table 29.3b: Poster presentations at professional meetings (virtual and in person). Center students are identified by asterisk (*). Center scientists' names appear in bold.

Poster presentations at professional meetings	Justification
Andrade*, E., Allison, R., Bland, A., Gadde, M., Nakazwe, M., Venello, T., **Ozbay, G**. 2022. Investigating the relationship between physical water quality parameters and chlorophyll-*a* in Rehoboth Bay, Delaware. Presented at the American Fisheries Society Meeting, Spokane, WA, August 2022 - Best Water Quality Poster AFS-WQ section ($100)	Cohort 4 Student
Andrade*, E., Allison, R., Bland, A., Gadde, M., Nakazwe, M., Venello, T., **Ozbay, G**. 2022. Investigating the relationship between physical water quality parameters and chlorophyll-*a* in Rehoboth Bay, Delaware. Presented at the Association of 1890 Research Directors Research Symposium, Atlanta, GA, April 2022	Cohort 4 Student

Andrade*, E., Allison, R., Bland, A., Gadde, M., Nakazwe, M., Venello, T., **Ozbay, G**. 2022. Investigating the relationship between physical water quality parameters and chlorophyll-*a* in Rehoboth Bay, Delaware. Presented at NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022	Cohort 4 Student
Cohn*, L., Harvey, C., Conway, F., Feist, B., and Whitmire, C. 2022. Using GIS to illustrate the intersection between climate change, energy and fisheries. Poster presentation at 2022 NOAA EPP Forum, Tallahassee, FL	Cohort 5 Student
Goffe*, S., Chigbu, P., **Ishaque, A.B**., **Cullen, D**. 2022. Population dynamics of Pinfish (*Lagodon rhomboides*) in the Maryland Coastal Bays. NOAA EPP Forum 2022, Tallahassee, FL	Cohort 4 Student
Hawkins*, P., Sharma, I. 2022. Ecophysiology of marine bacterial isolates from Trunk River. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022.	Cohort 4 Student
Layton*, J., Candelmon, A., Semmens, B., Pattengill-Semmens, C., Stock, B., Waterhouse, L., McCoy, C., Johnson, B., S., Heppell, S. 2022. Impacts of increased temperatures on early life history stages of Nassau Grouper. NOAA EPP Forum 2022, Tallahassee, FL	Cohort 4 Student
Richardson, C., **Chigbu, P**., **Ishaque, A**. 2022. Variations in the fatty acid trophic markers of fishes in Coastal Lagoons. Presented at the AFS meeting, August 20-25, 2022, Spokane, WA.	Leveraged
Richardson*, D. 2022. Genomic annotation of an alkaphilic methanogen. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022.	Cohort 5 Student
Rubalcava*, K., Townsend, H., **Chigbu, P**. 2022. An ecosystem model to assess the resiliency of a Lagoonal Estuary to anthropogenic pressures. 2022 NOAA EPP Forum, Tallahassee, FL	Cohort 2 Student
Silver*, A., Alade, L. 2022. Working Group collaboration to explore growth parameters of American Plaice (*Hippoglossoides platessoides*) in the Georges Bank and Gulf of Maine for 2022 Research Track Assessment. Presented at ASLO for Education and Outreach Posters, Honolulu, Hawaii, March, 2022. Poster Presentation	Cohort 3 Student
Tait*, N., **Adebola, T**. 2022. Developing a coupled human ecological system for modeling Chesapeake Bay shellfish fisheries. NOAA EPP/MSI Forum, Florida A&M University, Tallahassee, FL, April 2022.	Cohort 5 Student
Thalmann*, H., Laurel, B., **Miller, J. A**. 2022. Juvenile Pacific Cod foraging and growth in response to marine heatwaves in the Gulf of Alaska. 2022 NOAA EPP Forum, Tallahassee, FL	Cohort 4 Student
Wade*, K., Cullen, D. 2022. Sediment type habitat associations in Jonah and Rock crabs in Mid-Atlantic. Presentation at the NOAA EPP/MSI Biennial Education and Science Forum. Presented at NOAA EPP Forum, April 2022.	Cohort 5 Student
Wade*, K., Cullen, D. 2022. Environmental factors influence Jonah and Rock crab distributions in the northwest Atlantic. Presented at American Fisheries Society, Spokane, WA, August 2022. Poster Presentation	Cohort 5 Student
Wong-Ala*, J. A. T., K., Wren, J., Ciannelli, L., Robinson, S., Kobayashi, D, Rykaczewski, R. 2022. Transport of *Toxoplasma gondii* oocysts in coastal areas inhabited by the Hawaiian monk seal. 2022 NOAA EPP Forum, Tallahassee, FL	Cohort 5 Student

32. Other Products

Table 32: Theses and Dissertations produced by Center students during the current reporting period.

Theses/Dissertations	Justification
Frey*, B.A., 2022. Validation of age and growth using microconstituent analysis of fish hard parts. M.S. thesis, Univ. of MD Graduate School/UMCES. https://drum.lib.umd.edu/handle/1903/28815	Cohort 3 Student
Henson*, M. 2022. Linking Metabolic rate to growth rate in fishes of the Mid-Atlantic region. Senior Thesis (undergraduate)	Cohort 1 Student
Leslie*, J. 2022. Analyzing the effects of the 2013 cetacean morbillivirus (CEMV) outbreak on stranding frequency and body condition of common bottlenose dolphins (*Tursiops truncatus*) from Virginia.	Cohort 4 Student

33. What individuals worked on this project?

Last name	First Name	Total number of months worked during this time period	Project Role	Contribution to project (briefly describe)	State, U.S. territory, and/or country of residence	Collaborated with individual in a foreign	Country(ies) of foreign collaborator	Travelled to foreign country
Smith	Stacy	6	PD/PI	Program Director DSU	Delaware, U.S.A.	no		no
McIntosh	Dennis	6	Faculty	Mentored students	Delaware, U.S.A.	no		no
Ozbay	Gulnihal	6	Faculty	Mentored students	Delaware, U.S.A.			no
Czajkowski	Caitlyn	6	Graduate Student (research assistant)	Conducted research	Delaware, U.S.A.	no		no
Andrade	Emily	6	Graduate Student (research assistant)	Conducted research	Delaware, U.S.A.	no		no
Teat	Marcus	6	Graduate Student (research assistant)	Conducted research	Delaware, U.S.A.	no		no
Metz	Kendall	6	Undergraduate Student	Conducted research	Delaware, U.S.A.	no		no
McKinley	Kayla	6	Undergraduate Student	Conducted research	Delaware, U.S.A.	no		no
Gibson	Deidre	6	PD/PI	Project director;	Virginia	no		no

				advised Sierra Hildebrand, Derrick Richardson, Jonathan Nash, and co-advised Amani Tolin				
Lewallen	Carolina	6	Faculty	Advised Arona Bender, and Jaelyn Leslie	Virginia	no		no
Lewallen	Eric	3	Faculty	Co-advised Arona Bender	Virginia	no		no
Dash	Shawn	3	Faculty	Co-mentored all students in the program	Virginia	no		no
Sharma	Indu	6	Faculty	Advised PaShun Hawkins	Virginia	no		no
Horodysky	Andrij	6	Faculty	Advised Maria Henson, Jonathan Nash, and T'Kiyah Reeves	Virginia	no		no
Adebola	Tunde	6	Faculty	Advised Noah Tait and Derrick Richardson	Virginia	no		no
Bender	Arona	6	Graduate Student (research assistant)	Conducted research	Virginia	no		no
Leslie	Jaelyn	6	Graduate Student (research assistant)	Conducted research	Virginia	no		no
Hawkins	PaShun	6	Undergraduate Student	Conducted research	Virginia	yes	Mo'orea	yes
Nash	Jonathan	6	Undergraduate Student	Conducted research	Virginia	no		no
Richardson	Derrick	6	Undergraduate Student	Conducted research	Virginia	yes	Mo'orea	yes
Reeves	T'Kiyah	6	Undergraduate Student	Conducted research	Virginia	no		no
Henson	Maria	6	Undergraduate Student	Conducted research	Virginia	no		yes

Miller	Jessica	2.15	Co PD/PI	Program management, student mentoring, recruiting and retention activities	Oregon, USA	no		no
Layton	Janelle	6	Graduate Student (research assistant)	Conducted research	Oregon, USA	no		no
Leann	Cohn	6	Graduate Student (research assistant)	Conducted research	Oregon, USA	no		no
Jennifer	Wong-Ala	6	Graduate Student (research assistant)	Conducted research	Oregon, USA	no		no
Hillary	Thalmann	6	Graduate Student (research assistant)	Conducted research	Oregon, USA	no		no
Babcock	Elizabeth	0.6	PD/PI	PD for UM-RSMAS	Florida, USA	yes	Belize, Brazil, Canada, Guatemala, India, S. Korea, Ecuador	yes
Die	David	0.3	Co PD/PI	Co-PI for UM-RSMAS	Florida, USA	yes	Spain, Brazil, France, Madagascar, Canada, Australia	no
Wilson	Adrianne	4	Graduate Student (research assistant)	Working on dissertation on lane snapper growth variation	Florida, USA	no		no
Mayes	Cristin	6	Graduate Student (research assistant)	Working on dissertation on ecosystem modeling and data poor species assessment	Florida, USA	no		no

Best-Otubu	Chryston	6	Graduate Student (research assistant)	Working on dissertation on ecosystem modeling for Biscayne Bay	Florida, USA	no		no
Schott	Eric	1	Co PD/PI	Mentored Olivia Pares, research, outreach	Maryland, USA	Yes	Brazil	no
Frey	Ben	3	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		
Pares	Olivia	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		
Ramarui	Kyari	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		
Coleman	Nicholas	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		
Chigbu	Paulinus	3	Center Director	Administrative Leadership, conducted research, mentored students	Maryland, USA	no		no
Sexton	Margaret	6	Assistant Director	Administration, conducted research	Maryland, USA	no		no
Goffe	Shakira	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Wilburn	Imani	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Delgado	Angel	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Johnson	Tahirah	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Wade	Kaithlynn	6	Graduate Student	Conducted research	Maryland, USA	no		no

			(research assistant)					
Rubalcava	Kasondra	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Silver	Ashley	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Smalls	Jasmine	6	Graduate Student (research assistant)	Conducted research	Maryland, USA	no		no
Hankerson	Tanesha	2	Other Professional	Communications activities	Maryland, USA	no		no
Kessie	Alex	6	Other Professional	Budget and data management	Maryland, USA	no		no
Tilghman	Ida	6	Other Professional	Administrative activities	Maryland, USA	no		no
Wasike	Norrah	6	Other Professional	Administrative activities	Maryland, USA	no		no
Blackwood	Mikaela	6	Undergraduate Student	Conducted research	Maryland, USA	no		no
Brown	Malika	6	Undergraduate Student	Conducted research	Maryland, USA	no		no
Collins	Glen	6	Undergraduate Student	Conducted research	Maryland, USA	no		no
Clovis	Nina	6	Undergraduate Student	Conducted research	Maryland, USA	no		no
Day	Joe	5.5	Graduate Student (research assistant)	Taken classes, performed research	Georgia, U.S.A.	no		no
Lemaire	Cloe	5.5	Graduate Student (research assistant)	Taken classes, performed research	Georgia, U.S.A.	no		no
Spaulding	Chelsea	0	Undergraduate Student	Not active, received professional counseling	Georgia, U.S.A.	no		no

Hoskins-Brown	Dionne	5.5	Co PD/PI	Supervised students and staff, wrote proposals, performed research	Georgia, USA	no	n/a	no
Mackey	Shaneese	0	Graduate Student (research assistant)	Taken classes, performed fieldwork, pursued certifications	Georgia, USA	no	n/a	no
Howard	Kris	2.5	Graduate Student (research assistant)	Thesis writing	Georgia, USA	no	n/a	no
Clax	Savannah	2.5	Undergraduate Student	Taken classes, performed research	Georgia, USA	no	n/a	no
Young	Victoria	5.5	Faculty	Supervised students and staff, wrote proposals, performed research	Georgia, USA	no	n/a	no

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

PD/PI or key personnel name	Description of support	Source of support	Description of change
Eric Schott	IMET Summer Internship Program	The Mary Catherine Bunting Foundation	Additional funding $60,000
Eric Schott	IMET Summer Internship Program	The Venable Foundation	Additional funding $10,000
Eric Schott	IMET Summer Internship Program	The Charles A. and Lois H. Miller	Additional funding $20,000

35. What other organizations have been involved as partners?

Table 35: Organizations that have been involved as partners

Type of partner organization	Name	Location	Partners contribution to the project
State government	NE NREC	Dover, DE	Helped students collect samples
State government	NJ DEP	Hampton, NJ	NERTO river otter collector/co-mentor
Academia	UCLA	Los Angeles, CA	Accepted LMRCSC students to Diversity program
City government	Baltimore DPW	Baltimore MD	Water quality data and collections
NGO	Waterfront Partnership of Baltimore	Baltimore MD	Water quality data and collections
NGO	Blue Water Baltimore	Baltimore MD	Water quality data and collections
NGO	National Aquarium	Baltimore MD	Estuary health outreach, biodiversity
State agency	MD Dept. of Nat. Resources	Annapolis MD	Installation of a WQ con-mon in the Middle Branch
Federal Commission	Gullah Geechee Cultural Heritage Corridor Commission	Beaufort, SC	Included LMRCSC faculty as subawardee on NOAA grant
State government	GADNR	Brunswick, GA	Nets & gear, committee membership
private industry	BF Consultants	McDonough, GA	evaluation services and participation
State government	SCDNR	Charleston, SC	Grant development
State government	Florida Fish and Wildlife Commission	Jacksonville, FL	Research collaboration

36. Have other collaborators or contacts been involved?

Table 36.1: NOAA scientists who have collaborated with the Center during this reporting period.

Last name	First name	Title/Affiliation	Description of involvement
Ailloud	Lisa	SEFSC	Collaborator
Alade	Larry	NEFSC	Thesis committee of Shakira Goffe; NERTO mentor of Shakira Goffe and Ashley Silver
Allman	Robert	SEFSC	PhD committee member for Adrianne Wilson
Antoun	Helena	SEFSC	NERTO Mentor
Archer	Eric	SWFSC Fisheries Ecology Division Molecular Ecology and Genetic Analysis Team	NERTO Mentor
Blake	Suzana	SEFSC Social Science Research Group Branch	Grant Collaborator
Browder	Joan	SEFSC	NOAA mentor for Chryston Best-Otubu
Craig	Kevin	SEFSC	NERTO Mentor
Da Silva	Patricia	NEFSC Resource Evaluation and Assessment Social Sciences	Student Mentor
Denson	LaTreese	SEFSC	Collaborator
Deshpande	Ashok	NEFSC/JJ Howard Lab	NERTO mentor for Imani Wilburn, Marcus Teat, Collaborator in proposal and project
Dietrich	Joseph	NWFCS/Newport, Oregon	NERTO mentor
Doerr	Jennifer	SEFSC Habitat Ecology Branch	Grant Collaborator, NERTO Mentor
Galaska	Matthew	PMEL	NERTO Mentor
Garza	John	SWFSC Fisheries Ecology Division Molecular Ecology and Genetic Analysis Team	NERTO Mentor
Harvey	Chris	NWFSC	NERTO Mentor
Hill	Ron	SESFC Panama City	Committee member for Shaneese Mackey
Jacobs	John	NEFSC/Cooperative Oxford Lab	NERTO mentor for Tahirah Johnson and Jasmine Smalls
Johnson	Matthew	SEFSC Habitat Ecology Branch	Grant Collaborator, student mentor
Kaplan	Isacc	NWFSC	NERTO mentor for Chryston Best-Otubu
Karnauskas	Mandy	SEFSC	Collaborator
Laurel	Ben	AFSC	NERTO Mentor

Leo	Jennifer	SEFSC Habitat Ecology Branch	Grant Collaborator, NERTO mentor
MacPherson	Matthew	SEFSC Social Science Research Group Branch	Grant Collaborator
McAllister	Sean	PMEL	NERTO Mentor
Messick	Gretchen	NOAA, NCCO, Oxford MD	Crab disease and histology advice
Molineaux	Johnathan	Silver Spring	Internship mentor
Robeson	Kimberly	Grays Reef NMS	NOAA mentor to Kris Howard; microplastics research with Sue Ebanks
Schirippa	Michael	SEFSC	Collaborator
Serafy	Joe	SEFSC	NERTO mentor for Cristin Mayes
Shertzer	Kyle	SEFSC	NERTO Mentor
Smith	Brian	NEFSC	NERTO Mentor and committee member of Angel Delgado
Stoffle	Brent	SEFSC Social Science Research Group Branch	Grant Collaborator
Thorson	James	AFSC	Collaborator
Townsend	Howard	Oxford Laboratory	NERTO and outside committee member for Noah Tait, Kasondra Rubalcava
Walter	John	SEFSC	Collaborator
Wikfors	Gary	NEFSC	NERTO Mentor
Wren	Johnanna	PIFSC	NERTO Mentor
Wuenschel	Mark	NEFSC, Woods Hole, MA	Collaborator in research & proposal

Table 36.2: Other collaborators involved in Center activities during this reporting period.

Last name	First name	Title/Affiliation	Description of involvement
Venello	Theresa	Postdoctoral Researcher	Helped students with data, posters, sampling
Lewis	Nicole	Wildlife Vet/Research Scientist	NERTO river otter collector/co-mentor
Barber	Paul	Biology Professor, UCLA	Trained students in coral reef ecology research
Fong	Peggy	Biology Professor, UCLA	Trained students in coral reef ecology research
Lindquist	Adam	VP of Programs & Environmental Initiatives, Waterfront Partnership	Collaborates on urban estuary health
Dahlenberg	Charmaine	Director of Field Conservation	Events, data collection, outreach, fund-raising
Grove	Kim	Chief, Office of Compliance & Research, DPW	Data sharing, water quality
Volpitta	Alice	Baltimore Waterkeeper	Data sharing, water quality

Trice	Mark	Program Chief, Water Quality Informatics, MD DNR	Installation of a WQ con-mon in the Middle Branch
Gleason	Daniel	Professor, Georgia Southern University	Grant collaborator
Alber	Merryl	Professor, UGA	Grant collaborator
Watts	Josiah	100Miles	Grant collaborator
Kenworthy	Matthew	Marine Fisheries Management Habitat Coordinator, FWC	Student committee member

39. What were the outcomes of the award?

Table 39: LMRCSC Graduates during this period:

Last Name	First name	Institution	Degree	Cohort #	Graduation Date	Postgraduate information
Barry*	Teemer	UMES	B.S.	3	May-22	Ph.D. program at Rutgers University
Bender*	Arona	HU	M.S.	3	7-May	Ph.D. program at Duke Univ.
Fielding*	Semaj	UMES	B.S.	3	May-22	Env. Law J.D. Program at Southern Univ., Louisiana
Frey*	Benjamin	UMCES	M.S.	3	May-22	Knauss fellow, now working in NOAA Marine debris
Henson*	Maria	HU	B.S.	1	7-May	Accepted to Navy flight school and to any Marine Science graduate program in the country.
Leslie*	Jaelyn	HU	M.S.	4	7-May	Accepted workforce at UNC-Chapel Hill

50. What were the outcomes of the award?

a. **Education Outcomes**

i. **Outcome 1. Increased number, annually, of CSC post-secondary students, trained:** Students Recruited and trained: A total of 113 students have been recruited to the Center. Twenty-five (25) students have been identified/recruited to the Center as members of Cohort 1 (2016 – 2017), including 6 Ph.D., 6 M.S., and 13 B.S. Of these Cohort 1 students, nineteen (19) have graduated, including 4 Ph.D., 6 M.S., and 9 B.S. students. Twenty-five (25) students have been identified/recruited as members of Cohort 2 (2017-2018) including 8 Ph.D., 8 M.S., and 9 B.S. students. Of the Cohort 2 students, 18 have graduated, including 5 Ph.D., 7 M.S., and 6 B.S. students. Twenty-two (22) students have been identified/recruited as members of Cohort 3 (2018-2019) including 4 Ph.D., 7 M.S. and 11 B.S. students. Ten (10) students from Cohort 3 have graduated so far including 1 Ph.D., 4 M.S. and 5 B.S. Seventeen (17) students including 3 Ph.D., 8 M.S., and 6 B.S. students have been recruited into Cohort 4. Of the Cohort 4 students three (3) have graduated including 2 M.S. and 1 B.S. student. Twenty-four (24) students have been recruited into Cohort 5 including 5 Ph.D., 8 M.S., and 11

B.S. students. One B.S. student from Cohort 5 has graduated. A complete list of the students trained during this period along with the financial support provided to them is available in Appendix I. Outputs include:

a. Increased quantitative and analytical skills – Students are acquiring quantitative and analytical skills by taking courses such as Data Management for scientists that was offered in Fall 2018, 2019, and 2020, the Data Carpentry Workshop offered in Fall 2021, statistics courses, and by participating in internships and REU programs. We have also developed and deployed an online training module to introduce undergraduates to the principles of Data Management.
b. Increased competence in applying STEM to decision-making, policy and management - this is addressed by the Cohort Experience Workshop, which will begin during the next reporting period.
c. Increased skills to use large data sets, geographical information systems (GIS) and statistical analysis, computer modeling, and algorithm development – An online course was offered covering Data Management in Fall 2018, 2019, and 2020 and will be offered every subsequent Fall. In 2021, the course was replaced with a two-day workshop from Data Carpentry based on feedback from students. All graduate students are required to complete either the course or the workshop prior to graduation.

ii. **Outcome 2: Increase number of CSC post-secondary students educated and graduated annually:** Students Recruited and trained: A total of 113 students have been recruited to the Center. Twenty-five (25) students have been identified/recruited to the Center as members of Cohort 1 (2016 – 2017), including 6 Ph.D., 6 M.S., and 13 B.S. Of these Cohort 1 students, nineteen (19) have graduated, including 4 Ph.D., 6M.S., and 9 B.S. students. Twenty-five (25) students have been identified/recruited as members of Cohort 2 (2017-2018) including 8 Ph.D., 8 M.S., and 9 B.S. students. Of the Cohort 2 students, 18 have graduated, including 5 Ph.D., 7 M.S., and 6 B.S. students. Twenty-two (22) students have been identified/recruited as members of Cohort 3 (2018-2019) including 4 Ph.D., 7 M.S. and 11 B.S. students. Ten (10) students from Cohort 3 have graduated so far including 1 Ph.D., 4 M.S. and 5 B.S. Seventeen (17) students including 3 Ph.D., 8 M.S., and 6 B.S. students have been recruited into Cohort 4. Of the Cohort 4 students three (3) have graduated including 2 M.S. and 1 B.S. student. Twenty-three (24) students have been recruited into Cohort 5 including 5 Ph.D., 8 M.S., and 11 B.S. students. One B.S. student from Cohort 5 has graduated. A complete list of the students trained during this period and the financial support provided to them is available in Appendix I. Outputs include:

a. Number of degrees earned annually in NOAA mission-related disciplines: Six (6) students graduated during this period, including 3 M.S., and 3 B.S. student.
b. Number of students (total and URM) who participated in professional development opportunities, to include at least one on-site experiential research and training opportunity at a NOAA Lab, office, or facility with tangible training and research: Eighteen (18) graduate students completed NERTO internships under the supervision of NOAA scientists during this period.

iii. **Outcome 3. Increased CSC capacity to train and graduate students.** Six collaborative research projects were funded in the previous reporting period, which enable center scientists to be available to mentor and advice undergraduate and graduate students. In addition, 37 NOAA scientists have been identified to serve as mentors of the students during the NERTO program or as collaborators in the TAB funded projects. The NERTO has increased exposure to NOAA training and encouraged faculty to increase their flexibility in scheduling graduate students' fieldwork

and academic schedules. Outputs include:

a. Number of seminars: 3
b. New courses: 1
c. New programs: 1
d. New degrees offered to develop working skills and functional competencies to support the NOAA mission and workforce: 0
e. Total numbers of students supported by the LMRCSC: 57
f. Total degrees awarded: 6
g. Degrees awarded to URM students: 6

iv. **Outcome 4**: **The attainment gap for URMs in NOAA mission- relevant fields.** The recruitment of new URMs (graduate and undergraduate students) during this reporting period is an important first step needed for preparing the students for careers in NOAA mission-relevant fields. This will ultimately help to reduce the attainment gap for the URMs in the fields. Outputs include:

1. Increased number of URM students in student development activities that will lead them to the attainment of degrees and/or employment in NOAA mission fields = **51** URMs at the LMRCSC took part in student development activities.
2. Increased number of URM students who select to pursue higher education in NOAA mission fields = **51** URMs at the LMRCSC are pursuing higher education in NOAA mission fields during this reporting period.

b. **Research Outcomes:**

1. Outcome 1. Increased NOAA mission-relevant research capacity at MSIs: NOAA scientists are already collaborating with Center scientists as well as working with some of the graduate students; suitable mentors are being identified for the remaining students. Additionally, research funds provided to scientists at the Center are enabling them to purchase equipment and supplies for their research in addition to Graduate Research Assistantship provided to support research endeavors. Outputs include:

a. Number of research collaborations with NOAA and LMRCSC faculty, staff and students: Each of the six (6) LMRCSC TAB projects that were funded during the period has a NOAA scientist as a collaborator. Those projects are ongoing.

b. Number of NOAA scientists serving as mentors and advisors for student research: 37 NOAA scientists and collaborators are working with the Center.

c. Number of intra-institutional collaborative partnerships established and maintained in support of NOAA's mission = 26

d. Number of uses of NOAA data in research and tool development = 4. Kasondra Rubalcava (Ph.D. student at UMES) is using the long-term fish dataset collected by the Maryland Department of Natural Resources for her dissertation research aimed at developing an ecosystem model for the Maryland Coastal Bays. For their NERTO projects, Center students used long-term data sets (1980 – 2021) collected by NEFSC during spring and autumn bottom trawl surveys to conduct analyses and compare growth (Ashley Silver, Ph.D. student at UMES) and maturity (Shakira Goffe, M.S. student at UMES) parameters of American Plaice from the Georges Bank and Gulf of Maine regions. NOAA will use information from the studies in research track assessment of the species in 2022.

2. Outcome 2. CSC-supported faculty, staff and students' research directly aligned with

NOAA's mission and strategic priorities: Six (6) collaborative research projects funded by the LMRCSC are currently active. These projects were funded after they had been reviewed by the Technical Advisory Board (TAB) based on a number of criteria, one of which is their alignment with NOAA's mission and strategic priorities.

Outputs include:

	# from Projects Directly Supported with FY 16 Funds	# from Leveraged Projects
# of peer reviewed publications	2	9
# of presentations	40	3
# Tools developed	3	0
Use of LMRCSC research results and tools by NOAA & other stakeholders	3	0
# of instances LMRCSC publications are cited	188	1,125
# of LMRCSC students, staff or faculty recognized nationally for LMRCSC research	0	0

LMRCSC TAB-Funded Projects Currently Active

Project Number	Principal Investigator	Title	Thematic Research Area
19-07	Adrianne Wilson	Population structure and growth of lane snapper, a data limited species	SASI
20-03	Kyarii Ramarui	Proteomic analysis of two *Haematococcus pluvialis* strains as aquaculture feedstock	SNAP
20-04	Eric Schott	Life history and disease ecology of the blue crab, a key benthic-pelagic link in tropical and temperate American estuaries	SASI
20-06	Janelle Layton	Investigating the effects of climate change on heat shock proteins and development in the early life history stages of Nassau grouper	CLIME
21-01	Tunde Adebola	Developing a Coupled Human Ecological System for Chesapeake Bay Shellfish Fisheries	SASI
21-02	Nicholas Coleman	Sonar Censusing and Habitat Use by Spawning Run Atlantic and Green Sturgeon, *Acipenser oxyrinchus* and *A. medirostris*	SASI

**Only currently active projects are included. CLIME: Climate Impacts on Marine Ecosystems; HaBS: Habitats and Biological Systems; SASI: Stock Assessment Support and Information; SNAP: Seafood, Nutrition, Aquaculture, and Pathology; FESS: Fishery Economics and Social Sciences*

TAB Project Abstracts

Project Number 19-07

Title: Population structure and growth of lane snapper, a data limited species **Thematic Research Area** SASI: Stock Assessment Support and Information **Abstract**: Lane Snappers (*Lutjanus synagris*) are a data-limited species that range from North Carolina, the Gulf of Mexico (GOM) and south to Brazil. This study will collect 400 sagittal otoliths, fin clips, length/weight measurements from fish caught from East Florida to North Carolina. Otoliths will be processed, aged and two experienced readers will be used to ensure accurate ageing. A variety of growth models will be used to determine best fit. Genotyping by sequencing (GBS) will be used to determine genetic diversity. Results will complement a recent NOAA supported study that examined spatial and temporal variation in the age and growth of Lane Snapper in the

GOM and data will be used to support future NOAA stock assessments by providing information on population structure and growth.

Principal Investigator: Adrianne Wilson, University of Miami - Rosenstiel School of Marine and Atmospheric Science

Co-PI: Elizabeth Babcock, University of Miami - Rosenstiel School of Marine and Atmospheric Science

NOAA Partner: Robert Allman, SWFSC: Southwest Fishery Science Center

Other Partner: Dionne Hoskins-Brown, Savannah State University

Students: Adrianne Wilson (PhD, RSMAS); Savannah Clax (Undergraduate, RSMAS)

Keywords: Fisheries, Marine Biology, Population dynamics

Project Number 20-03

Title: Proteomic analysis of two *Haematococcus pluvialis* strains as aquaculture feedstock

Thematic Research Area SNAP: Seafood, Nutrition, Aquaculture, and Pathology **Abstract**: The green microalga *Haematococcus pluvialis* produces an antioxidant pigment, astaxanthin, which is widely used in salmon aquaculture as feed additive. Current algae industry uses phototrophic cultivation for *H. pluvialis* production, however, under these conditions the growth rate and astaxanthin productivity are low. Two mutant strains of *H. pluvialis* have been generated through chemical mutagenesis that demonstrate increased heterotrophic growth and astaxanthin productivity, addressing the bottlenecks of *Haematococcus* production. To understand the molecular underpinning of this phenotype, we propose further molecular characterization of these two mutant strains through LC-MS/MS based proteomic analysis. The knowledge generated will help development of rational engineering strategies for improved astaxanthin production in microalgae and promote its use in aquaculture.

Principal Investigator: Kyarii Ramarui, University of Maryland Center for Environmental Science

Co-PI: Yantao Li, University of Maryland Center for Environmental Science **NOAA Partner:** Gary Wikfors, NEFSC: Northeast Fishery Science Center **Other Partner:** Allen Place, Joseph Pitula, UMCES, UMES

Students: Kyarii Ramarui (PhD, UMCES)

Keywords: Aquaculture; Social science; Plankton; Feedstock

Project Number 20-04
Title: Life history and disease ecology of the blue crab, a key benthic-pelagic link in tropical and temperate American estuaries
Thematic Research Area SASI: Stock Assessment Support and Information
Abstract: The blue crab, *Callinectes sapidus*, is an adaptable estuarine species that lives in Atlantic coastal regions from New England to Argentina. The species is a crucial part of the estuarine food web and supports a fishery worth $200 million annually in the US. Across their range, blue crabs are infected by pathogenic viruses and protozoa that may interact with environmental and anthropogenic stressors to limit crab abundance. In Puerto Rico, *C. sapidus* is targeted by an artisanal fishery and provides income important to communities. Currently, no size or sex restrictions are in place to sustainably manage *Callinectes* spp. in Puerto Rico, and there is a lack of data on which to base fisheries management. In the tropics, *C. sapidus* is often sympatric with several other *Callinectes* species. Basic knowledge of *Callinectes* spp. distribution in estuaries in the San Juan metropolitan region can provide valuable insights into their ecological role and provide baseline data for monitoring abundance to inform resource management strategies. To address this knowledge gap, we plan to measure the abundance, sex ratio, female reproductive status, and diseases of *C. sapidus* and other *Callinectes* spp., including *C. exasperatus, C. ornatus, C. larvatus,* and *C. bocourti* by sampling 4 times per year, in a range of habitats (and environmental parameters) within a polyhaline estuary in the San Juan metropolitan area in Puerto Rico.
Principal Investigator: Eric Schott, University of Maryland Center for Environmental
Co-PI: Bradley Stevens, University of Maryland Eastern Shore (UMES) **NOAA Partner:** Mandy Bromilow, NOAA: Chesapeake Bay Office **Other Partner:**
Students: Olivia Pares (MS, UMCES)
Keywords: Fisheries; Ecology; Pathology

Project Number 20-06
Title: Investigating the effects of climate change on heat shock proteins and development in the early life history stages of Nassau grouper
Thematic Research Area CLIME: Climate Impacts on Marine Ecosystems
Abstract: Climate variability and change likely have major impacts on the early life history stages of commercially and recreationally valuable fish like Nassau grouper. Understanding these impacts will be essential to conservation and management efforts. Studies to date have noted phenotypic and survival differences in early life history stages of Nassau grouper reared at different temperatures. However, little is known on the drivers of these changes in bioenergetics and in gene expression during the early life history stages of this species. Our goal is to measure bioenergetic activity and use established genetic methods to investigate temperature induced changes in gene expression of early life stage Nassau grouper, collected from a spawning aggregation on Little Cayman, Cayman Island.
Principal Investigator: Janelle Layton, Oregon State University
Co-PI: Scott Heppell, Oregon State University
NOAA Partner: Steve Gittings, NOS: National Ocean Service
Other Partner:
Students: Janelle Layton (MS, OSU)
Keywords: Fisheries; Ecosystems

Project Number 21-01
Title: Developing a Coupled Human Ecological System for Chesapeake Bay Shellfish Fisheries
Thematic Research Area: Stock Assessment Support and Information
Abstract:
Achieving sustainable use of aquatic living resources is a key challenge facing humanity today. Several ecological models have been developed to address questions about the management and use of aquatic living resources, but these models often do not adequately capture human dimensions of natural resource management; making it necessary to direct more attention to human aspects of coastal fisheries such as in the Chesapeake Bay. Coupled human-environmental modeling of ecosystems can enable us to better understand fleet behavior and devise better approaches to reducing anthropogenic impacts on the Bay ecosystem. Humans impact Chesapeake Bay (either directly or indirectly) by reducing water quality, increasing wildlife disease, applying harvest pressures, and influencing habitat integrity. In our proposed project, we aim to extend the current Chesapeake Bay Fisheries Ecosystem Model (CBFEM) developed by NOAA partners to include social information so we can more directly verify human impacts on shellfishes and other living aquatic resources of Chesapeake Bay.

Principal Investigator: Tunde Adebola Lewallen **Institution**: Hampton University **Co-PI:** Eric
Partner: Howard Townsend **Institution**: Hampton University **NOAA Lab/Facility**: Oxford, Maryland **Graduate Student:** Noah Tait **Undergraduate Student:**

Project Number 21-02
Title: Sonar Censusing and Habitat Use by Spawning Run Atlantic and Green Sturgeon, *Acipenser oxyrinchus* and *A. medirostris*
Thematic Research Area: Assessment: Support and Information
Abstract: This TAB project supports (1) NERTO training and research on sonar censusing Sacramento River green sturgeon at the NOAA SWFSC Santa Cruz Laboratory; (2) tests to distinguish Atlantic sturgeon and gar sonar images for Chesapeake Bay Atlantic sturgeon; and (3) to provide field training opportunities for undergraduate minority students. Sturgeons across the US are managed by NMFS as protected species, where key challenges to recovery center on accurate assessment of spawner abundance and how spawner movement and reproduction is impaired by habitat alterations. In his thesis research, EPP LMRCSC Fellow Nicholas Coleman is deploying sonar censusing approaches on spawning run Atlantic sturgeon in the Marshyhope Creek system (Chesapeake Bay) and using telemetry to better understand how spawner incidence is shaped by flow, temperature, dissolved oxygen, and bottom substrate. SWFSC scientists pioneered sonar censusing approaches evaluating spawning green sturgeon in the Sacramento River, for which a decade of historical data is available. During a NERTO, LMRCSC Fellow Coleman will receive training in side-scan and DIDSON sonar censusing technologies with SWFSC Santa Cruz scientists (S. Lindley and P. Dudley) and evaluate historical habitat associations of spawning run adults. A key challenge to Coleman's Atlantic sturgeon thesis work is distinguishing sturgeon and gar, the two largest fishes within the Marshyhope Creek, through sonar (ARIS) deployments. Laboratory trials are proposed to compare acoustic images of gar from similar sized Atlantic sturgeon. This work will complement and enhance the Fellow's thesis research and training through comparisons of sturgeon settings (water-stressed but large Sacramento River v. very small Mashyhope Creek), spawning habitat associations in both systems, and exposure to the interface between science (sonar censusing) and conservation policy.

Principal Investigator: **Name**: Dr. Dave Secor **Institution**: UMCES/IMET **Co-PI: Name:** Dr. Rose Jagus
Name: Dr. Steven Lindley **Institution**: UMCES/CBL **NOAA Partner:**
Name: Dr. Peter Dudley **Lab/Facility**: SEFSC **Other Partner:**
Student: Mr. Nicholas Coleman **Lab/Facility:** SEFSC **Students: Graduate**
Undergraduate Student: Prevented by CoVID restrictions

Appendix I: Student Funding During the 6 month Reporting Period

First	Last	URM (y or n)	Cohort #	Degree	Partner	Tuition	Stipend	Travel	NERTO	One-time Research Support	Professional Development
Maria	Henson	Y	1	B.S.	HU			$992			
Adrianne	Wilson	Y	2	PhD	RSMAS	$8,852	$16,353	$1,687	$0		$208
Joe	Day	Y	2	M.S.	SSU	$3,060	$9,650	$299	$7,020		$0
Sena	Tay	Y	2	M.S.	SSU		$2,083	$302			
Nicholas	Coleman	Y	2	M.S.	UMCES		$22,263.71	$11,6185			
Kasondra	Rubalcava	Y	2	Ph.D.	UMES	$1,600	$44,468	$5,817			
Arona	Bender	Y	3	M.S.	HU		$3,000	$1,034			
Benjamin	Frey	Y	3	M.S.	UMCES			$2,390.62			
Teemer	Barry	Y	3	B.S.	UMES		$3,872	$41			
Caitlyn	Czajkowski	N	3	M.S.	UMES	$5,863	$18,000				
Ashley	Silver	Y	3	Ph.D.	UMES	$5,794	$25,382				
Emily	Andrade	N	4	M.S.	DSU	$8,707	$15,000				
PaShun	Hawkins	Y	4	B.S.	HU			$1,186			
Jaelyn	Leslie	Y	4	M.S.	HU		$3,000	$1,034			
Layton	Janelle	Y	4	MS	OSU	$10,307	$18,017	$6,386	$15,277		
Hillary	Thalmann	N	4	PhD	OSU	$7,403	$18,016	$6,995	$0	$2,404	$2,700

Cristin	Mayes	Y	4	PhD	RSMAS	$17,704	$16,353	$5,551	$0		$568
Kyarii	Ramarui	Y	4	Ph.D.	UMCES	$1323.84	$20,507.65	$6599.44	$7,347.07	$20,000.50	
Glen	Collins	Y	4	B.S.	UMES	$19,343	$1,901	$2,267			
Shakira	Goffe	Y	4	M.S.	UMES	$3,384	$21,201	$4,005			
Tahirah	Johnson	Y	4	M.S.	UMES	$5,468	$29,419	$5,646			
Imani	Wilburn	Y	4	M.S.	UMES	$5,477	$21,354		$4,813		
Marcus	Teat	y	5	M.S.	DSU	$4,045	$15,000				
Jonathan	Nash	Y	5	B.S.	HU			$1,044			
T'Kiyah	Reeves	Y	5	B.S.	HU			$992			
Derrick	Richardson	Y	5	B.S.	HU			$1,144			
Noah	Tait	N	5	M.S.	HU	$700	$9,000	$1,821			
Leann	Cohn	Y	5	MS	OSU	$18,346.39	$17,087.72	$1,381.55			
Jennifer	Wong-Ala	Y	5	PhD	OSU	$10,307.34	$22,206.74	$5,469.72	$2,683.75		
Chryston	Best-Otubu	Y	5	PhD	RSMAS	$17,704	$16,353	$3,485	$8,110		$1,217
Michon	Shaw	Y	5	B.S.	SSU	$6,000					
Alexandria	Tennant	Y	5	B.S.	SSU	$3,357					
Kristafer	Howard	Y	5	M.S.	SSU	$1,477	$2,667				
Cloe	Lemaire	N	5	M.S.	SSU	$7,977	$6,250	$1,834	$5,000		
David	Garcia	Y	5	Ph.D.	UMCES		$17,942.13	$2871.09	$14952.68		
Olivia	Pares	Y	5	Ph.D.	UMCES	$4,739.70	$43,846.27	$4,655.04	$10,341.53	$4,449.71	
Mikaela	Blackwood	Y	5	B.S.	UMES	$5,590					
Malika	Brown	Y	5	B.S.	UMES	$8,724	$54				
Nina	Clovis	Y	5	B.S.	UMES	$5,612	$675				
Kayla	McKinley	y	5	B.S.	UMES						
Kendall	Metz	n	5	B.S.	UMES						
Angel	Delgado	Y	5	M.S.	UMES	$25,010	$27,803	$41	$3,944		
Kaithlynn	Wade	Y	5	M.S.	UMES	$19,932	$21,515	$6,069	$3,391		

Jasmine	Smalls	Y	5	Ph.D.	UMES		$12,757				
Savannah	Clax	Y		Non-Degree	OSU			$2,126			
Keons	Adams	Y		Non-Degree	UMES						$7,050.90
Dajaa	Ajhar	Y		Non-Degree	UMES						$5,949.90
Kevin	Armstrong	Y		Non-Degree	UMES						$7,050.90
Eymani	Barias	Y		Non-Degree	UMES						$5,949.90
Myah	Bowie	Y		Non-Degree	UMES						$7,050.90
Daryl	Bullock	Y		Non-Degree	UMES						$5,949.90
Chaney	Galloway	Y		Non-Degree	UMES						$5,949.90
Xavier	Harrell	Y		Non-Degree	UMES						$5,949.90
Leianna	Jones	N		Non-Degree	UMES						$7,050.90
Moses	Nwakwuo	Y		Non-Degree	UMES						$7,050.90
Anazi	Pharrams	Y		Non-Degree	UMES						$7,050.90
Kayla	Winn	Y		Non-Degree	UMES						$7,050.90

Appendix II: TAB Reports

Project Number 19-07

Title: Population structure and growth of lane snapper, a data limited species

Thematic Research Area: Stock Assessment Support

Abstract: Lane Snappers (*Lutjanus synagris*) are a data-limited species that range from North Carolina, the Gulf of Mexico (GOM) and south to Brazil. This study will collect 400 sagittal otoliths, fin clips, length/weight measurements from fish caught from East Florida to North Carolina. Otoliths will be processed, aged and two experienced readers will be used to ensure accurate ageing. A variety of growth models will be used determine best fit. Genotyping by sequencing (GBS) will be used to determine genetic diversity. Results will compliment a recent NOAA supported study that examined spatial and temporal variation in the age and growth of Lane Snapper in the GOM and data will be used to support future NOAA stock assessments by providing information on population structure and growth

Principal Investigator:
Name: Adrianne Wilson
Institution: University of Miami - Rosenstiel School of Marine and Atmospheric Science
Co-PI:
Name: Dr. Elizabeth Babcock
Institution: University of Miami - Rosenstiel School of Marine and Atmospheric Science

NOAA Partner:
Name: Robert Allman
Lab/Facility: SEFSC: Southeast Fishery Science Center

Other Partner:
Name: Dr. Dionne Hoskins
Lab/Facility: Savannah State University/NOAA

Students:
Graduate Student; Adrianne Wilson
Undergraduate Student: Savannah Clax

Keywords: Fisheries, Marine Biology, Social science, Population dynamics

Start Date: 09/23/2019 End Date: 2023

Results to Date: I have received the ages for a set of fish collected from the SEAMAP cruise that took place in Fall 2021. I am working with their office to collect the ages from a second cruise that took place in Summer 2021. I have also received a number of samples from a NOAA employee located in La Marque, TX. This will allow examination of multiple life stages and fish collected throughout a large portion of the species range. Samples collected from North Carolina have been inventoried and are ready for processing.

The results below were presented in Savannah Clax's final presentation. Florida samples were from a subset of samples collected from southwest Florida to east Texas from January 2015 to

October 2017 by United States federal sampling programs. These samples were collected from both commercial and recreational fisheries. Samples from Belize were collected from May to June 2019 from commercial fisheries. Fork length and weight were collected from all samples before otoliths were removed and prepared for ageing.

After processing otoliths, it was determined that the Florida samples contained larger and older fish than the samples collected in Belize. The largest fish from the Florida samples was 495 mm in FL and the largest in Belize was 322 mm in FL. There was a greater range of sizes among the Florida samples as seen in the length frequency figures below (Figure 1 and 2). The lack of larger fish in the Belize sample made it difficult to calculate growth parameters covering the entire size range of the species. The lack of larger fish collected during sampling may indicate the presence of overfishing in the Belizean lane snapper fishery. As a result, more efforts have been made to conduct additional sampling in Belize to retrieve additional fish larger than 35 cm in FL.

The oldest fish reported from the Florida samples was 13 years of age, whereas the oldest fish collected from Belize was just under 5. The growth parameters are displayed in the table below (Table 1). The t_o values are closer in value at -2.15 and -2.39 and this is due to the lack of young of the year samples from both locations. The L_∞ value is much higher for the Florida samples, and this is due to the larger sizes and greater range of sizes collected. The L_∞ value for Belize is 232.21. This value is much lower than the Florida samples due to the smaller fish collected from this area. The lack of size and age diversity also impacted the K value for Belize. K represents the exponential rate of approach to asymptotic size. The lack of large fish in the Belize resulted in the higher K value of .852 for these samples. The Florida samples had a K value of 0.257. This is due to the larger sample size, larger range of sizes, and larger max size in the samples, causing the exponential rate to asymptotic size to be slower.

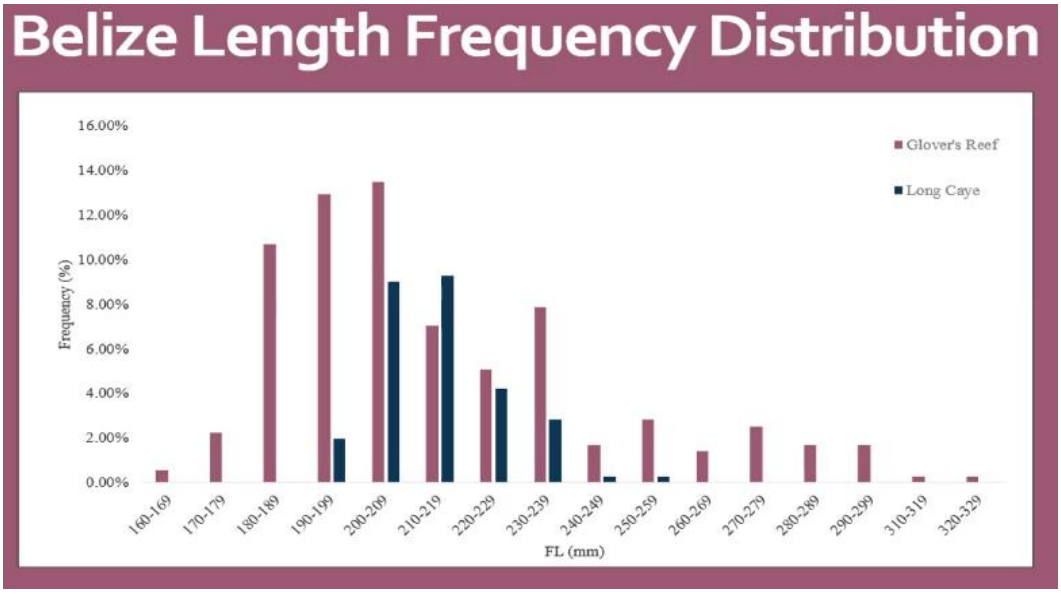

Figure 1

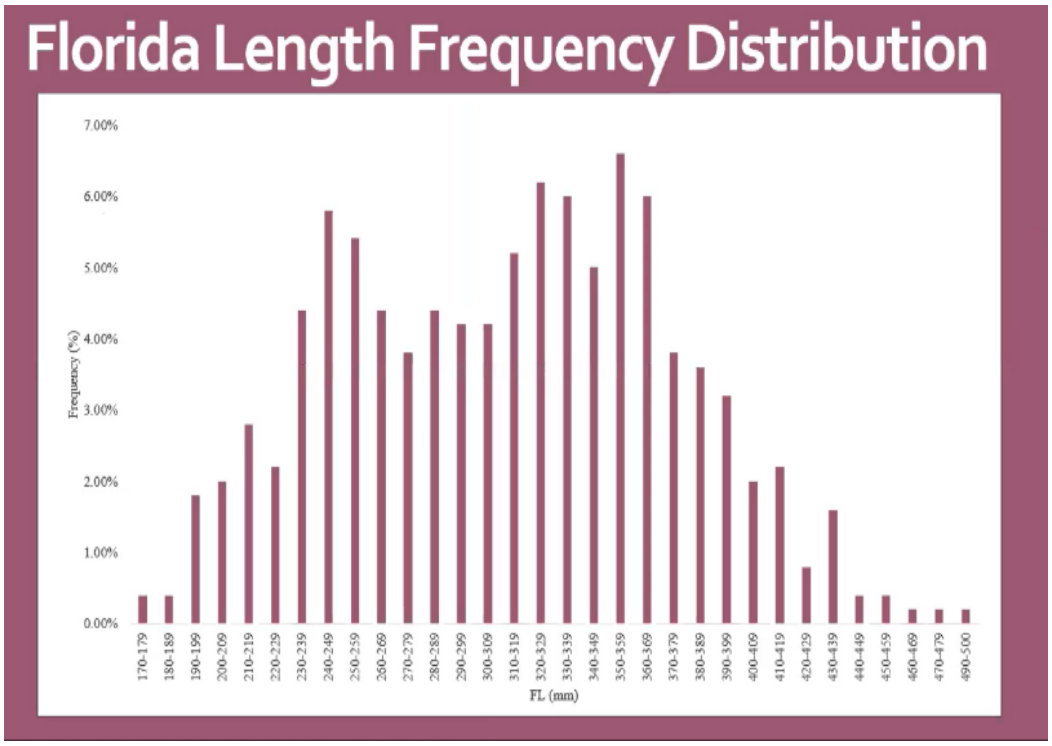

Figure 2

Belize	Florida
L∞:232.21	L∞:397.05
K:0.852	K:0.257
To:-2.39	To:-2.15

Table 1

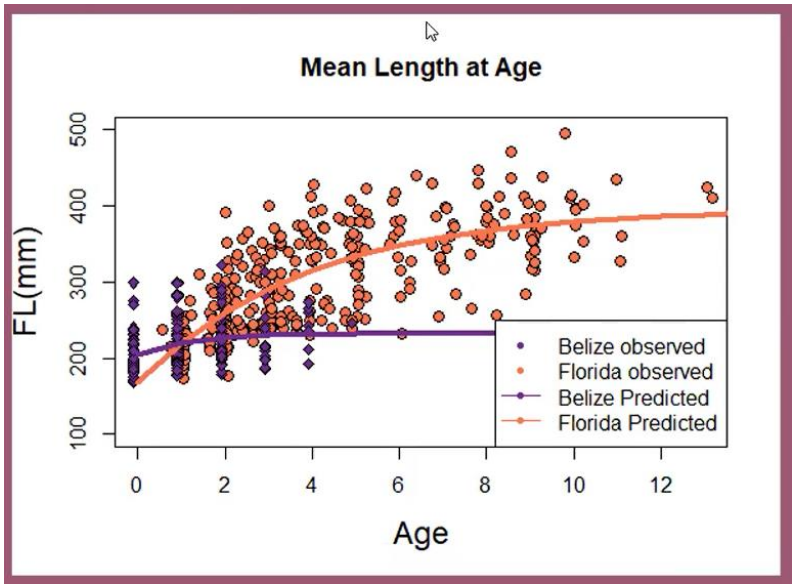

Figure 3

Relevance to NOAA: This study aims to address concerns raised in the recent SEDAR 49 data poor species assessment by increasing sampling of otoliths and tissue samples to examine stock structure and growth over the lane snappers US range. The evidence of multiple stocks will be investigated using the data we collect, thus improving the accuracy of assessment and allowing better advice on management decisions and the impact these decisions may have on anglers and coastal communities. Our project objectives directly align with NOAA's goal of the conservation of living marine resources. We will provide reliable and current information on Lane Snapper populations, growth, and age structure. Furthermore, the spatial and temporal comparisons will examine impacts caused by fishing and will enhance managers' ability to accurately quantify the abundance and distribution of Lane Snapper. Previous studies indicated the potential for female Lane Snapper to experience heavier fishing pressure than males (Aiken 2001). This selection likely has an influence on the size structure of the species must be further examined. Using the data collected from this study, we can determine if different populations have different life history traits, which will enhance stock assessment and management recommendations. The genetic analysis will provide data that will define how populations are connected and also rates of adaptive change (Crawford and Oleksiak 2016). Data from this study will be used to increase confidence in estimates of population size, demographic patterns, and stock status. In the past, Lane Snapper have been grouped with other data limited species when developing management plans, landings data, and annual catch limits. This study will provide new age, growth, and genetic data that may find that Lane Snapper have unique life history traits and should be managed as such. Since Lane Snapper are data-limited, this study is vital to maintain the sustainability of the species and develop "optimal harvest strategies and determine the tradeoffs between alternative policy choices" (Hilborn and Walters 1991).

Broader Impacts: Assessing a data-limited species can be very difficult for the scientists; however, the outcome of a stock assessment, and the management decisions that are made, can influence the lives of the communities that depend on the Lane Snapper. This study aims to collect data that will contribute to the long-term sustainability of the fishery and the genetic information will be used to identify population connectivity, thus increasing "the resilience of ecosystems, economies, and communities" that depend on Lane Snapper (Hilborn and Walters 1991). Collecting specimens through dockside sampling will encourage collaboration with local fishermen and allow us to build upon the relationship NOAA has within the fishing communities. These relationships are vital in order to have better cooperation with fishermen when management practices are being developed. The Lane Snapper fishery is driven by recreational fishermen. The NOAA Fisheries Economics of the United States Report, 2016 stated that Florida had the highest number of recreational fishing trips, the most money spent on trips ($646.3 million), and the most recreational anglers to participate in fishing (3.7 million anglers), in the nation. Landings in the South Atlantic Region (East Florida, Georgia, North Carolina and South Carolina) totaled $190.9 million and North Carolina had the highest revenue in the region (NOAA 2016). With Lane Snapper falling within the regions with the largest number of recreational fishers and landings, new and accurate data is needed immediately. This study will provide much needed information on the population structure and growth of Lane Snapper. Our findings will then be used to conduct a management strategy evaluation so we can provide new recommendations for management practices, such as regional size and catch limits. Therefore, with the collaboration of the anglers, we will increase our understanding of Lane Snapper and assist managers in making better predictions to prevent overfishing or even the collapse of the stock. Thus, our results will help protect the livelihoods of the coastal communities and people that depend on the Lane Snapper fishery.

Presentations & Publications:

Wilson, A. (2022, September 27). Management Strategy Evaluation on Lane Snapper: A Data Limited Species. Lecture presented at Student Seminar Series in Florida, Miami.

Wilson, A. (2019). Age and Growth of Lane Snapper in the Gulf of Mexico. Oral session presented at the annual American Fisheries Society meeting, Reno, NV. LMRCSC Section

Wilson, A. (2019, April 12). Age and Growth of Lane Snapper in the Gulf of Mexico. Lecture presented at Student Seminar Series in Florida, Miami. University of Miami Student Seminar Series

Project Number 21-01

Title: Developing a Coupled Human Ecological System for Chesapeake Bay Shellfish

Thematic Research Area: Stock Assessment Support and Information

Abstract: Achieving sustainable use of aquatic living resources is a key challenge facing humanity today. Several ecological models have been developed to address questions about the management and use of aquatic living resources, but these models often do not adequately capture human dimensions of natural resource management; making it necessary to direct more attention to human aspects of coastal fisheries such as in the Chesapeake Bay. Coupled human-environmental modeling of ecosystems can enable us to better understand fleet behavior and devise better approaches to reducing anthropogenic impacts on the Bay ecosystem. Humans impact Chesapeake Bay (either directly or indirectly) by reducing water quality, increasing wildlife disease, applying harvest pressures, and influencing habitat integrity. In our proposed project, we aim to extend the current Chesapeake Bay Fisheries Ecosystem Model (CBFEM) developed by NOAA partners to include social information so we can more directly verify human impacts on shellfish and other living aquatic resources of Chesapeake Bay.

Principal Investigator: **Name**: Tunde Adebola **Institution**: Hampton University
Co-PI: Name: Eric Lewallen **Institution**: Hampton university
NOAA Partner: **Name**: Howard Townsend **Lab/Facility**: NOAA/Oxford MD
Students: Graduate Student: Noah Tait **Undergraduate Student:** Langston Jackson
Keywords:
Start Date: January 2022 **End Date:** May 2024

Results to Date: We were able to successfully recruit a graduate student, Mr. Noah Tait, in the spring semester of 2022. Noah presented preliminary work based on our TAB research grant at the EPP Forum last spring semester. He also conducted research through the NERTO program in the summer under the guidance of Dr. Howard Townsend. Langston Jackson worked with us during the summer using Unity 3D and the sound design software Wwise. He is continuing his internship in the ecological modeling lab in the fall semester of 2022. We are continuing construction on the AI plugin using Unity 3D SDK with the aim to integrate this plugin into EwE using Goal Oriented Action Planning. Ecospace the spatial dynamic simulation module of EwE already has rudimentary agent-based modeling capabilities. Our goal is to improve this using AI algorithms in Unity Engine that will drive outcomes in the simulated world modeled in both EwE and Unity Engine.

Relevance to NOAA: We propose the use of cutting-edge technologies that will be at the

intersection of ecological, behavioral, and social science with the potential of improving our understanding of how human behaviors impact managed common pool resources. Our goal for this project is to develop a methodology that will improve harvest strategies for Chesapeake Bay Shellfish species to promote their assessment and sustainable utilization in the face of alternative options for management.

Broader Impacts: We aim to involve and train an early career scientist from a minority and underrepresented population in the US. Hampton University is very well positioned to do this, because we are situated right at the mouth of the Chesapeake Bay where it opens into the Atlantic Ocean and are a Historically Black University. Our faculty collaborate among the Biological and Marine Sciences, Engineering and Computational Sciences researchers and have a range of expertise that we can use as leverage to achieve maximum impact. Furthermore, we will work closely with other LMRCSC research centers including the RASMAS program at the University of Miami, and with researchers across the US and beyond as this project grows and improves over time.

Presentations & Publications:
Mr. Noah Tait will presented preliminary work on the model we are developing during the EPP Forum in Florida this past spring.

Project Number: 20-03

Title: Proteomic analysis of two *Haematococcus pluvialis* strains as aquaculture feedstock

Thematic Research Area: Seafood, Nutrition, Aquaculture, and Pathology (SNAP)

Abstract: The green microalga *Haematococcus pluvialis* produces an antioxidant pigment, astaxanthin, which is widely used in salmon aquaculture as a feed additive. The current algae industry uses phototrophic cultivation for *H. pluvialis* production, however, under these conditions the growth rate and astaxanthin productivity are low. A mutant strain of *H. pluvialis* has been generated through chemical mutagenesis that demonstrates increased heterotrophic growth and astaxanthin productivity, addressing the bottlenecks of *Haematococcus* production. To understand the molecular underpinning of this phenotype, we propose further molecular characterization of these two mutant strains through LC-MS/MS-based proteomic analysis. The knowledge generated will help the development of rational engineering strategies for improved astaxanthin production in microalgae and promote its use in aquaculture.

Principal Investigator:	**Name**: Kyarii Ramarui	**Institution**: UMCES
Co-PI 1:	**Name:** Dr. Yantao Li	**Institution**: UMCES
Co-PI 2:	**Name:** Dr. Allen Place	**Institution**: UMCES
Co-PI 3:	**Name:** Dr. Joseph Pitula	**Institution**: UMES
NOAA Partner:	**Name**: Dr. Gary Wikfors	**Lab/Facility**: Milford Lab (NEFSC)
Other Partner:	**Name:** N/A	**Lab/Facility:** N/A

Graduate Student: Kyarii Ramarui, PhD, Marine Estuarine Environmental Sciences Program

Keywords: Aquaculture, Social Science, Plankton Other: Feedstock

Start Date: May 1, 2020 **End Date:** August 31, 2022

Results to Date:

During this summer I completed my NERTO at the NEFSC Milford Laboratory in Milford, Connecticut. I was supervised by Dr. Gary Wikfors, my NOAA mentor and NOAA partner for this TAB project. For my NERTO project I conducted two rounds of this two-step cultivation experiment at a slightly larger scale. Additionally, flow cytometry was used to investigate chlorophyll, carotenoid, and lipid content on a per-cell basis in heterotrophically grown cells upon transition to high light and through adaptation to high light conditions. Plotting of cellular chlorophyll autofluorescence (proportional to chlorophyll content) with forward light scatter (proportional to cell size) identified the cell population in the cytograms. BODIPY lipid dye was applied to stain cellular lipids so they can be detected by the flow cytometer. Additionally, the dsDNA dye SYBR Green was applied to cells to monitor the nuclear DNA content of dividing *H. pluvialis* cells. Flow cytometry was also used to count cells to determine cell density throughout the growth period. Before I started my NERTO at the Milford lab, I was familiar with flow cytometry technology and how it worked, but I had never used the technique myself. As part of my NERTO, I was trained on how to operate a BD Accuri C6+ flow cytometer as well as more in-depth data interpretation and analysis. I was also trained on a JSAN benchtop cell sorter, which is a flow cytometer with additional cell sorting capacity. Flow cytometry is a versatile and powerful tool for microalgal biologists, and the Milford lab was an ideal place to obtain these skills and experience. More extensive analysis of the flow cytometric data is ongoing, with continued guidance from my NOAA mentor.

My experimental design for my NERTO project mirrored earlier rounds of this experiment, with slight modifications. The two steps of the cultivation period included a 6-day heterotrophic growth period in which cultures were grown heterotrophically with a carbon source provided in the liquid growth medium in the form of sodium acetate. On Day 6, when cultures reached their maximum cell densities (cells mL^{-1}), they were transferred to carboys and provided with 1.5% CO_2. When cultures were transferred, they were also diluted with supernatant from spare cultures grown under the same conditions to the same cell density, since the two mutant strains had achieved significantly higher cell densities than the wild type during the heterotrophic stage. For the first 24 hours after transfer, the cultures were exposed to “medium” light intensity (*c.a.* 100 µmol m^{-2} s^{-1}). This intermediate level of light intensity acts as a light acclimation stage. After 24-hours of light acclimation, the cultures were exposed to high light stress (*c.a.* 400 µmol m^{-2} s^{-1}) for 6 days. Throughout this entire cultivation period, various samples were collected to understand the growth characteristics and nutrient consumption rates of the two strains. Cell density (cells mL^{-1}) and cell composition (chlorophyll, lipid, and DNA content) were measured using flow cytometry, and biomass concentration (g L^{-1}) was measured by weighing biomass samples. Supernatant samples were also harvested to measure the rate of consumption of acetate, nitrate, and phosphate. Additionally, biomass samples for proteomic, phosphoproteomic, and transcriptomic analyses were collected. At various time points during high light stress, biomass samples were harvested, for astaxanthin content, lipid content, and lipid composition analysis.

During my NERTO, I investigated the growth performance of mutants KREMS 23D-3 and JWHIB 27-38 in comparison with the wild type *H. pluvialis* strain. Mutant KREMS 23D-3 was generated by myself using a chemical mutagenesis approach, and I have done extensive investigation of this mutant in earlier rounds of this TAB experiment. Mutant JWHIB 27-38 was generated using heavy ion beam mutagenesis, and this was my first time investigating this mutant strain. Flow-cytometric cell counts showed that, under heterotrophic conditions, both mutant strains achieved higher cell densities than the wild type, with statistical significance starting on Day 4 of the growth period (Figure 1, t-test, p-value < 0.05). For mutant KREMS 23D-3, these results are consistent with previous experiments. Mutant JWHIB 27-38 had not been tested previously but appeared to have similar growth characteristics to mutant KREMS 23D-3. Under high light conditions, mutant KREMS 23D-3 and the wild-type demonstrated similar growth characteristics.

Mutant JWHIB 27-38, however, had much lower cell densities than the other two strains (Figure 1). In addition to samples harvested for flow cytometry, I harvested samples to measure biomass concentration (dry weight in g L^{-1}), nutrient depletion from the growth medium (supernatant samples for measuring the concentration of acetate, nitrate, and phosphate), astaxanthin accumulation (measured later with HPLC), and for omics analyses. Nutrient depletion and astaxanthin accumulation measurements are ongoing. Biomass concentration showed that all strains had similar biomass concentrations throughout the entirety of the growth period (Figure 2). Later during the high light stage, however, mutant JWHIB 27-38 demonstrated much higher biomass per cell than the wild-type strain (Figure 3). This makes sense because the cell density of JWHIB 27-38 was much lower than the wild-type, but biomass concentrations were comparable.

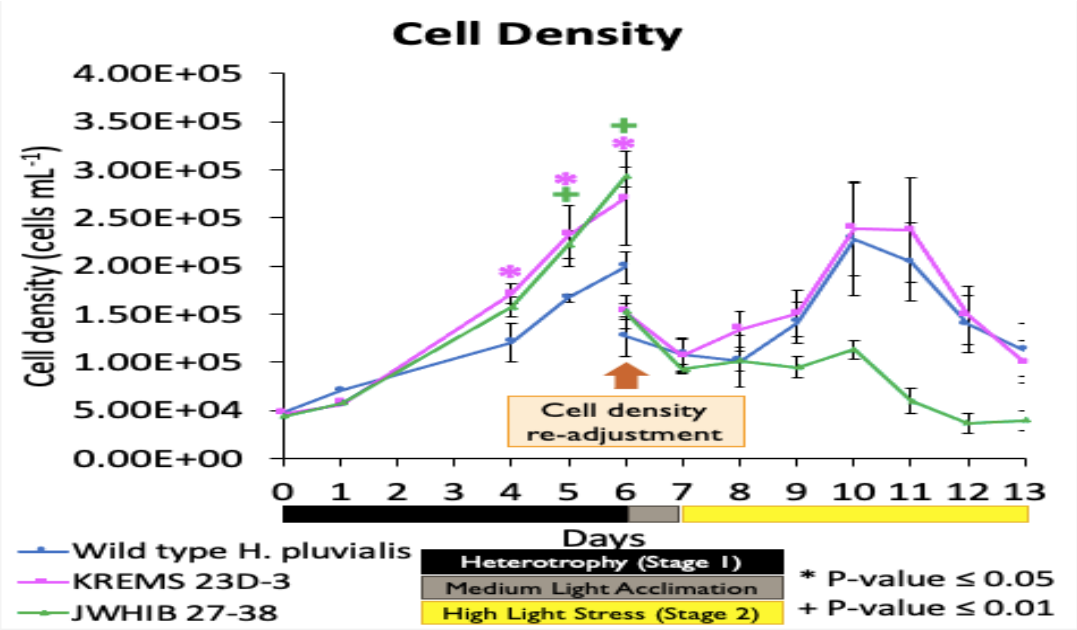

Figure 2: Mutant cell densities vs. the wild type in a small-scale two-step cultivation experiment.
Under the heterotrophic stage, both mutant strains achieve higher cell densities than the wild-type. Under the high-light stage, the wild-type and mutant KREMS 23D-3 performance is similar; whereas the mutant JWHIB 27-38 shows declining cell density.

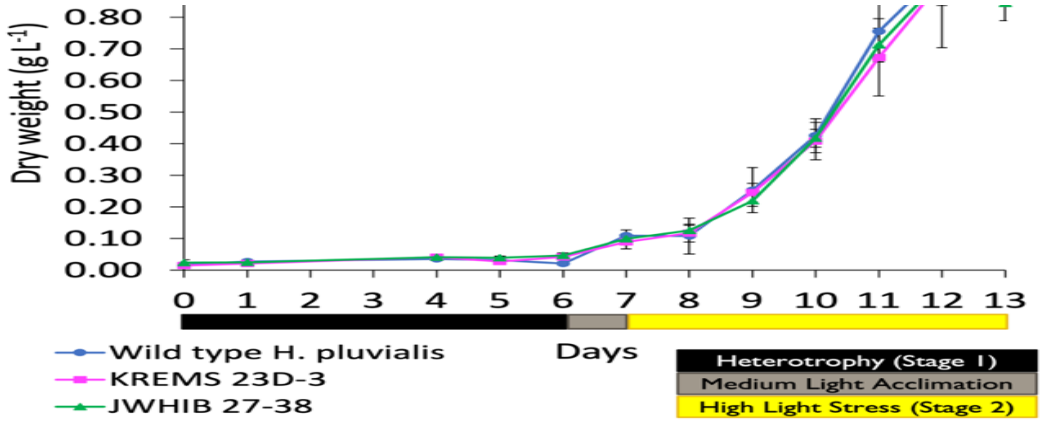

Figure 3: Mutant biomass concentration vs. the wild type in a small-scale two-step cultivation experiment.
Although cell density differences existed, overall biomass concentration was the same for all strains.

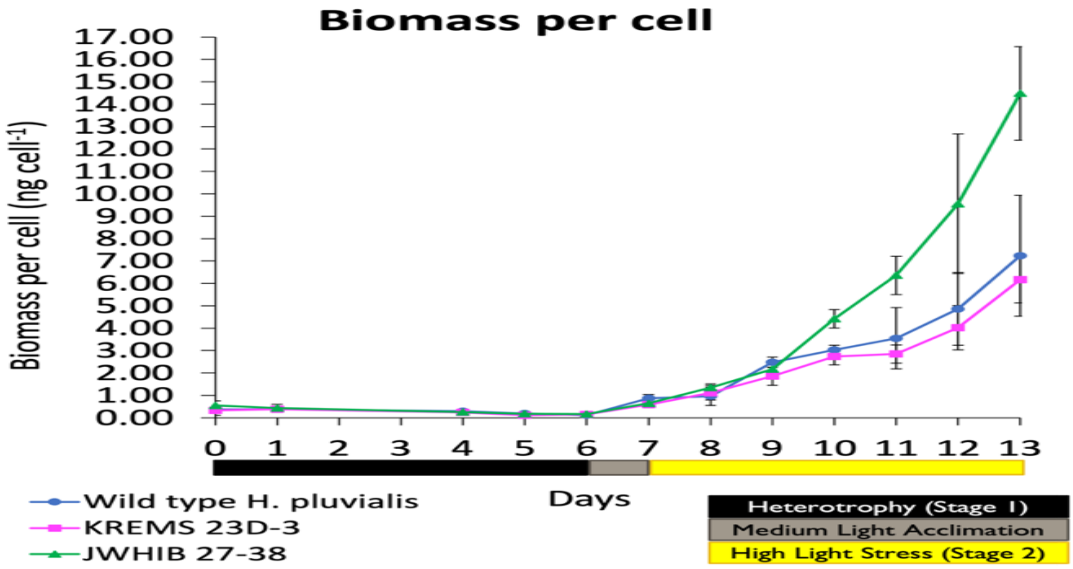

Figure 4: Mutant biomass per cell vs. the wild type in a small-scale two-step cultivation experiment. Cultures with lower cell density, such as mutant JWHIB 27-38, had much higher biomass per cell, allowing biomass concentrations to be comparable.

Continued analysis of cytograms is ongoing with guidance from my NOAA scientific mentor. Additionally, various samples collected during my NERTO are being processed, and data are being analyzed. Omics samples also will be analyzed to better characterize the metabolic pathways active in the three strains under different growth conditions and as they transition between growth conditions. The results of these analyses may reveal novel genes, proteins, or pathways in *H. pluvialis* which will help identify targets for future strain engineering.

Proteomic and phosphoproteomic analysis has also been done on samples from an earlier repeat of this experiment (completed before my NERTO). Triplicate wild type and mutant KREMS 23D-3 samples harvested at 48-hours of the heterotrophic stage have been submitted to the proteomics service company, DeltaOmics, where TMT-based proteomic and phosphoproteomic analysis was conducted by LC-MS/MS on an Orbitrap-equipped mass spectrometer. These samples were selected for proteomic and phosphoproteomic analysis because at this time point, the mutant KREMS 23D-3 demonstrated a clear phenotypic difference from the wild type, characterized by rapid cell density increase and a high acetate consumption rate. The raw data identified 5125 proteins and 6053 phosphoproteins. The data were then parsed based on significance thresholds which include p-values lower than 0.05 and fold-changes greater than 1.5-fold. Of the 5125 proteins identified, 289 met the statistical significance cutoff of a p-value less than 0.05. Within this subset, 10 peptides are 2-fold down-regulated, 160 peptides are 1.5-fold down-regulated, 4 peptides are 1.5-fold up-regulated, and 0 peptides were 2-fold up-regulated. One peptide is almost 2-fold up-regulated (1.94-fold). This peptide is also highly statistically significant (p-value = 0.0026). Table 1 summarizes the 2-fold down-regulated and 1.5-fold up-regulated peptides.

Table 1: All 2-fold down-regulated and 1.5-fold up-regulated peptides

Maj. prot. ID	Name	p-value	Fold-change
A0A699ZCA9	Uncharacterized	0.011470748	0.346281914
A0A6A0AFV5	Uncharacterized	0.006175426	0.430666696
A0A6A0AKQ7	Uncharacterized	0.00149257	0.443007214
A0A6A0ACN8;	Transmembrane domain-containing protein	0.015656612	0.443166725

A0A699ZM87			
A0A699ZDE8	ANK_REP_REGION domain-containing protein	0.000550123	0.452516907
A0A6A0AGQ0	Protein-serine/threonine kinase	0.002195149	0.468404354
A0A699YTB0	Uncharacterized	0.000547534	0.475570384
A0A699YZ10	Uncharacterized	0.029839218	0.487943291
A0A6A0A5H9	S1 motif domain-containing protein	0.002442053	0.489907954
A0A699ZY83	Low CO2-induced aldose reductase	0.03009788	0.496591848
A0A699YD11	Coproporphyrinogen oxidase	0.013498448	1.565121213
A0A6A0AJJ0	Adenosylhomocysteinase	0.015926316	1.585912595
A0A699ZNM8	Uncharacterized	0.017980053	1.590411949
A0A699ZE23	Adenosylhomocysteinase	0.002642424	1.941943306

Phosphoproteomics data was also parsed based on significance thresholds which include p-values lower than 0.05 and fold-changes greater than 1.5-fold. The data was also split into singly-, doubly-, and triply-phosphorylated peptides. There are 1259 singly-phosphorylated peptides with statistical significance. Within this, 48 are 2-fold down-regulated, 643 are 1.5-fold down-regulated, 12 are 1.5-fold up-regulated, and 6 are 2-fold upregulated. The most highly up-regulated singly-phosphorylated peptide is an uncharacterized peptide, that is 3-fold up-regulated. There are 247 doubly-phosphorylated peptides with statistical significance. Within this, 8 are 2-fold down-regulated, 137 are 1.5-fold down-regulated, 5 are 1.5-fold up-regulated, and 0 are 2-fold upregulated. There are 8 triply-phosphorylated peptides with statistical significance. Within this, 0 are 2-fold down-regulated, 4 are 1.5-fold down-regulated, 0 are 1.5-fold up-regulated, and 0 are 2-fold upregulated. The next analysis step will be to compare between these sets to identify which peptides are singly- and doubly-, singly- and triply-, doubly- and triply-, and singly-, doubly-, and triply- phosphorylated. Table 2 summarizes some selected significant phosphoproteins.

Table 2: Selected highly up- and down-regulated singly-, doubly-, or triply-phosphorylated phosphopeptides

Prot. ID	Name	Singly-, Doubly-, or Triply-?	p-value	Fold-change
A0A699ZBT6	Malate dehydrogenase, chloroplastic	Singly	0.0045	2.4867
A0A699YJ12	Anaphase promoting complex (APC) subunit 2	Singly	0.0105	1.5755
A0A6A0A5S3	Aldo keto reductase	Singly	0.0282	0.7403
A0A699YEB6	Fatty acyl-CoA reductase	Singly	0.0071	0.4485
A0A699ZUG1	DNA-directed RNA polymerase	Doubly	0.0018	0.23
A0A6A0AJ37	Mitogen-activated protein kinase	Doubly	0.0149	0.66
A0A699YGQ6	Uncharacterized	Triply	0.0482	0.64

There are a large number of uncharacterized peptides that have been identified in this analysis, so the next step is to investigate ways to characterize these peptides and phosphopeptides.

Relevance to NOAA: This research addresses the Seafood, Nutrition, Aquaculture, and Pathology (SNAP) Research Thematic Area. This study will elucidate the molecular basis of acetate metabolism and astaxanthin biosynthesis in the microalga *H. pluvialis*. The knowledge generated

will help the development of rational engineering strategies for improved astaxanthin production in the algae and aquaculture industry. A greater yield of algae-derived astaxanthin can allow its increased use as a feedstock in aquaculture, where astaxanthin is beneficial both for achieving a pink flesh color and for improving the health of fish stocks. Our work will thus address NOAA's mission in developing economically and environmentally sustainable marine aquaculture. The project findings will be continuously reported to the LMRCSC in six-month reports, submitted for publication in peer-reviewed journals, and presented at scientific conferences.

Broader Impacts: Currently, the primary bottlenecks for the algae astaxanthin industry are the low biomass and astaxanthin yield of the producer microalga *H. pluvialis.* As a result, the algae astaxanthin price is as high as *ca.* $7000/kg. Our work will address these challenges to reduce cost and allow for stable, high-yield production of *Haematococcus* astaxanthin. The success of this technology will generate a novel culture system for commercial-scale production of natural astaxanthin that could ultimately lower the production cost to <$1,000/kg crystalline, much lower than the current algae industry (*ca.* $7000/kg). This would lead to a paradigm shift in algae astaxanthin production and its application in aquaculture, making algae astaxanthin competitive in the aquafeed market (predicted to be about $500M in 2022). We will estimate and compare the production cost and economic efficiency of our technology with current technology in the aquafeed market. Through this project, one LMRCSC Ph.D. student (Ms. Ramarui) and at least one undergraduate intern from UMES will be trained. The broader impact of our work including the improved economics of aquafeed will be communicated to the public through NOAA EPP meetings, the annual IMET Open House event (over 600 attendees in 2019), etc.

Presentations & Publications: Data from this project was presented as a poster at The Tenth Biennial NOAA EPP/MSI Education and Science Forum at Florida A&M University on April 6-April 8. I also presented my preliminary NERTO data to my colleagues at the Milford Laboratory at an informal seminar hosted by my NOAA mentor at the end of my NERTO.

Performance Measure: 3.4a1: Fish Stock Sustainability Index (FSSI) (cumulative)

DOC Strategic Plan: 3.4.2: Improve recovery of listed species through innovative partnerships

NOAA RD Linkage 1; Key Questions: Key Question C5: How can we ensure aquaculture is sustainable?

Next Gen Priorities: Sustainable fisheries and safe seafood for healthy populations and vibrant communities

Project Number 20-04

Title: *Life history and disease ecology of the blue crab, a key benthic-pelagic link in tropical and temperate American estuaries*

Thematic Research Area: Assessment: Support and Information

Abstract: The blue crab, *Callinectes sapidus*, supports fisheries that define a way of life in coastal communities from New Jersey to Texas. Across their range, crabs display life-history variation: overwintering in the north and year-round activity in the subtropics. They also inhabit true tropics, where there is a lack of data on crab biology. In Puerto Rico, crabs are harvested in an artisanal

fishery that may grow as conch and lobster fisheries decline. If so, crucial data (size at maturity, sex ratio, habitat use) will be needed for management and have value for understanding Puerto Rico estuaries. Across their range, blue crabs are infected by viruses and protozoa that may interact with environmental and anthropogenic stressors to limit abundance. This project will enable a graduate student to gather blue crab life history and pathogen data in Puerto Rico and learn how life history data is applied to management by NOAA.

Principal Investigator Dr. Eric Schott **Institution**: UMCES/IMET
Co-PI: Dr. Bradley Stevens, **Institution**: UMES
[Dr. Stevens retired during the project period, but stayed to advise for the first year]
NOAA Partner: Original partner was B. Vogt **Lab/Facility**: NCBO
Other Partner(s): Gretchen Messick at NOAA Oxford, Jorge Bauzá-Ortega, San Juan Bay Estuary Program
Graduate Student: Olivia Pares **Undergraduate Student:** A summer intern from UMBC (an MSI) was trained in summer 2022.

Start Date: 1 September 2020 **End Date:** August 2022

Results to Date:

***Callinectes* life history:**

We looked at the abundance and reproductive activity of *Callinectes* sp. in the Torrecillas Lagoon. *Callinectes sapidus* was the most abundant crab in October 2020 (n=34) and January 2021 (n=26). However, in April (n= 35), July (n=33), and October 2021 (n= 31), *C. bocourti* was the most abundant crab in the lagoon (**Figure 1**). Overall, a total of 97 *C. sapidus* crabs were collected. Of those, 83 were female with a mean carapace width of 120 mm (**Table 1**). Fourteen males were collected with a mean carapace width of 108 mm. A total of 139 *C. bocourti* crabs were collected. Of those, 113 were female with a mean carapace width of 101 mm. A total of 26 males were collected with a mean carapace width of 108 mm. The third most abundant *Callinectes* species was *Callinectes similis*, with 47 crabs collected throughout the study. Of those, 29 were female with a mean carapace width of 92 mm and a total of 18 males with a mean carapace width of 111 mm.

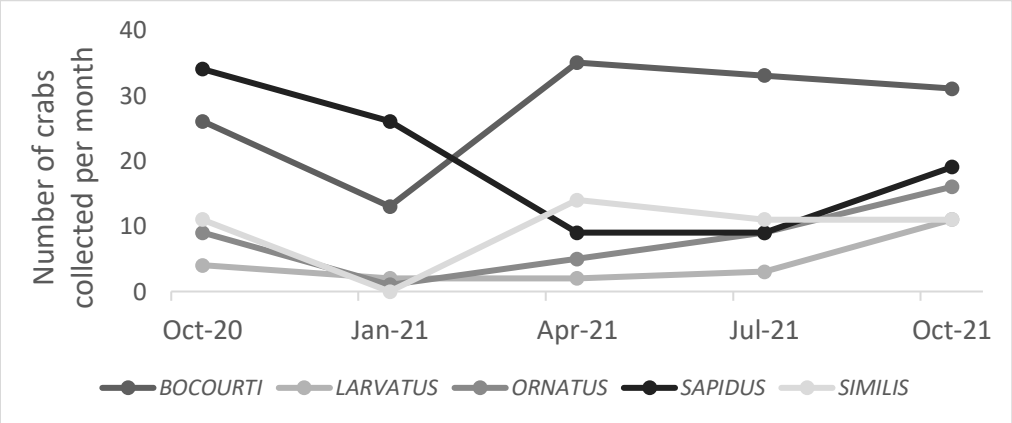

Figure 1. Number of each *Callinectes* sp. collected per month.

The sex ratio of *C. sapidus* in October 2020, January 2021, and October 2021 was significantly skewed towards females ($p<0.05$). When abundance was low in April and July 2021, the sex ratio was closer to the 1:1 ratio. The sex ratio of *C. bocourti i*n October 2020, April, July, and October 2021 was significantly skewed towards females ($p<0.05$). In January 2021, the sex ratio was closer to a 1:1 ratio between males and females. Mature female *C. sapidus* demonstrated spawning peaks in October, with 13-14% ovigerous females. In January, when the abundance of *C. sapidus* was high, only 4% of the mature females were ovigerous. Mature female *C. bocourti* spawning peaked in October and April with 20-30% ovigerous females. There was a gap in spawning in July with 0% ovigerous females.

***Callinectes* spp. disease ecology**:

Using PCR assays specific for infectious agents, all crabs were assessed for the presence of the virus CsRV1 and the protozoan parasite *Hematodinium perezi. The* presence of CsRV1 was not found in any of the crabs. *Hematodinium* sp. was present in *C. sapidus, C. bocourti, C. similis*, *C. ornatus*, and *C. larvatus.* The overall prevalence of *Hematodinium* sp. was highest in *C. sapidus* with 40%, followed by *C. similis (27%), C. bocourti (23%), C. ornatus (21%),* and *C. larvatus (16%).* The prevalence of *Hematodinium* sp. and abundance of *C. sapidus* was highest in October 2020 and January 2021. The percent of infection of *Hematodinium* sp. in *C. sapidus* and the quantity of the species declined in April compared to the other months (**Figure 2**). *Hematodinium* sp. was not present in *C. sapidus* in July, and in October of the following year, the prevalence was at 12%. The prevalence of *Hematodinium sp.* in *C. bocourti* was 35% in October 2020, with 25 individuals sampled. In January 2021, the prevalence of *Hematodinium* sp. increased to 64%, while the abundance of *C. bocourti* reached its lowest at 11 individuals sampled. In the following months, the quantity of *C. bocourti* remained at over 20 individuals while the prevalence of *Hematodinium* sp. continued to decline each month.

Table 1. Summary of the mean carapace width of male and female *Callinectes* sp. and total species collected.

Species	n	Male	Female	Mean CW± SE- Males	Mean CW± SE
Callinectes sapidus	97	14	83	108 ± 7.6	120 ± 1.23
Callinectes bocourti	139	26	113	108 ± 1.6	101 ± 0.82
Callinectes similis	47	18	29	111 ± 2.4	92 ± 2.1
Callinectes ornatus	40	2	38	97 ± 10	102 ± 1.65
Callinectes exasperatus	5	3	2	104 ± 0.64	117 ± 17.7
Callinectes larvatus	22	18	4	101 ± 1.86	75 ± 7.18

CW: Carapace width, SE: Standard Error, n: Sample size

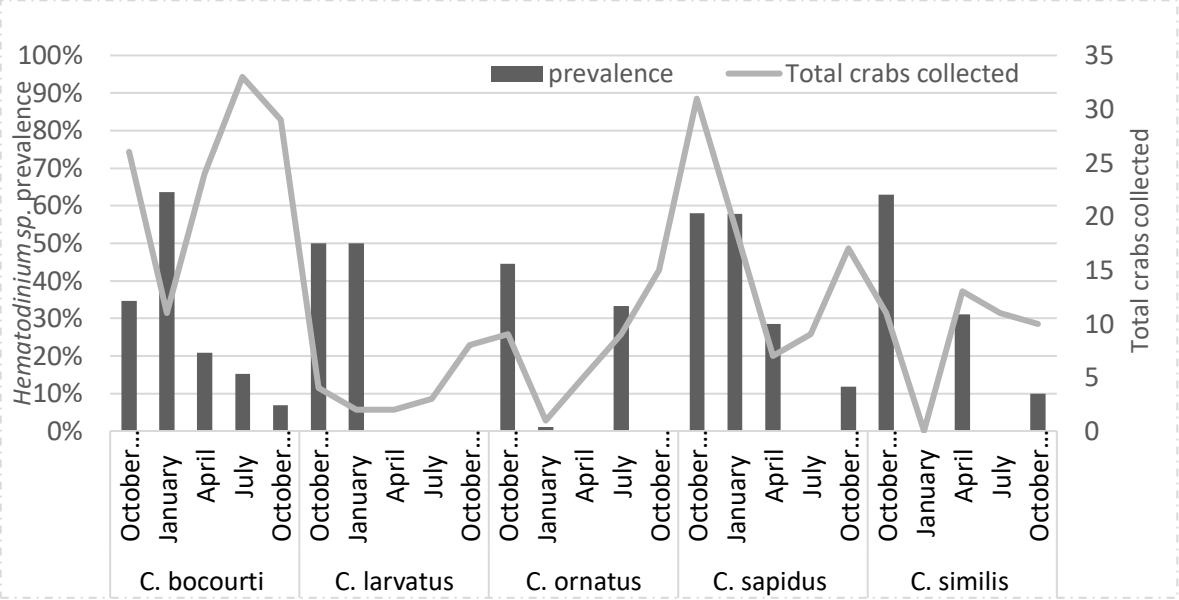

Figure 2. Prevalence of *Hematodinium* sp. in all *Callinectes* spp. hosts, and number of *Callinectes* spp. collected per month.

Importance to Puerto Rico living resource management:
The preliminary data on the number of *Callinectes* spp. is an indication that there is much to learn about the life history of this important artisanal fishery resource in PR. Questions of where the spawning stock resides, how larvae make their way into estuaries, and many other unknowns. Improved understanding of ecosystems to inform resource management decisions- the artisanal fishery for the blue crabs is "regulated" by PR DNR. However, there is no local data on the species *C. sapidus* and its congenerics. The information on species ratios, abundance over the year, and reproductive state will establish the first baseline of data on *Callinectes* in the PR estuaries. The finding that a parasite known to cause mortality in blue crabs is prevalent in PR should be further investigated. Most important is to assess whether the prevalence in wild crabs has an effect on their health in the wild.

Relevance to NOAA: This is the first systematic survey of blue crabs in the San Juan estuary. Though not a federally managed fishery, the *Callinectes* harvest is crucially important to an unknown number of Puerto Rico fishers, which may shift effort to/from other critical fisheries of spiny lobster and conch as those species become more or less abundant. Produced the first data on the ecology of the blue crab (a data-poor species) in the San Juan area.

Broader Impacts: Communications with managers in PR Dept. of Natural Resources (including Jobos Bay NERR), ISAMR (an after-school climate science program of The Park School Baltimore), students at San Juan Schools, information exchanged with artisanal fishers of *Callinectes* spp.; information exchanged with a charter boat captain (Armando, at Magic Tarpon) who has come to trust Olivia Pares over the five trips that she made on La Torrecillas estuary.

Presentations & Publications:
Pares O.*, Zhao M., Stevens B., Schott E. Bridging the knowledge gap of the life history of the blue

crab, *Callinectes sapidus*, a key benthic-pelagic link in tropical and temperate American estuaries Presented at NOAA EPP Forum, April 2022

Performance Measure: 3.4b: Percentage of FSSI fish stocks with adequate population assessments and forecasts

DOC Strategic Plan: Fulfill Constitutional Requirements and Support Economic Activity 4.2 - Provide Accurate Data to Support Economic Activity

NOAA RD Linkage: C1b: Increase our knowledge and understanding of the mechanisms and impacts of environmental changes on marine species and ecosystems.

Next Gen Priorities: Sustainable fisheries and safe seafood for healthy populations and vibrant communities.

Project Number: 20-06

Title: Investigating the effects of increasing temperatures on heat shock proteins and development of early life history stages of Nassau grouper

Thematic Research Area: CLIME: Climate Impacts on Marine Ecosystems

Abstract:
Climate variability and change likely have major impacts on the early life history stages of commercially and recreationally valuable fish like Nassau grouper. Understanding these impacts will be essential to conservation and management efforts. Studies to date have noted phenotypic and survival differences in early life history stages of Nassau grouper reared at different temperatures. However, little is known on the drivers of these changes in bioenergetics and in gene expression during the early life history stages of this species. Our goal is to measure bioenergetic activity and use established genetic methods to investigate temperature induced changes in gene expression of early life stage Nassau grouper, collected from a spawning aggregation on Little Cayman, Cayman Island.

Principal Investigator:
Name: Janelle Layton
Institution: Oregon State University
Co-PI: Name: Scott Heppell
Institution: Oregon State University
NOAA Partner: Name: Steve Gittings
Lab/Facility: Silver Spring, NOS
Students: Graduate Student: Janelle Layton
Undergraduate Student: NA

Keywords: Early life history stages, tropical marine fishes, climate change, heat shock proteins
Start Date: 09/2020 **End Date:** 09/2022

Results to Date: Graduate student has successfully completed her research review. Research progress was delayed by 1 year because of covid restrictions. Sample collection has been completed during the months of January and February of 2022. Sample stored in formalin and ethanol have been photographed. Currently in the process of measuring various morphometric traits from the photographed samples. Also, still finalizing heat shock protein analysis procedures.

Relevance to NOAA: As stated in the request for proposals for this funding mechanism: "The LMRCSC will conduct research that supports effects of climate on the distribution and production of living marine resources, including reproduction, growth, mortality, diseases and contaminants, and

sustainability." We will specifically provide fundamental data for the direct assessment of Nassau Grouper by analyzing and comparing the impacts of climate change on the early life history stages of this species in tropical water. We will have the ability to perform student training in fish collection and rearing, laboratory-based genetics, and data analysis. In addition, the data directly relate to the mission of NOAA fisheries by influencing science-based conservation and management of living marine resources that will lead to the protection of healthy ecosystems. Given that Nassau Grouper are part of the management portfolio of three different Fishery Management Councils (SAFMC, GFMC, CFMC), these results have a direct impact on a federally managed species.

Broader Impacts: The results of this study will help us evaluate the physiological response of early life stage Nassau Grouper to thermal stress both at the population and individual level. The individual variability could be extremely important, because if there is phenotypic variability in response, then it would directly argue for maintaining as large and diverse a genetic pool in the population as possible so that the species has the highest probability of success in adapting to a changing climate. Furthermore, this work will determine whether HSPs may be used as (1) a tool for better understanding morphological and physiological changes in the early life history of Nassau Grouper and (2) novel biomarkers for future climate change studies in marine organisms.

Presentations & Publications:

Janelle Layton, Scott Heppell, Alli Candelmo, Brice Semmens, Christy Semmens, Brian C. Stock, Lynn Waterhouse, Croy M. McCoy, and Bradley Johnson. Investigating the Impacts of Increasing Temperatures on Early Life History Stages of Nassau Grouper. American Fisheries Society 151st Annual Meeting. Baltimore, MD November 6-10, 2021 – Poster

Janelle Layton, Scott Heppell, Alli Candelmo, Brice Semmens, Christy Semmens, Brian C. Stock, Lynn Waterhouse, Croy M. McCoy, and Bradley Johnson. Investigating the Impacts of Increasing Temperatures on Early Life History Stages of Nassau Grouper 2022 NOAA EPP Forum. Tallahassee, FL April 6-8, 2022 – Poster

Layton, J., Candelmon, A., Semmens, B., Pattengill-Semmens, C., Stock, B., Waterhouse, L., McCoy, C., Johnson, B., Heppell, D., Huber, S., Barkdoll, S., Heppell, S. (2022). Early Life History Stages of Yellowfin Grouper in Little Cayman, Cayman Islands. American Fisheries Society Meeting, Spokane, WA – Poster

Performance Measure: Number and percentage of actions ongoing or completed to recover endangered and threatened species

DOC Strategic Plan: Strengthen capabilities to assess and monitor fish and protected resources

NOAA RD Linkage: How do environmental changes affect marine ecosystems?

Next Gen Priorities: Recovered and Healthy Marine and Coastal Species

Project Number 21-02

Title: *Sonar Censusing and Habitat Use by Spawning Run Atlantic and Green Sturgeon, Acipenser oxyrinchus and A. medirostris*

Thematic Research Area: Assessment: Support and Information

Abstract: This TAB project supports (1) NERTO training and research on sonar censusing Sacramento River green sturgeon at the NOAA SWFSC Santa Cruz Laboratory; (2) tests to distinguish Atlantic sturgeon and gar sonar images for Chesapeake Bay Atlantic sturgeon; and (3) to provide field training opportunities for undergraduate minority students. Sturgeons across the US are managed by NMFS as protected species, where key challenges to recovery center on accurate assessment of spawner abundance and how spawner movement and reproduction is impaired by habitat alterations. In his thesis research, EPP LMRCSC Fellow Nicholas Coleman is deploying sonar censusing approaches on spawning run Atlantic sturgeon in the Marshyhope Creek system (Chesapeake Bay) and using telemetry to better understand how spawner incidence is shaped by flow, temperature, dissolved oxygen, and bottom substrate. SWFSC scientists pioneered sonar censusing approaches evaluating spawning green sturgeon in the Sacramento River, for which a decade of historical data is available. During a NERTO, LMRCSC Fellow Coleman will receive training in side-scan and DIDSON sonar censusing technologies with SWFSC Santa Cruz scientists (S. Lindley and P. Dudley) and evaluate historical habitat associations of spawning run adults. A key challenge to Coleman's Atlantic sturgeon thesis work is distinguishing sturgeon and gar, the two largest fishes within the Marshyhope Creek, through sonar (ARIS) deployments. Laboratory trials are proposed to compare acoustic images of gar from similar sized Atlantic sturgeon. This work will complement and enhance the Fellow's thesis research and training through comparisons of sturgeon settings (water-stressed but large Sacramento River v. very small Mashyhope Creek), spawning habitat associations in both systems, and exposure to the interface between science (sonar censusing) and conservation policy.

Principal Investigator: **Name**: Dr. Dave Secor **Institution**: UMCES/IMET
Co-PI: Name: Dr. Rose Jagus **Institution**: UMCES/CBL

NOAA Partner: **Name**: Dr. Steven Lindley **Lab/Facility**: SEFSC

Other Partner: **Name:** Dr. Peter Dudley **Lab/Facility:** SEFSC

Students: Graduate Student: Mr. Nicholas Coleman

Undergraduate Student: prevented by CoVID restrictions

Keywords:

Start Date: 1 April 2021 **End Date:** 31 August 2022

Results to Date: Project goals were to (1) support LMRCSC Fellow N. Coleman's NERTO, which will exceed available funds ($5000); (2) overcome a key constraint in application of sonar censusing – distinguishing similar size Atlantic sturgeon and gar *Lepisosteus osseus* species; and (3) provide field training opportunities to undergraduate LMRCSC students. Principal support for N. Coleman's thesis research comes from a separate NOAA Section 6 Award to PI D. Secor and Maryland DNR collaborators, entitled "Spawning movement behaviors, habitat dependencies and run size of Nanticoke River Atlantic sturgeon." This award provides funding for fieldwork and analyses related to ARIS, side scan, and telemetry deployments in the Marshyhope Creek during Aug-Oct 2019-2021. Thesis research focuses on developing robust estimates of abundance

through intensive assessment of key spawning reach segments, simultaneously deploying ARIS, side-scan sonar, and biotelemetry. TAB support will augment thesis research through support of the NERTO, mentoring undergraduate interns, and conducting a key test to confirm identification of Atlantic sturgeon.

Green sturgeon assessment —— LMRCSC Fellow Coleman engaged in all parts of the Sacramento green sturgeon acoustic surveys. DIDSON sturgeon sampling took place from June 7th to June 18th, 2021, from just above Chico (river km 323) to Keswick Dam (river km 477), covering an area of approximately 154 kilometers (Figure 1). A total of 42 units (sites) were sampled in 2021. DIDSON was towed on the side of the vessel at an angle of approximately 85º to optimize field of view of the river bottom. As depth changed, the camera was manually adjusted to maintain field of view of the river bottom. Each transect was surveyed with seven DIDSON passes and three side scan passes. A GPS unit attached to the boat recorded the paths of each transect pass to estimate the area surveyed. Side scan sonar surveys were also conducted. After acoustic videos were collected, three reviewers analyzed the video from each transect and counted the number of observed sturgeon. Buffer width was measured from the width of the DIDSON beam on each video recording and the number of observed fish in each transect was divided by the area to obtain a value of density. Densities from all seven passes were averaged and multiplied by total area surveyed to get estimated abundances. The sum of estimated abundancies from each spawning location was summed to obtain an annual spawning run estimate. Annual estimates of abundance were corrected with telemetry data to account for fish that migrated out of the sampled area before sampling occurred, migrated into the spawning area after sampling, and fish that were missed because they were moving between spawning areas.

Figure 1. Map of the extent of the Upper Sacramento River sampled during DIDSON surveys. Cities are marked by blue hexagons, major dams are marked by grey circles, and the red area highlights the survey extent.

Temperature (ºC) and flow ($m^3\ s^{-1}$) data for the surveyed area were obtained from the River Assessment for Forecasting Temperature (RAFT). RAFT simulates river temperature and flow using in the longitudinal direction as a one-dimensional model. In this analysis, RAFT modeled daily temperature and flow from 2010 to 2017. Average temperature for each month from March to August was used to index the temporal window in which sturgeon occupied the sampled reaches of the Sacramento River. Annual estimates of abundance were correlated with mean monthly temperature and flow to explore the possibility of cueing behavior to monthly environmental conditions. Visualizations to examine the relationship between Average Distance Upstream (ADU) and average temperature were produced to understand how temperature may influence the extent of travel for sturgeon. ADU was calculated from the following equation:

$$ADU = \frac{annual\ sum\ of (rkm\ at\ transect\ x\ \times fish\ obsered\ at\ transect\ x)}{total\ annual\ estimation\ of\ fish}$$

"Hot spots" were defined as units where 50 or more sturgeon were observed for at least three years

or areas that had 100 or more sturgeon for a given year. The abundances from 2010-2019 were plotted for four identified hotspots to examine annual fluctuations in habitat utilization. Average flow for April and average temperature for March had the strongest correlation with spawning run abundance on the basis of R-squared values (Figures 2; temperature not shown). These results have implications on how spawning run estimates are interpreted in terms of green sturgeon conservation and rebuilding.

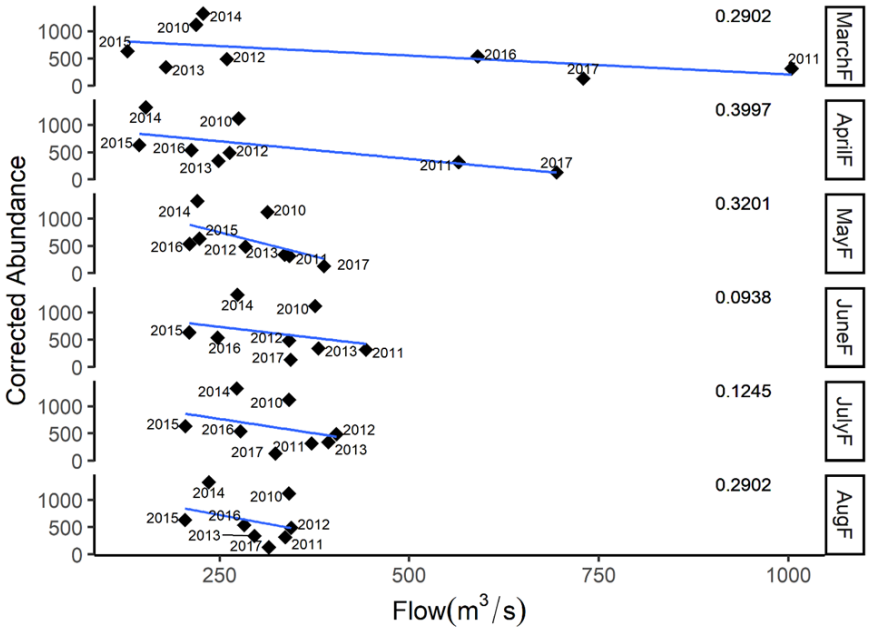

Figure 2. Scatter plot showing the relationship between average monthly flow and annual abundance from 2010 to 2017. R-squared values each month are represented in the top right of each graph.

ARIS identification of sturgeon —— Experimental pond trials to assess limitations in the ability to distinguish sturgeon and gar targets from ARIS images were conducted on March 28, 2022 at the UMCES Horn Point Laboratory (Figure 3). Eight individual Atlantic sturgeon and longnose gar were placed in floating pens and imaged by the ARIS at two distances: 4 m and 8 m. During each treatment, fish were imaged for five minutes to document swimming style and the morphological details of acoustic images. After imaging, each fish was assigned a unique number and measured for total length. In order to assess the video examiner's ability to distinguish sturgeon from gar targets, a single blind experiment was conducted. Tail length, girth, and snout length were identified as features that could be consistently identified and measured.

Figure 3. Trials to evaluate species identification and length estimation using ARIS camera system. Floating pen within pond held individual sturgeon and gar.

Based on assessment of swimming style and tail type, the examiner correctly identified the species in 25 (96%) of the analyzed trials. In the single misidentification, a sturgeon was mistaken for a gar. ARIS length measures were substantially biased low by about 30 cm in comparison to observed lengths, with the bias higher for the 8 m camera distance in comparison to the 4 m camera (Figure 4). These findings support suspected biases in the field deployment of ARIS in the Marshyhope Creek, where a substantial number of sturgeon-shaped targets yielded smaller sizes than expected.

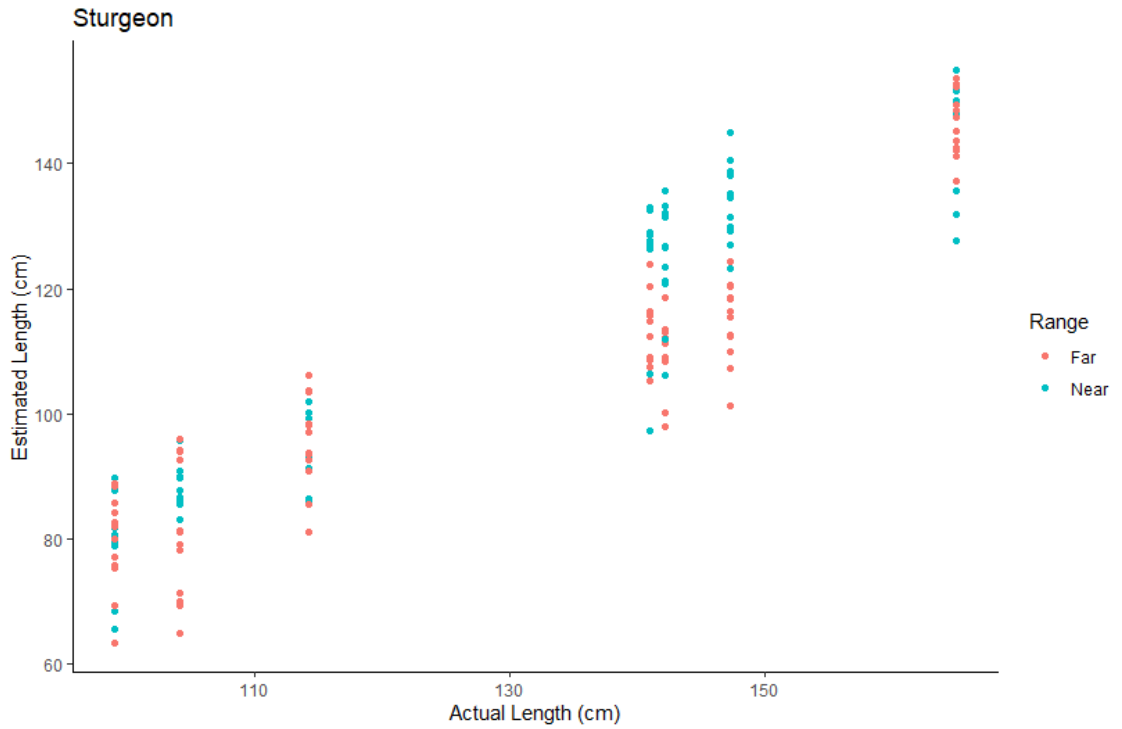

Figure 4. Scatter plot showing the relationship between estimated length and actual length for sturgeon. Near camera and far camera treatments were at 4 and 8 meters.

Relevance to NOAA: NOAA is committed to the management and conservation of marine resources and the ecosystems that support them. The NMFS Office of Protected Resources is responsible for implementing the Endangered Species Act (ESA), which assesses the vulnerability of native species and the habitat they use, does so through a process that collaboratively engages fishery managers and stockholders to develop recovery plans and continued monitoring programs. The Chesapeake Bay distinct species segment (DPS) of Atlantic sturgeon is “Endangered” (NOAA 2017) and the southern distinct species segment (sDPS) of green sturgeon is “Threatened” (NMFS 2018). Spawning reaches for Nanticoke River Atlantic sturgeon and Sacramento River green sturgeon, although vastly different in dimension and legacy threats represent key assessment areas for quantifying population recovery. Further, habitat protections and restoration projects have been put into place for both species. Despite major advances in sturgeon sonar censusing approaches, uncertainties related to biases and efficiencies of these methods persist, which can be evaluated through (1) deployment and integration of multiple platforms (ARIS/DIDSON and side scan sonar) and biotelemetry, and (2) laboratory tests of key sonar censusing assumptions related to size estimates and species identification.

Broader Impacts: A key outcome of this proposal is the training of LMRCSC student Nicholas Coleman and possible future recruitment into a NOAA science career path through his thesis research, course work, and NERTO experience. NERTO Advisors were Dr. Steve Lindley and Dr. Peter Dudley. Dr. Lindley is the director of the Fisheries Ecology Division at the Southwest Fisheries Science Center (SWSFC) in Santa Cruz, California where he serves as a member of the Green Sturgeon Recovery Team. Dr. Peter Dudley, is a quantitative ecologist and also a member of the Fisheries Ecology Division and will support NERTO training and green sturgeon data analysis. Mr. Coleman has accepted a contractual position with Sustainable Fisheries at NMFS Silver Spring Headquarters. He plans to defend his Master’s thesis 28 October 2022.

Presentations & Publications:

Secor, D.H., M.H.P. O'Brien, N. Coleman, A. Horne, I. Park, D. Kazyak, D. Bruce, and C. Stence. (2022). Atlantic sturgeon status in an extremely small spawning habitat: the Nanticoke-Marshyhope Creek Estuary, Chesapeake Bay. Reviews in Fisheries Science and Aquaculture 30:195-215. DOI: 10.1080/23308249.2021.1924617

Coleman, N.C. and Dudley, P.N. (2021). Using DIDSON to estimate green sturgeon abundance in the Sacramento River. Oral Presentation at the Interagency Ecological Program, Sturgeon Project Work Team Biannual Meeting. August 6th, Santa Cruz, California.

Coleman, N.C., Lankowicz, K.M., O'Brien, M.H.P., Secor, D.H. (2021) Using Adaptive Resolution Imaging Sonar (ARIS) to estimate the fall spawning run of Atlantic sturgeon in the Nanticoke River-Marshyhope Creek. Poster Presented at American Fisheries Society 151st Annual Meeting. November 6-10, Baltimore, Maryland.

Coleman, N.C., Lankowicz, K.M., O'Brien, M.H.P., Secor, D.H. (2022) Using Adaptive Resolution Imaging Sonar (ARIS) to estimate the fall spawning run of Atlantic sturgeon in the Nanticoke River-Marshyhope Creek. Oral Presentation at American Fisheries Society Tidewater Division. March 24-26. Nag's head, North Carolina.

Coleman, N.C., O'Brien, M.H.P., Lankowicz, K.M., Secor, D.H. (2022) ARIS Sonar imaging of adult Atlantic Sturgeon in the Nanticoke-Marshyhope System. American Fisheries Society 152nd Annual Meeting. August, Spokane, Washington.

Coleman, N.C. (2022 - anticipated). Using Adaptive Resolution Imaging Sonar (ARIS) to estimate the fall spawning run of Atlantic sturgeon in the Nanticoke River-Marshyhope Creek. MS thesis. University of Maryland Center for Environmental Science.

Appendix III: Leveraged funds

Source	Type	Start date - end date	Total amount	Current 6 month period	PI	Project title	Contribution to Center
NSF	Grant	2/23/2021-2/22/24	$323,985	$100,000	P. Chigbu; M. Sexton	REU Site: University of Maryland Eastern Shore Research Experience for Undergrad.	Funds support summer interns
NASA	Grant	2021-2026	$158,335	$15,833	P. Chigbu	Student Airborne Science Activation for MSI (SaSa) for training students in remote sensing	Funds support student training
USDA NIFA	Grant	2/1/2020-8/312022	$200,000	$15,000	Marikis Alvarez	Cooperative Research for 1890s	Support for LMRCSC staff and student travel
NSF-HRD	Grant	09/01/2019-08/31/22	$400,000	$3,000	Horodysky and Gibson	Targeted Infusion Project: Mathematical Engagement for the Marine, Biological, and Environmental Realms of Science (MEMBERS)	Funds are used to support Horodysky and and Gibson, and student internships.
NSF-OCE	Grant	8/1/18-7/31/22	$741,820	$120,000	Gibson and Cuker	Multicultural Diversity in the Aquatic Sciences	Funds are used to support students to ASLO conference.
NSF-OCE	Grant	5/1/21-4/30/26	$60,500	$6,050	Gibson	Cold Tongue Mixing	Funds used to support student travel for research in Ghana.
NSF-BIO-IOS	Grant	8/1/2019 - 7/31/2024	$700,000	$10,000	Horodysky	CAREER: Investigating environmental acidification and temperature as drivers of morphological alteration and physiological deficits in auditory systems of soniferous fishes	Research topics provided for LMRCSC funded student
NSF RIA	Grant	8/1/2020-7/31/2023	$299,999	$5,000	Lewallen	Epigenomic adaptations of dolphin skin	Research topics and supplies provided for LMRCSC funded student

NSF-OCE	Grant	8/1/21-7/31/23	$914,000	$20,000	Gibson and Cuker	Multicultural Diversity in the Aquatic Sciences	Funds are used to support students to ASLO conference.
NSF-ECCS	Grant	08/01/21-07/31/24	$600,235	$2,000	Sun and Gibson	Excellence in Research: Integrated Sensor-Robot Networks for Real-time Environmental Monitoring and Marine Ecosystem Restoration in the Hampton River	Funds will be used to fund research projects for LMRCSC students.
NSF GRFP	Fellowship	9/2022-9/2025	$180,000	$30,000	Janelle Layton	GRFP	Supports Janelle Layton here forward
NSF GRFP	Fellowship	9/2022-9/2024	$180,000	$30,000	Hillary Thalmann	GRFP	Supports Hillary Thalmann here forward
Shark Conservation Fund via Dalhousie Univ.	Grant	7/1/2021-6/30/2025	$82,500	$10,312	Elizabeth Babcock	Unlocking the global shark meat trade	Provides partial salary support for E. Babcock
CIMAS	Grant	Sept 2021-Aug 2022	$98,396	$24,599	Elizabeth Babcock	Bycatch estimation project	Funding supports one MS student and partial salary support for E. Babcock
NOAA/NMFS	MOU	Jan. 2000-continuing	$100,000	$50,000	Dionne Hoskins	NOAA CMER	Support a NMFS FTE for a CMER program
Ocean Leadership	Grant	December 1, 2021 – June 30, 2022	$10,000	$10,000	Dionne Hoskins, Victoria Young	NOSB Regional Site	Produce the GA-SC NOSB competition

Appendix IV: LMRCSC External Evaluation: Year 6 Mid-Year Report

LMRCSC Year Final Evaluation Report
September 10, 2022

The Living Marine Resources Cooperative Science Center (LMRCSC) was "established in October 2001 as a cooperative agreement between NOAA's Educational Partnership Program (EPP), and a collective of universities to address environmental, natural resources management and STEM workforce challenges…." The mission of the Center "is to prepare a diverse student body for careers in marine and fisheries science through exemplary academic and research collaborations" (all quotes from the Project Narrative). The LMRCSC received an additional five years of funding, which began in Fall 2016. The project leadership contracted with The College of Exploration's (TCOE) Dr. Tina Bishop, Peter Tuddenham, and Dr. Howard Walters to develop and implement an external evaluation of the project. This evaluation plan was reviewed and approved by internal project leadership, and was submitted with the project proposal for review and approval by NOAA EPP. During year five, there were substantial impacts to the LMRCSC due to the SARS-COVID Emergency Response conditions which have been implemented across the nation. These were described in the annual report for year five submitted in early fall 2021. These responses included shifting of face-to-face activities to online communications methods, and numerous program planning and implementation complications which affected student research, access to laboratories and other research settings, and program participation and travel. Due to these responses, NOAA EPP issued a one year, no-cost extension to the LMRCSC to continue and finalize planned activities for the project period.

This current report is the final summary of continued evaluation efforts in this sixth year. As in previous years, the first half of the year included collection of impact assessments from undergraduate and graduate students. In addition, a revised workshop focused on student data skills, i.e., the Data Carpentry workshop, was implemented in fall 2021, to include both internal and external impact survey data collection from participants. These data are summarized for this report below. Finally, the NERTO projects are a significant programming element for the LMRCSC and in some ways, constitute a capstone science research project for participants. A NERTO completion survey was distributed in summer 2022 to students completing these NERTO projects to capture perceptions of these graduate students about the impact of these projects.

Undergraduate Student Impact Survey

A group of six undergraduate students representing Hampton University, Savannah State University, and the University of Maryland-Eastern Shore, completed a mid-year survey to identify perceptions of the program and potential impacts on their educational and career trajectories. Five indicated they are pursuing degrees in Marine and Environmental Sciences or (one) Environmental Sciences. Each has remained confirmed in their selection of college major—which is atypical as the normal pathway for undergraduates is to exhibit regular changes of major.

Item five on the survey asked students for their career goals. Two indicated research, two indicated work as environmental lawyers, one each in environmental consulting and resource management. The students' motivation for careers in science (item six) seemed highly related to environmental and global stewardship issues. Respondents perceive a value-laden focus to science careers. Interestingly, even though they are undergraduates, four of the six describe research or field experiences (item eight) in which they have participated under the funding or auspices of the LMRCSC. This is a stronger response from undergraduates and suggests a growing refinement and expertise in the education programs for LMRCSC and particularly in the communications efforts to link, in the minds of students, their college experiences with LMRCSC as an umbrella entity.

Items nine and ten solicited descriptions of any professional mentors which the students/respondents had. Three of the five respondents to this item noted undergraduate

professors as fulfilling this professional role for them. This is a valuable observation from a programmatic standpoint. LMRCSC leadership may wish to consider whether there is sufficient outreach to the undergraduate faculty members at the respective institutions about the need for student mentoring, with orientation on the LMRCSC and opportunities connected to it, as well as further professional opportunities through LMRCSC for the faculty members themselves.

Finally, in this pool of questions, item eleven revealed that four of the six respondents had received LMRCSC orientation and information from faculty members or program representatives at their home institutions. This observation addresses the question of administrative effectiveness of the LRCSC and suggests that communications and program orientation, recruitment, and onboarding of students is occurring and embedded down into the institutional faculty level.

Items twelve through seventeen sought to identify pre- or co-collegiate/co-curricular activities related to science among the responding pool. These have been found in related research in science career pipeline issues to have some relationship with students choosing or persisting in the STEM employment pipeline. While this response pool was small, interesting observations in response data include little family background for STEM careers for these students, but some evidence of involvement in other STEM related activities beyond the LMRCSC project. There was evidence of family encouragement for STEM careers from parents and grandparents. One individual participated in an REU program.

Item eighteen reflects that these respondents believe there are strong employment possibilities for STEM careers which they are pursuing.

Item twenty asked respondents to identify other potential activities of interest which could be offered by the LMRCSC. Among the activities suggested were visits to other LMRCSC institutions, additional workshops for statistics, policy or justice issues, and scuba diving or other research opportunities. The respondents perceived (item twenty-one) that these additional activities would supplement their knowledge and also have important social affects by linking students with other LMRCSC participants and institutions.

Item twenty-three asked respondents how their knowledge of NOAA had changed over the recent year. This item is related to one of the mission objectives of the LMRCSC for communication of NOAA mission and research objectives to students in the LMRCSC. Three of the respondents answered this item and provided detailed information. One had served as a NOAA/EPP fellow over the previous year. One specified that a workshop offered by LMRCSC provided NOAA information. A final respondent simply noted affirmatively that his/her knowledge of NOAA had increased without specifying a source of this knowledge.

Items twenty-four through twenty-six solicited additional information specific to the LMRCSC more broadly. Four of the six respondents reported little interaction with other LMRCSC institutions. All six of the respondents reported high to medium knowledge of LMRCSC as a NOAA EPP network—a strong response and further evidence of effective administrative/communications efforts in the LMRCSC. And finally, all six reported high levels of interest in continuing involvement with LMRCSC through a potential alumni organization in the future.

The remaining items, twenty-seven through thirty-two, suggest that these respondents continue to have some concerns about support structures for transitioning to graduate school, even though all six report a high level of interest in doing so. Some of their concerns relate to preparing for the GRE and identifying and transitioning to graduate schools and programs. There is evidence in these questions that many of these respondents are already interacting with graduate students and obtaining some input from program leadership and faculty at their institutions.

Graduate Student Impact Survey

A larger response pool—eighteen individuals—was obtained from the graduate students for the mid-term cycle of survey collection. It may be that this far into the program, the graduate students have grown more accustomed to receiving these information requests from the evaluation team, or simply may be more mature in viewing this as a professional responsibility and reality in the workplace. There was wide distribution of the respondents across the LMRCSC, with each of the

institutions having representation in the response pool (there may have been some misinterpretation of the "home school" question, so some individuals may have pointed back to an undergraduate home school as alumni. Thirteen of the respondents are seeking MS degrees, and five are seeking Ph.D. degrees. The primary content disciplines for all of these students are marine related, suggesting strong success in the recruitment processes for LMRCSC, and a strong NOAA-aligned academic and research focus. None of the respondents have changed their focus while working within the LMRCSC. All reported undergraduate preparation in related disciplines including marine science, biology, environmental science or oceanography. One outlier is an individual respondent out of nutritional sciences tied to an agricultural orientation. Each of the respondents (item six) identified future career orientations pertaining to the professoriate or research positions, either for a university or a government agency. Three respondents specifically named NOAA as a future opportunity for employment, although most of the other responses align with NOAA mission science.

Item seven asked respondents to describe how and when they began considering a career in science. Again, this type of background information can be useful in formulating an effective recruitment plan. The largest cluster of responses (n=6) pointed back to childhood, followed by high school (3) or middle school (2) as the time when perceptions of science careers or desires for science careers began to form. This is a critical observation, as there remains some institutional perception, particularly in the federal science agencies, that targeting career recruitment education and outreach below the undergraduate level is not a valuable use of funds. For this group of graduate students pursuing STEM careers, those decisions formed in childhood and adolescence were crystalizing and powerful.

Item eight asked respondents *why* they wanted to pursue a career in science, seeking to ascertain motivation. The most interesting and powerful cluster to emerge from these response data using content analysis were the ideas of *meaning and passion*. Although the specific vocabulary differed—terms such as love, passion, joy, happiness, fun and related terms—the emergent motivation was very similar. Students perceived an affective, positive response when thinking about a STEM career. Several used the terms meaningful or fulfilling. These ideas are thoroughly consistent with adult learning principles, where adult and young adult students pursue life goals through an attachment of personal fulfillment and meaning to the pursuit. Again, this observation may be useful in planning education programs for these young adults and as an additional theoretical framework (adult learning theory) to describe the important work of the LMRSC.

Items nine through thirteen prompted very rich and lengthy narrative responses from these graduate students which described a wide range of research and/or field experiences in which they had participated as a result of LMRCSC. Clearly, this reflects that LMRCSC is aligned with and supporting NOAA Mission Science concerns in the opportunities that it is providing to its graduate students. The respondents also described powerful mentorship experiences which they had had, many of which came through LMRCSC personnel or undergraduate or graduate course faculty. Several respondents mentioned their NERTO mentors. And LMRCSC personnel, Dr. Chigbu, Dr. Dionne Hoskins-Brown, Dr. Rose Jagus, Dr. Liz Babcock and Dr. Victoria Young were mentioned specifically as valued and valuable career mentors. As a final note, it seems clear from the responses that these graduate students indeed view the NERTO assignment as an authentic and valuable research experience which has supported them professionally. Finally, thirteen of seventeen responses had received orientation to LMRCSC formally from someone at their home institution, with four additional respondents stating that they were unsure whether they had received orientation or not. Again, a positive reflection for the administrative functions of communication.

Items fourteen and fifteen sought to identify whether these graduate students had a "track record" of participation in STEM related activities from high school forward through college. The responses were rich and inspiring. The data reflect a veritable "who's who" of the national or regional, federally funded opportunities. Responses listed the EPP MSI scholarship, NOSB, the McNair Scholar program, NSF STEM Fellow programs, and REU programs. There is support for

concluding that this holistic community of scaffolded STEM experiences are functioning as somewhat of an incubation system for emerging young science scholars. This complex-systems view of the formal and informal connections among these background supports for LMRCSC students certainly has contributed to these students current "moment" and should likely be researched or evaluated as contributory factors in the LMRCSC program.

Items sixteen and seventeen reveal an interesting divergent observation. While most respondents (15/18) remain in communication with key high school teachers or undergraduate faculty members, the inverse (3/18) describes these student's family members employment in STEM fields. As observed in other research, teachers at the secondary and post-secondary level can be valuable vectors for career pipeline development of young adults, even in the absence of parental support for these STEM disciplines.

Given this previous observation, item eighteen does demonstrate that parents who are not employed in STEM areas do value STEM careers for their children. Many of these graduate student respondents describe how parents encouraged their passion and interest in science. This encouragement was viewed as very important and memorable by these respondents.

Item nineteen asked respondents to gauge their employability in their chosen career aspirations. Fifteen of eighteen rated this as Very or Moderately employable over the next ten years. Previous concerns expressed by earlier students were absent in these ratings.

The next set of interesting data to emerge in the survey was in item twenty-one. Respondents identified the most engaging or significant LMRCSC activity from the past year. Several respondents listed the Data Carpentry Workshop, a significant and positive improvement in responses to data workshops or courses from previous years. Further, and again a notable positive observation, several respondents used the term "cohort" or "cohort experience." In earlier years, it was difficult to ascertain whether the concept for cohort relationships was being adequately "pushed down" into the awareness of students, even though it was very much a goal of the LMRCSC leadership. Refinements to workshops and orientation (which these survey data demonstrate is happening) may have contributed, or likely contributed, to this emergence of the cohort language in the survey data. These experience responses demonstrate positive administrative oversight, growth and improvement in the program, and positive impact on the students.

Item twenty-two asked respondents to explain why the previously mentioned experience was perceived as valuable. This question elicited rich and detailed responses. Several explained how the cohort experience workshop enhanced valued work skills. This comment was made about the data workshop as well. Several described the social interactions with other students, and also the ability to meet potential mentors. Given the context of Covid response that drove this experience online last year, it was interesting to observe from several comments that the experience helped them navigate and manage the "covid era."

Item twenty-three asked respondents to name and describe the most beneficial university course which they had taken in the past year. The intent of this question was, again, to identify the integration of LMRCSC experiences and opportunities for students with NOAA Mission Science. The courses identified by the respondents indeed demonstrated this. Courses listed included Coastal Pollution, Environmental Law, Population Dynamics, Ocean Law, and Marine Ecotoxicology among others. Fourteen of the eighteen responses were from science or science policy areas which clearly matched NOAA concerns. Interestingly, other courses mentioned—Technical Writing, Programming in R, and Skills for Team Science—overlapped the professional work skills that are also objectives for the LMRCSC and NOAA EPP.

Item twenty-four drilled explicitly into enhanced student understanding of NOAA Mission Science and Fisheries Science from this past year's experiences. Students described a number of examples of how they had grown professionally, and the full response data set it powerful. Example quotes include:

- *My knowledge NOAA mission science has been enhanced by attending conferences and seminar series that described what role different scientists played in the NOAA mission.*

- *I have been very lucky to meet NOAA scientists and to learn more about the various areas they work in at the Gulf of Maine Research Institute this summer.*
- *Becoming a NOAA EPP/MSI Graduate Fellow helped me understand how my role as a NOAA supported student contributes to NOAA's mission and also ways that I can enhance my contributions to NOAA's mission and fisheries science.*
- *I actually recently had a meeting with Dr. Sexton that increased my knowledge on the mission statement and NOAA as a whole. Making sure to include MSI after EPP, how to address myself properly, and other important things to know were discussed. This year that knowledge was greatly enhanced.*

Items twenty-five and twenty-six were rating questions which reflected, as in earlier years, a perception that there was low to medium interaction with students and professors at other LMRCSC institutions (other than their home school), but a medium to high level of knowledge about the LMRSC as a NOAA EPP overall. In the former case, that response pattern is not unusual and is a function of a "home school advantage" for connections and networking. In the latter case, this seems to reflect a positive growth in the LMRCSC administrative, and communications functions this past year.

As with the undergraduate students, item twenty-seven indicates a strong interest in participating in a future potential Alumni Association for the LMRCSC. Item twenty-eight continued last year's concern about Covid responses and revealed some concerns about a loss of work time on research, the loss of hands-on experience due to social distancing, and the compression of time for those students where they are attempting to maintain a completion calendar or schedule to finish schooling. Item twenty-nine solicited descriptions of changes at their home universities required by Covid. Again, these descriptions validate the responses to the prior item by revealing that the most likely mitigation efforts for Covid did indeed isolate students, eliminate interpersonal contact and limit use of labs and research capability. The final item, seeking ideas for additional supports and resources, did not reveal strong clusters of similar items that would inform practice, but the evaluators encourage the leadership at LMRCSC to review these raw data responses regardless. Two respondents did suggest a common idea of writing support for theses and dissertations which might be discussed at a leadership monthly meeting.

Data Carpentry Workshop Survey

As noted in the graduate student survey responses above, there was a very positive receptivity to the Data Carpentry Workshop in fall 2021 that carried over into the general survey for the fall semester. The evaluators did develop a short survey specifically for this workshop and include it at the end of the workshop for students to garner additional, program specific information about this LMRCSC opportunity.

Item one asked respondents how many credit hours in statistics or data management they had taken prior to this course. Four respondents indicated from 1-3 hours. Five respondents indicated from 4-6 hours, and two respondents indicated over six hours. One respondent had not taken statistics or data management coursework at all prior to this workshop. This response pattern suggests a widely divergent preparation for the student group.

Item two asked how respondents perceived the course would support or had supported their NERTO or TAB projects. Each of the twelve respondents perceived a benefit and use for the content of this course—which is a significant, positive improvement from earlier iterations of the data course and reflects significant work by the LMRCSC team to create a course that accommodated the widely divergent background preparation noted above. This is a commendable accomplishment. Item three suggests that only three of the twelve perceived the course moved too quickly (these were the students with the least background preparation via credit hours in related studies). All twelve respondents (item four) asserted that the workshop would be useful for their future career and eight respondents added open comments to expand on this. Select responses included:

- *I did not know much about any statistical tests before this workshop, it was very interesting to learn about more complex functions;*
- *Being able to use R will help with data analysis and the ability to find career opportunities;*
- *I have been hearing about R and needed an introduction but didn't know where to start on my own, so this was very valuable.*

Interestingly, item five on the survey revealed that only four of the twelve respondents perceived that the course fostered their developing relationships with other students. It is likely that the instructional modality (online) and the intensity of the content and study was not orientated to social development as was the Cohort Experience course. This is not viewed as a deficiency by the students, however. The overall rating of the course (item six) did not reflect a single negative evaluation: nine respondents rated the course as excellent and three rated it at the mid-point of the scale or as okay.

The remaining items explored the various content elements of the course and student perceptions of the value and importance of these. Item seven suggested that the data visualization skills were a strong and valuable part of the course. Item eight revealed nine of the twelve respondents perceived the sequencing of materials was appropriate and came at an appropriate moment in their academic program. The negative responses were from students who had a stronger background in statistics, and likely perceived that they were already past the difficult stage of concept development in this area. And finally, item nine records that nine of the twelve perceived that the online instructional modality was extremely or somewhat effective, with only three perceiving that it was not. One respondent qualified his/her negative rating by suggesting that the negative only applied to the course section on R, and that the other materials were very effective online. The final item (ten) solicited areas for improving this experience, and the largest cluster related to the intensity of the schedule, with suggestions that perhaps it could be disseminated over a longer time frame. Nevertheless, the evaluators discount this suggestion as it is a typical response to an intense experience, and there is no other evidence that student performance was negatively affected by the pace of instruction.

There are select, additional response data from this Data Carpentry workshop which will be reviewed holistically and included as necessary in the summer 2022, final annual report of the LMRCSC sixth year activities for this extension year. Initial review of these does not reveal any differing responses than those contained above or in the previous graduate fall survey.

Additional Evaluator Efforts (visit to SSU, participation in meetings, discussions on new evaluation plan for new funding)

As final summary of evaluator efforts this first half of the extension year, the following work effort was undertaken to maintain momentum in holistic evaluation of the LMRCSC. First, Dr. Tina Bishop visited Savannah State University and had an update conversation with Dr. Victoria Young, the LMRCSC Education Coordinator, to continue monitoring of program implementation. Second, the evaluation team regularly participated in the monthly LMRCSC Executive Committee video conference call, and on select Education Committee meetings to report formative information to the team for immediate review, and to continue to monitor project implementation. And finally, this second Covid response year has continued to foster the use of threaded email discussions and information sharing, and the evaluation team monitors and participates in these communication efforts as part of the overall administrative and communications plan.

NERTO Student Survey

The evaluators prepared and distributed a survey to students completing there NERTO project during the 2022 calendar year. This research project is a culmination of student work in the LMRCSC and has been found by previous students to contribute substantively to their preparation for eventual career success.

Twelve students completed the twenty-five question survey this year. The responses included a nearly even distribution across the four content areas around which the NERTO projects are organized (the four key NOAA science concerns) with slightly more responses in stock assessment and living resources management. All but one person out of the twelve respondents reported that they had manipulated and analyzed large data sets. The responses concerning social science implications of research evoked responses for half of the respondents as neutral; five agreed and one strongly disagreed that their work had social impacts. From these responses it appears that social sciences impacts requires additional definitional work with students, as they seem to misunderstand or understate what seems to be clear alignment with social impacts. This suggests that discussion of what social science means as related to the STEM research somewhere in the LMRCSC program orientation might be beneficial. There needs to be a better definition of social science and what the variety of social science fields and topics should be—a conclusion that has emerged over the previous five years of the LMRCSC and verbalized by several key senior personnel.

Four of the twelve respondents worked only this summer on their NERTO; two worked a semester, and two worked a full year. Several others reported working over a period of two to four years. Three respondents worked with their mentor less than five hours a week while others had much more extensive weekly engagement. For communication they used Google Meet and Zoom (predominantly) and it was mostly virtual engagement with only two students able to work in person due to continued Covid restrictions. Two respondents said their mentor had not supported their academic work and one said only little—but these responses were a small proportion overall. Fifty percent (six students) indicated their mentor supported them *significantly* related to their academic work. This may indicate a need to better define mentor support for student projects moving forward. There was similar feedback regarding mentor support for the professional careers of students. Half (six) of the mentors were deemed to be *significantly* supportive by the students. The support included developing skills, especially data analysis such as R, and helping students identify career possibilities within NOAA. Other respondents described introductions and connections with other researchers that were facilitated by the mentors; other respondents described learning research processes and participating in field work that was “beneficial career lessons in building connections with scientists that could lead to collaborations.” Overall, the mentoring provided through the NERTO was highly regarded by the student participants.

The next questions focused on benefits which accrued to the participants from NERTO or LMRCSC more broadly. Respondents described developing new skills such as statistical analyses and learning how to use NOAA datasets. Others described meeting new people and networking with NOAA personnel. Other new skills included how to write papers and to communicate in English and Spanish, and learning what it is like to work in NOAA. One respondent wrote that “it was very informative to be surrounded by projects and people thinking about how their current projects fit into the broader scheme of NOAA research generally.”

Item twelve asked respondents to list specific skills they learned in their NERTO project which might be beneficial in their eventual careers. Students listed: data analysis, research design, techniques for scientific writing, various data analysis techniques and procedures, and the use of several pieces of laboratory equipment. Other students listed data coding, and several lab techniques including coral husbandry and cell sorting.

Item thirteen asked students how their NERTO project had influenced their career decision. Ten of the twelve respondents agreed or strongly agreed that the project had indeed influenced their career trajectory. One person strongly disagreed, although the evaluators are not sure what that means and would need to probe more into that response to understand, as the respondent failed to clarify.

Item fourteen asked if NERTO helped with other academic work. eight out of twelve respondents agreed or strongly agreed that it helped. Two were neutral and two disagreed with the prompt.

Item fifteen asked how the NERTO project might have inspired thinking or decisions on

career choices. The responses confirmed interest in fisheries work generally, and particularly in NOAA. It was perceived that the NERTO project gave insight into career paths and supported interest in modeling work. In general, NERTO narrowed down interest and helped identify what respondents wanted or didn't want to do professionally. Two respondents said it increased their interest in government science and helped visualize the daily work of a NOAA employee. Respondents agreed that it helped them gain insight into NOAA and a desire to work for NOAA. One respondent said, "It exposed me to the ins and outs of fisheries management."

To the prompt in item sixteen, Eleven of twelve respondents indicated that it helped them gain insight into NOAA and its organizational culture. And in item seventeen, ten out of twelve respondents reported that NERTO "helped create a network for success in the workforce."

Item eighteen asked about perceptions about eventual careers as a result of the NERTO project—again trying to isolate detailed understandings about the impact of this project on students' professional growth. Respondents agreed that it increased interest in a government/STEM agency career and increased interest in NOAA fisheries specifically. It showed different career possibilities and showed the positives of working for the government. One respondent said, "it showed NOAA as an organization that supports diversity." Another respondent said, "it broadened my view of fisheries management to include the stakeholder community and fishermen."

Item nineteen asked the extent to which the NERTO project mentor introduced the participant to colleagues in the field. This surprisingly led to diverse responses: four said that the mentor *significantly* introduced them to colleagues; four said quite a lot; three said a little, while only one said there was no wider introduction to colleagues in the field. This set of respondents demonstrates the strong socialization into the research community that is associated to these LMRCSC projects—beyond the academic or science skills and knowledge.

Item 20 asked about challenges respondents might have faced in their NERTO project. Several people said that having to do the NERTO virtually was a challenge. This was complicated by time issues and time zone differences. It was hard for one student to find a time that worked for both the mentor and the student. COVID was another major challenge. One student reported he/she/they contracted COVID; one mentor got COVID and COVID led to only a few weeks of in-person work for one respondent. One respondent had to delay their in-person work and that was a challenge. Other challenges were equipment malfunctions, items on back order and a lab which was relocated or under construction. One person needed to work at the lab on weekends and this created a bit of a logistical concern. Another opportunity reported by one individual was that the completion and submittal of the application for NERTO should have a website and it should use clearer language to make it easier to fill out.

Item twenty-one (the last substantive response item) solicited respondents to describe any other support they might have needed to enhance their NERTO experience. Responses included a desire for in person work opportunities, a clearer NERTO information web page (several people noted this). Other potentially constructive comments to consider included a smoother application process, better communication with EPP and CSC, and a designated support person for NERTO in the LMRCSC office to enhance communications. It should be noted that several of these suggestions seem to be in place already—suggesting that the basic issue is awareness by students and not the process itself.

Report Conclusions

It was a given that, with a second year of Covid emergency responses ongoing at the LMRCSC partner institutions, there was a possibility of program disruption. Nevertheless, the evaluation efforts for this no-cost-extension year reveal that the team has substantively adapted its project to the use of distancing and technologically mediated communications and work methods. Students, faculty, and team members demonstrate success in key project elements relying on these communication technologies.

Further, there is evidence that the opportunities to strengthen the LMRCSC which were identified by the external panel review have been or are being addressed. A substantively revised

data course was implemented to wide acclaim by the students. Students perceive they are part of a cohort of graduate and undergraduate learners that relates to the LMRCSC as an overarching Center of which they are a part, and in which they have professional peers and colleagues across the various institutions. This should only benefit and strengthen the recruitment of undergraduate to graduate students in years to come. And finally, these revisions and others suggest a highly functioning administrative culture for the LMRCSC. The leadership team is capable of affecting positive change and program enhancement and growth as data inform their work.

The NERTO survey collected from a robust group of graduate students at the very end of the extension year are highly positive and promising. Even in the significant interruptions that the Covid crisis engendered, these respondents perceived that they received strong mentoring, a career-related project that allowed them to gain skills, professional networking connections, and soft-skills (writing, problem solving and critical thinking, data analysis) which will be immediately applicable in the work setting after they graduate.

The LMRCSC leadership team worked through numerous challenges the last two years, but the students themselves—while recognizing the limitations of the virtual work setting—nevertheless perceived that they were supported and were receiving strong academic experiences to prepare them for their chosen professions.

Appendix V: Performance Metrics from Implementation Plan

Education Performance Metrics:

Activities/Programs	Proposed (12 months)	Accomplished (3/1/22-8/31/22)
# Students trained in NOAA related	56 (42*)	57 (51*)
# B.S. Students who graduate in NOAA	6 (4*)	3 (3*)
# M.S. Students who graduate in NOAA	11 (9*)	3 (3*)
# Ph.D. Students graduating in NOAA	1*	0
# of internships (e.g. NERTO) at NOAA facilities	12	18
# of URM students in development activities that will lead them to attain degrees and/or employment	12*	51
# of EPP-funded graduates who participate in and complete agency mission-related postdoc. Level programs	2	2
Amount of leveraged funds ($) for education and training	500K	$451,794
# of student presentations at conferences (average)	20	40
# of student co-authored publications	10	3

Research Performance Metrics:

	Proposed (12 months)	Accomplished (3/1/22-8/31/22)
Science Meeting date	June	None during this period
# of collaborative research projects (TAB Proposals) funded	6 to 10	None during this period
# of new & continuing proposals funded (leveraged funding)	12	20
# of scientific presentations at conferences	50 (15*- 90)	39 (37*)
# of theses & dissertations produced	12	3
# of peer-reviewed publications	10*-30 (25)	11(3*)
Amount of leveraged funds ($)	$3 million	$451,794
Number of NOAA scientists serving as mentors and advisors for student research each year	>20	27
# of intra-institutional partnerships in support of NOAA's mission	Average of 4	26
# of times LMRCSC publications have been cited	Will be documented	1313

Administrative Performance Metrics:

Activities	Proposed (12 months)	Accomplished (3/1/22 - 8/31/22)
Submission of monthly invoices to UMES	Monthly	Average time between invoices = 2.11 months
Successful execution of sub-awards (<60 days of receiving award notification from NOAA EPP)	October or earlier	N/A during no-cost extension period
Evaluate budget to ensure center funds are expended in accordance with budgets approved by NOAA EPP and incompliance with federal and state guidelines	Every 6 months	Every 6 months
Holding of LMRCSC Science meetings at NOAA facilities	Summer	Not during this period
Funding of collaborative research projects via TAB review process	Spring	N/A during no-cost extension period
Submission of semi-annual reports	Every 6 months	Every 6 months
Submission of student tracker data	Every 6 months	Not in this reporting period
Executive Committee meetings	Monthly	Monthly
Updating of the LMRCSC Website	Weekly	Weekly
Meeting of the LMRCSC Education/Outreach Committee	Once every four months	August 2022
# of featured articles in print or digital media per year referencing LMRCSC	At least 50	